Sapphire to Woolgoolga Pacific Highway Upgrade

Annual Ecological Monitoring Report

Year 3 of Operation

Roads and Maritime Services | June 2019

NSW GOVERNMENT

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Contents

Introduction

This report provides an update on the ecological monitoring of the Sapphire to Woolgoolga Pacific Highway upgrade. This report covers the period for Year 3 of Operation and is prepared accordance with the Sapphire to Woolgoolga Ecological Monitoring Program (Roads and Maritime 2018), for submission to the Department of Planning and Environment and Environment Protection Authority (EPA).

The operational monitoring reports required to be submitted for the period Year 3 (2017 – 2018) are:

- Giant barred frog population monitoring
- Fauna connectivity monitoring (including fauna underpasses, aerial crossings and vegetated median), and
- Threatened flora (including in-situ plants and translocation areas).

Statutory and planning framework

In December 2006, the Minister for Planning declared that the Sapphire to Woolgoolga upgrade was a project to which Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A) applied. In December 2006, the Minister also declared the Project to be critical infrastructure under Section 75C of the EP&A Act.

The Project involved the construction of approximately 25 km of dual carriageway with a duplication of the existing Highway from Korora to Woolgoolga and a bypass of the main township of Woolgoolga.

The Sapphire to Woolgoolga Pacific Highway upgrade approval included the requirement to develop an ecological monitoring program. Condition 3.12 of the Approval states::

> *Prior to the commencement of construction, the Proponent shall develop and implement a Monitoring Program to monitor the effectiveness of the mitigation measures identified in Condition 2.12(e) for threatened species directly impacted by the project. The Program shall be developed in consultation with the Department, EPA, DPI (Fisheries and Forestry divisions), and suitably qualified ecologist(s) and shall include but not necessarily be limited to:*
>
> *a) monitoring methodology for threatened species in and adjacent to the project footprint. The methodology shall be decided in consultation with EPA;*
>
> *b) an adaptive monitoring program to assess the effectiveness of the mitigation measures identified in Condition 2.12(e) and allow their modification if necessary. The monitoring program shall nominate appropriate and justified monitoring periods and targets against which effectiveness will be measured;*
>
> *c) monitoring shall be undertaken during construction (for construction-related impacts) and from opening of the project to traffic (for operation/ongoing impacts) until such time as the effectiveness of mitigation measures can be demonstrated to have been achieved over a minimum of three successive monitoring periods following establishment of vegetation planted as part of mitigation and after opening of the project to traffic, or as otherwise agreed by the Director-General in consultation with EPA;*
>
> *d) provision for the assessment of the data to identify changes to habitat usage and if this can be attributed to the project;*
>
> *e) details of contingency measures that would be implemented in the event of changes to habitat usage patterns directly attributable to the construction or operation of the project; and*
>
> *f) provision for annual reporting of monitoring results to the Director-General and the EPA, or as otherwise agreed by those agencies.*

The Program shall be submitted to the Director-General prior to the commencement of construction.

The Department approved Revision 3 of the Ecological Monitoring Program on 24 February 2014

Appendix A Giant Barred Frog

Pacific Highway Upgrade – Sapphire to Woolgoolga

Operational Phase Fauna Monitoring

Year 3 – Giant Barred Frog (*Mixophyes iteratus*) Population Monitoring

Sandpiper Ecological

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Cover Photo: Adult female giant barred frog (*Mixophyes iteratus*) observed at Arrawarra Creek, NSW.

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1. Introduction

1.1 Background

Roads and Maritime Services (RMS) NSW contracted Sandpiper Ecological Surveys (SES) to monitor a giant barred frog (*Mixophyes iteratus*) population identified along the Sapphire to Woolgoolga (S2W) Pacific Highway Upgrade alignment (hereafter referred to as the Upgrade). Giant barred frog is listed as endangered under the NSW *Biodiversity Conservation Act 2016* and Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*.

The Environmental Assessment (EA) prepared for the S2W Upgrade identified potential habitat for giant barred frog at four sites within the Upgrade corridor. These sites included Woolgoolga Creek, Poundyard Creek, Arrawarra Creek and Little Arrawarra Gully. The species was subsequently detected at two of the predicted sites – Woolgoolga Creek and Arrawarra Creek. During the construction phase giant barred frog was recorded at three additional sites - a dam on Halls Creek (referred to as Freeman's Dam) (Chainage 27400), a dam north of Grey's Road (referred to as Grey's Dam) (Ch. 24600) and a dam north of Barkhut Road (referred to as Barkhut Dam) (Ch. 27730).

In response to the above records the Office of Environment and Heritage (EOH) requested amendments be made to the approved Ecological Monitoring Program (in accordance with MCoA 3.1) and Biodiversity Offset and Management Strategy (in accordance with MCoA 2.12e and 2.12h) to reflect potential impacts of the upgrade on giant barred frogs.

A Construction Phase Management Strategy (CPMS) for the giant barred frog population was prepared (BEM 2011) and included a requirement to conduct population monitoring at all sites where the species was detected during both the construction and operational phases of the project. Revegetation monitoring was also required at Woolgoolga Creek and Greys Dam. Construction phase population monitoring was undertaken in 2011/12 and 2012/13 (BEM 2012 & 2013). Operational phase monitoring was required over three consecutive breeding seasons. Year 1 population monitoring occurred during 2014/15 after the Upgrade became operational in July 2014 (Sandpiper Ecological 2015). Year 2 population monitoring occurred during 2015/2016. This report presents the results of year 3 (i.e. 2016/17) operational phase population monitoring. The results form previous monitoring is presented with the 2016/17 data for contextual reasons. Survey methods have been consistent across years.

1.2 Species Ecology

The giant barred frog is a large (up to 120 mm) ground dwelling Myobatrachid frog found within areas of wet sclerophyll forest and rainforest at elevations below 1000 m (Lemckert & Brassil 2000; Anstis 2013; NPWS 2002). The species is associated with permanent flowing drainages, from shallow rocky rainforest streams to slow-moving rivers in lowland open forest (NSW Scientific Committee 1999).

The species forages and lives amongst deep, damp leaf litter where it feeds primarily on large insects and spiders (NPWS 2002). Individuals generally remain within 20 to 30 m of the edge of a stream (Lemckert & Brassil 2000). Breeding usually occurs from late spring to summer around permanent shallow flowing streams (Lemckert & Brassil 2000; NPWS 2002; Tyler &

Knight 2009). Males call from leaf litter along the banks of creeks and streams (Robinson 1993). Females deposit eggs onto moist banks or rocks above the water level, where the eggs adhere to a surface above water (Knowles *et al.* 2015; Anstis 2013; NPWS 2002). Hatchlings fall or wriggle down into the water (Anstis 2013; NPWS 2002). Tadpoles grow up to 100mm total length and take from 10 to 14 months to reach metamorphosis (Lemckert & Brassil 2000; Hines 2002; NPWS 2002; Tyler & Knight 2009; Anstis 2013).

1.3 Monitoring Aims and Objectives

The aim of the giant barred frog population monitoring is to assess presence/absence and long-term viability of giant barred frog sub-populations in areas directly affected by the Upgrade.

The objectives of the monitoring program are to:

- identify changes to giant barred frog presence and relative abundance at all known sites affected by the Upgrade;
- identify any changes to key habitat components caused by the Upgrade that have the potential to impact on the long-term viability of giant barred frog sub-populations in the locality; and
- assess the presence, developmental stages and relative abundance of giant barred frog larvae, juveniles (sub-adults) and adults.

2. Study Area

The study area includes three watercourses traversed by the Upgrade project corridor between chainage 24600 and chainage 31000. The watercourses include an unnamed stream north of Grey's Road (Ch. 24600) referred to as Grey's Dam, Woolgoolga Creek (Ch. 25400) and Arrawarra Creek (Ch. 31000). All sample sites are located within 600 m of the Upgrade corridor (Figure 1). An additional site at Darkhum Creek was sampled during construction phase monitoring. However, that site was subsequently excluded due to lack of suitable habitat for giant barred frog.

An additional Grey's Dam site (Grey Dam additional) was sampled during year 3 (2016/17) monitoring. Grey Dam additional is situated immediately downstream of the Upgrade corridor and was included due to the known occurrence of giant barred frogs during construction and as a comparison with the "Grey Dam Upstream" site which occurs on the opposite side of the highway. It was considered that sampling this site would provide useful data in relation to the objectives of the monitoring program.

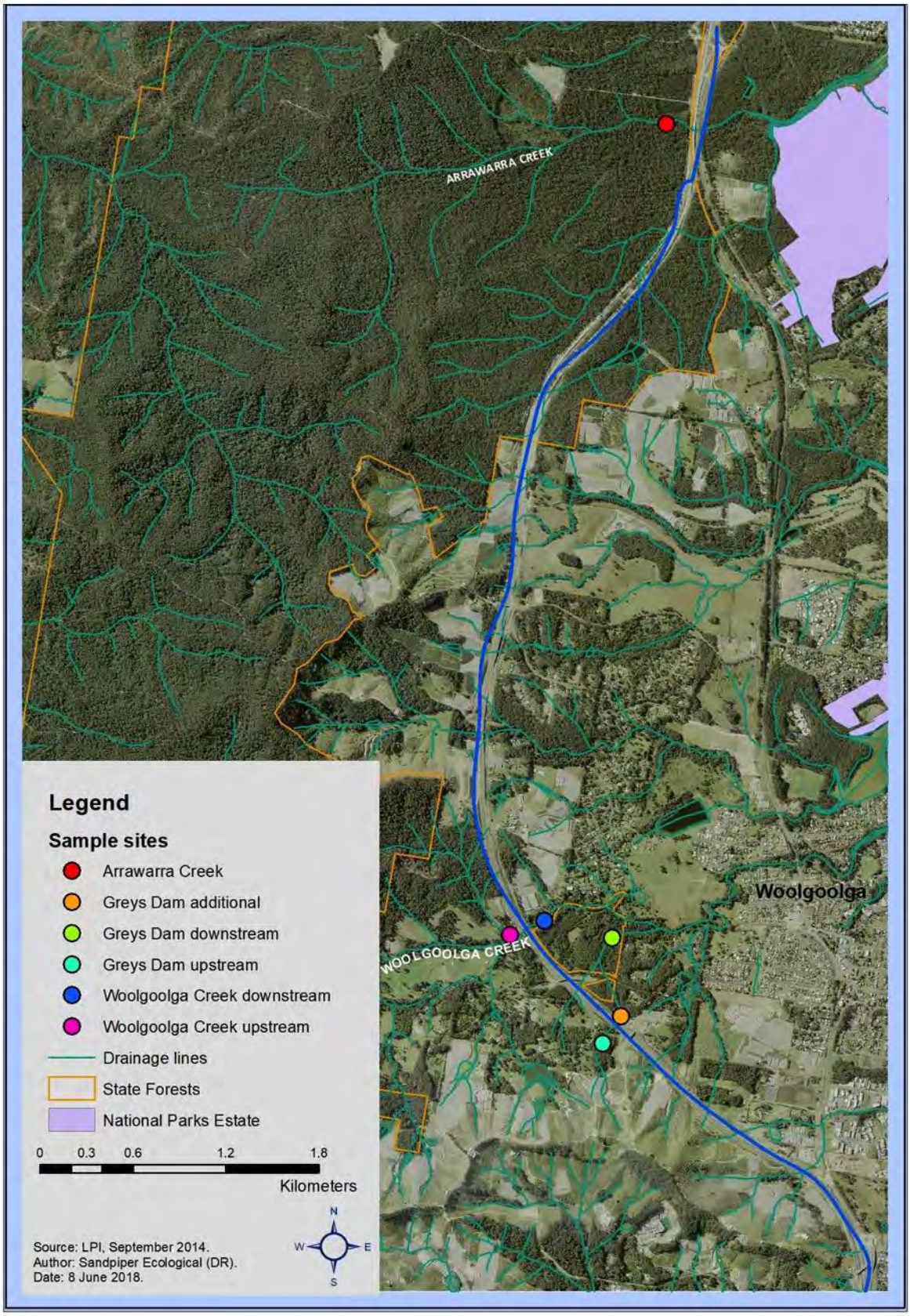

Figure 1: Giant barred frog population monitoring sites adjoining the Sapphire to Woolgoolga Pacific Highway Upgrade.

3. Methods

3.1 Monitoring Sites

Six monitoring sites were sampled during the 2016/2017 monitoring period (Figure 1). Sampling sites upstream and downstream of the project corridor occur at Grey's Dam (two downstream sites) and Woolgoolga Creek. A monitoring site upstream of the project corridor occurs at Arrawarra Creek. There was insufficient suitable habitat for giant barred frog at Freeman's Dam, Barkhut Dam or downstream of the project alignment at Arrawarra Creek to enable monitoring of the species.

Each monitoring site consisted of a 200m section of riparian habitat, following Lewis and Rohweder (2005). Sampling transect widths corresponded with the extent of suitable giant barred frog habitat (e.g. dense leaf litter and intact riparian vegetation) within 30m of the stream edge (Lemckert and Brassil 2000). Grey's Dam downstream and Woolgoolga Creek downstream incorporate release points used to relocate giant barred frog adults and tadpoles displaced during the Upgrade construction phase (see BEM 2013).

3.2 Timing of Sampling Events

3.2.1 Construction Phase

The CPMS states that, "the timing of sampling events will be spaced throughout the breeding season in order to detect the relative abundance of tadpoles in different development stages (i.e. between early October and late March)". Construction phase sampling was completed during 2011/12 and 2012/13 breeding seasons. Spring (early season) sampling was not undertaken in the 2011/12 breeding season due to delays in approval of the CPMS and associated monitoring methodology and funding.

The timing of construction phase surveys was delayed several times because of heavy rain and flooding in the study area yet were consistent with the recommended survey guidelines for the species prepared by the Department of Environment, Water, Heritage and the Arts (DEWHA 2010).

3.2.2 Operational Phase

Operational phase surveys have been conducted between October and April 2014/15 (year 1), 2015/16 (year 2) and 2016/17 (year 3). Three sampling events were completed during each year, with the timing of sample events influenced by weather, particularly rainfall and flood events. Sample events have been timed to avoid unsuitable weather conditions, such as dry periods, or to capitalize on wet periods. In 2016/17 the second sample event was delayed until early March due to dry conditions in January and February. The third (2016/17) sample event commenced in late March (2017) but was temporarily postponed due to a major flood event, with surveys resuming a week later in early April. The third tadpole survey event in 2016/17 was delayed until June due to concern about the impact of major flooding in late March on tadpole survival. Year 3 sample dates are presented in Table 1.

Table 1: Timing of giant barred frog monitoring events undertaken in the 2016/17 breeding season.

Monitoring Event	Visual Search/Call Playback	Tadpole Sampling
1	15/11/2016 - 17/11/2016	16/11/2016 - 18/11/2016
2	6/3/2017 - 8/3/2017	7/3/2017 - 8/3/2017
3	29/3/2017 - 5/4/2017	28/3/2017 - 29/3/2017

3.2.3 Weather Conditions

Suitable weather conditions for sampling giant barred frog include warm air temperature (>18^{0}C), high relative humidity and rainfall either during or recently preceding sampling (i.e. up to one week prior to sampling) (DEWHA 2010). Sampling should not be undertaken during periods of heavy rainfall or high stream flow (DEWHA 2010).

3.3 Sampling Hygiene Protocol

All field sampling was conducted in accordance with the hygiene protocol for the control of disease in frogs (NPWS 2001). Relevant control measures included:

- vehicles not traversing potential frog habitat
- cleaning and disinfection of boots and waders prior to entering frog habitat
- disinfection of dip-nets and bait traps prior to entering frog habitat
- a fresh pair of surgical gloves worn for the handling of each individual frog
- captured frogs and tadpoles placed separately into plastic bags and aquariums. All plastic bags were disposed of after a single use. Aquariums were disinfected after each use.

Captured frogs and tadpoles were kept isolated from other captured individuals throughout the entire capture/release process.

3.4 Frog Surveys

Each sampling event for frogs consisted of a combined nocturnal visual search and a call playback survey. Field sampling was generally undertaken between 1900 and 0100 hours. Visual searches consisted of a walk traverse of each 200m transect for a minimum duration of 1.5 hours (3 person hours/event). Two experienced field personnel using spotlights undertook each traverse. Captured individuals were measured (snout-vent length), weighed, and photographed (dorsal surface pattern) to determine approximate age and sex. Individuals with a snout to vent length less than 68mm were considered to be juveniles (Tyler & Knight 2009). Males were determined either by call or by presence of nuptial pads. Photographs of the dorsal surface were taken to enable possible identification of recaptured individuals between sampling events. The location of each captured individual was recorded using a handheld Garmin GPS62.

Weather conditions were recorded immediately prior to and after sampling each site with a Kestrel 3000 handheld weather meter. The weather variables recorded included relative humidity, air temperature, dew point, cloud cover, wind speed and direction. Rainfall during the previous 24 hours and moon phase were also recorded.

3.5 Tadpole Surveys

Tadpole sampling using dip-nets and bait traps was conducted to assess giant barred frog breeding activity. Dip-netting was performed for a minimum of one hour per 200m transect by two experienced field personnel (i.e. two person hours per monitoring event) (Plate 1). Bait traps (three per transect) were set prior to dip-net sampling and checked upon completion of other sampling tasks. Tadpole length and development stage (as per Anstis 2013) was recorded for each capture.

Plate 1: Dip-netting being conducted at Woolgoolga Creek.

3.6 Water Quality Sampling

Water quality was assessed during each tadpole sampling event. Variables recorded were pH, water temperature, and turbidity. Water quality variables were measured using a Horiba water quality meter.

3.7 Revegetation Monitoring

The aim of revegetation monitoring was to compare structural and floristic characteristics of vegetation within the riparian areas at Grey's Dam and Woolgoolga Creek impacted by the project with adjacent riparian areas unaffected by the project. At each site, four 25m-long transects were established perpendicular to the stream, two transects positioned within the impacted riparian area and two transects within the adjacent unaffected riparian area.

Floristic composition was assessed by establishing 25m^2 sampling plots (quadrat dimensions 5m x 5m) at three locations along each transect: top of streambank (0-5m); mid riparian (10-15m); and outer riparian (20-25m). Each sampling plot was randomly located either side of the transect. All plant species within each sampling plot were recorded, along with a visual estimate of vegetative cover for each species using a modified Braun-Blanquet cover value ranging from 1 to 6: 1 (<5% sparse); 2 (<5% many individuals); 3 (6-25%); 4 (26-50%); 5 (51-75%) or 6 (>75%). Nomenclature followed Harden (1990-93, 2000, 2002), with subsequent updates as provided by 'PlantNet', the online version of the Flora of NSW.

The Foliage Projective Cover (FPC) of overstorey and groundcover vegetation was recorded using FPC tubes at 1m intervals along each 25m transect to enable a quantitative measure of foliage cover of both native and introduced species. The proportion of leaf litter cover was recorded using the same technique.

Leaf litter depth was recorded at 5m intervals along each transect. The method of measuring leaf litter depth involved:

1. scraping a small hole in the leaf litter to the soil surface;
2. placing one end of a ruler into the hole on the soil surface;
3. obtaining a plate with a slot in the centre in which to insert the ruler;
4. slide the plate down the ruler until it rests (unweighted) on the leaf litter surface; and
5. reading the depth measurement on the ruler as indicated by the top surface of the resting plate.

4. Results

4.1 Weather Conditions

Weather conditions during 2016/17 nocturnal frog sampling were largely consistent with those suitable for giant barred frog surveys. Humidity exceeded 66% and temperature 18^{0}C during all surveys except the final survey at Grey Dam additional when the temperature ranged from 18.9 to 17.4^{0}C. Nocturnal surveys were suspended if ambient air temperature at the start of a survey was below 18°C, the threshold temperature at which giant barred frogs are thought to burrow beneath the leaf litter (Koch and Hero 2007). All sampling events occurred during or after periods of low to moderate rainfall (Table 2). Rainfall and humidity are considered to be the primary triggers for frog activity (Hauselberger & Alford 2005).

Table 2: Weather variables recorded during the 2016/17 monitoring period.

Site	Sampling Date	Air Temp[1] (C°)	Humidity[1] (%)	Rainfall[2] 7 days prior (mm)
Arrawarra Creek	16/11/2016	21.8 - 23.6	74 - 80.7	24.2
	6/03/2017	23 - 23.2	74.2 - 70.2	75.6
	5/04/2017	20 - 19.5	77.3 - 82.6	143.6
Grey's Dam upstream	17/11/2016	23.8	69.9	4.6
	8/03/2017	23.4 - 21	81.6 - 84.2	55.2
	4/04/2017	18.9 - 17.4	71.5 - 87	125.6
Grey's Dam additional	17/11/2016	23 - 22.1	74.1 - 73.6	4.6
	8/03/2017	21.1 - 20.5	84.2 - 86.7	55.2
	4/04/2017	18.9 - 17.4	83 - 85	125.6
Woolgoolga Creek upstream	15/11/2016	23.3	64.2	31
	7/03/2017	22.6 - 21.2	73.3 - 75.1	55.2
	29/03/2017	25.3 - 26.2	86.1 - 91.4	4.4
Woolgoolga Creek downstream	15/11/2016	18.7 - 18.5	89 - 90	31
	7/03/2017	22.3 - 21.7	66.4 - 69.7	55.2
	29/03/2017	25.9 - 25. 9	84 - 82.5	4.4
Greys Dam downstream	16/11/2016	24.6 - 21.8	66.8 - 83.2	24.2
	6/03/2017	24.4 - 23.1	72.6 - 75.5	75.6
	29/03/2017	25.6 - 25.1	89.7 - 87.3	4.4

1 – temperature and humidity range measured at start and finish of sampling;

2 – daily rainfall data source Bureau of Meteorology Lower Bucca Station No. 059006.

Comparison of total rainfall for the period September to March from 2008/09 to 2016/17, from the Lower Bucca station, shows a general downward trend in total rainfall (Figure 2). Above 20 year (Sept to March) average totals occurred between 08/09 and 12/13, with below average rainfall recorded in two of the four years between 13/14 and 16/17. Below average rainfall was recorded in two of the four years since construction phase monitoring ended, with total rainfall in 2016/17 only just above the long-term average (Figure 2).

Comparison of cumulative totals can mask high variability in monthly totals. For example, in 2014/15, 62% of rainfall in the Sept-Mar period fell in January and February. The 2015/16 (year 2 operational phase) sample occurred during a period of rainfall, which was 30% below the long-term average for the Sept-Mar period (Figure 2). Rainfall during the 2016/2017 (year 3 operational phase) sample was comparable to the long-term average although the majority of rainfall occurred during the March 2017 flood event.

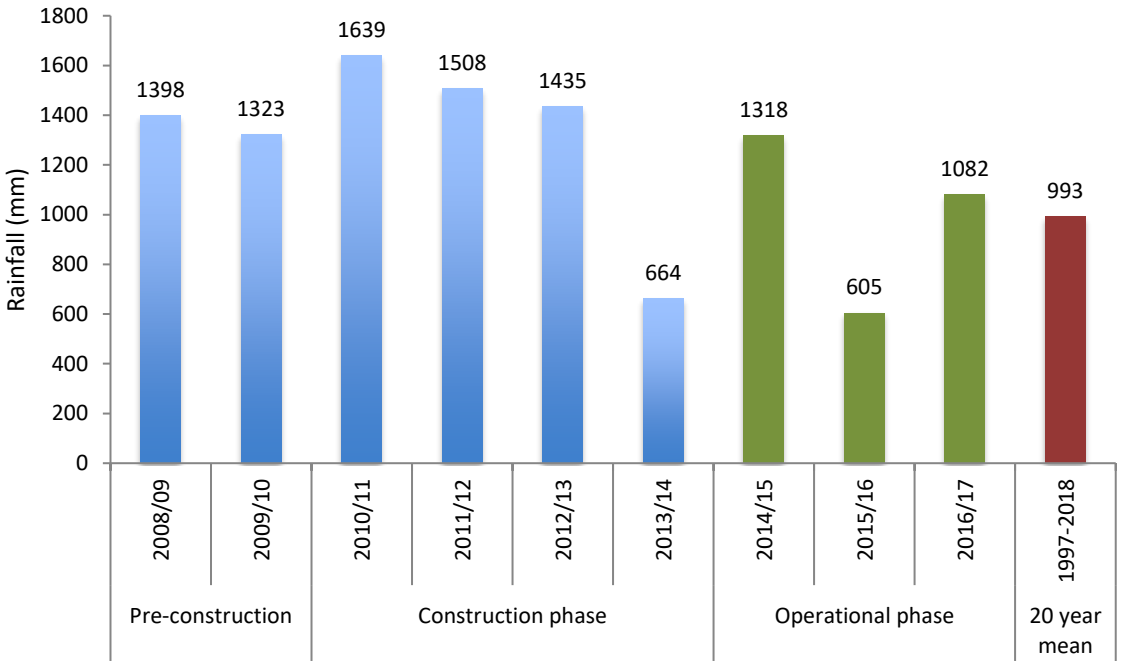

Figure 2: A comparison of long-term mean rainfall (1901 to 2015) and annual rainfall (Sep – April) for the S2W area 2008/09 through 2016/17. Construction phase monitoring was conducted during 2011/12 and 2012/13 and operation phase monitoring during 2014/15, 2015/16 and 2016/2017. Source: Bureau of Meteorology Lower Bucca Station No. 059006.

4.2 Frog Surveys

4.2.1 Presence/Absence

Giant barred frogs were recorded during the 2016/17 monitoring period at Arrawarra Creek, Greys Dam upstream, Greys Dam downstream, Greys Dam additional and Woolgoolga Creek upstream (Figure 3). Woolgoolga Creek downstream was the only site where giant bared frog was not recorded. Three male, five female, and one juvenile frog were recorded at Arrawarra Creek. One male was recorded at Grey's Dam upstream and three males and one female were recorded at Grey's Dam additional. Two males and one juvenile were recorded at Grey's Dam downstream and three females were recorded at Woolgoolga Creek upstream. The highest number of individuals was recorded at Arrawarra Creek (n = 9). Full details of frog surveys are provided in Table A1, Appendix A.

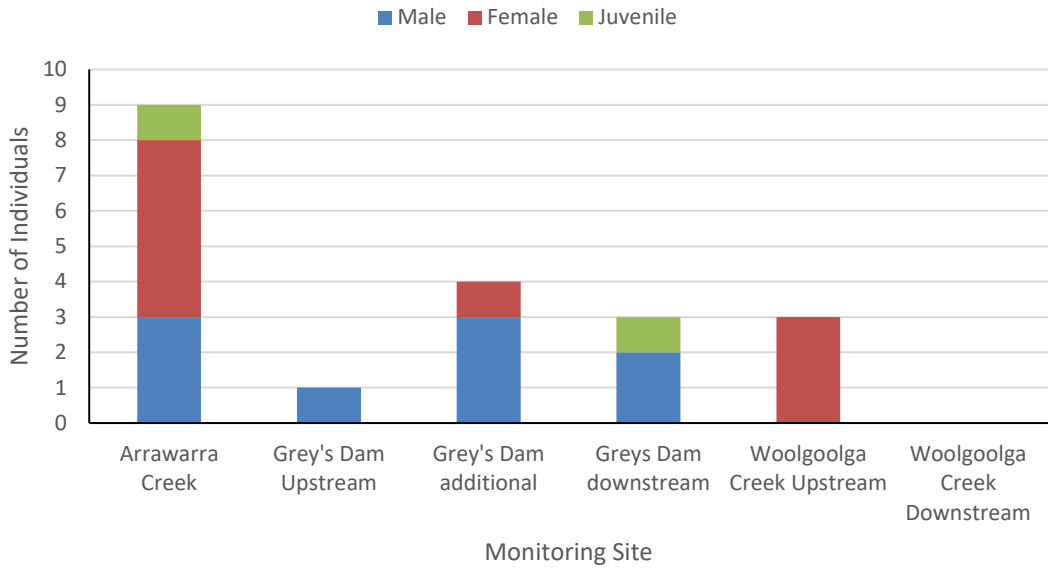

Figure 3: Number of adult (male and female) and juvenile giant barred frogs recorded during the 2016/17 monitoring period.

4.2.2 Recaptures

Based on the dorsal pattern photographs, two individuals were recaptured during the 2016/17 sample period. An adult female captured at Woolgoolga Creek upstream on 16/11/2016 was recaptured at the same site on 29/3/2017. An adult male captured at Grey Dam additional on 17/11/16 was recaptured at the same site on 8/3/2017 and 4/4/2017 (Plate 2). Both individuals were recaptured in proximity to their original point of capture.

Within season recaptures have occurred in each year of monitoring except 2015/16. In 2011/12 one individual was recaptured once at Grey Dam upstream, with one individual recaptured on three occasions at the same site in 2012/13. Also in 2012/13 one individual initially captured in survey 1 at Greys Dam downstream was recaptured at the same site in survey 3. In 2014/15 one individual captured at Arrawarra Creek in March was recaptured in April.

Recaptures between years were uncommon, with only three recorded over the monitoring period. At Woolgoolga Creek downstream, a female captured on 5/3/2015 was recaptured at the same site on 28/1/2016 (Plate 3). A female was also recaptured at Arrawarra Creek on 10/12/2015 after first being captured at that site on 1/4/2015. An adult female captured at Greys Dam downstream in April 2012 was recaptured at the same site in December 2012 and April 2013. No individuals captured during construction phase monitoring were recaptured during operational phase monitoring and no recaptures have occurred more than 12months after initial capture.

Plate 2: Adult male (M1) captured at Greys Dam additional on 17/11/2016 (left) and 8/3/2017 (right).

Plate 3: Adult female captured at Woolgoolga Creek downstream site on 5/3/2015 (L) during year one operational phase monitoring and recaptured at the same site on 28/1/2016 (R) during year two surveys.

4.2.3 Abundance

Mean abundance of giant barred frogs per sample event across the five monitoring periods shows a general downward trend at all sites except Arrawarra Creek, which demonstrated a general upward trend (Figure 4). The decrease in mean abundance has been most pronounced at Greys Dam upstream. Indeed, the individual recorded at that site in 2017 was the first recorded since 2012/13. The two individuals recorded at Woolgoolga Creek upstream in 2016/17 were also the first recorded at that site since 2012/13. Pronounced temporal declines in mean abundance have occurred at Grey Dam downstream and Woolgoolga Creek downstream with no frogs recorded at the latter site in 2016/17.

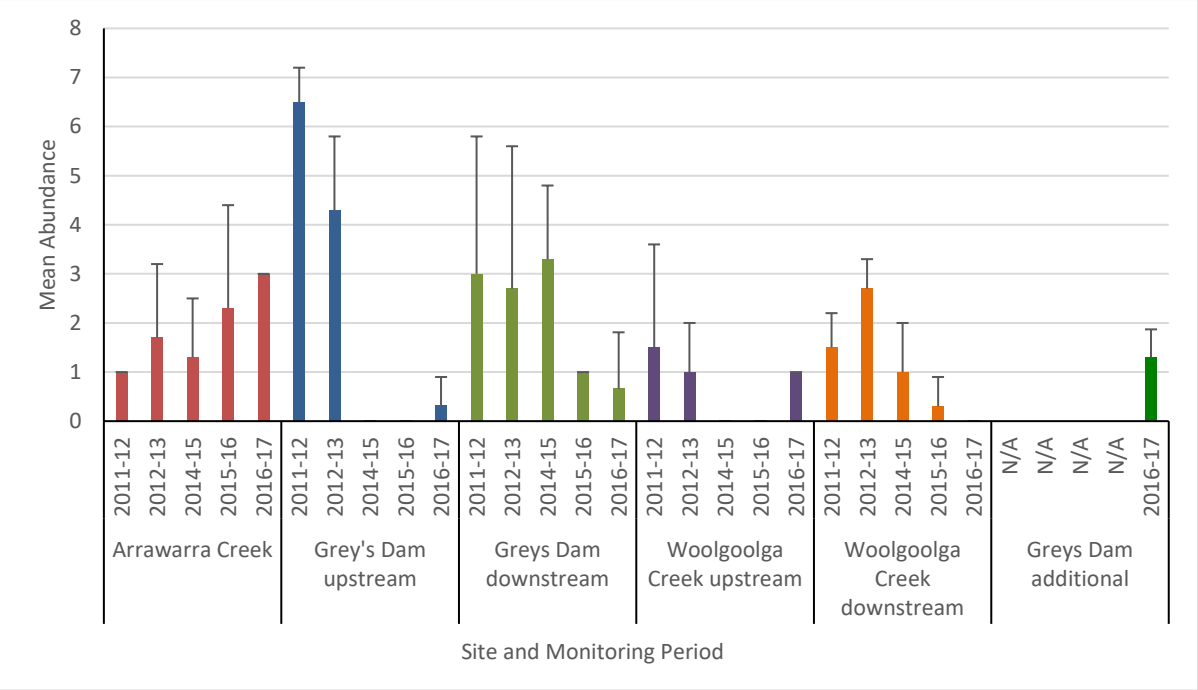

Figure 4: Comparison of giant barred frog mean abundance (+ standard deviation).

4.3 Tadpole Surveys

In 2016/17 giant barred frog tadpoles were recorded at Greys Dam upstream (4 tadpoles) and Greys Dam downstream (1 tadpole). Two of the four tadpoles recorded at Greys Dam upstream were deemed as probable giant barred frog and two as definite. Tadpoles have been consistently recorded at these sites throughout the monitoring period (Figure 5). The developmental stage of captures ranged between stages 25-30 (Plate 4). Tadpoles were captured in November 2016 and June 2017. Importantly, the tadpoles recorded at Greys Dam upstream were captured adjacent to the partially submerged pipe culverts. Tadpole captures from Greys Dam upstream in 2011/12 and 2012/13 occurred in the dam further upstream. Full details of tadpole surveys are provided in Table A2, Appendix A.

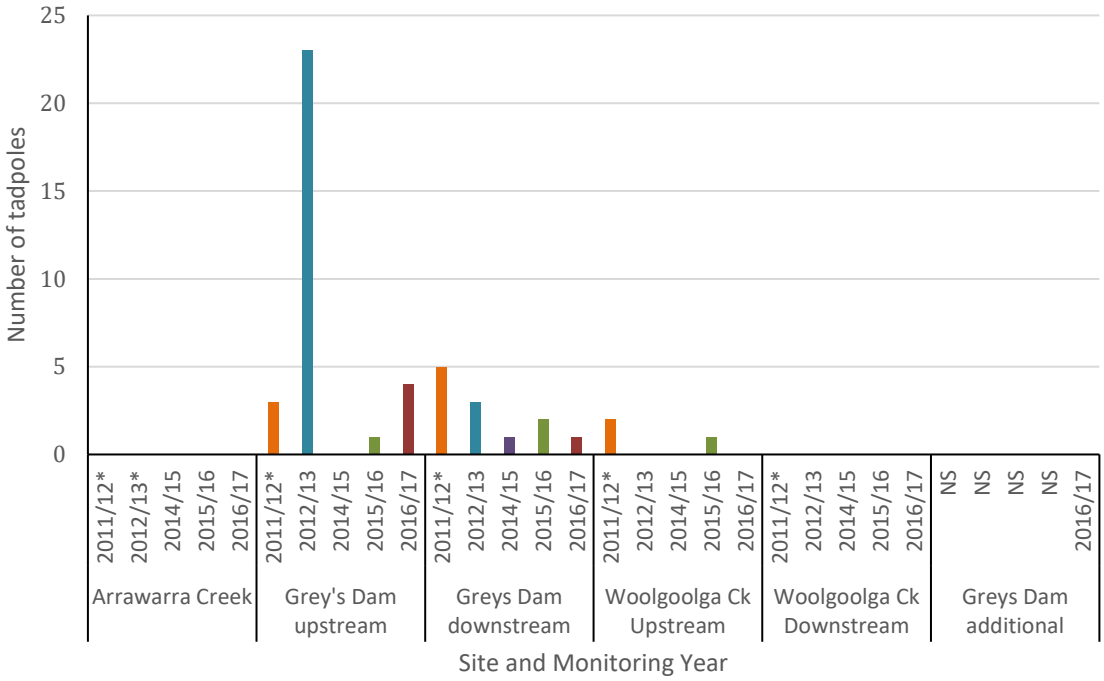

Figure 5: Number of giant barred frog tadpoles captured during five monitoring periods. * 2011/12 = only two sampling events during period.

Plate 4: Giant barred frog tadpole captured at Grey's Dam downstream in June 2017. Total length was 72mm. The approximate development stage was 25-30. Note the high arch and angular spots on the tail fin, which are diagnostic of this species.

4.4 Water Quality Sampling

Overall, the water quality sampling indicated little difference in water quality parameters between upstream and downstream sites and between monitoring events (Table 3). In comparison to the 2015/2016 monitoring period, increased pH levels and decreased temperatures were observed across all sites. This is most likely due to an increase in rainfall prior to and during the 2016/2017 monitoring period compared to the below average rainfall recorded during the previous year.

Previous monitoring events provided a measure of turbidity (water transparency) using a Secchi disk. In 2016/17 water quality monitoring measured total dissolved solids (ppm) and electrical conductivity (µS/cm). Both parameters were observed to be within the normal range for a lowland freshwater stream (ANZECC 2000).

Table 3: Water quality variables recorded at each site during 2016/2017 monitoring.

Sample Site	Date	pH	Temp (C)	TDS (ppm)	Conductivity (µS/cm)
Arrawarra Creek	17/11/2016	6.82	21.1	284	569
	7/03/2017	6.88	23.7	183	360
	28/06/2017	7.3	15.1	138	277
Greys Dam Upstream	18/11/2017	7.15	21.1	238	472
	8/03/2017	6.72	22	148	297
	29/06/2017	7.31	15.6	128	259
Greys Dam Downstream	18/11/2017	7.36	24.9	155	310
	7/03/2017	7.58	23.3	144	288
	29/06/2017	6.32	16.1	120	239
Woolgoolga Creek West	16/11/2017	6.54	23.4	135	270
	8/03/2017	6.54	21.6	180	359
	28/06/2017	7.1	15.1	93.5	187
Woolgoolga Creek East	16/11/2017	6.54	23.4	155	310
	8/03/2017	6.72	22	152	303
	28/06/2017	7.15	17.4	95.2	190
Greys Release	17/11/2017	6.54	19.5	232	448
	7/03/2017	7.36	21.8	136	270
	29/06/2017	6.59	17	151	300

4.5 Revegetation Monitoring

4.5.1 Floristic Composition

The richness of native and exotic plant species showed different trends at disturbed sites (i.e. WCI and GDI) and undisturbed sites (i.e. WCA and GDA). Native species richness was substantially higher at undisturbed sites (Figure 6). Exotic species richness was higher at disturbed sites, particularly at the Grey's Dam sites. At disturbed sites, native species richness peaked in 2015/16 and then declined in 2016/17, whereas exotic species richness showed both slight upward (GDI) and downward (WCI) trends. Undisturbed sites showed downward trends between monitoring years, for both native and exotic species abundance, although the relative differences were small.

The richness of native vine and woody species was greater at undisturbed sites compared to disturbed sites (Figure 7). All sites showed overall downward trends between monitoring years for both native vine and woody species abundance.

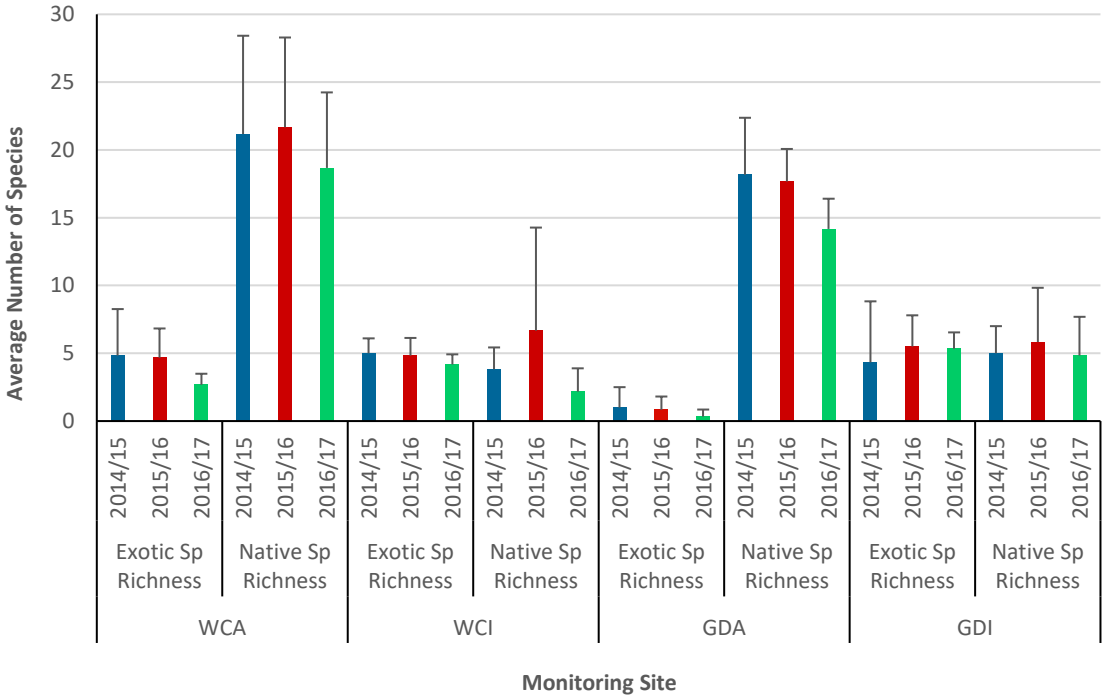

Figure 6: Average number (richness) of native and exotic flora species at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15, 2015/16 and 2016/17 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Grey's Dam undisturbed; GDI=Grey's Dam impacted.

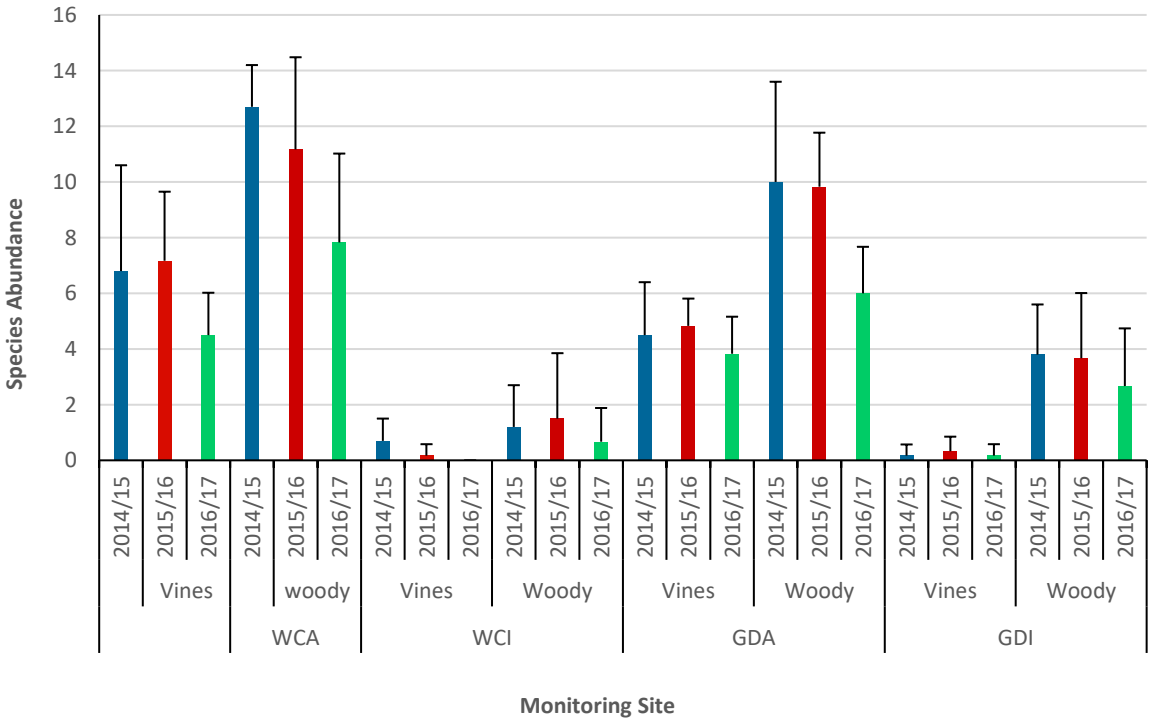

Figure 7: Native vine and woody species abundance at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15, 2015/16 and 2016/17 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Grey's Dam undisturbed; GDI=Grey's Dam impacted.

4.5.2 Vegetation Structure

The projective cover of introduced vegetation was markedly lower within adjacent undisturbed forest areas compared to disturbed riparian areas within the project alignment, whereas the converse was evident for native species (Figures 8 & 9). Cover of introduced species has gradually increased over the monitoring period at impacted sites and stayed the same or declined at undisturbed sites (Figure 8). Results for native species cover has varied between impacted sites (Figure 9). In 2016/17 native cover increased substantially at Greys Dam impact but declined at Woolgoolga Creek impact (Figure 9). At undisturbed sites native species cover increased over the monitoring period at Grey Dam but has fluctuated at Woolgoolga Creek.

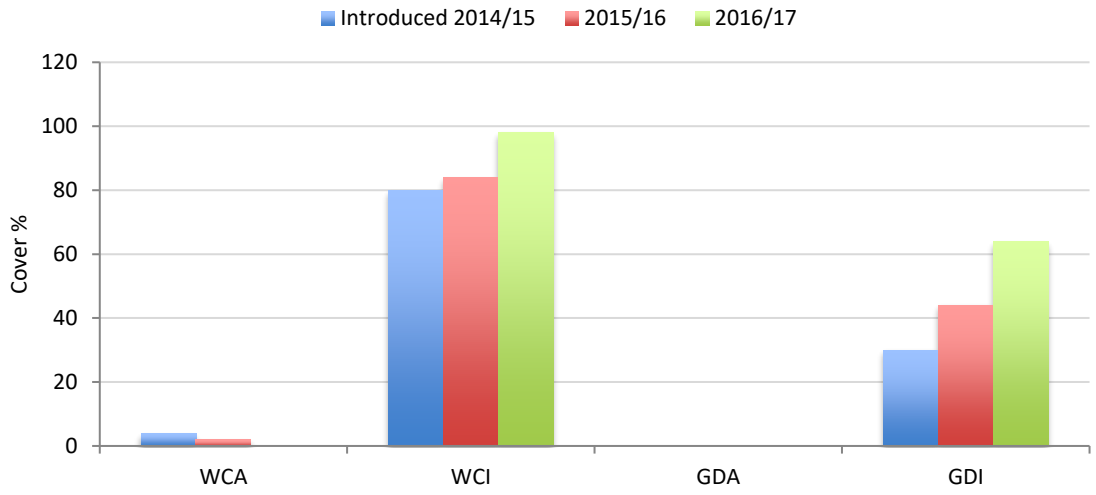

Figure 8: Comparison of Foliage Projective Cover (%) of introduced species at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15, 2015/16 and 2016/17 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Grey's Dam undisturbed; GDI=Grey's Dam impacted.

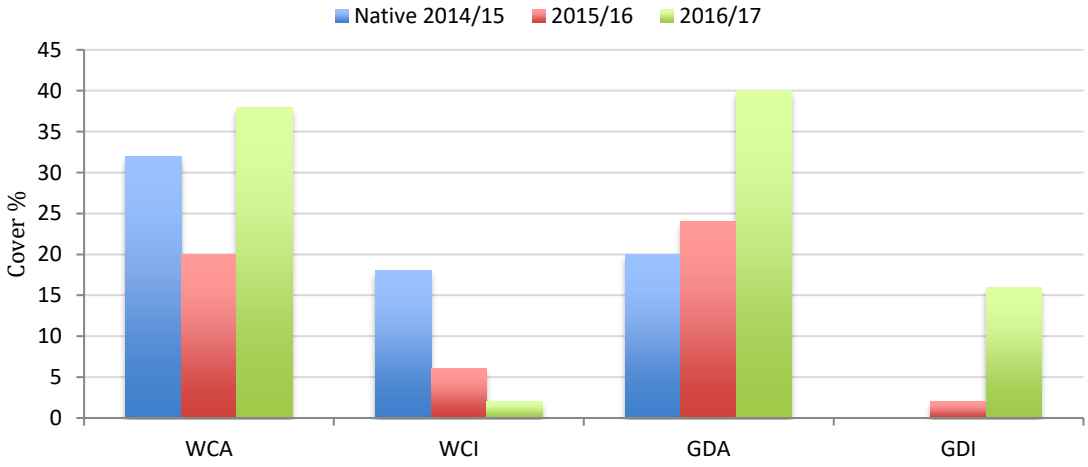

Figure 9: Comparison of Foliage Projective Cover (%) of native species at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15, 2015/16 and 2016/17 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Grey's Dam undisturbed; GDI=Grey's Dam impacted.

Leaf litter cover was markedly greater in undisturbed forest compared to disturbed riparian areas (Figure 10). Litter cover declined at all sites in 2016/17, with no litter recorded at the Woolgoolga Creek impact transects. This result is attributed to the flood event that occurred in late March 2017, prior to the vegetation survey. At Greys Dam undisturbed mulch formed the majority of 'litter' cover and the 2016/17 result indicates that grasses and herbs are gradually covering mulch.

Grass cover was substantially higher at disturbed sites, than undisturbed sites, during all monitoring years, with a slight decline in grass cover evident in 2016/17 (Figure 11). At Greys Dam impact grass cover has declined by 50% over the monitoring period. Grass cover increased slightly at undisturbed sites in 2016/17 but remains below 10% in both areas (Figure 11).

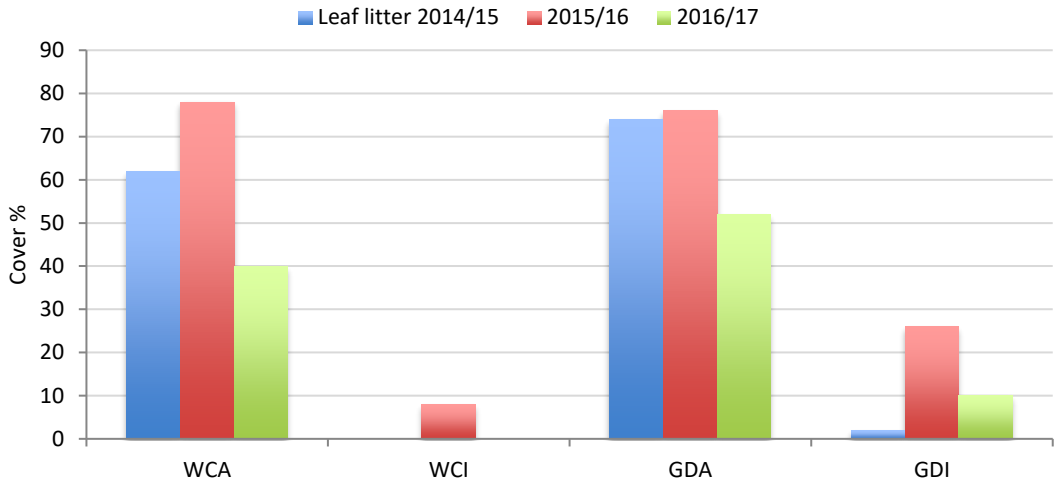

Figure 10: Comparison of Foliage Projective Cover (%) of leaf litter at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15, 2015/16 and 2016/17 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Grey's Dam undisturbed; GDI=Grey's Dam impacted.

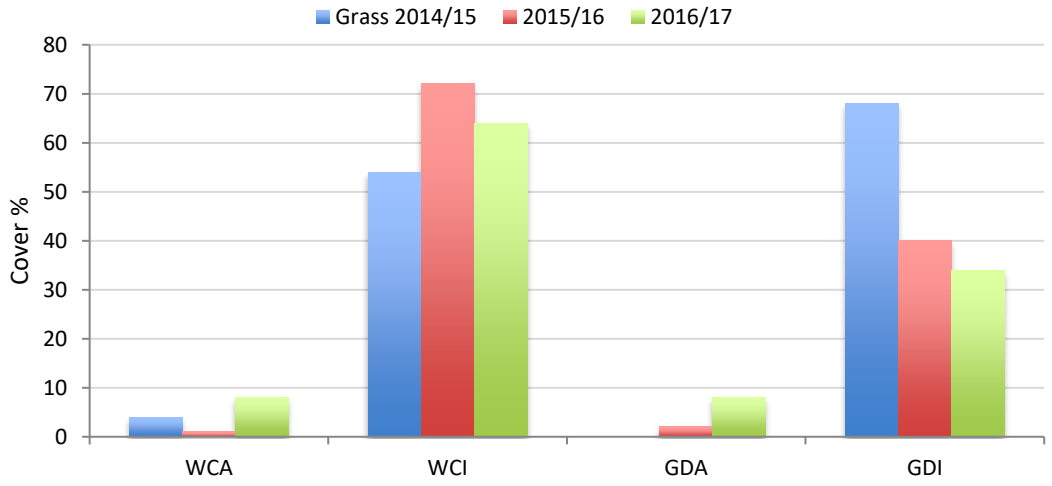

Figure 11: Comparison of Foliage Projective Cover (%) of grasses at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15, 2015/16 and 2016/17 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Grey's Dam undisturbed; GDI=Grey's Dam impacted.

Mean litter depth declined at all sites in 2016/17, although depth has not been measurable at Woolgoolga Creek impact over the monitoring period (Figure 12). The limited extent of litter at that site is attributed to scouring of the banks during flood events.

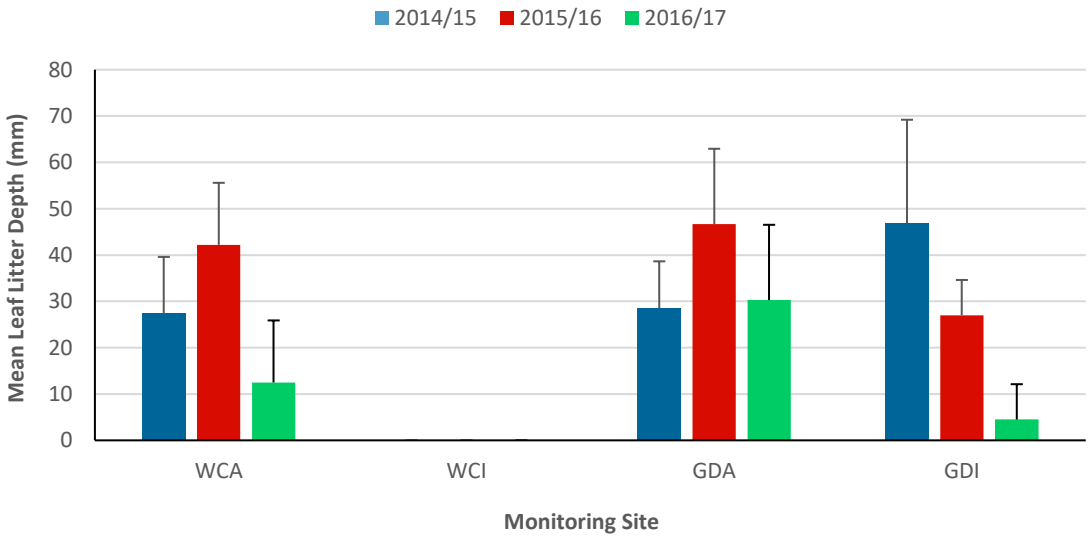

Figure 12: Mean leaf litter depth (mm) at disturbed (impact (I)) sites and undisturbed (control/away (A)) sites during 2014/15, 2015/16 and 2016/17 monitoring years. WCA=Woolgoolga Creek undisturbed; WCI=Woolgoolga Creek impacted; GDA=Grey's Dam undisturbed; GDI=Grey's Dam impacted.

5. Discussion

5.1 Giant Barred Frog Presence/Absence and Abundance

The 2016/17 giant barred frog surveys were typified by mixed results. The Arrawarra Creek site produced relatively high capture rates, including nine captures across the three surveys, resulting in a gradual increase in abundance across the five monitoring periods (2011/12 to 2016/17). At Grey's Dam and Woolgoolga Creek, however, low capture rates largely reflected the downward trend in population abundance at those sites. Some encouraging results in 2016/17 were two adult females at Woolgoolga Creek upstream, one adult male at Greys Dam upstream and one adult male and one adult female at Greys Dam additional. Giant barred frogs were not recorded at Woolgoolga Creek upstream or Greys Dam upstream during 2014/15 and 2015/16 surveys. The result at Woolgoolga Creek upstream is attributed to the inclusion of a small section of a side channel in 2016/17. Without inclusion of the side-channel no frogs would have been recorded at that site.

Greys Dam additional, which is situated immediately downstream of the highway, was sampled for the first time since clearing. The presence of both male and female frogs at that site shows there is an opportunity for breeding and possible dispersal upstream, via culverts. Despite the low number of adults recorded at Greys Dam upstream several tadpoles were recorded in a small pond immediately upstream of the highway. Whilst it is possible that tadpoles have moved upstream from Greys Dam additional breeding is more likely to have occurred onsite. It seems likely that adult frogs continue to reside at Greys Dam upstream albeit in very low numbers.

The number of juvenile frogs and tadpoles recorded in 2016/17 was consistent with previous operational phase surveys but substantially less than construction phase surveys, when breeding conditions were better. Small numbers of juvenile frogs and tadpoles is consistent with surveys in adjacent catchments in 2014 (Lewis 2014). Low juvenile recruitment is probably typical for barred frogs, which tend to be long-lived. Long-lived species with low recruitment tend to also have low levels of adult mortality. The low recapture rates during this study suggest this is not the case in the study area. A combination of high adult mortality and low recruitment in a long-lived species is likely to result in population decline.

Interpreting the apparent decline in giant barred frog abundance at Grey's Dam and Woolgoolga Creek sites should be informed by broader understanding of amphibian population dynamics. That is, frogs mostly exist in meta-populations that feature highly variable sub-populations which can fluctuate greatly over time (Alford & Richards 1999). Typically, populations may experience years of decline punctuated by years of high recruitment when environmental conditions are favourable (Green 2003). Indeed, two populations of Fleay's barred frog (*M. fleayi* - a congener of the giant barred frog) reportedly recovered over a seven-year period after suffering dramatic declines (Newell *et al.* 2013).

Frogs in the Woolgoolga Creek section of the study area, including Greys Dam could be considered a meta-population, with sub-populations around Greys Dam and on Woolgoolga Creek. A range of threatening processes influence frogs in each sub-population. Historically the lower section of the Woolgoolga Creek catchment (i.e. the study area) most likely consisted of several interconnected sub-populations with high abundance at Greys Dam. During clearing for the highway upgrade 30 individual giant barred frogs (23 male and 7 female) were relocated from Greys Dam (BEM 2011). Even assuming some return movement during the six-month construction phase capture period, Greys Dam supported a large breeding population of giant barred frog. In comparison, the largest number of giant barred frogs recorded by Lewis (2014), during targeted surveys between Woolgoolga and Glenugie, was 30 individuals over a 500m section of habitat along the Wooli River.

Prior to highway construction, Greys Dam may have been the primary giant barred frog breeding site in the lower Woolgoolga Creek catchment, with dispersal from that site supporting nearby sub-populations, including areas upstream of the highway. The male biased sex ratio recorded at Grey Dam (during construction) may be an artifact of sampling, as males are easier to detect, but it could also be indicative of a breeding congregation (Stratford *et al.* 2010). The male biased sex ratio continued into the first two years of population monitoring when no females were recorded (BEM 2012; 2013). Despite the absence of female frogs during population surveys the presence of tadpoles in 2012 and 2013 indicates females were present. The abrupt decline in frog abundance at Greys Dam upstream over a period of 18 months (i.e. April 2013 and November 2014) suggests the occurrence of a catastrophic event, or natural dieback of an age-cohort and low recruitment due to isolation. The low incidence of between year recaptures suggests a high mortality rate across the entire study area, which would contribute to a decline in numbers.

Observation at Woolgoolga Creek downstream suggests that abundance of other stream dwelling frogs, such as *Litoria wilcoxii and L. phyllochroa* have also declined over the monitoring period (D. Rohweder pers obs). Habitat at Woolgoolga Creek downstream and Greys Dam downstream looks suitable for giant-barred frogs with both sites having intact riparian zones, permanent pools, and undercut banks. The continued presence of frogs on the

Greys Dam tributary, which includes Greys Dam upstream, Greys Dam additional, and Greys Dam downstream, despite a similar range of obvious threats, suggests that Woolgoolga Creek downstream may be affected by less obvious threats such as pathogens or declining water quality.

Changes in frog abundance during the monitoring period cannot be attributed to a single issue. There appears to a complex interplay of anthropogenic and natural processes that have affected frog abundance in the study area. The ability to tease out key factors is influenced by limitations of the survey design, and specifically the absence of suitable controls.

A decline in abundance in the below average rainfall years since construction is not unexpected. However, it is unlikely that the scale of declines at Woolgoolga Creek downstream and Greys Dam downstream, and upstream are solely attributable to rainfall. The small size of Woolgoolga Creek and the Greys Dam tributary mean these creeks are likely to be more affected by dry conditions than larger systems, such as Corindi River and Wilson Creek where frogs have persisted in narrow riparian strips. The increasing population trend recorded at Arrawarra Creek indicates that rainfall is not the only factor influencing abundance in the study area. Factors contributing to changes in frog abundance over the monitoring period include:

1. Rainfall – Above average rainfall prior to, and during the construction phase most likely enabled frog abundance to increase and the construction phase surveys most likely occurred during a population peak. Below average rainfall in two of the four years since the operational phase may have suppressed recruitment and contributed to lower abundance.

2. Clearing and pesticides – The highway upgrade resulted in clearing of small sections of Woolgoolga and Arrawarra Creeks, and Greys Dam. Greys Dam upstream was under-scrubbed between 2014/15 and 2015/16 surveys.

3. Habitat fragmentation – The highway upgrade has contributed to fragmentation of frog habitat in the Greys Dam tributary and Woolgoolga Creek populations. Movement between separated habitat may be insufficient to maintain populations given the myriad of threatening processes.

4. Disease, pathogens, chemicals – Greys Dam and Woolgoolga Creek sites are subject to threats from new blueberry plantations, and potential transfer of pathogens from pedestrian activity (archery club and Greys Dam) and runoff from roads.

5. Recovery following logging – State forest adjacent to Arrawarra Creek was intensively logged prior to highway construction. Logging may have suppressed frog abundance at that site and the upward trend in abundance recorded over the monitoring period may be due to population recovery.

6. Changes in hydrology – A barrier installed in Woolgoolga Creek upstream of the alignment may contribute to variable stream flow in periods of low-flow. The subject barrier was not part of the S2W upgrade and may have been installed prior to 2011.

5.2 Effect of fragmentation on frog movement

The highway upgrade has isolated sections of Woolgoolga Creek and the Greys Dam tributary. Maintaining connectivity is critical for long-term viability of small populations that experience numerous threatening processes. Habitat beneath the alignment at Woolgoolga Creek is dominated by long grass that would represent a barrier to frogs moving upstream or downstream.

The 2016/17 survey confirmed that giant barred frogs persist upstream and downstream of the highway alignment at Greys Dam. For frogs to move in either direction they need to traverse areas with sparse ground cover and 50m pipe culverts. Movement during rain events is possible (see Sandpiper Ecological 2016) and rehabilitation of ground vegetation near the culvert entrances has improved habitat quality. More work is required to ensure that native ground cover is self-sustaining and links culverts to breeding habitat.

5.3 Effectiveness of Mitigation Measures

5.3.1 Sediment Controls

Water quality sampling recorded similar pH and turbidity levels upstream and downstream of the upgrade corridor indicating that site disturbance associated with the upgrade did not cause any noticeable impact on water quality parameters likely to affect giant barred frogs.

5.3.2 Site Rehabilitation

Site rehabilitation works were conducted during November 2015 at the Grey's Dam disturbed/impact sites. Work included removal of herbaceous weeds, thinning of woody regrowth blocking frog pipe entrances and spreading a layer of wood chip mulch to suppress weed growth/recruitment. The aim of such work was to encourage giant barred frog use of frog pipes to cross the project corridor. The rehabilitation works were evident in the increased cover of leaf litter/mulch/grass at this site in 2015/16 but cover declined in 2016/17 indicating that more work is required.

Rehabilitation work at Woolgoolga Creek (at completion of construction) largely consisted of re-shaping the stream channel after bridge construction, planting of mat rush (*Lomandra histrix*) and placement of some woody debris in the channel. No rehabilitation work appears to have been undertaken since bridge construction. Rehabilitation of the creek banks is required to improve connectivity. Rehabilitation should include removing grass, planting native ground cover (i.e. mat rush), and planting native shrubs.

Disturbed sites demonstrated declines in cover of woody shrubs, vines and overall native species richness. The cover of exotic species also increased substantially between monitoring years (particularly from 2015/16 to 2016/17) at disturbed sites but not at undisturbed sites suggesting rehabilitation has been inadequate. Additional weed control and rehabilitation should endeavour to improve floristic and structural variables to more closely resemble undisturbed forest sites.

6. Conclusion and Recommendations

The aim of giant barred frog population monitoring was to assess presence/absence and long-term viability in areas directly affected by the Upgrade project (BEM 2011). The operational phase monitoring program has confirmed that giant barred frogs persist and continue to breed in parts of the Greys Dam tributary. No evidence of breeding and low frog abundance was recorded in the lower Woolgoolga Creek meta-population of giant barred frog and the long-term viability of frogs along the section of creek immediately upstream and downstream of the highway is questionable. This is attributed to the cumulative effect of several threatening processes. The most appropriate remedial action, available to the Roads and Maritime Service, is to improve connectivity between upstream and downstream sections of Greys Dam and Woolgoolga Creek through weed control and revegetation.

Successive years of above average rainfall may lead to some recovery of the lower Woolgoolga Creek/Greys Dam catchment population but abundance is likely to remain below pre-impact level due to the absence of Greys Dam and number of threatening processes. The small size of Woolgoolga Creek means that frogs may be more affected by prolonged dry periods and severe storm events during the breeding season. In this regard the Woolgoolga Creek population differs to populations along larger watercourses.

Continuation of population monitoring would be useful to confirm population trends. However, due to limitations of the survey design it would be difficult to confirm the factors affecting frog abundance and therefore further population monitoring is not recommended. Recommendations to improve viability of the giant barred frog population in the study area include:

- Continue weed control and infill plantings within disturbed riparian areas of the project corridor adjacent Grey's Dam frog pipes and between Woolgoolga Creek upstream and downstream monitoring sites. Rehabilitation should aim to create a self-sustaining ground cover of native vegetation dominated by mat rush, and a native shrub layer that provides a source of leaf litter.
- Monitoring of frog pipes at Greys Dam should include targeted frog surveys at the upstream and downstream monitoring sites to confirm frog presence and sex ratio. Arrawarra Creek should be included as a reference site.

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Appendix A – Field Survey Data

Table A1: Frog survey data for 2016/17 monitoring period; Observers: DR = David Rohweder, NP = Nick Priest, SR = Sam Rohweder, GM = Greg McDonald; Sex/Age: M = Male, F = Female, J = Juvenile, UK = Unknown; Observation Type: V = Visual, C = Call.

Site	Date	Personnel	Time start	Time end	Mixophyes iteratus No.	Method of detection	Sex	Snout-Vent (mm)	Weight	Micro-habitat	Easting	Northing	Photo No.	Other species
Woolgoolga Creek upstream (WCUS)	15.11.16	DR/NP	2000	2130	Nil									Rough scale snake, Lit. peronii, Lit. tyleri, Lit. fallax
WCUS; captured during tadpole survey	16.11.16	DR/NP	1740		F1	OBS	F	94.2		1.2m from water; within small clump of bl paspalum	516472	6668605		
Woolgoolga Creek downstream	15.11.16	DR/NP	2140	2310	Nil									Lit. willcoxii, Lit. tyleri
Greys Dam downstream (GDD)	16.11.16	DR/NP	2013	2145	J1	OBS	JUV	53.1		Creekbed, lomandra	517045	6668430	yes	Lit. fallax, Ps. coreacea, A. brevis.
					A1	OBS	UK	69.3		3m from Ck, sparse bl paspalum	517059	6668646	yes	
GDD recorded during tadpole survey but not captured	17.11.16	DR/NP	1535		unid	OBS	UK	nr		Scattered grass & lomandra, 0.5m from water	517069	6668649	no	
Arrawarra creek	16.11.16	DR/NP	2205	2350	A2	OBS	UK	74.2		Leaf litter; 3.5m from Ck	517523	6673946		Lim. Peronii
					F2	OBS	F	92.2-95.1		Beneath leaves; 15m from Ck	517384	6673919		
					F3	OBS	F	107.0		Leaf litter; 10m from Ck	517417	6673928		

Site	Date	Personnel	Time start	Time end	Mixophyes iteratus No.	Method of detection	Sex	Snout-Vent (mm)	Weight	Micro-habitat	Easting	Northing	Photo No.	Other species
Greys Dam upstream	17.11.16	DR/NP	1950	2210	Nil									Lit. tyleri, Lit. peronii, A. brevis, Lit. wilcoxii, Lit. fallax,
Greys dam additional	17.11.16	DR/NP	2120	2250	M1	OBS	?	78.4		Leaf litter, open ground layer, 3m from water	517120	6668171	yes	
Greys Dam downstream	6.3.17	DR, NP, SR	2000	2130	Nil									nil
Arrawarra Creek	6.3.17	DR, NP, SR	2205	23.35	M2	Call	M	nc		Crk bank	517542	6673902		Lim. peronii, M. fasciolatus
	6.3.17		2245		F4	OBS	F	100	125	Leaf litter; 10m from water	517400	6673914		
	6.3.17		2245		M3	Call	M	nc		Ck bank	20m us			
Woolgoolga Creek upstream	7.3.17	DR, NP, SR	1945	2110	F5	OBS	F?	90.5	96	5m from water in mod paspalum	516456	6668593		Ps. coreacea, Lit wilcoxii
					F5 Captured at same site during tadpole									
Woolgoolga Creek downstream	7.3.17	DR, NP, SR	2120	2240	Nil									Lit peronii.
Greys Dam upstream	8.3.17	DR, NP, SR	1947	2055	Nil									A. brevis, Lit fallax, Lit wilcoxii
Greys Dam additional	8.3.17	DR, NP, SR	2105	2220	M1	Call	M	78.4	60	Beneath fern, 2m from water, dam wall	517104	6668175		Lit. fallax, Lit. peronii
Woolgoolga Creek downstream	29.3.17	NP/GM	1925	2055	Nil									
Woolgoolga creek upstream	29.3.17	NP/GM	2058	2240	F1	OBS	F	96	117.5	6m from Crk, amongst leaf litter	538454	6800614		M. fasciolatus

Site	Date	Personnel	Time start	Time end	Mixophyes iteratus No.	Method of detection	Sex	Snout-Vent (mm)	Weight	Micro-habitat	Easting	Northing	Photo No.	Other species
Greys Dam downstream	29.3.17	NP/GM	2300	0030	Nil									
Greys Dam upstream	4.4.17	NP/GM	2030	22:00	M1	OBS	M	86.8	80.5	2m from NE edge of dam, amongst leaf litter	517032	6667985		M. fasciolatus
Greys Dam additional	4.4.17	NP/GM	22:08	2340	F1	OBS	F	104.9	133, poss. gravid	4m from dam, under forested edge	517108	6668169		Lit. fallax
					M1	Call	M	83.3	66	2m from dam, on path	517124	6668187		Lit. fallax
Arrawarra Creek	5.4.17	NP/GM	1830	2035	J1	OBS	J	48.4	12	3m from Crk, on exposed soil	517506	6673916		
					F1	OBS	F	94.5	101	9m from Crk, up steep bank	517531	6673949		
					F2	OBS	F	105	164	10m from creek, up steep bank	517536	6673946		

Table A2: Tadpole survey data for 2016/17 monitoring period. Observers: DR = David Rohweder, NP = Nick Priest, SR = Sam Rohweder

Site	Date	Personnel	Time start	Time end	Dip netting				Comments
					Tadpole No.	Length (mm)	Stage	Photo No	
Woolgoolga Creek downstream	16.11.16	DR & NP	1500	1600	0				
Woolgoolga Creek upstream	16.11.16	DR & NP	1630	1730	0				
Greys Dam downstream	17.11.16	DR&NP	1445	1545	0				
Arrawarra Creek	17.11.16	DR&NP	1630	1735	0				
Greys Dam upstream	18.11.16	DR&NP	1030	1145	1 x M. iteratus	67.8	25	yes	
					1 x M. iteratus	93.9	25	yes	
Greys Dam additional	18.11.16	DR&NP	1205	1300	Lit fallax, Lit. peronii				
Greys Dam additional	7.3.17	DR, NP, SR	1255	1335	Lit fallax, Lit spp.				
Greys Dam downstream	7.3.17	DR, NP, SR	1410	1505	Nil				
Arrawarra Creek	7.3.17	DR, NP, SR	1535	1620	Nil				
Woolgoolga Creek upstream	8.3.17	DR, NP, SR	1215	1320	Nil				
Woolgoolga Creek downstream	8.3.17	DR, NP, SR	1330	1425	Nil				
Greys Dam upstream	8.3.17	DR, NP, SR	1500	1605	Nil				
Arrawarra Creek	28.6.17	NP, SR	1109	1220	1x Mixo sp.	40mm	25-30	1148	Prob M. fasciolatus
Woolgoolga Creek downstream	28.6.17	NP, SR	1309	1415	Nil				
Woolgoolga Creek upstream	28.6.17	NP, SR	1525	1625	Nil				

Site	Date	Personnel	Time start	Time end	Dip netting				Comments
					Tadpole No.	Length (mm)	Stage	Photo No	
Greys Dam upstream	29.6.17	BP, SR	0735	0940	1 x M. iteratus (prob)	60mm	25-30	9.09am	
					1 x M. iteratus (poss)	45mm	25-30	9.12am	
					1 x M. fasciolatus	62mm	25-30	9.14am	Prob M. fasciolatus
					1 x M. fasciolatus	47mm	25-30	9.17am	Prob M. fasciolatus
					1 x M. fasciolatus	51mm	25-30	9.20am	Prob M. fasciolatus. Tail looks longer and slender, blotches not as marked.
					1 x M. fasciolatus	35mm	25-30	9.24am	Prob M. fasciolatus, longer slender tail and pale blotches.
					1 x M. fasciolatus	65mm	25-30	9.39am, 9.43am	M. fasciolatus.
					1 x M. fasciolatus	45mm	25-30	9.39am, 9.43am	Prob M. fasciolatus.
Greys dam additional	29.6.17	NP, SR	1015	1130	Nil				
Greys Dam downstream	29.6.17	NP,SR	1156	1300	1 x M. iteratus	72mm	25-30	1221 pm	Large, very golden. Caught DS 5m from deep pool where GBF recorded.

Pacific Highway Upgrade – Sapphire to Woolgoolga

Operational Phase Fauna Monitoring Year 3 – Greys Dam Frog Pipes

Sandpiper Ecological

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Version 2 – Final Report

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Cover Photo: *Mixophyes iteratus* photographed by a white-flash camera inside the west end of the north pipe (21 March 2017).

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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. The final version (version 3) was completed in February 2014 (BEM 2014).

The updated EMP included an operational phase requirement to monitor dedicated frog pipes, located at Grey's Dam, for use by giant barred frogs (*Mixophyes iteratus*) as part of project-wide population monitoring of that species. The giant barred frog is listed as endangered by the NSW *Threatened Species Conservation Act 1995* (TSC Act) and Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Annual giant barred frog population monitoring has been undertaken between October and April for the first three years of the operational phase (Sandpiper 2015, 2016, unpublished data).

1.1 Background

In January 2015, Roads and Maritime Services NSW (RMS) contracted Sandpiper Ecological Surveys (Sandpiper) to conduct year one operational phase monitoring of fauna mitigation measures and to assess their effectiveness. The contract was based on a monitoring proposal submitted by Sandpiper in early 2014 and subsequently accepted and approved by RMS (Sandpiper 2014a). Sandpiper was subsequently contracted by RMS to conduct year two and three operational monitoring in October 2015.

Due to delays in awarding of initial contracts and the time required to source and supply equipment to monitor frog pipes at Grey's Dam, year one monitoring was not undertaken. Year 2 frog pipe monitoring was completed from November 2015 to April 2016 (Sandpiper 2016a).

The following report presents results of year three operational phase frog pipe monitoring conducted between October 2016 and May 2017. The results are compared with year two results and discussed in relation to performance indicators detailed in the EMP (BEM 2014). The report concludes with several management recommendations.

2. Study Area and Site Features

Two dedicated frog pipes were located at chainage 24600, approximately 50m north of Grey's Road and 2km west of Woolgoolga (Figure 1. The frog pipes were each 1050mm diameter reinforced concrete (RC) and extended under the highway for 55m (south pipe) and 56m (north pipe). Pipes were perpendicular to the highway and oriented in a south-west to north-east direction (Plates 1-4; Figure 2). Pipe inlets/outlets were fronted by a short head-wall and up to 2m-wide wing-walls (Plate 3). Frog exclusion fence (1200mm high) extended either side of each pipe for up to 20m beyond wing-walls (Plate 5). The floor/invert of each pipe was covered by a layer of mulch 50-100mm thick designed to retain moisture and encourage frog movement (Plate 5). Pipe inlets (i.e. west side) were positioned either side of, and approximately 10m from, a 4m-wide creek-line. The creek contained permanent water, which fed into a quad-cell RC pipe array. Pipe inlets featured an open drain approximately 10m to the west which sloped down to the creek (Plate 1 & 2). On the eastern side, pipe outlets were 5-10m from Grey's Dam which featured deep, permanent water. The dedicated pipes were approximately 30m apart.

Adjoining habitat beyond the 20-40m-wide highway construction footprint was largely riparian and moist open forest. The construction footprint area featured natural regrowth and was planted with a variety of native trees and shrubs, particularly mat rush (*Lomandra longifolia*), an important plant species associated with giant barred frog habitat (Lewis & Rohweder 2005) (Plates 1-4). Plantings extended up to the pipe outlets to encourage frog access. Weed control and infill plantings were carried out by bush regenerators in November 2015 and February 2017 and included spreading a 100mm-thick layer of mulch around the pipe outlets. As at July 2017, the restoration works were progressing satisfactorily around the west entrances apart from a light infestation of the weed cobbler's pegs (*Bidens pilosa*) around the south-west entrance (Plate 1 & 2). Infill plantings had largely failed around the south-east entrance and heavy exotic grass infestation was still evident around the north-east entrance (Plate 3 & 4).

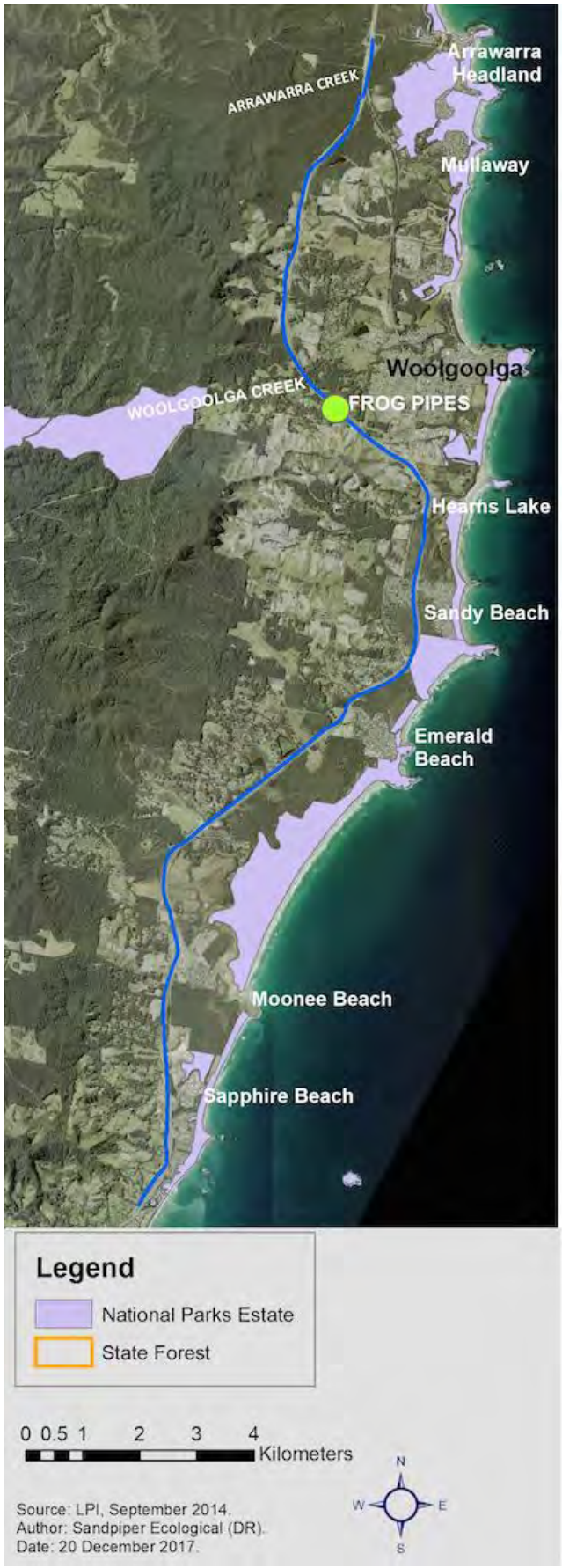

Figure 1: Location of Grey's Dam frog pipes (chainage 24600) along the S2W upgrade.

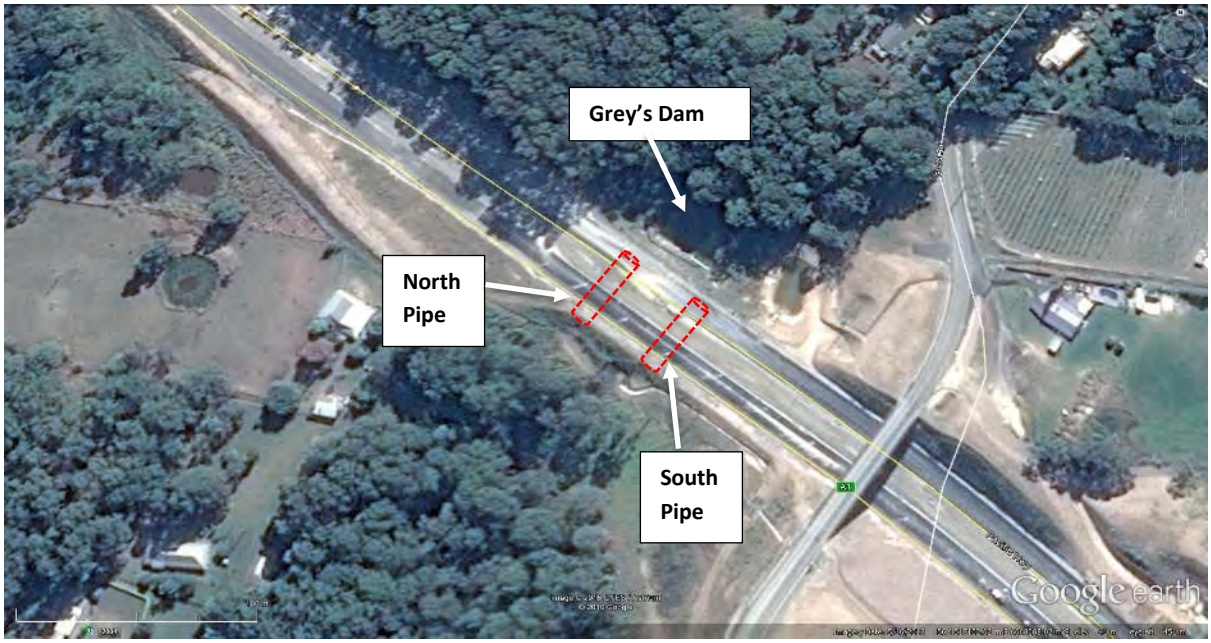

Figure 2: Position of frog pipes at Grey's Dam

Plate 1: Habitat surrounding south-west frog pipe. (Picture taken 6 July 2017).

Plate 2: Habitat surrounding north-west frog pipe. (Picture taken 6 July 2017).

Plate 3: Habitat surrounding south-east frog pipe. (Picture taken 6 July 2017).

Plate 4: Habitat surrounding north-east frog pipe. The frog exclusion fence can be seen extending off the wing walls. (Picture taken 6 July 2017).

3. Methods

3.1 Monitoring pipe usage

Monitoring cameras were installed on 20 October 2016 on the pipe obverts (crowns) on mounting points established in the previous monitoring year. Camera mounting points were each approximately 5m from and facing the outlet. Cameras were labelled according to pipe location (north or south) and road side (i.e. east or west). Reconyx HC550 white flash cameras (i.e. photographs in colour) were used on the west side and Reconyx SC950 infra-red flash cameras (i.e. photographs in colour by day, black & white at night) used on the east side.

Cameras were set on time-lapse mode and programmed to take a picture each minute between 1800 and 0500 hours, the primary period of frog activity. Cameras were checked at three-week intervals during which SD cards and lithium batteries were replaced.

Cameras were operational for 190-195 days (27-28 weeks) and decommissioned on 4 May 2017 (Table 1). During this period, the four cameras recorded 514 010 photographs. Three cameras were active for 100% of the period and one camera (NE camera) was active for 97.4% of the monitoring period (Table 1). The NE camera suffered early battery fatigue on one occasion resulting in loss of five days of monitoring. Full details of monitoring effort are provided in Table A1, Appendix A.

Table 1: Grey's Dam frog pipes monitoring effort.

Camera Position	Pictures	Days Active	% Monitoring Period Active
NE	126 082	190	97.4
NW	129 208	195	100
SE	129 360	195	100
SW	129 360	195	100

3.2 Photo analysis

All photographs were uploaded to a computer and viewed using Windows Photo Viewer. Photographs were reviewed by an ecologist, and identification was based on experience, reference to standard field guides (i.e. Tyler & Knight 2009; Swan et al. 2004; Barker et al. 1995; Van Dyck et al. 2013), field guide Apps (i.e. Wilson & Swan 2012; Hoskin et al. 2015) and advice from senior ecologists. Multiple ecology staff reviewed photographs featuring fauna that was difficult to identify until a consensus on identification was reached.

A hierarchical approach was adopted to species identification that included: species, genus or group. Data recorded during analysis included: site, date, time, species, accuracy (definite (90%+ certainty), probable (75-90% certainty), possible (60-75% certainty)), movement direction (east or west), image numbers and crossing likelihood. Another feature recorded, where possible, were 'disturbance trails'. Disturbance trails were observable trails in consecutive time-lapse images created by animal

movement through the mulch. For example, species such as echidnas showed clear, continuous trails, whereas macropods and bandicoots exhibited discontinuous/hopping trails. Recognition of disturbance trails assisted in determining both presence and direction of animal movement. Movement trails were obvious when scanning through sequential images.

Determining the likelihood of a completed crossing was assessed according to criteria described in Table 2. All detections of microbat species were scored as possible crossings due to the often-unpredictable nature of movement.

Table 2: Criteria used to determine crossing type.

Crossing Type	Criteria
Definite	An animal of the same species was photographed at both ends of a pipe moving in the same direction (within 30 minutes for mammals and 60 minutes for reptiles and frogs),
	An animal was photographed making directional movement at one end and a proportionally sized disturbance trail showing the same directional movement and pattern was detected at the other end within 30 minutes
Probable	An animal was photographed showing strong directional movement into a pipe but not detected at the other end and not photographed exiting the same entry end
	A disturbance trail in one direction was detected at both ends within 30 minutes (unidentified animal)
Non-crossing movements	Animals photographed at a pipe entrance but not displaying any strong directional movement or that entered, turned around and exited the pipe were regarded as unlikely crossings

Use of a 30-minute timeframe for determining crossings when a disturbance trail was detected reduced the likelihood of double-counting. Disturbance trails were largely a feature of crossing movement by mammals, particularly those the size of a bandicoot and larger. Such animals were relatively fast moving and generally completed crossings in less than 15 minutes. Reptiles and frogs generally took 20-30 minutes and occasionally up to 60 minutes to complete a crossing but mostly left undetectable trails.

4. Results

4.1 Pipe usage

Camera monitoring of the Grey's Dam frog pipes during the 2016/17 monitoring period revealed 220 definite crossings, 294 probable crossings and 190 possible crossings by fauna (Table 2, 3 & 4; Plates 5-11). A further 139 detections were scored as non-crossing movements. More crossings were detected in the south pipe (435) compared to the north pipe (399).

Twenty-eight fauna species were identified and a further 12 genus/groups. Three groups of unidentifiable animal trails were recorded, small, medium and large. Species diversity was greatest amongst mammals (16 spp.) followed by reptiles (9 spp.) and amphibians (6 spp.).

4.2 Pipe use by giant barred frogs and other frog species

Giant barred frog was detected on one occasion during the 28 weeks of monitoring (Table 3). The individual was photographed <1m inside the west end of the north pipe at 12:37am on 21 March 2017 (Plate 5). The individual appeared to enter the pipe and exit soon after which suggests a crossing was highly unlikely. Another non-crossing movement by a barred frog sp. (giant or greater barred frog) was recorded on 17 March. The individual could not be positively identified to species level.

Striped marsh frog (*Limnodynastes peroni*) and eastern stony creek frog (*Litoria wilcoxii*), both regarded as medium-sized frogs, were recorded completing pipe crossings (Table 3). The striped marsh frog made five definite and one probable crossing of the north pipe and one definite and two probable crossings of the south pipe. The eastern stony creek frog was recorded making 10 definite and five probable crossings of the south pipe (Plate 6). Another medium-sized frog, the graceful tree frog (*Litoria gracilenta*), was recorded making a non-crossing movement of the south pipe on one occasion (Table 3).

Un-identifiable frogs were assigned to one of three size categories: small (<30mm), medium (30-70mm) and large (>70mm). Medium sized frogs were recorded completing seven probable and two possible crossings. Identification of small frogs, particularly to species level, was difficult because of their size and grainy image resolution. Small frogs recorded during monitoring were mostly ground and fossorial species of low-mobility. Probable species were red-backed toadlets (*Pseudophryne coriacea*) and species of the genus *Uperoleia.* It was decided not to record the movements of small frogs unless there was evidence of strong directional movement into a pipe. Photo records showed almost daily movement of one to two individual small frogs entering the pipe at pre-dawn and burrowing under the mulch within a meter of the entrance then emerging at dusk and exiting the pipe. No occasions of directional movement to suggest a crossing were observed.

Table 3: Frog species and taxa groups detected by pipe cameras and crossing likelihoods. Def = Definite; Prob = Probable; Poss = Possible; NCM = Non-crossing Movement; NR = not recorded.

Common Name	Species Name	North Pipe Detections	Crossing likelihood				South Pipe Detections	Crossing likelihood			
			Def	Prob	Poss	NCM		Def	Prob	Poss	NCM
Giant Barred Frog	*Mixophyes iterates*	1				1	0				
Barred Frog	*Mixophyes* spp.	1				1	0				
Striped Marsh Frog	*Limnodynastes peronei*	9	5	1		3	3	1	2		
Eastern Stony-creek Frog	*Litoria wilcoxii*	1				1	22	10	5		7
Graceful Tree Frog	*Litoria gracilenta*	0					1				1
Medium Frog		5		1	1	3	10		6	1	3
Small Frog		Frequent				NR	Frequent				NR
Totals		17	5	2	1	9	36	11	13	1	11

Plate 5: Giant barred frog (red circle) was detected on one occasion, inside the west end of the north pipe. It did not display any directional movement and a full crossing is considered unlikely.

Plate 6: A stony-creek frog (red circle) photographed moving east at the west end of the south pipe. The same individual was photographed 31 minutes later exiting the east end.

4.3 Pipe use by other fauna

4.3.1 Pipe use by reptiles

At least nine reptile species were detected in the frog pipes (Table 4). Carpet python (*Morelia spilota*) and golden-crowned snake (*Cacophis squamulosus*) were both recorded completing crossings of both pipes (Plate 7). Eastern water dragon (*Intellagama leseurii*) and southern dwarf crowned snake (*Cacophis krefftii*) were recorded making probable crossings (Plate 8). Several other species, including eastern small-eyed snake (*Cryptophis nigrescens*) and bandy-bandy (*Vermicella annulata*) were recorded making non-directional movements (Plate 8). A total of 51 detections were made during the monitoring period (Table 4).

Table 4: Reptile species and taxa groups detected by pipe cameras and crossing likelihoods. Def = Definite; Prob = Probable; Poss = Possible; NCM = Non-crossing Movement

Common Name	Species Name	North Pipe Detections	Crossing likelihood				South Pipe Detections	Crossing likelihood			
			Def	Prob	Poss	NCM		Def	Prob	Poss	NCM
Carpet Python	*Morelia spilota*	12	5		1	6	6	2	1		3
Eastern Small-eyed Snake	*Cryptophis nigrescens*	2				2	1				1
Golden Crowned Snake	*Cacophis squamulosus*	1	1				3	1	1		2
Southern Dwarf Crowned Snake	*Cacophis krefftii*	3		2		1	2				2
Bandy bandy	*Vermicella annulata*	3				3	0				
Snake spp.		3			1	2	5			1	4
Eastern Water Dragon	*Intellagama lesueurii*	6		2	1	3	1				1
Dragon sp.	*Agamidae spp.*	0					1		1		
Three-clawed Worm Skink	*Anomalopus verreauxii*	0					1				1
Land Mullet	*Bellatorias major*	0					1		1		
Totals		**30**	**6**	**4**	**3**	**17**	**21**	**3**	**4**	**1**	**14**

Plate 7: A carpet python (L) and a golden-crowned snake (R) moving east in the north pipe.

Plate 8: The north pipe featured more reptile detections, including eastern small-eyed snake (L) and eastern water dragon (R).

4.3.2 Pipe use by mammals

Mammals were the most diverse group of pipe users with 16 species/groups recorded (Table 5). Long-nosed bandicoot (*Perameles nasuta*) was the most frequent user (98 definite crossings; Plate 9) followed by echidna (*Tachyglossus aculeatus*) (24 definite crossings). Other native species confirmed making definite and/or probable crossings included common brushtail possum (*Trichosurus vulpecula*), bush rat (*Rattus fuscipes*), swamp rat (*Rattus lutreolus*), brown Antechinus (*Antechinus stuartii*), swamp wallaby (*Wallabia bicolor*) and red-necked wallaby (*Macropus rufogriseus*) (Plate 9 & 10; Table 5). Microbats were observed in photographs on numerous occasions but due to their erratic flight patterns they were not assigned to a movement category. The only positive species identification was eastern horseshoe bat (*Rhinolophus megaphyllus*).

Introduced mammals, including black rat (*Rattus rattus*), house mouse (*Mus musculus*), and cat (*Felis catus*) were recorded making definite and/or probable crossings (Table 5). Cats were recorded making 16 definite and/or probable crossings of the two pipes (Plate 11). Red fox (*Vulpes vulpes*) was detected making non-crossing movements on two occasions at the south pipe (Plate 11).

Table 5: Mammal species and taxa groups detected by pipe cameras and crossing likelihoods. Def = Definite; Prob = Probable; Poss = Possible; NCM = Non-crossing Movement

Common Name	Species Name	North Pipe Detections	Crossing likelihood				South Pipe Detections	Crossing likelihood			
			Def	Prob	Poss	NCM		Def	Prob	Poss	NCM
Long-nosed Bandicoot	*Parameles nasuta*	63	36	16	1	10	88	62	22		4
Northern Brown Bandicoot	*Isoodon macrourus*	7	3	1	1	2	8	5	2		1
Bandicoot	*Paramelidae* spp.	14	11	2		1	21	15	3	2	1
Short-beaked Echidna	*Tachyglossus aculeatus*	21	14	4	2	1	12	10		1	1
Common Brushtail Possum	*Trichosurus vulpecula*	4		2		2	3				3
Black Rat	*Rattus rattus*	40	10	16	7	6	28	7	12	4	5
Bush Rat	*Rattus fuscipes*	4	1	1	1	1	0				
Swamp Rat	*Rattus lutreolus*	3		2		1	3		2	1	
Rat	*Rattus sp.*	3		3			2		1		1
Rodent	*Rodentia* spp.	6	2	4			5		4	1	
House mouse	*Mus musculus*	2		1	1		0				
Brown Antechinus	*Antechinus stuartii*	10	1	3		6	2		1		1
Eastern Grey Kangaroo	*Macropus giganteus*	3				3	2			1	1
Eastern Horseshoe Bat	*Rhinolophus megaphyllus*	4			4		1			1	
Microbat	*Microchiropteran* spp.	Frequent					Frequent				
Swamp Wallaby	*Wallabia bicolor*	5			1	4	5	1			4
Red-necked Wallaby	*Macropus rufogriseus*	1	1				2	2			
Small mammal		4	1	2	1		4	2	1	1	
Medium mammal		2	2				4	2	2		
Red Fox	*Vulpes vulpes*	0					2				2
Cat	*Felis catus*	14	2	5	1	6	11	5	4		2
Small trail of UnID animal		50		23	24	3	48		12	34	2
Med trail of UnID animal		88		48	37	3	120		67	52	1
Large trail of UnID animal		4		2	2		6		3	3	
Totals		**352**	**84**	**135**	**83**	**49**	**377**	**111**	**136**	**101**	**29**

Plate 9: Long-nosed bandicoot was the most frequent user of the frog pipes, including recording 36 definite crossings of the north pipe (L). Infrequent users, such as brown Antechinus, was recorded making one definite crossing of the north pipe (R).

Plate 10: A swamp wallaby exits after completing a crossing of the south pipe (L). A common brushtail possum is seen entering the east end of the north pipe (R).

Plate 11: Cats were detected making crossings of both pipes (L) whereas red fox was only recorded twice at the south pipe making non-crossing movements (R).

4.4 Comparison between monitoring periods

A comparison of detections by fauna group between monitoring periods showed mixed results (Figure 2). Frog detections dropped from 8.5/week in 2015/16 to 1.9/week during 2016/17. Reptile detections also dropped between the two periods from 3.2 to 1.8 detections/week. Conversely, mammal detections rose between the periods from 11.3 to 14.6 detections/week.

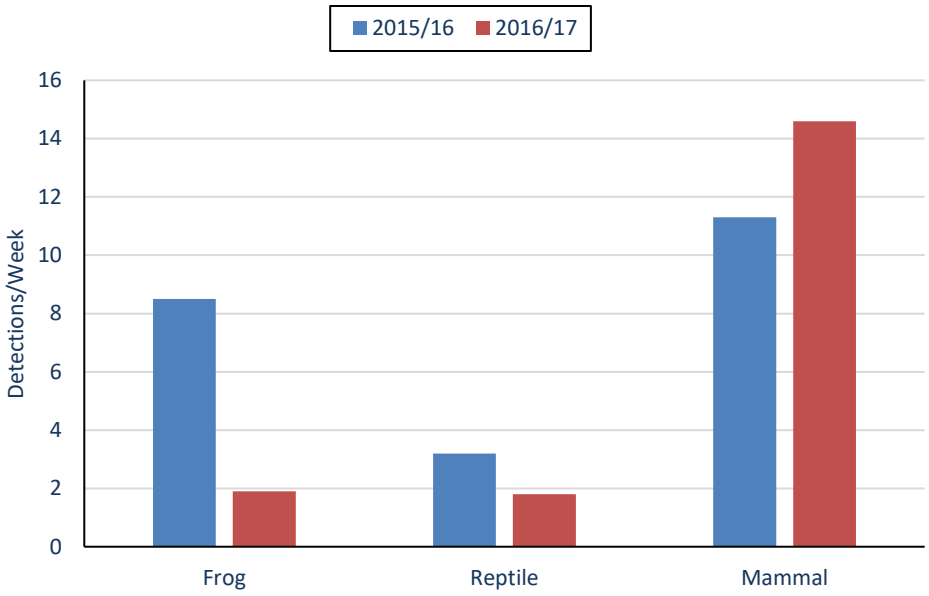

Figure 3: Weekly fauna detections by fauna group. Detections are pooled for all four cameras and converted to a weekly rate to control for differences in survey effort. Microbat detections were not included. 2015/16 data from Sandpiper (2016).

5. Discussion

5.1 Pipe use by giant barred frog and other frog species

Reconnecting frog populations severed by large road corridors has proven challenging, particularly as frogs are rarely reported using fauna box culverts (e.g. AMBS 2002; Taylor & Goldingay 2003). Most reported records of frogs using box culverts are associated with wet conditions, such as wetlands (see Gilmore & Koehler 2014). On the Pacific Highway upgrade at Nambucca to Urunga Pacific Highway, several hylid/tree frogs were observed within box culverts after heavy rainfall, though complete crossings could not be confirmed (Sandpiper 2015). Both *Crinia signifera* and *C. parinsignifera* have been recorded in flooded culverts on the Glenugie section of the Pacific Highway Upgrade (Sandpiper Ecological 2017).

At the S2W frog pipes, no crossings by giant barred frog or greater barred frog (common congener) were recorded during the 2016/17 period. This contrasts with a probable crossing by a giant barred frog (north pipe) and one definite (south pipe) and one probable crossing (north pipe) by *Mixophyes* spp (possibly giant barred frog) during 2015/16 monitoring. Importantly, crossings recorded during the previous period suggest that giant barred frogs are not behaviourally averse to moving through a

55m-long, mulch-line pipe linking known habitat. Such information advances our understanding of using engineered crossing structures to reconnect upstream and downstream populations. Confirmed crossings by at least two other medium-sized frog species (i.e. striped marsh frog and eastern stony-creek frog) further demonstrate the applicability of this form of mitigation for a variety of medium to large ground-dwelling frog species. The lack of confirmed crossings by small frogs (i.e. <30mm) suggests that movements through such structures by frogs of this size class may be infrequent or only triggered by large rain events. Both monitoring periods featured below average rainfall. This is discussed further below.

As discussed in the year two report, several factors are likely constraining the scale of giant barred frog use and access to the Grey's Dam frog pipes. Firstly, giant barred frogs are largely cover-dependent and prefer a closed sub-canopy with reasonably dense ground vegetation, notably mat rush (*Lomandra longifolia*) and dense leaf litter to move within (Lewis & Rohweder 2005). Revegetation and weed control of the construction footprint around the frog pipes has only occurred during the past two to three years and may take up to five years to establish. Moreover, the east entrance areas continue to suffer from significant weed incursion by a range of exotic grasses and the mat-forming ground cover Singapore daisy (*Spagneticola trilobata*). Further weed control and infill plantings is required to improve habitat quality and facilitate giant barred frog movement.

Secondly, giant barred frog abundance upstream and downstream of the site is both small and variable. Operational phase giant barred frog population monitoring has been conducted at two sites (three sites in 2016/17), upstream and downstream of the highway since 2011/12 (Sandpiper 2016b; 2018). The upstream monitoring site is approximately 20m from the western entrance to the pipes and has documented variable results. In the first two monitoring seasons (i.e. 2011/12 and 2012/13) up to seven individuals, all male, were recorded. During 2014/15 no frogs were recorded and during the 2016/17 season one was recorded. Habitat disturbance at Greys Dam upstream combined with the removal of Greys Dam may explain the decline in frog abundance upstream (sandpiper Ecological 2018). Nonetheless, tadpoles continue to be recorded in the pond immediately upstream of the highway suggesting that males and females are present, or tadpoles and/or adults are moving upstream through the flooded pipes.

Two individuals, one male and one female, were recorded in the downstream section of Greys Dam in 2016/17. This compares with 20 individuals captured around Grey's Dam during pre-construction surveys conducted in 2010/11 (BEM 2011). Importantly, construction removed some of the dam habitat and part of the remaining habitat is unsuitable. Despite this, results from seven years of population monitoring at Grey's Dam confirms the persistence of giant barred frog at that site, albeit in lower numbers. Annual surveys at the monitoring site 300m downstream between 2011 and 2017 have recorded 2-6 individuals/survey (BEM 2014; Sandpiper 2016a; Sandpiper 2018).

Thirdly, frogs mostly exist in meta-populations that feature highly variable sub-populations (Alford & Richards 1999). Sub-populations can fluctuate greatly over time and typically experience years of decline punctuated by years of high recruitment when environmental conditions are favourable (Green 2003). The provision of appropriate crossing structures across highway corridors become critically important in enabling recruitment both up and downstream during favourable periods. The area surrounding the Grey's Dam monitoring site received average rainfall for the period September

to April but experienced below average rainfall during the same period in two of the three preceding years (Lower Bucca rainfall data, BOM, 2017). This compares to periods of high rainfall for the years 2010 through 2013. Such variable and below average rainfall in recent years may have affected giant barred frog breeding success and movement. Several years of average and/or above average rainfall may be required to trigger population recovery and facilitate greater use of the pipes by giant barred frogs. The high counts of giant barred frogs during construction coincided with successive years of average or above rainfall.

5.2 Pipe use by other fauna

Use of the Grey's Dam frog pipes by non-frog fauna rose in both diversity and frequency of use between 2015/16 and 2016/17. Although reptile use dropped (i.e. 3.2 to 1.8 detections/week) and the number of species detected remained the same (i.e. 9 spp.), three new species were recorded using the pipes in 2016/17 – bandy bandy (*Vermicella annulata*), three-clawed worm skink (*Anomalopus verreauxii*) and land mullet (*Bellatorias major).* Land mullet was the only new species observed making a crossing (one probable crossing of the south pipe). Despite this, the number of reptile species recorded using the frog pipes in either or both monitoring periods was 11, including 6 species that completed definite and/or probable crossings.

The rise in diversity of species using the frog pipes was also evident for mammals. Mammal species diversity increased from 14 spp. to 16 spp. between the two periods. Most notable amongst the new records were confirmed crossings (i.e. definite and/or probable) by swamp wallaby and red-necked wallaby. This contrasts with non-crossing movement records by eastern grey kangaroo, which are considerably larger. This implies a probable upper limit on the body size of users of 1050mm pipes although the similarly-sized western grey kangaroo (*Macropus fuliginosus*) reportedly used a 900mm pipe under a road in Perth on several occasions (Chachelle *et al.* 2016).

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). Red fox was detected making two crossings during 2015/16 and two non-crossing movements during 2016/17, including an instance of predation of a swamp rat. Such infrequent use contrasts with almost nightly use at the nearby Moonee Beach box culvert underpass and frequent use at other Pacific Highway upgrade underpass sites (e.g. Sandpiper 2016c,d). Cats were not detected during 2015/16 but at least two individuals were recorded on 25 occasions making at least 16 crossings during 2016/17. The presence of introduced predators is of concern particularly with giant barred frog population numbers so low and may require a management response.

The overall diversity and frequency of use of the Grey's Dam frog pipes by native fauna and relative low use by introduced fauna highlights their high value as a cross-highway conduit. Indeed, the location of the Grey's Dam frog pipes beside a drainage line which links contiguous moist forest habitat amid a broader landscape that is becoming increasingly fragmented and heterogeneous further highlights it's importance. The fauna detected using the frog pipes are typical of this habitat type and the frequency of use by some species, such as echidna and bandicoot spp., suggests they are using the pipes to access resources on both sides of the highway (see Sprent 2012). Habitat connectivity, particularly across linear barriers such as highways, becomes increasingly important to species survival as landscapes become more fragmented (e.g. Fitzgibbon et al. 2007).

5.3 Monitoring methodology

Other Pacific Highway upgrade underpass monitoring programs have rarely detected frogs or small reptiles with passive IR cameras (e.g. Sandpiper 2015, 2016d). To address this, the current monitoring project utilised a scheduled, time-lapse IR and white-flash camera system. This method proved to be highly successful in detecting frogs and small reptiles as well as larger more mobile fauna typically detected using passive IR cameras. Due to the small size and low thermal signature of frogs, it is unlikely that passive IR cameras would have detected frog movement.

Another unexpected benefit of time-lapse was detection of disturbance trails, which assisted in confirming crossings of larger fauna. Because of the continuous nature of time lapse photography any prominent disturbance to the ground material (in this case, mulch) was largely noticeable.

5.5 Project compliance

5.5.1 Monitoring requirements

The EMP required monitoring of dedicated frog pipes located at Grey's Dam for use by giant barred frogs during the period of population monitoring (i.e. October to April during the first three years of operation). For the 2016/17 monitoring period, cameras were installed on 20 October 2016 and de-commissioned 4 May 2017. During this 28-week period, three cameras were active for 100% of this period and one camera active for 97.4% of this period. This complies with monitoring requirements.

5.5.2 Monitoring aim and performance indicators

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). The EMP further describes a range of performance indicators with which to assess the success of fauna mitigation measures. Section 3.3 (Giant Barred Frog Monitoring) describes four Potential Indicators of Success, three of which relate to population monitoring and one to frog pipe monitoring. This indicator states:

1. Recorded use of crossing structures by giant barred frogs

In addition to this and because frog pipes are a type of fauna underpass, indicators of success described for Fauna Underpasses (Section 3.4) are also worthy of consideration. Fauna underpass performance indicators include:

2. Low rates of use of fauna underpasses and adjacent habitats by feral predators;
3. High levels of fauna underpass use by a wide variety of native fauna species;
4. Evidence of use by dispersing individuals and different age cohorts;
5. Use by cover-dependent species and species with low mobility;
6. Low incidence of fauna road strike mortality.

Each of the above six indicators are considered separately.

1. A probable crossing by giant barred frog and definite crossings by barred frog spp. (possible giant barred frog) during 2015/16 suggests that the Grey's Dam frog pipes have facilitated movement by giant barred frog, albeit by few individuals. Importantly, the low level of use is

likely an artefact of very low population numbers upstream and downstream (refer to Sandpiper 2018). Successful breeding of giant barred frogs, as determined by the presence of tadpoles, suggests that males and females occur upstream of the highway, or that frogs and/or tadpoles move upstream through the flooded pipe culvert. Improvements in environmental conditions conducive to population recovery and frog movement, control of exotic weeds, and further infill plantings should lead to an increase in crossing frequency within the dedicated frog pipes.

2. Red fox was detected infrequently during both monitoring periods and a moderate number of cat detections were made during the 2016/17 monitoring period. Considering the low fox detections and low likelihood of success in controlling cats, particularly with the high number of nearby houses, fox and/or cat control is probably not warranted. Natural thickening of vegetation cover around pipe entrances should discourage use by feral predators and encourage use by cover-dependent fauna.
3. Over 30 species of fauna were detected using the Grey's Dam frog pipes. Such diversity is much higher than that recorded at four underpass sites along the S2W upgrade. This clearly demonstrates that the Grey's Dam frog pipes are being utilized by a wide variety of fauna species.
4. Differences in age cohorts are difficult to establish but the range and frequency of species use suggests different age cohorts used the Grey's Dam pipes.
5. Confirmed use by giant barred frogs and other small, ground-dwelling frogs confirms use by cover-dependent frog species. Other cover dependent species using the pipes include bush rats, swamp rats, brown antechinus, golden crowned snake and three-clawed worm skink.
6. Fauna road mortality monitoring was not a requirement of giant barred frog monitoring in the Ecological Monitoring Program.

6. Recommendations

1. Conduct one more session of weed suppression and infill planting of mat-rush (*Lomandra* spp) between pipe entrances and drainage line/Grey's Dam to promote continuous giant barred frog habitat, particularly on the east side of the alignment. Improving habitat quality and cover will also discourage use by feral predators. This should occur during autumn 2019.
2. Conduct one more year of monitoring (i.e. third monitoring year/event) within the next five years following above average rainfall during the preceding late winter-spring period. If above average late winter-spring rainfall does not occur within five years, then monitoring should occur in the fifth year.
3. When the third year of frog pipe monitoring occurs as per recommendation 2, it should be combined with frog population monitoring upstream and downstream of the highway at Greys Dam, with Arrawarra Creek used as a reference site.

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Appendix A – Camera Monitoring Effort

Table A1: Camera monitoring effort for 2016/17 Grey's Dam frog pipe monitoring.

Pipe End	Check Date	Battery %	Pics	Days Active	Cam settings & changes
NE	20/10/2016	99	0	Install	TL=1min; On=1800; Off=0500
	10/11/16	99	13860	21	
	30/11/16	99	13200	20	
	20/12/16	99	13200	20	
	13/1/17	0	12562	19	
	1/2/17	99	12540	18	
	22/2/17	99	13860	21	
	15/3/17	99	13860	21	
	6/4/17	93	14520	22	
	4/5/17	0	18480	28	
NW	20/10/16	99	0	Install	TL=1min; On=1800; Off=0500
	10/11/16	0	13824	21	
	30/11/16	99	13200	20	
	20/12/16	99	13200	20	
	13/1/17	99	15840	24	
	1/2/17	99	12540	18	
	22/2/17	99	13860	21	
	15/3/17	99	13860	21	
	6/4/17	99	14520	22	
	4/05/2017	5	18364	28	
SE	20/10/16	99	0	Install	TL=1min; On=1800; Off=0500
	10/11/16	93	13860	21	
	30/11/16	99	13200	20	
	20/12/16	99	13200	20	
	13/1/17	48	15840	24	
	1/2/17	99	12540	18	
	22/1/17	99	13860	21	
	15/3/17	99	13860	21	
	6/4/17	99	14520	22	
	4/05/2017	43	18480	28	
SW	20/10/16	99	0	Install	TL=1min; On=1800; Off=0500
	10/11/16	99	13860	21	
	30/11/16	99	13200	20	
	20/12/16	99	13200	20	
	13/1/17	99	15840	24	
	1/2/17	99	12540	18	
	22/2/17	89	13860	21	
	15/3/17	89	13860	21	
	6/04/2017	99	14520	22	
	4/05/2017	78	18480	28	

Appendix B – Grey's Dam Frog Pipes Fauna Detections

Table B1: Fauna detected during 2016/17 camera monitoring of Grey's Dam NORTH frog pipe.

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
							21/10/16	2109		LN Bandicoot	D	W	0850	Pr
21/10/16	2338	LN Bandicoot - med trail	Pr	NDM	0999-1000	D	21/10/16	2336	2min	LN Bandicoot	Pr	E	0997	D
22/10/16	0025	Bandicoot spp	Pr	E	1046	Pr								
22/10/16	2154	Med trail	D	NDM	1555-1556	Pr	22/10/16	2152	2min	Med trail	D	E	1553-1554	Pr
22/10/16	2158	Med trail	D	NDM	1559-1560	Pr	22/10/16	2159	1min	Med trail	D	W	1560-1561	Pr
22/10/16	2351	LN Bandicoot	D	E	1672	D	22/10/16	2348	3min	LN Bandicoot - Med trail	D	E	1669-1670	D
							23/10/16	0144		LN Bandicoot	D	E	1785-1800	Pr
23/10/16	0201	Med trail	D	NDM	1802-1803	Po								
23/10/16	2208	LN Bandicoot	D	W	2229	D	23/10/16	2210	2min	LN Bandicoot	D	W	2231-2242	D
24/10/16	0103	LN Bandicoot	D	W	2404	D	24/10/16	0106	3min	LN Bandicoot	Pr	W	2408	D
24/10/16	0114	Small trail	D	NDM	2413-2415	Pr	24/10/16	0116	2min	Small trail	D	W	2417-2418	Pr
							24/10/16	0130		Black Rat	D	EE	2431-2434	Un
							24/10/16	0310		LN Bandicoot	D	E	2531	Pr
24/10/16	1925	Cat	D	EE	2726	Un								
24/10/16	2006	LN Bandicoot - Large trail	D	NDM	2767-2768	D	24/10/16	2008	2min	LN Bandicoot	D	W	2769	D
24/10/16	2058	Bandicoot spp	Pr	W	2819	D	24/10/16	2100		Bandicoot spp	D	W	2821	D
24/10/16	2232	Med trail	Pr	NDM	2913-2914	Pr	24/10/16	2234	2min	Med trail	D	W	2914-2915	Pr
25/10/16	0009	LN Bandicoot - Small trail	Pr	NDM	3010-3011	D	24/10/16	0008	1min	LN Bandicoot	D	E	3009-3010	D
25/10/16	0136	LN Bandicoot	D	E	3097-3105	D	25/10/16	0126	10min	LN Bandicoot	D	E	3087-3096	D
25/10/16	1943	LN Bandicoot	Pr	W	3404	D	25/10/16	1945	2min	LN Bandicoot	D	W	3406-3415	D
25/10/16	2036	LN Bandicoot - Small hopping trail	D	NDM	3457-3458	D	25/10/16	2037	1min	LN Bandicoot	D	W	3458-3484	D
							25/10/16	2236		Domestic cat	D	W	3577	Pr

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
							25/10/16	2252		LN Bandicoot	D	W	3593-3599	Pr
25/10/16	2341	Small hopping trail	D	NDM	3642-3643	Pr	25/10/16	2340	1min	Small hopping trail	D	NDM	3641-3642	Pr
26/10/16	1905	Med trail	D	NDM	4026-4027	Pr	26/10/16	1906	1min	Med trail	D	W	4027-4028	Pr
26/10/16	2034	Med trail	D	NDM	4115-4116	Pr	26/10/16	2035	1min	Med trail	D	W	4116-4117	Pr
26/10/16	2124	small trail	D	NDM	4165-4167	Po								
26/10/16	2202	LN Bandicoot	Pr	EE	4203	Un								
26/10/16	2241	Med trail	D	NDM	4242-4243	Pr	26/10/16	2239	2min	Med trail	D	E	4240-4241	Pr
26/10/16	2247	Med hopping trail	D	NDM	4248-4249	Pr	26/10/16	2248	1min	Med hopping trail	D	W	4249-4250	Pr
26/10/16	2311	med trail	D	NDM	4283-4284	Po								
							26/10/16	2323		Med trail	D	NDM	4284-4285	Po
27/10/16	0233	CBtP	D	EE	4474-4475	Un								
27/10/16	1839	Small trail	D	NDM	4660-4661	Pr	27/10/16	1840	1min	Small trail	D	W	4662-4663	Pr
27/10/16	2010	Med trail	D	NDM	4751-4752	Pr	27/10/16	2009	1min	Med trail	D	E	4750-4751	Pr
27/10/16	2143	Med hopping trail	D	NDM	4844-4845	Pr	27/10/16	2141	2min	Med hopping trail	D	E	4842-4843	Pr
27/10/16	2203	LN Bandicoot - small trail	D	NDM	4864-4865	D	27/10/16	2201	2min	LN Bandicoot	D	E	4862	D
27/10/16	2221	small trail	D	NDM	4882-4883	Po								
28/10/16	1959	Bandicoot spp.	D	E	5400	D	28/10/16	2001	2min	Bandicoot sp - Small trail	D	W	5402-5403	D
29/10/16	0009	NB Bandcoot	Pr	E	5650	D	29/10/16	0007	2min	NB Bandicoot	Prob	E	5648	D
29/10/16	0037	Striped Marsh Frog	D	EE	5678-5679	Un								
29/10/16	0039	Med trail	D	NDM	5680-5681	Pr	29/10/16	0040	1min	Med trail	D	W	5681-5682	Pr
29/10/16	2226	Med hopping trail	D	NDM	6207-6208	Pr	29/10/16	2225	1min	Med hopping trail	D	E	6206-6207	Pr
30/10/16	0326	LN Bandicoot	D	E	6507-6516	D	30/10/16	0323	3min	LN Bandicoot - Med trail	D	E	6504-6505	D

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
							30/10/16	0423		Echidna	D	ETE	6564-6573	Un
30/10/16	1935	Small Mammal - small trail	D	NDM	6696-6697	D	30/10/16	1936	1min	Small mammal	Pr	W	6699-6700	D
							31/10/16	0036		Med trail	D	NDM	6997-6998	Po
							31/10/16	1853		LN Bandicoot	D	W	7314-7316	Pr
31/10/16	1922	Small trail	D	NDM	7343-7344	Pr	31/10/16	1924	2min	Small trail	D	W	7344-7345	Pr
31/10/16	2145	NB Bandicoot	Pr	ETE	7486-7489	Un								
31/10/16	2225	Med trail	D	ETE	7525-7528	Un								
							31/10/16	2233		LN Bandicoot	D	W	7534-7542	Pr
1/11/16	0154	Small hopping trail	D	ETE	7735-7739	Un								
							1/11/16	0159		LN Bandicoot	Pr	E	7740	Pr
							1/11/16	0239		Med trail	D	NDM	7780-7781	Po
1/11/16	0259	LN Bandicoot	Pr	W	7800	Pr								
							1/11/16	1844		Striped Marsh Frog	Pr	W	7966-7968	Pr
1/11/16	1858	LN Bandicoot - Med trail	D	NDM	7979-7980	D	1/11/16	1859	1min	LN Bandicoot	D	W	7979-7980	D
1/11/16	2301	Med trail	D	NDM	8222-8223	Po								
2/11/16	1921	Swamp Wallaby	D	EE	8662	Un								
							2/11/16	1950		Med trail	D	NDM	8691-8692	Po
2/11/16	2214	Black Rat	Pr	E	8835	Pr								
2/11/16	2331	Bandicoot sp	D	W	8912-8914	D	2/11/16	2333	2min	Bandicoot sp	Pr	W	8914-8918	D
3/11/16	0205	Med trail	D	NDM	9066-9067	Pr	3/11/16	0204	1min	Med trail	D	E	9065-9066	Pr
3/11/16	1940	Med trail	D	NDM	9341-9342	Pr	3/11/16	1941	1min	Med trail	D	W	9342-9344	Pr
							4/11/16	0034		Uperolia sp.	Pr	ETE	9635-9669	Un
4/11/16	0307	Small trail	D	NDM	9788-9789	Po								
4/11/16	1956	Domestic cat	D	E	0018-0022 (2nd folder)	D	4/11/16	1953	3min	Cat - Med trail	D	E	0015-0016 (2nd folder)	D

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
5/11/16	0239	Med trail	D	NDM	0421-0422	Pr	5/11/16	0238	1min	Med trail	D	E	0420-0421	Pr
5/11/16	2209	Bandicoot spp. - Med hopping trail	D	NDM	0811-0812	D	5/11/16	2209	1min	Bandicoot spp.	Pr	W	0812	
5/11/16	2233	LN Bandicoot - Small hopping trail	D	NDM	0835-0836	D	5/11/16	2235	2min	LN Bandicoot	D	W	0837	D
6/11/16	0028	Swamp Wallaby	D	EE	0950-0954	Un								
6/11/16	2105	Bandicoot spp.	D	E	1407	D	6/11/16	2103	2min	Bandicoot spp. - Med trail	D	E	1405	D
7/11/16	0436	Domestic cat	D	E	1858	Pr								
7/11/16	2005	Swamp Wallaby	D	EE	2007-2008	Un								
7/11/16	2209	Small trail	D	NDM	2131-2132	Pr	7/11/16	2208	1min	Small trail	D	E	2130-2131	Pr
							7/11/16	2255		Small trail	D	NDM	2177-2178	Po
8/11/16	0105	Med hopping trail	D	NDM	2307-2308	Po								
8/11/16	0111	Swamp Rat	Pr	ETE	2313-2315	Un								
8/11/16	0230	Med trail	D	NDM	2392-2393	Pr	8/11/16	0229	1min	Med trail	D	E	2391-2392	Pr
8/11/16	0305	LN Bandicoot	D	E	2427-2430	D	8/11/16	0300	5min	LN Bandicoot - Med hopping trail	D	E	2422-2423	D
8/11/16	1951	Domestic cat	D	E	2653-2659	D	8/11/16	1955	4min	Domestic cat	D	E	2657	D
9/11/16	0154	Small trail	D	NDM	3016-3017	Un								
9/11/16	0222	Cat	D	EE	3044-3045	Un								
9/11/16	1841	Med frog	D	W	3243-3244	Pr								
9/11/16	2323	Med hopping trail	D	NDM	3525-3526	Pr	9/11/16	2324	1min	Med hopping trail	D	W	3526-3527	Pr
							10/11/16	0134		Black Rat	Pr	E	3656	Pr
10/11/16	0343	Small hopping trail	D	NDM	3785-3786	Pr	10/11/16	0342	1min	Small hopping trail	D	E	3784	Pr

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
10/11/16	2356	UnID animal	D	W	357-358	D	10/11/16	2356	1min	UnID animal - Med trail	D	NDM	0357-358	D
11/11/16	0327	Small hopping trail	D	NDM	568-569	Pr	11/11/16	0326	1min	Small hopping trail	D	E	567-568	Pr
							11/11/16	2147		Snake sp.	D	EE	888	Un
12/11/16	0304	Small hopping trail	D	NDM	1205-1206	Pr	12/11/16	0306	2min	Small hopping trail	D	W	1207-1208	Pr
13/11/16	0040	Echidna	D	W	1721	D	13/11/16	0048	8min	Echidna	D	W	1729	D
13/11/16	0115	Lit. wilcoxii	Pr	ETE	1756-1779	Un								
13/11/16	2131	Domestic cat	D	EE	2192	Un								
14/11/16	2139	Small hopping trail	D	NDM	2860-2861	Pr	14/11/16	2142	3min	Small hopping trail	D	W	2863-2864	Pr
15/11/16	2047	Echidna	D	E	3468	D	15/11/16	2041	6min	Echidna - Large trail	D	E	3462-3463	D
15/11/16	2220	Bandicoot spp.	Pr	W	3561-3562	D	15/11/16	2220	1min	Bandicoot spp. - Med trail	D	NDM	3561-3562	D
16/11/16	2001	Bandicoot spp. - Med trail	D	NDM	4082-4083	D	16/11/16	2004	3min	Bandicoot sp.	D	W	4084-4105	D
							17/11/16	0136		Bandicoot	D	ETE	4417-4424	Un
17/11/16	0437	Domestic cat	D	E	4598-4599	Pr								
17/11/16	2136	Med trail	D	NDM	4837-4838	Pr	17/11/16	2134	2min	Med trail	D	E	4835-4836	Pr
17/11/16	2151	Med mammal	Pr	E	4852-4853	D	17/11/16	2153	2min	Med mammal - Med trail	D	W	4854-4855	D
19/11/16	1822	EW Dragon	D	EE	5963	Un								
19/11/16	2247	NB Bandicoot - Med trail	D	NDM	6628-6629	D	19/11/16	2244	3min	NB Bandicoot	D	E	6225-6226	D
							20/11/16	0013		NB Bandicoot	Pr	ETE	6314-6331	Un
20/11/16	2016	LN Bandicoot - Med hopping trail	D	NDM	6737-6738	D	20/11/16	2018	2min	LN Bandicoot	D	W	6739	D
20/11/16	2021	Small hopping trail	D	NDM	6742-6743	Po								
23/11/16	0019	Med trail	D	NDM	8300-8301	Pr	23/11/16	0024	5min	Med trail	D	W	8305-8306	Pr
23/11/16	0051	Bandicoot spp.	Pr	E	8333	D	23/11/16	0050	1min	Bandicoot sp. - Med trail	D	E	8331-8332	D

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
23/11/16	0135	Black Rat	Po	EE	8376-8377	Un								
23/11/16	2046	Small hopping trail	D	NDM	8747-8748	Pr	23/11/16	2044	2min	Small hopping trail	D	E	8745-8746	Pr
23/11/16	2100	Med hopping trail	D	NDM	8761	Pr	23/11/16	2103	3min	Med hopping trail	D	W	8764-8765	Pr
23/11/16	2109	Med trail	D	NDM	8770-8771	Pr	23/11/16	2110	1min	Med trail	D	W	8771-8772	Pr
23/11/16	2139	Med trail	D	NDM	8799-8800	Pr	23/11/16	2136	3min	Med trail	D	E	8797-8798	Pr
24/11/16	0011	Small trail	D	NDM	8952-8953	Pr	24/11/16	0010	1min	Small trail	D	E	8951-8952	Pr
							24/11/16	1846		Cat	D	EE	9287-9288	Un
24/11/16	2215	Med trail	D	NDM	9496-9497	Pr	24/11/16	2213	2min	Med trail	D	E	9494-9495	Pr
24/11/16	2228	LN Bandicoot	D	W	9509	D	24/11/16	2229	1min	LN Bandicoot - Med trail	D	W	9510-9511	D
25/11/16	0250	Small trail	D	NDM	9771-9772	Pr	25/11/16	0249	1min	Small trail	D	E	9770-9771	Pr
25/11/16	2216	Med trail	D	NDM	158-159 (2nd folder)	Pr	25/11/16	2215	1min	Med trail	D	E	157-158(2nd folder)	Pr
							26/11/16	2349		Med trail	D	NDM	0911-0912	Po
							27/11/16	2045		Large trail	D	NDM	1387-1388	Po
27/11/16	2119	Black Rat	D	EE	1421-1431	Un								
27/11/16	2308	Med trail	D	NDM	1530-1531	Pr	27/11/16	2307	1min	Med trail	D	E	1529-1530	Pr
28/11/16	2227	Echidna	D	W	2149-2150	D	28/11/16	2237	10min	Echidna	D	W	2159-2160	D
29/11/16	0212	Med trail	D	NDM	2374-2375	Pr	29/11/16	0211	1min	Med trail	D	E	2373-2374	Pr
							29/11/16	0756		Med trail	D	NDM	2658-2659	Po
							30/11/16	2155		Med trail	D	NDM	236-237	Po
30/11/16	2308	Small mammal	D	E	309	Pr								
30/11/16	2316	Med trail	D	E	317-318	Pr	30/11/16	2314	2min	Med trail	D	E	315-316	Pr
1/12/16	0132	Bandicoot sp.	D	E	453	D	1/12/16	0129	3min	Bandicoot sp. - Med trail	D	E	450-451	D

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East End							**West End**							
1/12/16	1948	LN Bandicoot	D	W	769	D	1/12/16	1948	1min	LN Bandicoot - Med trail	D	W	768-769	D
3/12/16	0016	Med Frog	D	EE	1697-1716	Un								
4/12/16	0447	Cat	D	W	2628	Pr								
4/12/16	1801	E. Water Dragon	D	W	2642	Pr								
4/12/16	2052	Med Trail	D	NDM	2813-2814	Po								
5/12/16	0057	Black Rat	D	NDM	3058-3059	Po								
5/12/16	0454	E. Water Dragon	D	NDM	3295	Po								
5/12/16	1855	Striped Marsh Frog - Med Frog	D	W	3356-3358	D	5/12/16	1908	13min	Striped Marsh Frog	Pr	W	3369	D
							5/12/16	1947		Med Frog	D	EE	3408-3422	Un
5/12/16	2106	Striped Marsh Frog	Pr	E	3487	D	5/12/16	2036	30min	Striped Marsh Frog	D	E	3457-3463	
							5/12/16	2256		Swamp Rat	D	E	3597	Pr
6/12/16	0436	E. Water Dragon	D	E	3937-3946	Pr								
6/12/16	1935	Striped Marsh Frog - Med Frog	D	W	4056-4058	D	5/12/16	1954	19min	Striped Marsh Frog	D	W	4075	D
							6/12/16	2314		LN Bandicoot	D	ETE	4275-4278	Un
7/12/16	0036	LN Bandicoot	Pr	EE	4357-4360	Un								
7/12/16	0407	Striped Marsh Frog	Pr	E	4568	D	7/12/16	0351	16min	Stiped Marsh Frog - Med Frog	D	E	4549	D
7/12/16	2159	Med hopping trail	D	W	4860-4861	Pr	7/12/16	2200	1min	Med trail	D	W	4861-4862	Pr
7/12/16	2254	Domestic Cat	D	NDM	4915	Po								
7/12/16	2317	LN. Bandicoot	D	E	4938-4940	D	7/12/16	2312	5min	LN Bandicoot - Med hopping trail	D	E	4933-4934	D
8/12/16	0131	Small hopping trail	D	NDM	5072-5073	Pr	8/12/16	0132	1min	Small hopping trail	D	W	5074-5075	Pr
8/12/16	0147	Bandicoot sp.	D	E	5088	D	8/12/16	0143	4min	Bandicoot sp - Med trail	D	E	5084-5085	D
8/12/16	2129	Small trail	D	NDM	5490-5491	Po								
8/12/16	2204	Small trail	D	NDM	5525-5526	Po								

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East End							**West End**							
							10/12/16	1816		Kookaburra	D	EE	6617	Un
10/12/16	2309	Med Frog	D	EE	6910-6933	Un								
11/12/16	2024	Med hopping trail	D	NDM	7405-7406	D	11/12/16	2024	1min	Med hopping trail	D	NDM	7405-7406	D
11/12/16	2316	Med hopping trail	D	NDM	7577-7578	D	11/12/16	2314	2min	Med hopping trail	D	E	7575-7576	D
12/12/16	2119	Domestic Cat	D	E	8000-8005	Pr								
12/12/16	2239	Med trail	D	NDM	8200-8201	Pr	12/12/16	2233	6min	Med trail	D	E	8194-8195	Pr
14/12/16	0220	Med trail	D	NDM	9081-9082	Pr	14/12/16	0218	2min	Med trail	D	E	9079-9080	Pr
15/12/16	0244	Med trail	D	NDM	9765-9766	Pr	15/12/16	0242	2min	Med trail	D	E	9763-9764	Pr
16/12/16	0238	Med hopping trail	D	NDM	0420-0421 (2nd folder)	Pr	16/12/16	0237	1min	Med hopping trail	D	E	419-420 (2nd folder)	Pr
18/12/16	0123	Rattus sp.	D	W	1665	Pr								
18/12/16	2023	Med trail	D	NDM	2025-2026	Po								
19/12/16	1957	Echidna	D	W	2659	Pr	19/12/16	2000	3min	Echidna - Med trail	D	W	2662-2663	D
19/12/16	2151	Echidna	D	E	2772	D	19/12/16	2146	5min	Echidna - Med trail	D	E	2768-2769	D
20/12/16	0201	Small mammal	D	W	3023-3024	Pr								
							21/12/16	2104		Med hopping trail	D	NDM	845-846	Po
							21/12/16	2238		Small trail	D	ETE	938-940	Un
23/12/16	0102	Med mammal	D	E	1743	D	23/12/16	0058	4min	Med hopping trail	D	E	1739-1740	D
24/12/16	1928	Med hopping trail	D	NDM	2729-2730	Pr	24/12/16	1925	3min	Med hopping trail	D	NDM	2066-2067	Pr
24/12/16	2206	Brown Antechinus	Pr	E	2886-2887	Pr								
24/12/16	2214	LN Bandicoot - Small hopping trail	D	NDM	2895-2896	D	24/12/16	2208	6min	LN Bandicoot	D	E	2889-2893	D
							24/12/16	2231		LN Bandicoot	D	W	2912-2914	Pr

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East End							**West End**							
26/12/16	1954	Med hopping trail	D	NDM	4075-4076	Pr	26/12/16	1952	2min	Med hopping trail	D	E	4073-4074	Pr
26/12/16	2018	Small trail	D	NDM	4099-4100	Pr	26/12/16	2019	1min	Small trail	D	W	4100-4101	Pr
							26/12/16	2309		Small trail	D	E	4270-4271	Pr
26/12/16	2321	Small trail	D	NDM	4282-4283	Pr	26/12/16	2322	1min	Small trail	D	W	4283-4284	Pr
							26/12/16	2323		Small trail	D	ETE	4284-4286	Po
							26/12/16	2328		Echidna	D	W	4289	Pr
26/12/16	2337	Echidna	D	E	4298	Pr								
27/12/16	0112	Echidna	D	E	4393-4394	D	27/12/16	0059	13min	Echidna	D	E	4380-4381	D
27/12/16	0127	Horseshoe bat	Pr	W	4408	Po								
							27/12/16	0237		Echidna	D	E	4478	Pr
27/12/16	1928	Small hopping trail	D	NDM	4709-4710	Po								
27/12/16	2223	LN Bandicoot	D	E	4884-4894	D	27/12/16	2219	4min	LN Bandicoot - Small hopping trail	D	E	4880-4881	D
27/12/16	2313	LN Bandicoot	D	W	4934-4935	D	27/12/16	2317	4min	LN Bandicoot	D	W	4938-4995	D
28/12/16	0001	Med hopping trail	D	NDM	4982-4983	Pr	27/12/16	2359	2min	Med hopping trail	D	E	4980-4981	Pr
28/12/16	2137	Golden Crowned Snake	D	E	5498-5500	D	28/12/16	2033	57min	Golden Crowned Snake	D	E	5434-5437	D
28/12/16	2243	LN Bandicoot	D	ETE	5564-5566	Un								
29/12/16	0031	Black Rat	D	ETE	5672-6575	Un								
							29/12/16	1846		Brown Antechinus	D	EE	5987-5993	Un
30/12/16	0041	Black Rat	D	E	6342-6350	Pr								
							30/12/16	2135		Brown Antechinus	D	EE	6816	Un
							31/12/16	0420		Brown Antechinus	D	EE	7221-7260	Un
1/1/17	0444	Brown Antechinus	Pr	EthenW	7905-7915	Un								

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East End							**West End**							
1/1/17	1838	Brown Antechinus	Pr	EthenW	7959-7960	D	1/1/17	1831	7min	Brown Antechinus	D	W	7952-7964	D
1/1/17	2258	Black Rat	D	EE	8219-8229	Un								
2/1/17	0219	LN Bandicoot	D	E	8420	D	2/1/17	0209	10min	LN Bandicoot - Med trail	D	E	8410-8411	D
2/1/17	0308	C. Carpet Python	D	E	8469-8493	D	2/1/17	0216	52min	C. Carpet Python	D	E	8417-8431	D
2/1/17	0449	Brown Antechinus	Pr	E	8570	Pr								
2/1/17	1952	Swamp Rat	Pr	E	8693	Pr								
2/1/17	2050	Striped Marsh Frog - Med Frog	D	E	8751-8752	D	2/1/17	2006	16min	Striped Marsh Frog	D	E	8707-8712	D
							3/1/17	0330		Med hopping trail	D	NDM	9151-9152	Po
							3/1/17	1924		S. Dwarf Crowned Snake	D	ETE	9325-9420	Un
3/1/17	2306	Med hopping trail	D	NDM	9547-9548	Po								
4/1/17	0252	Med trail	D	NDM	9773-9774	Pr	4/1/17	0247	5min	Med trail	D	E	9768-9769	Pr
							4/1/17	0320		CBtP	D	EE	9801	Un
							4/1/17	0444		Brown Antechinus	Pr	EE	9885	Un
4/1/17	1835	E. Water Dragon	D	EE	9936	Un								
							4/1/17	1846		Brown Antechinus	Pr	EE	9947	Un
4/1/17	2207	Black Rat	D	WthenE	157-162 (2nd folder)	Un								
							4/1/17	2208		Med hopping trail	D	NDM	150-151 (2nd folder)	Po
5/1/17	0013	Black Rat	D	E	275	Pr								
5/1/17	0358	LN Bandicoot	Pr	EE	499-500	Un								
							5/1/17	1907		Brown Antechinus	D	W	629	Pr
							6/1/17	1854		Small trail	Pr	NDM	1276-1277	Po
							7/1/17	0434		Small trail	D	NDM	1856-1857	Po

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
							9/1/17	0310		Black Rat	D	W	3092-3094	Pr
							12/1/17	0241		CBtP	D	E	5043	Pr
							12/1/17	0247		CBtP	D	E	5049	Pr
							12/1/17	0255		LN Bandicoot	Pr	W	5057	Pr
13/1/17	2004	C. Carpet Python	D	W	125-128	D	13/1/17	2031	27min	C Carpet Python	D	W	152-181	D
13/1/17	2251	Echidna - Med trail	D	W	292-293	D	13/1/17	2257	6min	Echidna	D	W	298	D
16/1/17	2055	Small trail	D	NDM	2156-2157	Po								
							18/1/17	0057		LN Bandicoot	D	W	3058	Pr
							18/1/17	2037		S. Dwarf Crowned Snake	Pr	E	3458	Pr
18/1/17	2357	C. Carpet Python	D	E	3658	D	18/1/17	2323	34min	C. Carpet Python	D	E	3624-3628	Po
							19/1/17	0025		C. Carpet Python	D	ETE	3686-3690	Un
19/1/17	0158	Med trail	D	E	3779-3780	Pr	19/1/17	0153	5min	Med trail	D	NDM	3774-3775	Pr
							20/1/17	0132		S. Dwarf Crowned Snake	Po	W	4413-4416	Pr
20/1/17	1903	C. Carpet Python	D	W	4684-4685	D	20/1/17	1935	32min	C. Carpet Python	D	W	4716-4718	D
21/1/17	1844	C. Carpet Python	Pr	ETE	5325-5331	Un								
							21/1/17	2328		Small Snake	D	ETE	5609-5610	Un
							22/1/17	2045		NB Bandicoot	D	E	6106-6130	Pr
23/1/17	0012	NB Bandicoot - Small hopping trail	D	W	6313-6314	D	23/1/17	0014	2min	NB Bandicoot	Pr	W	6315-6317	D
24/1/17	1834	RN Wallaby	D	W	7295-7296	D	24/1/17	1834	1min	RN Wallaby - Med hopping trail	D	NDM	7295-7296	D
24/1/17	1844	E. Water Dragon	D	ETE	7306-7317	Un								
							24/1/17	2125		Med trail	D	NDM	7466-7467	Po
25/1/17	0146	Black Rat	Pr	E	7727	Pr								
							25/1/17	0148		Small trail	Pr	NDM	7729-7730	Po
25/1/17	0233	Med trail	D	E	7774-7775	Pr	25/1/17	0227	6min	Med trail	D	NDM	7768-7769	Pr

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East End							**West End**							
							25/1/17	2241		Small trail	D	NDM	8202-8203	Po
26/1/17	2023	Rattus sp.	Pr	W	8064	Pr								
26/1/17	1944	Small trail	D	NDM	8685-8686	Po								
							26/1/17	1947		LN Bandicoot	Pr	E	8688-8689	Pr
26/1/17	2238	Black Rat	D	E	8859	D	26/1/17	2235	3min	Black Rat - Small trail	D	NDM	8856-8857	D
27/1/17	1949	Black Rat	Pr	W	9350	D	27/1/17	1950	1min	Black Rat - Small trail	D	NDM	9351-9352	D
28/1/17	0050	Small hopping trail	D	E	9651-9652	Pr	28/1/17	0047	3min	Small hopping trail	D	NDM	9648-9649	Pr
							28/1/17	2126		Black Rat	D	W	108 (2nd folder)	Pr
29/1/17	0151	Black Rat	D	E	373 (2nd folder)	Pr								
							31/1/17	0308		C. Carpet Python	D	ETE	1770-1777	Un
4/2/17	2320	Echidna	D	W	2301	D	4/2/17	2323	3min	Echidna - Med trail	D	NDM	2304-2305	D
7/2/17	0429	Med trail	D	E	3930-3931	Pr	7/2/17	0424	5min	Med trail	D	NDM	3925-3926	Pr
							7/2/17	2139		Carpet Python	D	ETE	4180-4235	Un
8/2/17	0152	LN Bandicoot	Pr	E	4433-4434	D	8/2/17	0149	3min	LN Bandicoot - Med trail	D	NDM	4430-4431	D
8/2/17	0216	LN Bandicoot - Med trail	D	E	4457-4458	D	8/2/17	0215	1min	LN Bandicoot	D	E	4456-4458	D
							8/2/17	0219		Carpet Python	D	ETE	4460-4468	Un
8/2/17	0220	Med trail	D	NDM	4461-4462	Po								
8/2/17	0229	Med trail	D	NDM	4470-4471	Pr	8/2/17	0229	0min	Med trail	D	NDM	4471-4472	Pr
8/2/17	2236	Med hopping trail	D	NDM	4897-4898	Pr	8/2/17	2236	0min	Med hopping trail	D	NDM	4897-4898	Pr
							9/2/17	0141		LN Bandicoot	D	W	5082-5085	Pr
							9/2/17	2313		LN Bandicoot	D	ETE	5594-5615	Un
							10/2/17	0219		Medium trail	D	NDM	5780-5781	Po
							10/2/17	2104		LN Bandicoot	D	ETE	6125-6128	Un
							11/2/17	2323		Med hopping trail	D	NDM	6924-6925	Po

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East End							**West End**							
12/2/17	0308	Swamp Wallaby	Pr	ETE	7149	Un								
12/2/17	1918	Carpet Python	D	ETE	7339-7350	Un								
							12/2/17	1955		LN Bandicoot	D	ETE	7376-7377	Un
12/2/17	2111	Echidna	D	W	7452	Pr								
							12/2/17	2155		Small trail	D	NDM	7455-7456	Po
							12/2/17	2218		Small hopping trail	D	NDM	7519-7520	Po
15/2/17	2100	Small trail	D	NDM	9421-9422	Pr	15/2/17	2100	0min	Small trail	D	NDM	9421-9422	Pr
							16/2/17	2019		Bandy bandy	D	ETE	41-61 (2nd folder)	Un
							17/2/17	0001		Bandy bandy	D	ETE	263-275	Un
							17/2/17	1843		Horseshoe Bat	Pr	E	605	Po
19/12/17	2120	Med trail	D	W	2082 (2nd folder)	Po								
20/2/17	0020	Rodent sp	D	W	2262	Pr								
20/2/17	2152	Bandicoot sp	D	W	2774	D	20/2/17	2151	1min	Bandicoot sp. - Small hopping trail	D	NDM	2773-2774	D
							20/2/17			Med trail	D	NDM	2802-2803	Po
21/2/17	0048	Med hopping trail	D	W	2950-2951	Pr	21/2/17	0050	2min	Med trail	D	NDM	2952-2953	Pr
21/2/17	2227	Rodent sp.	D	W	3469	Pr								
21/2/17	2352	Small trail	D	NDM	3554	Po								
22/2/17	2201	Black Rat - Med trail	D	NDM	242-243	D	22/2/17	2157	4min	Black Rat	D	E	238	D
23/2/17	0239	Carpet Python	D	E	520-527	D	22/2/17	2206	27min	Carpet Python	D	E	247-397	D
24/2/17	2155	Horseshoe bat x 2	Pr	W	1556	Po								
24/2/17	2344	LN Bandicoot	D	E	1665	D	24/2/17	2342	2min	LN Bandicoot - Med trail	D	E	1663-1664	D
25/2/17	2146	Echidna - Med trail	D	NDM	2207-2208	D	25/2/17	2151	5min	Echidna	D	W	2212	D
27/2/17	2257	Small hopping trail	D	NDM	3598-3599	Pr	27/2/17	2258	1min	Small hopping trail	D	W	3599-3600	Pr
							28/2/17	2018		Med hopping trail	D	NDM	4099-4100	Po

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
28/2/17	2241	Med trail	D	NDM	4242-4243	Pr	28/2/17	2235	6min	Med trail	D	W	4236-4237	Pr
1/3/17	0254	Small trail	D	NDM	4495-4496	Pr	1/3/17	0251	3min	Small trail	D	E	4492-4493	Pr
2/3/17	0321	Med hopping trail	D	NDM	5182-5183	Po								
3/3/17	0135	Black Rat	Pr	E	5736	Pr								
4/3/17	0111	Small trail	D	NDM	6372-6373	Po								
4/3/17	2110	Striped Marsh Frog	Pr	ETE	6791-6805	Un								
							4/3/17	2309		Small trail	D	NDM	6910-6911	Po
							5/3/17	0314		E. Small Eyed Snake	D	E	7155-7182	Un
5/3/17	2247	Small hopping trail	D	NDM	7548-7549	Po								
							6/3/17	2004		E. Small Eyed Snake	D	W	8045-046	Un
							6/3/17	2142		Small trail	D	E	8143-8144	Po
							7/3/17	0115		LN Bandicoot	D	NDM	8356	Pr
							8/3/17	0459		Med trail	D	NDM	9240	Po
9/3/17	2138	Echidna	Pr	E	120-121 (2nd set)	D	9/3/17	2132	6min	Echidna Med trail	D	E	114-115 (2nd set)	D
							10/3/17	2108		Black Rat	D	E	750	Po
10/3/17	1846	Carpet Python	D	ETE	608-633	Un								
10/3/17	2151	Med trail	D	E?	793-794	Pr	10/3/17	2143	8min	Med trail	D	E	785-786	Pr
							12/3/17	2123		Bandy bandy	D	ETE	2085-2086	Un
14/3/17	0040	Med trail	D	NDM	2942-2943	Po								
							14/3/17	0034		Med trail	D	NDM	2936-2937	Po
							14/3/17	0233		Striped Marsh Frog	D	ETE	3055-3078	Un
24	1900	NB Bandicoot	D	NDM	61	Po								
16/3/17	2309	Echidna	D	W	970	D	16/3/17	2320	11min	Echidna - Med Trail	D	W	981-982	D
							17/3/17	0334		Barred frog sp.	Po	E	1235-1239	Un

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
19/3/17	1932	Echidna	D	E	2733	D	19/3/17	1920	12min	Echidna - Med trail	D	E	2721-2722	D
20/3/17	0142	Med trail	D	NDM	3102-3103	Pr								
20/3/17	0426	Small trail	D	NDM	3267-3268	Pr	20/3/17	0424	2min	Small trail	D	W	3265-3266	Pr
							21/3/17	1200		M.iteratus	D	ETE	3673-3712	Un
21/3/17	2104	Med trail	D	NDM	4145-4146	Po								
21/3/17	2120	Rattus sp	D	W	4161	Pr								
21/3/17	2126	Large trail	D	NDM	4167-4168	Po								
23/3/17	2300	Med trail	D	NDM	5581-5582	Pr								
23/3/17	2353	Echidna	D	E	5634	Po								
24/3/17	0437	Echidna - Med trail	D	NDM		D	24/3/17	0433	4min	Echidna	D	E	5914	D
							27/3/17	2008		Snake sp.	D	EE	8049	Po
27/3/17	2038	Large trail	D	NDM	8079-8080	Pr	27/3/17	2050	12min	Large trail	D	W	8091-8092	Pr
27/3/17	2102	Large trail	D	NDM	8103-8104	Pr	27/3/17	2058	4min	Large trail	D	E	8099-8100	Pr
28/3/17	2102	House mouse	Pr	W	8763	Po								
							28/3/17	0429		Bush Rat	Pr	NDM	8550	Po
30/3/17	2212	Rodent sp. - Small trail	Pr	NDM	154-155 (2nd set)	D	30/3/17	2215	3min	Rodent sp.	D	W	157 (2nd set)	D
							31/3/17	2308		Med trail	D	NDM	870-871	Po
1/4/17	0131	LN Bandicoot	D	ETE	1013-1016	Un								
							1/4/17	2352		Carpet Python	Pr	E	1568-1577	Po
							2/4/17	1812		Med frog	D	E	1894	Po
3/4/17	2155	Bandicoot sp.	Pr	E	2777	Po								
4/4/17	2225	LN Bandicoot	D	W	3467	Po								
5/4/17	2233	Bush Rat	Pr	W	4135-4142	D	5/4/17	2300	27min	Bush Rat	Pr	W	4162	D
6/4/17	0227	Med trail	Pr	NDM	4369-4370	Po								
6/4/17	0233	House mouse	Pr	E	4375	Pr								

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
							6/4/17	2020		Black Rat	Pr	NDM	141	Po
6/4/17	2149	Med trail	D	ETE	230-232	Un								
6/4/17	2340	Bandicoot sp.	D	W	341	Pr								
6/4/17	2354	Bush Rat	Pr	EE	355-361	Un								
							7/4/17	0229		Black Rat	Pr	E	510	Pr
							7/4/17	0400		Black Rat	Pr	W	601-604	Pr
8/4/17	0004	Black Rat	D	W	1025	D	8/4/17	0006	2min	Black Rat	Pr	W	1027	D
9/4/17	0409	Black Rat	D	E	1930	D	9/4/17	0328	41min	Black Rat	Pr	E	1889	D
9/4/17	1958	Black Rat	D	E	2099	D	9/4/17	1937	21min	Black Rat	Pr	E	2078	D
11/4/17	0457	Swamp Wallaby	D	EE	3298-3300	Po								
11/4/17	1905	Rodent sp	D	E	3366	D	11/4/17	1858	7min	Rodent sp. - Small trail	D	NDM	3359-3360	D
11/4/17	2013	Bush Rat	Pr	E	3434	Pr								
11/4/17	2319	Echidna	D	W	3620	D	11/4/17	2305	14min	Echidna	D	E	3606-3607	D
12/4/17	1915	Echidna	D	W	4036	Pr								
							12/4/17	2049		Black Rat	D	EE	4131	Po
							13/4/17	0247		Small trail	D	NDM	4488-4489	Po
							13/4/17	0305		Med hopping trail	D	NDM	3747-3749	Po
							13/4/17	0317		EG Kangaroo x 2	D	EE	4518	Un
							13/4/17	1959		Black Rat	D	EE	4740	Po
14/4/17	0444	Black Rat	Pr	W	5265	D	14/4/17	0448	4 min	Black Rat - Small trail	D	NDM	5269-5270	D
16/4/17	0151	Black Rat	Pr	W	6412	Pr								
							16/4/17	1959		Small trail	D	NDM	6720-6721	Po
18/4/17	0204	Black Rat	Pr	E	7745	Pr								
18/4/17	1833	Rodent sp.	D	E	7954-7955	Pr								
							19/4/17	0245		Black Rat	D	W	8446-8453	Pr
19/4/17	1813	LN Bandicoot	Pr	W	8594	Pr								
							20/4/17	1947		Small trail	Pr	NDM	9348-9349	Po
21/4/17	0135	LN Bandicoot	D	E	9696	Pr								
21/4/17	0202	LN Bandicoot	D	E	9723	D	21/4/17	0158	4min	LNBandicoot - Med hopping trail	D	NDM	9719-9720	D
21/4/17	1834	Black Rat	D	E	9935	Pr								
							21/4/17	1929		Small trail	Pr	NDM	9930-9931	Po

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
21/4/17	1930	Small mammal	Pr	EE	652 (2nd set)	Po								
22/4/17	1949	Black Rat	Po	E	671	D	22/4/17	1936	13min	Black Rat	Pr	W	658 (2nd set)	D
22/4/17	2131	LN Bandicoot	D	W	773	D	22/4/17	2134	3min	LN Bandicoot - Med trail	D	NDM	776-777	D
							23/4/17	0300		Med hopping trail	D	NDM	1102-1103	Po
23/4/17	1938	Small Trail	D	E	1320-1321	Pr	23/4/17	1933	5min	Small trail	D	NDM	1315-1316	Pr
							24/4/17	2325		EG Kangaroo	D	EE	2207	Un
25/4/17	0009	LN Bandicoot	D	W	2251	D	25/4/17	0011	2min	LN Bandicoot	D	W	2253	D
25/4/17	0020	LN Bandicoot	D	E	2262	D	25/4/17	0016	4min	LN Bandicoot - Med trail	D	NDM	2258-2259	D
26/4/17	0131	LN Bandicoot - Med hopping trail	D	W	2993-2994	D	26/4/17	0133	2min	LN Bandicoot	Pr	W	2995-2996	D
26/4/17	1829	Med trail	D	E	3231-3232	Pr	26/4/17	1828	1min	Med trail	D	NDM	3230-3231	Pr
26/4/17	2245	Med trail	Pr	NDM	3487-3488	Po								
27/4/17	0130	LN Bandicoot	Pr	E	3652	D	27/4/17	0125	5min	LN Bandicoot - Med trail and urine mark	D	NDM	3647-3648	D
27/4/17	0241	Black Rat	D	EE	3723-3794	Po								
27/4/17	1820	Med trail	D	NDM	3882-3883	Pr	27/4/17	1820	0min	Med trail	D	NDM	3882-3883	Pr
27/4/17	2156	Black Rat	Pr	EE	4098	Po								
28/4/17	0110	LN Bandicoot	D	E	4292	D	28/4/17	0107	3min	LN Bandicoot - Med trail	D	NDM	4289-4290	D
28/4/17	1836	LN Bandicoot	D	W	4558	D	28/4/17	1836	0min	LN Bandicoot - Med trail	D	NDM	4558-4559	D
28/4/17	2238	LN Bandicoot	Pr	W	4800	Pr								
29/4/17	0037	Cat	D	EE	4919-4921	Un								
29/4/17	0214	LN Bandicoot	D	E	5016	D	29/4/17	0211	3min	LN Bandicoot - Med hopping trail	D	NDM	5013-5014	D
29/4/17	0437	Black Rat - Small trail	D	W	5159-5160	D	29/4/17	0441	4min	Black Rat	Pr	W	5163	D

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accu-racy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
30/4/17	1903	Med trail	D	NDM	5905-5906	Po								
30/4/17	1949	Black Rat	Pr	E	5951	D	30/4/17	1944	5min	Black Rat - Small trail	D	NDM	5946-5947	D
1/5/17	0232	LN Bandicoot	D	E	6354-6355	D	1/5/17	0229	3min	LN Bandicoot - Med trail	D	NDM	6351-6352	D
1/5/17	2225	LN Bandicoot	D	W	6767	D	1/5/17	2225	0min	LN Bandicoot - Med trail	D	NDM	6767-6768	D
2/5/17	1908	Small trail	D	E	7230-7231	Pr	2/5/17	1904	4min	Small hopping trail	D	NDM	7226-7227	Pr
2/5/17	1914	Med trail	D	E	7236-7237	Pr	2/5/17	1912	2min	Med hopping trail	D	NDM	7234-7235	Pr

Table B2: Fauna detected during 2015/16 camera monitoring of Grey's Dam SOUTH frog pipe.

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
20/10/16	1938	LN Bandicoot - Small hopping trail	D	NDM	99-100	D	20/10/16	1939	1min	LN Bandicoot	D	W	100-115	D
							20/10/16	2216		Black Rat	D	ETE	257-261	Un
21/10/16	0406	Bandicoot spp.	Pr	E	608	D	21/10/16	0405	1min	Bandicoot sp. - Med trail	D	E	606-607	D
21/10/16	1910	Bandicoot sp. - Small Hopping trail	D	NDM	731-732	D	21/10/16	1912	2min	Bandicoot spp.	Pr	W	732-733	D
							21/10/16	2046		Bandicoot spp.	Pr	NDM	826-827	Po
22/10/16	0223	Fox with Swamp Rat prey	D	EE	1164-1169	Un								
22/10/16	2136	Med trail	D	NDM	1537-1538	Pr	22/10/16	2134	2min	Med trail	D	E	1535-1536	PR
							22/10/16	2138		Med mammal	Pr	W	1539	Pr
							23/10/16	0052		EG Kangaroo	D	EE	1733	Un
23/10/16	2038	LN Bandicoot	Pr	W	2139-2140	D	23/10/16	2051	13min	LN Bandicoot - Med trail	D	W	2151-2152	D
24/10/16	0430	Domestic cat	D	EE	2611	Un								
24/10/16	1848	Domestic cat	D	EE	2689	Un								
							24/10/16	2030		LN Bandicoot	D	W	2791-2830	Pr
							24/10/16	2147		LN Bandicoot	D	W	2868-2882	Pr
24/10/16	2312	Bandicoot spp.	Pr	W	2953	D	24/10/16	2315	3min	Bandicoot spp. - Med trail	D	W	2956-2957	D
24/10/16	2318	LN Bandicoot	D	W	2959-2965	D	24/10/16	2321	3min	LN Bandicoot - Med hopping trail	D	W	2962-2963	D
							25/10/16	2109		Med hopping trail	D	NDM	3490-3491	Po
							25/10/16	2115		LN Bandicoot	D	EE	3496-3520	Un
25/10/16	2332	Med trail	D	NDM	3633-3634	Pr	25/10/16	2332	0min	Med trail	D	NDM	3633-3634	Pr

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
25/10/16	2352	LN Bandicoot	D	E	3652	D	25/10/16	2346	6min	LN Bandicoot - Med trail	D	E	3648-3649	D
26/10/16	0135	Med hopping trail	D	NDM	3756-3757	Pr	26/10/16	0134	1min	Med hopping trail	D	E	3755-3656	Pr
							26/10/16	2159		Med hopping trail	D	NDM	4200-4201	Po
27/10/16	0213	LN Bandicoot	Pr	W	4454	D	27/10/16	0213	1min	LN Bandicoot - Med trail	D	NDM	4454-4455	D
							27/10/16	0316		Med hopping trail	D	NDM	4518-4519	Po
27/10/16	0412	Med hopping trail	D	NDM	4573-4574	Pr	27/10/16	0410	2min	Med hopping trail	D	E	4571-4572	Pr
27/10/16	1809	Small trail	D	NDM	4630-4631	Pr	27/10/16	1810	1min	Small trail	D	W	4731-4632	Pr
27/10/16	2000	LN Bandicoot	Pr	E	4741	Pr								
27/10/16	2102	Small hopping trail	D	NDM	4803-4804	Pr	27/10/16	2104	2min	Small hopping trail	D	W	2805-4806	Pr
28/10/16	0253	Med trail	D	NDM	5154-5155	Pr	28/10/16	0253	0min	Med trail	D	NDM	5154-5155	Pr
28/10/16	0341	LN Bandicoot	D	E	5202	D	28/10/16	0329	12min	LN Bandicoot	D	E	5190-5198	D
28/10/16	0405	LN Bandicoot	Pr	E	5226	D	28/10/16	0403	2min	LN Bandicoot	D	E	5224	D
28/10/16	1811	Med trail	D	NDM	5292-5293	Po								
							28/10/16	1945		Small trail	D	NDM	5385-5386	Po
							28/10/16	1949		Med trail	D	NDM	5390-5391	Po
28/10/16	2008	Small mammal	D	E	5409	Pr								
							28/10/16	2212		Med trail	D	NDM	5533-5534	Po
							28/10/16	2214		Med trail	D	NDM	5535-5536	Po
29/10/16	0044	Med hopping trail	D	NDM	5685-5686	Po								

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
29/10/16	0157	**Striped Marsh frog - Med frog**	D	E	5758	D	29/10/16	0059	2min	**Striped Marsh Frog**	D	E	5700-5704	D
							29/10/16	0232		Med trail	D	NDM	5793-5794	Po
							29/10/16	0341		CBTP	D	EE	5862	Un
29/10/16	0402	Med mammal	Pr	E	5883	D	29/10/16	0359	3min	Med mammal - Med trail	D	E	5880-5881	D
29/10/16	1819	Med trail	D	NDM	5960-5961	Pr	29/10/16	1820	1min	Med trail	D	W	5961-5962	Pr
29/10/16	1920	Med trail	D	NDM	6021-6022	Pr	29/10/16	1918	2min	Med trail	D	E	6019-6020	Pr
29/10/16	2017	LN Bandicoot	Pr	W	6078	D	29/10/16	2019	2min	LN Bandicoot	D	W	6080-6081	D
29/10/16	2049	Med trail	D	NDM	6110-6111	Po								
29/10/16	2118	Med trail	D	NDM	6139	Pr	29/10/16	2116	2min	Med trail	D	W	6137-6138	Pr
29/10/16	2156	Med trail	D	NDM	6177-6178	Pr	29/10/16	2200	4min	Med trail	D	W	6181-6182	Pr
30/10/16	0021	Small trail	D	NDM	6322-6323	Pr	30/10/16	0018	3min	Small trail	D	E	6319-6320	Pr
							30/10/16	0109		Small trail	D	NDM	6369-6370	Po
30/10/16	0410	Small mammal	D	E	6551	D	30/10/16	0408	2min	Small mammal - Med hopping trail	D	E	6549-6550	D
30/10/16	1846	Small trail	D	NDM	6647-6648	Po								
30/10/16	1904	Small hopping trail	D	NDM	6665-6666	Po								
30/10/16	1911	NB Bandicoot - Med trail	D	NDM	6672-6673	D	30/10/16	1909	2min	NB Bandicoot	D	E	6670	D
30/10/16	1950	Med trail	D	NDM	6711-6712	Pr	30/10/16	1951	1min	Med trail	D	W	6712-6713	Pr
30/10/16	2101	Small hopping trail	D	NDM	6782-6783	Pr	30/10/16	2102	1min	Small hopping trail	D	W	6783-6784	Pr

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
30/10/16	2108	Med hopping trail	D	NDM	6789-6790	Pr	30/10/16	2109	1min	Med hopping trail	D	W	6790-6791	Pr
31/10/16	0159	Bandicoot spp.	Pr	E	7080-7081	D	31/10/16	0146	13min	Bandicoot sp. - Med hopping trail	D	E	7068-7069	D
31/10/16	0211	Med trail	D	NDM	7092-7093	Pr	31/10/16	0213	2min	Med trail	D	W	7094-7095	Pr
31/10/16	0222	Med trail	D	NDM	7103-7104	Pr	31/10/16	0220	2min	Med trail	D	E	7100-7101	Pr
31/10/16	0348	LN Bandicoot	D	E	7189-7196	D	31/10/16	0342	6min	LN Bandicoot - Small hopping trail	D	E	7183-7184	D
31/10/16	1858	Med trail	D	NDM	7319-7320	Pr	31/10/16	1856	2min	Med trail	D	E	7317-7318	Pr
31/10/16	1951	Med trail	D	NDM	7372-7373	Pr	31/10/16	1952	1min	Med trail	D	W	7373-7374	Pr
31/10/16	2118	Bandicoot spp.	D	E	7459	D	31/10/16	2116	2min	Bandicoot sp. - Med trail	D	E	7457-7458	D
							31/10/16	2143		LN Bandicoot	D	W	7484	Pr
							1/11/16	0008		CBTP	D	ETE	7629-7635	Un
1/11/16	0407	Med trail	D	NDM	7868-7869	Pr	1/11/16	0407	0min	Med trail	D	NDM	7868-7869	Pr
1/11/16	0413	LN Bandicoot	Pr	E	7874-7878	D	1/11/16	0408	5min	LN Bandicoot - Med trail	D	E	7869-7870	D
							1/11/16	0448		Domestic cat	D	W	7909	Pr
1/11/16	1921	Med trail	D	NDM	8002-8003	Po								
1/11/16	1950	Small hopping trail	D	NDM	8031-8032	Pr	1/11/16	1950	1min	Small hopping trail	D	NDM	8031-8032	Pr
							2/11/16	0107		**Lit. wilcoxii**	D	ETE	8348-8389	Un
2/11/16	0255	**Lit. wilcoxii - Med frog (40mm wide)**	D	E	8456-8457	D	2/11/16	0221	34min	**Lit. wilcoxii**	D	E	8422-8426	D
2/11/16	0411	Bandicoot spp.	Pr	E	8532-8534	Po	2/11/16	0410	1min	Bandicoot spp. - Small hopping trail	D	E	8531-8532	D

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
2/11/16	0425	Domestic cat	D	W	8546-8546	D	2/11/16	0426	1min	Domestic Cat - Small trail	D	W	8547-8548	D
2/11/16	1810	Swamp Wallaby	D	EE	8591-8592	Un								
2/11/16	2101	LN Bandicoot	D	EE	8762	Un								
2/11/16	2127	Bandicoot spp.	D	E	8788	D	2/11/16	2125	2min	Bandicoot spp. - Med hopping trail	D	E	8786-8787	D
2/11/16	2229	Med hopping trail	D	NDM	8850-8851	Pr	2/11/17	2227	2min	Med hopping trail	D	E	8848-8849	Pr
2/11/16	2253	Med mammal	D	E	8874	D	2/11/16	2251	2min	Med mammal - Med trail	D	E	8872-8873	D
2/11/16	2309	Med trail	D	NDM	8890-8891	Pr	2/11/16	2310	1min	Med trail	D	W	8891-8892	Pr
2/11/16	2325	LN Bandicoot - Med hopping trail	D	NDM	8906-8907	D	2/11/16	2325	1min	LN Bandicoot	D	W	8907	D
2/11/16	2326	Med hopping trail	D	NDM	8907-8908	Pr	2/11/16	2326	0min	Med hopping trail	D	E	8907-8908	Pr
2/11/16	2352	Bandicoot spp. X 2	D	EE	8933-8939	Un								
3/11/16	0133	NB Bandicoot	Pr	E	9034	D	3/11/16	0131	2min	NB Bandicoot - Med trail	D	E	9032-9033	D
3/11/15	0352	Med trail	D	NDM	9173	Pr	3/11/16	0350	2min	Med trail	D	E	9171	Pr
3/11/16	0418	Domestic cat	D	W	9919-9920	D	3/11/16	0419	1min	Domestic cat	D	W	9200	D
3/11/16	1919	Large trail	D	NDM	9320-9321	Pr	3/11/16	1917	2min	Large trail	D	E	9318-9319	Pr
3/11/16	1920	Small hopping trail	D	NDM	9321-9322	Pr	3/11/16	1920	0min	Small hopping trail	D	NDM	9321-9322	Pr
3/11/16	2024	Med trail	D	NDM	9385-9386	Pr	3/11/16	2022	2min	Med trail	D	E	9383-9384	Pr
3/11/16	2120	Large trail	D	NDM	9441-9442	Pr	3/11/16	2120	0min	Large trail	D	NDM	9440-9441	Pr
3/11/16	2235	LN Bandicoot	Pr	W	9516-9517	D	3/11/16	2235	1min	LN Bandicoot - Small trail	D	NDM	9516-9517	D

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
4/11/16	0203	LN Bandicoot	D	E	9723	D	4/11/16	0159	4min	LN Bandicoot - Med trail	D	E	9720-9721	D
4/11/16	0214	LN Bandicoot	D	E	9735	D	4/11/16	0212	2min	LN Bandicoot - Med trail	D	E	9733-9734	D
4/11/16	1835	Cat - small trail	Po	NDM	9935-9936	D	4/11/16	1836	1min	Domestic cat	D	W	9937-9938	D
4/11/16	1931	LN Bandicoot	D	W	9992	Pr								
4/11/16	2008	LN Bandicoot - Small trail	D	NDM	0030-0031 (2nd folder)	D	4/11/16	2008	1min	LN Bandicoot	Pr	W	0030 (second folder)	D
5/11/16	1825	EW Dragon	D	EE	0587-0596	Un								
5/11/16	1952	Med trail	D	NDM	0674-0675	Pr	5/11/16	1950	2min	Med trail	D	E	0672-0673	Pr
5/11/16	2323	LN Bandicoot	Pr	E	0885-0886	D	5/11/16	2321	2min	LN Bandicoot - Med trail	D	E	0883-0884	D
							6/11/16	0028		Med trail	D	NDM	0950-0951	Po
6/11/16	0041	LN Bandicoot	D	E	0963	D	6/11/16	0038	3min	LN Bandicoot - Med hopping trail	D	E	0960-0961	D
6/11/16	0147	Med trail	D	NDM	1029-1030	Pr	6/11/16	0145	2min	Med trail	D	E	1027-1028	Pr
6/11/16	0312	Med trail with scat	D	E	1113-1114	Pr	6/11/16	0311	1min	Med trail	D	E	1113-1114	Pr
6/11/16	0357	Med mammal	D	E	1159	Pr								
6/11/16	0954	Small hopping trail	D	NDM	1456-1457	Po								
							6/11/16	1929		Med trail	D	NDM	1311-1312	Po
6/11/16	2212	Med trail	D	NDM	1474-1475	Po								
6/11/16	2213	Med trail	D	NDM	1475-1476	Pr	6/11/16	2214	1min	Med trail	D	W	1476-1477	Pr

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
7/11/16	0024	LN Bandicoot - Med hopping trail	D	NDM	1606-1607	D	7/11/16	0021	3min	LN Bandicoot	D	E	1603-1604	D
7/11/16	0347	Domestic cat	D	W	1809	D	7/11/16	0348	1min	Domestic cat	D	W	1810	D
7/11/16	0411	Bandicoot spp.	Pr	E	1833	Pr								
							7/11/16	1801		EG Kangaroo	D	E	1883	Po
7/11/16	1931	Small hopping trail	Pr	NDM	1973-1974	Pr	7/11/16	1931	1min	Small hopping trail	D	NDM	1973-1974	Pr
							7/11/16	2105		Med trail	D	NDM	2067-2068	Po
8/11/16	0229	Swamp Wallaby	D	EE	2391-2392	Un								
							8/11/16	1953		Southern Dwarf Crown Snake	D	ETE	2654-2661	Un
9/11/16	0417	Bandicoot spp.	Pr	E	3159	D	9/11/16	0415	2min	Bandicoot - Small trail	D	E	3157-3158	D
							9/11/16	2240		LN Bandicoot	D	W	3482	Pr
10/11/16	0311	LN Bandicoot	D	W	3753-3754	D	10/11/16	0325	14min	LN Bandicoot - Med hopping trail	D	W	3767-3768	D
10/11/16	1857	Med frog	D	W	58-62	Pr								
10/11/16	1905	Small hopping trail	D	NDM	66-67	Po								
10/11/16	1927	Med Frog	D	E	88-100	Pr								
12/11/16	0403	LN Bandicoot	D	E	1264	D	12/11/16	0400	3min	LN Bandicoot - Med hopping trail	D	E	1261-1262	D
							12/11/16	1953		Domestic cat	D	E	1434	Pr
							12/11/16	2302		Med hopping trail	D	NDM	1623-1624	Po
13/11/16	0313	Med hopping trail	D	NDM	1874-1875	Pr	13/11/16	0311	2min	Med hopping trail	D	E	1872-1873	Pr
13/11/16	1951	LN Bandicoot - Small hopping trail	D	NDM	2092-2093	D	13/11/16	1956	5min	LN Bandicoot	D	W	2097-2101	D
14/11/16	0339	LN Bandicoot	Pr	E	2560	D	14/11/16	0337	2min	LN Bandicoot - Med hopping trail	D	E	2558-2559	D

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East End							**West End**							
15/11/16	0227	Bandicoot sp	D	E	3148	D	15/11/16	0224	3min	Bandicoot sp. - Small trail	D	E	3145-3146	D
16/11/16	2119	LN Bandicoot - Small hopping trail	D	NDM	4160-4161	D	16/11/16	2121	2min	LN Bandicoot	D	W	4162	D
							16/11/16	2212		Carpet Python	D	ETE	4213-4245	Un
16/11/16	2154	Snake sp	D	ETE	4195-4204	Un								
17/11/16	0227	Domestic cat	D	W	4468	D	17/11/16	0228	1min	Domestic Cat - Small trail	D	W	4469-4470	D
17/11/16	2007	LN Bandicoot	Pr	E	4748	D	17/11/16	2001	6min	LN Bandicoot - Small hopping trail	D	E	4743-4744	D
17/11/16	2129	LN Bandicoot	D	W	4830	D	17/11/16	2131	2min	LN Bandicoot - Med hopping trail	D	W	4832-4833	D
17/11/16	2146	Med trail	D	NDM	4847-4848	Pr	17/11/16	2145	1min	Med trail	D	E	4846-4847	Pr
17/11/16	2339	LN Bandicoot	D	E	4960	D	17/11/16	2337	2min	LN Bandicoot - Med trail	D	E	4958-4959	D
18/11/16	0222	Med trail	D	NDM	5123-5124	Pr	18/11/16	0221	1min	Med trail	D	E	5122-5123	Pr
19/11/16	2052	LN Bandicoot - Med hopping trail	D	NDM	6113-6114	D	19/11/16	2051	1min	LN Bandicoot	D	W	6112-6115	D
19/11/16	2159	Bandicoot sp. -Small hopping trail	D	NDM	6179-6180	D	19/11/16	2201	2min	Bandicoot sp	D	W	6182	D
20/11/16	2340	RN Wallaby	Po	E	6940-6947	D	20/11/16	2341	1min	RN Wallaby -Large hopping trail	D	W	6941-6942	D
20/11/16	2354	RN Wallaby	Pr	W	6955	D	20/11/16	2358	4min	RN Wallaby	D	W	6959	D
21/11/16	1933	LN Bandicoot - Med hopping trail	D	NDM	7354-7355	D	21/11/16	1934	1min	LN Bandicoot	D	W	7355	D
22/11/16	0331	LN Bandicoot	D	E	7832	Pr								
22/11/16	1939	LN Bandicoot - Med trail	D	NDM	8020-8021	D	22/11/16	1941	2min	LN Bandicoot	D	W	8022	D
							23/11/16	2254		**Lit wilcoxii**	Pr	E	8875-8899	Pr

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East End							**West End**							
							24/11/16	0029		Med Frog	D	W	8969-8970	Pr
25/11/16	2124	LN Bandicoot - Med hopping trail	D	NDM	106-107 (2nd folder)	D	25/11/16	2123	1min	LN Bandicoot	D	E	104 (2nd folder)	D
25/11/16	2323	Med trail	D	NDM	226-227	Pr	25/11/16	2318	5min	Med trail	D	E	220-221	Pr
26/11/16	0009	LN Bandicoot - Med hopping trail	D	NDM	271-272	D	26/11/16	0010	1min	LN Bandicoot	D	W	272	D
26/11/16	0101	Bandicoot spp.	D	E	323	Pr								
26/11/16	2244	Med hopping trail	D	NDM	846-847	Pr	26/11/16	2247	3min	Med hopping trail	D	E	849-850	Pr
27/11/16	1834	Swamp Wallaby	D	ETE	1256-1259	Un								
							27/11/16	2315		LN Bandicoot	D	E	1536	Pr
28/11/16	2208	Black Rat	Pr	EE	2130-2132	Un								
							29/11/16	2046		LN Bandicoot	Pr	W	2708	Pr
30/11/16	0032	LN Bandicoot	Pr	E	2934	D	30/11/16	0030	2min	LN Bandicoot	D	E	2932	D
							30/11/16	1909		L. wilcoxii	Pr	ETE	70-112	Un
30/11/16	2216	LN Bandicoot - Med trail	D	W	257-258	D	30/11/16	2218	2min	LN Bandicoot	D	W	259	D
30/11/16	2228	Med trail	D	W	269-270	Pr	30/11/16	2229	1min	Med trail	D	NDM	270-271	Pr
1/12/16	2000	Swamp Rat	Pr	E	781	Pr								
2/12/16	0303	Black Rat	D	E	1204	D	2/12/16	0257	6min	Black Rat	D	E	1198	D
2/12/16	2055	Med trail	D	NDM	1496-1497	Po								
4/12/16	0159	Med hopping trail	D	E	2460-2461	Pr	4/12/16	0157	2min	Med hopping trail	D	NDM	2458-2459	Pr
5/12/16	1900	E.Small Eyed Snake	Pr	ETE	3361-3376	Un								
5/12/16	2130	L. wilcoxii	D	E	3511-3527	D	5/12/16	2053	23min	L. wilcoxii	Pr	E	3474-3477	D
5/12/16	2235	Med frog	D	ETE	3576-3581	Un								

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East End							**West End**							
5/12/16	2348	Med Frog	D	E	3649-3654	Pr								
							6/12/16	0030		Small trail	D	NDM	3691-3692	Po
							7/12/16	0040		L. wilcoxii	Pr	ETE	4361-4375	Un
7/12/16	0149	Med hopping trail	D	NDM	4430-4431	Po								
							7/12/16	0158		L. wilcoxii	Pr	ETE	4439-4447	Un
							7/12/16	2113		L. wilcoxii	Pr	W	4814	Pr
							9/12/16	0005		L. wilcoxii	Pr	ETE	5646-5683	Un
							9/12/16	0147		Small trail	D	NDM	5748-5749	Po
9/12/16	2118	Echidna	D	W	6139	D	9/12/16	2122	4min	Echidna - Large trail	D	NDM	6143-6144	D
10/12/16	0108	Rattus sp.	Pr	ETE	6369-6371	Un								
11/12/16	0218	Med hopping trail	D	E	7099-7100	Pr	11/12/16	0217	1min	Med hopping trail	D	NDM	7098-7099	Pr
11/12/16	0354	LN Bandicoot	D	W	7195-7196	D	11/12/16	0355	1min	LN Bandicoot - Small trail	D	NDM	7196-7197	D
							11/12/16	1909		Domestic cat	Pr	W	7330	Pr
12/12/16	0048	LN Bandicoot	D	E	7669	D	12/12/16	0044	4min	LN Bandicoot - Med hopping trail	D	NDM	7665-7666	D
12/12/16	0336	LN Bandicoot - Med hopping trail	D	W	7837-7838	D	12/12/16	0338	2min	LN Bandicoot	D	W	7839	D
							12/12/16	1813		Small trail	D	NDM	7934-7935	Po
13/12/16	0012	Small trail	D	NDM	8293-8294	Po								
13/12/16	0356	LN Bandicoot	D	W	8517-8518	Po	13/12/16	0356	1min	LN Bandicoot - Med hopping trail	D	NDM	8517-8518	D

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
13/12/16	2011	LN Bandicoot - Med hopping trail	D	W	8712-8713	D	13/12/16	2012	1min	LN Bandicoot	D	W	8713-8715	D
13/12/16	2226	L. wilcoxii	Pr	E	8847-8849	D	13/12/16	2126	60min	L. wilcoxii	D	E	8787-8791	D
							13/12/16	2242		S. Dwarf Crown Snake	D	ETE	8863-8881	Un
13/12/16	2304	Med hopping trail	Pr	E	8885-8886	Pr	13/12/16	2302	2min	Med hopping trail	D	NDM	8883-8884	Pr
							14/12/16	0322		LN Bandicoot	Pr	W	9143-9144	Pr
14/12/16	1952	LN Bandicoot	Pr	W	9353	D	14/12/16	1952	1min	LN Bandicoot - Med hopping trail	D	NDM	9353-9354	D
15/12/16	1944	LN Bandicoot	D	W	6 (2nd folder)	D	15/12/16	1944	1min	LN Bandicoot - Med trail	D	NDM	6-7 (2nd folder)	D
17/12/16	0033	Med trail	D	W	955-956	Pr	17/12/16	0037	4min	Med trail	D	NDM	959-960	Pr
							17/12/16	1955		Swamp Rat	Pr	E	1337	Pr
							18/12/16	2139		Med trail	D	NDM	2101-2102	Po
19/12/16	0253	LN Bandicoot - Med hopping trail	D	W	2415-2416	D	19/12/16	0253	1min	LN Bandicoot	D	W	2416-2417	D
							21/12/16	2257		Lit. gracilenta	Pr	ETE	957-958	Un
							21/12/16	2329		Med hopping trail	D	NDM	990-991	Po
22/12/16	0205	Small hopping trail	D	NDM	1146-1147	Po								
22/12/16	0210	Small hopping trail	D	NDM	1151-1152	Po								
22/12/16	0229	LN Bandicoot - Med hopping trail	D	NDM	1170-1171	D	22/12/16	0231	2min	LN Bandicoot	D	W	1172	D
							22/12/16	0427		Small trail	D	NDM	1287-1288	Po
22/12/16	2331	Med hopping trail	D	NDM	1652-1653	Po								
23/12/16	2059	LN Bandicoot	D	E	2160-2164	D	23/12/16	2003	4min	LN Bandicoot	D	E	2104-2157	D

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
24/12/16	0239	LN Bandicoot - Med hopping trail	D	NDM	2500-2501	D	24/12/16	0243	4min	LN Bandicoot	D	W	2504-2506	D
24/12/16	2002	Med trail	D	NDM	2763-2764	Pr	24/12/16	2005	3min	Med trail	D	W	2766-2767	Pr
24/12/16	2215	Small hopping trail	D	NDM	2896-2897	Po								
25/12/16	0244	LN Bandicoot	D	E	3165	D	25/12/16	0242	2min	LN Bandicoot - Med trail	D	E	3163-3164	D
25/12/16	1920	Med trail	D	NDM	3381-3382	Pr	25/12/16	1920	0min	Med trail	D	W	3381-3382	Pr
25/12/16	1942	Med trail	D	NDM	3403-3404	Pr	25/12/16	1942	0min	Med trail	D	NDM	3403-3404	Pr
25/12/16	1943	LN Bandicoot - Med hopping trail	D	NDM	3405-3406	D	25/12/16	1943	1min	LN Bandicoot	Pr	W	3404-3405	D
							25/12/16	2044		LN Bandicoot	D	E	3465-3468	Pr
26/12/16	0002	LN Bandicoot	D	W	3663-3664	D	26/12/16	0008	6min	LN Bandicoot - Med hopping trail	D	W	3669-3670	D
26/12/16	1955	LN Bandicoot	D	E	4076	D	26/12/16	1951	4min	LN Bandicoot - Med hopping trail	D	E	4072-4073	D
26/12/16	2049	LN Bandicoot	D	E	4130	D	26/12/16	2047	2min	LN Bandicoot - Med trail	D	E	4128-4129	D
26/12/16	2256	Med hopping trail	D	NDM	4257-4258	Pr	26/12/16	2258	2min	Med hopping trail	D	W	4259-4260	Pr
							26/12/16	2351		Large trail	D	NDM	4312-4313	Po
27/12/16	0126	Echidna	D	ETE	4407-4416	Un								
							27/12/16	0235		Bandicoot sp.	D	W	4476	Pr
28/12/16	0159	LN Bandicoot	D	E	5100	D	28/12/16	0154	5min	LN Bandicoot - Med hopping trail	D	E	5095-5096	D
28/12/16	0328	Med hopping trail	D	NDM	5189	Po								
28/12/16	2016	LN Bandicoot	Pr	E	5417	Pr								
29/12/16	0309	Swamp Wallaby	D	E	5830	D	29/12/16	0307	2min	Swamp Wallaby - Med hopping trail	D	E	5228	D

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East End							**West End**							
29/12/16	2226	LN Bandicoot	D	E	6507	D	29/12/16	2221	5min	LN Bandicoot	D	E	6202-6203	D
							30/12/16	0016		LN Bandicoot	D	W	6317-6320	Pr
31/12/16	2019	Large hopping trail	D	NDM	7400-7401	Pr	31/12/16	2008	11min	Large hopping trail	D	E	7389-7390	Pr
31/12/16	2358	LN Bandicoot	D	W	7619-7620	Pr								
1/1/17	0054	C. Carpet Python	D	E	7675-7677	D	31/12/16	2352	62min	C. Carpet Python	D	E	7613-7620	D
							1/1/17	0201		LN Bandicoot	Pr	W	7742-7750	Pr
2/1/17	0057	Med Frog	D	W	8338-8350	Pr								
2/1/17	0322	Small hopping trail	D	NDM	8483-8484	Pr	2/1/17	0324	2min	Small hopping trail	D	W	8485-8486	Pr
							2/1/17	2154		Striped Marsh Frog	D	W	8815-8820	Pr
2/1/17	2228	Echidna	D	W	8849	D	2/1/17	2234	6min	Echidna - Med trail	D	W	8855-8856	D
4/1/17	0028	Small erratic trail	D	NDM	9629-9630	Pr	4/1/17	0029	1min	2 trails	D	NDM	9629-9630	Pr
							5/1/17	0409		Brown Antechinus	Pr	ETE	511 (2nd folder)	Un
							5/1/17	0432		Med Frog	Pr	ETE	534-540	Un
							5/1/17	0443		Brown Antechinus	D	W	545	Pr
5/1/17	1917	Lit. wilcoxii - Med Frog	D	W	639 (2nd folder)	D	5/1/17	1933	16min	Lit. wilcoxii	D	W	655-656	D
5/1/17	2229	Bandicoot sp.	D	W	831	D	5/1/17	2229	1min	Bandicoot sp - Med hopping trail	D	NDM	831-832	D
6/1/17	0104	Black Rat	D	EE	986	Un								
6/1/17	2024	Lit wilcoxii - Med Frog	D	W	1366-1395	D	6/1/17	2142	78min	Lit. wilcoxii	D	W	1444-1453	D

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East End							**West End**							
							7/1/17	2042		Lit wilcoxii	D	E	2044-2046	Pr
							7/1/17	2051		Small hopping trail	D	NDM	2053-2054	Po
							7/1/17	2220		Lit. wilcoxii	D	W	2142	Pr
7/1/17	2241	LN Bandicoot - Med hopping trail	D	NDM	2163-2164	D	7/1/17	2244	3min	LN Bandicoot	D	W	2166-2177	D
8/1/17	2334	Small trail	D	NDM	2876-2777	Pr	8/1/17	2331	3min	Small trail	D	E	2873-2874	Pr
9/1/17	0347	Med hopping trail	D	NDM	3120-3130	Po								
							11/1/17	2020		Med hopping trail	D	NDM	4662-4663	Po
12/1/17	0058	Lit. wilcoxii - Med Frog	D	E	4940-4961	D	12/1/17	0039	19min	Lit. wilcoxii	D	E	4921	D
12/1/17	1945	Small hopping trail	D	NDM	5287-5288	Po								
							12/1/17	2333		LN Bandicoot	D	W	5515	Pr
							15/1/17	1942		Small hopping trail	D	NDM	1423-1424	Po
							15/1/17	2253		Med trail	D	E	1614-1615	Po
16/1/17	2048	LN Bandicoot	D	W	2149-2150	D	16/1/17	2048	1min	LN Bandicoot	D	W	2149	D
16/1/17	2341	Bandicoot spp. Med trail	D	NDM	2322-2323	D	16/1/17	2352	11min	Bandicoot spp.	Pr	W	2333	D
16/1/17	2343	Med trail	D	NDM	2324-2325	Pr	16/1/17	2353	10min	Med trail	D	NDM	2334	Pr
17/1/17	0022	LN Bandicoot	D	E	2363	D	17/1/17	0019	3min	LN Bandicoot - Med trail	D	W	2360-2361	D
17/1/17	1843	Land Mullet	D	E	2684-2696	Pr								
17/1/17	2154	NB Bandicoot - Med trail	D	NDM	2875-2876	D	17/1/17	2155	1min	NB Bandicoot	D	W	2876	D

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
17/1/17	2209	NB Bandicoot - Small trail	D	NDM	2890-2891	D	17/1/17	2206	3min	NB Bandicoot	D	E	2887	D
17/1/17	2240	LN Bandicoot - Large hopping trail	D	NDM	2921-2922	D	17/1/17	2236	4min	LN Bandicoot	Pr	E	2910-2918	D
18/1/17	0034	Small hopping trail	D	NDM	3035-3036	Po								
18/1/17	0038	Small hopping trail	D	NDM	3039-3040	Po								
							18/1/17	2202		Black Rat	Pr	E	3543	Pr
							19/1/17	0309		Lit. wilcoxii	Pr	E	3850-3855	Pr
							25/1/17	2035		Three-clawed Worm Skink	D	ETE	8076	Un
							25/1/17	2217		Med trail	D	ETE	8178	Un
28/1/17	1953	Small mammal	Pr	E	15 (2nd folder)	D	28/1/17	1954	1min	Small mammal - Small trail	D	NDM	16 (2nd set)	D
							29/1/17	2059		Black Rat	D	NDM	741	Po
29/1/17	2309	Carpet Python	D	W	871-879	D	30/1/17	0007	2min	Carpet Python	D	W	929	D
30/1/17	2349	Med trail	D	NDM	1571-1572	Pr	30/1/17	2355	6min	Med trail	D	W	1577-1578	Pr
31/1/17	2147	Carpet Python	D	W	2109-2172	Pr								
2/2/17	0407	Echidna	D	E	608	D	2/2/17	0401	6min	Echidna - Med trail	D	E	602-603	D
							2/2/17	2122		Lit. wilcoxii	Pr	ETE	863-876	Un
							2/2/17	2325		Med trail	D	NDM	986-987	Po
3/2/17	2145	Bandicoot sp. - Med trail	D	E?	1546-1547	D	3/2/17	2145	1min	Bandicoot sp	D	W	1546-1547	D
							4/2/17	0043		Med hopping trail	D	NDM	1724-1725	Po
							4/2/17	0222		CBtP	D	EE	1823	Un
4/2/17	0313	Med trail	D	NDM	1874-1875	Pr	4/2/17	0312	1min	Med trail	D	E	1873-1874	Pr

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
4/2/17	2011	Med trail	D	NDM	2112-2113	Pr	4/2/17	2011	0min	Med trail	D	NDM	2112-2113	Pr
4/2/17	2230	Med trail	D	NDM	2231-2232	Po								
5/2/17	2249	NB Bandicoot sp - Small trail	D	NDM	2930-2931	D	5/2/17	2250	1min	NB Bandicoot	Pr	W	2931	D
6/2/17	0316	Med trail	D	NDM	3197-3198	Pr	6/2/17	0314	2min	Med trail	D	E	3195-3196	Pr
							6/2/17	2306		Med trail	D	NDM	3607-3608	Po
7/2/17	0241	Med trail	D	NDM	3822-3823	Po								
7/2/17	2101	Lit. wilcoxii - Med Frog	D	E	4142-4145	D	7/2/17	2005	4min	Lit. wilcoxii	D	E	4086-4087	D
7/2/17	2129	LN Bandicoot - Med mammal	D	E	4170	D	7/2/17	2127	2min	LN Bandicoot	Pr	E	4168	D
8/2/17	0113	Small hopping trail	D	NDM	4394-4395	Pr	8/2/17	0114	1min	Small hopping trail	D	W	4395-4396	Pr
							8/2/17	0304		LN Bandicoot	Pr	W	4505	Pr
							8/2/17	0316		Small hopping trail	D	ETE	4513-4517	Un
8/2/17	2116	Med frog	D	ETE	4817-4832	Un								
9/2/17	2154	Golden Crowned Snake	Pr	ETE	5514-5515	Un								
							10/2/17	0243		Large trail	D	NDM	5804-5805	Po
10/2/17	1935	Lit. wilcoxii - Med Frog	D	W	6036-6037	D	10/2/17	2014	21min	Lit. wilcoxii	Pr	W	6075-6089	D
							10/2/17	2118		Med hopping trail	D	NDM	6139-6140	Po
10/2/17	2106	Med Frog	D	W	6127-6131	Pr								
							12/2/17	0255		LN Bandicoot	D	EE	7136-7172	Un

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
12/2/17	0313	Swamp Wallaby	D	ETE twice	7154-7163	Un								
							12/2/17	2018		Snake sp.	D	NDM	7399	Po
13/2/17	2022	Black Rat	Pr	E	8063	D	13/2/17	2026	4min	Black Rat	D	W	8067	D
						Pr	13/2/17	2134		Lit. wilcoxii	Pr	E	8135-8136	Pr
14/2/17	0335	Golden Crowned Snake	D	ETE	8496-8535	Un								
15/2/17	2003	Rattus sp.	D	E	9364	Pr								
15/2/17	2138	Bandicoot spp. - Med trail	D	NDM	9459-9460	D	15/2/17	2144	6min	Bandicoot sp	D	W	9465	D
15/2/17	2143	Black Rat	D	E	9464	Pr								
15/2/17	2322	Med hopping trail	D	NDM	9563-9564	Pr	15/2/17	2319	3min	Med hopping trail	D	E	9560-9561	Pr
17/2/17	0015	Lit. wilcoxii - Med Frog	D	E	277-285 (2nd folder)	D	16/2/17	2319	56min	Lit. wilcoxii	D	E	221-245 (2nd folder)	D
17/2/17	0208	Med trail	D	NDM	390-391	Pr	17/2/17	0203	5min	Med trail	D	E	385-386	Pr
17/2/17	2158	Small trail	D	NDM	800-801	Pr	17/2/17	2159	1min	Small trail	D	W	801-802 (2nd folder)	Pr
18/2/17	0109	Carpet Python	D	EthenW	991-997	Un	17/2/17	2344		Carpet Python	D	EthenW	904-1033	Un
19/2/17	1930	Black Rat	Pr	W	1972	Pr								
20/2/17	0218	Med hopping trail	D	NDM	2380-2381	Po								
20/2/17	1935	Black Rat	Pr	W	2637	D	20/2/17	1936	1min	Black Rat	D	W	2638	D
							20/2/17	2157		Small hopping trail	D	NDM	2779-2780	Po
22/2/17	0118	Golden Crowned Snake	Pr	W	3640-3644	D	22/2/17	0228	10min	Golden Crowned Snake	D	W	3710-3711	D
							22/2/17	1938		Small trail	D	NDM	99-100	Po
							22/2/17	2233		LN Bandicoot	D	W	274	Pr
23/2/17	0107	Small hopping trail	D	NDM	428-429	Po								

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
							24/2/17	2022		LN Bandicoot	D	W	1463	Pr
							25/2/17	0206		Small hopping trail	D	NDM	1807-1808	Po
25/2/17	2314	Med hopping trail	D	NDM	2295-2296	Pr	25/2/17	2313	1min	Med hopping trail	D	E	2294-2295	Pr
26/2/17	0228	Med trail	D	NDM	2489-2490	Pr	26/2/17	0222	6min	Med trail	D	E	2483	Pr
							27/2/17	0354		Med hopping trail	D	NDM	3235	Po
27/2/17	2005	Med hopping trail	D	NDM	3426-3427	Pr	27/2/17	2005	0min	Med hopping trail	D	NDM	3426-3427	Pr
27/2/17	2044	Med trail	D	NDM	3465-3466	Pr	27/2/17	2052	8min	Med trail	D	W	3473-3474	Pr
27/2/17	2208	Med trail	D	NDM	3549-3450	Pr	27/2/17	2206	2min	Med trail	D	E	3547-3548	Pr
28/2/17	0208	Snake sp	D	ETE	3789-3791	Un								
							28/2/17	0320		Med hopping trail	D	NDM	3861-3862	Po
							1/3/17	1906		Small hopping trail	D	NDM	4687-4688	Po
1/3/17	1927	Med hopping trail	D	NDM	4708-4709	Pr	1/3/17	1927	0min	Med hopping trail	D	NDM	4709-4710	Pr
2/3/17	0027	Med hopping trail	D	NDM	5008-5009	Pr	2/3/17	0029	2min	Med hopping trail	D	W	5010-5011	Pr
2/3/17	0247	NB Bandicoot	Pr	E	5148	Pr								
							2/3/17	1917		Black Rat	D	W	5358	Pr
2/3/17	1922	Med hopping trail	D	NDM	5363	D	2/3/17	1923	1min	Med hopping trail	D	W	5363-5364	D
							2/3/17	2048		NB Bandicoot	D	ETE	5449-5451	Un
							2/3/17	2238		Med hopping trail	D	NDM	5559-5560	Po
							3/3/17	0434		LN Bandicoot	Pr	W	5915	Pr

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
3/3/17	2042	Med Frog	D	W	6103-6104	Po								
							3/3/17	2300		Black Rat	Pr	E	6241	Pr
4/3/17	1936	Small hopping trail	D	NDM	6697-6698	Po								
6/3/17	0000	Black Rat	D	W	7621	D	6/3/17	0001	1min	Black Rat - Small trail	D	W	7622-7623	D
							6/3/17	0208		Small hopping trail	Pr	ETE	7749-7754	Un
6/3/17	2047	Echidna	D	W	8088-8089	D	6/3/17	2052	5min	Echidna - Med trail	D	W	8093-8094	D
							7/3/17	0017		Med trail	D	NDM	8298-8299	Po
7/3/17	0123	Med hopping trail	D	NDM	8364-8365	Pr	7/3/17	0122	1min	Med hopping trail	D	E	8363-8364	Pr
8/3/17	2317	Small mammal	D	W	9558	Po								
							9/3/17	2223		Small trail	D	NDM	165-166 (2nd set)	Po
							10/3/17	2051		Large Black Rat	D	ETE	733-741	Un
10/3/17	2046	Echidna - Med trail	D	NDM	728-729	D	10/3/17	2106	20min	Echidna	D	W	748	D
12/3/17	2108	Med trail	D	NDM	2070-2071 (2ndset)	Po								
14/3/17	2154	Med trail	D	NDM	3436-3437	Po								
14/3/17	2241	Med trail	D	NDM	3483-3484	Po								
							19/3/17	2125		Med hopping trail	D	NDM	2846	Po
21/3/17	2200	Echidna	Pr	W	4201	D	21/3/17	2226	26min	Echidna	D	W	4227	D
23/3/17	2314	Echidna	D	E	5595	D	23/3/17	2249	25min	Echidna - Med trail	D	E	5570-5571	D
24/3/17	0046	Echidna - Med trail	D	NDM	5687-5688	D	24/3/17	0050	4min	Echidna	D	W	5691	D

Date	Time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Movement	Pic No.	Crossing Likelihood
East End							**West End**							
							24/3/17	0357		Small hoppig trail	D	NDM	5848-5849	Po
							25/3/17	0152		Black Rat	Pr	ETE	6413-6470	Un
25/3/17	2104	Carpet Python	D	EE	6785	Un								
							26/3/17	2313		Small hopping trail	D	NDM	7574-7575	Po
							27/3/17	0306		Black Rat	Pr	E	7807-7810	Po
27/3/17	2017	Black Rat	Pr	E	8058	D	27/3/17	2014	3min	Black Rat - Rodent sp.	D	E	8055-8056	D
							30/3/17	1809		Small trail	D	NDM	9910-9911	Po
							30/3/17	2311		Small trail	D	NDM	213-214 (2nd set)	Po
31/3/17	2114	Echidna	D	E	756 (2nd set)	D	31/3/17	2122	8min	Echidna - Med Trail	D	W	764-765	D
							1/4/17	0327		LN Bandicoot	Pr	W	1129	Pr
1/4/17	0215	Swamp Rat	Po	W	1057	Po								
1/4/17	2357	Small Snake sp.	D	NDM	1579	Un								
6/4/17	2112	Med trail	D	NDM	193-194	Po								
6/4/17	2142	Echidna	D	E	223	Po								
							6/4/17	2234		Black Rat	D	EE	275	Po
							7/4/17	0037		Med trail	D	ETE	398-401	Po
7/4/17	2338	Med trail	D	NDM	999-1000	Pr	7/4/17	2336	2min	Med hopping trail	D	NDM	997-998	Pr
							8/4/17	0209		LN Bandicoot	D	E	1150-1151	Pr
8/4/17	0218	LN Bandicoot - Med trail	D	W	1159-1160	D	8/4/17	0221	3min	LN Bandicoot	D	W	1162	D
							8/4/17	0327		Med hopping trail	D	NDM	1228-1229	Pr

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
9/4/17	0341	Black Rat	D	E	1902-1904	D	9/4/17	0334	7min	Black Rat	D	E	1895	D
9/4/17	2109	Echidna - Med trail	D	W	2170-2171	D	9/4/17	2112	3min	Echidna	Pr	W	2173	D
							10/4/17	0200		Rodent sp	D	EE	2461-2463	Un
10/4/17	0243	Med trail	D	E	2504-2505	Pr	10/4/17	0239	4min	Med trail	D	NDM	2500-2501	Pr
							10/4/17	2000		Rodent sp.	Pr	W	2761	Pr
10/4/17	2044	Small snake sp	D	EE	2805	Un								
11/4/17	2333	Med trail	D	ETE	3634-3645	Un								
							12/4/17	2300		Black Rat	Po	ETE	4261-4274	Pr
13/4/17	0153	Small trail	D	E	4434-4436	Pr	13/4/17	0146	7min	Small trail	D	NDM	4427-2228	Pr
							13/4/17	2002		Small trail	D	NDM	4743-4744	Po
14/4/17	2113	Agamidae spp.	D	E	5474	Pr								
16/4/17	1922	Rodent sp.	Pr	E	6683	Pr								
							16/4/17	1945		Black Rat	Po	W	6706	Pr
							16/4/17	1953		Black Rat	D	W	6714	Pr
							16/4/17	2038		Med trail	D	E?	6758-6760	Po
							16/4/17	2043		Fox	D	EE	6764-6769	Un
							17/4/17	1843		Small trail	D	NDM	7304-7305	Po
							17/4/17	2242		Striped Marsh Frog	Pr	E	7543	Pr
17/4/17	2324	Black Rat	D	W	7585	Pr								
20/4/17	1923	LN Bandicoot	D	W	9324	D	20/4/17	1923	0min	LN Bandicoot	Pr	W	9324-9325	D

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
21/4/17	1143	Black rat	D	ETE	246-263 92nd set)	Po								
22/4/17	0137	Med hopping trail	D	E	359-360	Pr	22/4/17	0134	3min	med trail	D	NDM	357-358 (2nd set)	Pr
							22/4/17	0211		Black Rat	D	E	393	Pr
							22/4/17	0337		Black Rat	D	W	479	Pr
22/4/17	1853	LN Bandicoot - Med hopping trail	D	E	615-616	D	22/4/17	1854	1min	LN Bandicoot	D	W	616	D
22/4/17	2335	Black rat	D	W	897-898	Pr								
23/4/17	0023	LN Bandicoot	D	ETE	945-955	Un								
23/4/17	0203	Bandicoot sp. - Med trail	D	E	1045-1046	D	23/4/17	0200	3min	Bandicoot sp	D	E	1042	D
23/4/17	2103	LN Bandicoot	D	E	1405	D	23/4/17	2059	4min	LN Bandicoot -Med hopping trail	D	NDM	1401-1402	D
23/4/17	2323	LN Bandicoot	D	E	1545	D	23/4/17	2315	8min	LN Bandicoot - Med trail	D	NDM	1537-1538	D
							23/4/17	2320		Large trail	D	NDM	1542-1543	Po
							23/4/17	2327		Med hopping trail	D	NDM	1549-1550	Po
24/4/17	1838	Med hopping trail	D	E	1920-1921	Pr	24/4/17	1838	0min	Med hopping trail	D	NDM	1920-1921	Pr
25/4/17	0121	Black Rat	Pr	W	2323	D	25/4/17	0122	1min	Black Rat	Pr	W	2324	D
25/4/17	0223	Med hopping trail	D	E	2385-2386	Pr	25/4/17	0222	1min	Med trail	D	NDM	2384-2385	Pr
25/4/17	1808	Med trail	D	E	2550-2551	Pr	25/4/17	1808	0min	Med trail	D	NDM	2550-2551	Pr
							25/4/17	1825		NB Bandicoot	D	E	2567	Pr
							25/4/17	1919		Med trail	D	NDM	2621-2622	Po
26/4/17	0150	Med trail	D	W	3012-3013	Pr	26/4/17	0154	4min	Med hopping trail	D	NDM	3016-3017	Pr

Date	Time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood	Date	Time	Crossing time	Species	Accuracy	Move ment	Pic No.	Crossing Likelihood
East End							**West End**							
							26/4/17	0209		Small trail	Pr	NDM	3032-3033	Po
							26/4/17	0215		Small trail	D	NDM	3037-3038	Po
							26/4/17	0216		Med hopping trail	D	NDM	3038-3039	Po
							26/4/17	0230		Bandicoot sp	Pr	NDM	3052-3053	Po
26/4/17	0342	Med trail	D	E	3124-3125	Pr	26/4/17	0324	8min	Med trail	D	NDM	3106-3107	Pr
							26/4/17	0336		Med trail	D	NDM	3118-3119	Po
26/4/17	2354	Med trail	D	NDM	3556-3557	Po								
27/4/17	0151	Med trail	D	E	3673-3674	Pr	27/4/17	0146	5min	Med trail	D	NDM	3668-3669	Pr
27/4/17	2102	LN Bandicoot - Med trail	D	W	4044-4045	D	27/4/17	2106	4min	LN Bandicoot	D	W	2106	D
							27/4/17	2156		Med trail	D	NDM	4098-4099	Po
29/4/17	0151	Med hopping trail	D	NDM	4993-4994	Po								
29/4/17	0206	Cat	D	W	5008	Pr								
29/4/17	1829	Med hopping trail	D	NDM	5211-5212	Po								
29/4/17	2108	Rodent sp.	Pr	NDM	5370-5371	Po								
							30/4/17	0132		Rodent sp	D	E	5634	Pr
30/4/17	0156	Med trail	D	E	5658-5659	Pr	30/4/17	0153	3min	Med trail	D	NDM	5655-5456	Pr
							1/5/17	2158		Rodent sp	Pr	E	6740	Pr
2/5/17	0148	Horsehoe Bat	D	NDM	6970-6974	Po								
							3/5/17	2006		Med hopping trail	D	NDM	7948-7949	Po

Appendix B Fauna Crossings

Pacific Highway Upgrade – Sapphire to Woolgoolga

Operational Phase Fauna Crossings Monitoring Program – Year 3 (2017)

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Version 2 – Final Report

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Cover Photo: A squirrel glider (*Petaurus norfolcensis*) recorded gliding east off the lower/north-south oriented arm of the Arrawarra Creek glide pole.

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1. Introduction

1.1 Background

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: 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).

The EMP identified 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 along the Pacific Highway, 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:**

    1. Low rates of use of fauna underpasses and adjacent habitats by feral predators;
    2. High levels of fauna underpass use by a wide variety of native fauna species;
    3. Evidence of use by dispersing individuals and different age cohorts;
    4. Use by cover-dependent species and species with low mobility;
    5. Low incidences of fauna road strike mortality.

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

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

2. Evidence of use by dispersing individuals and different age cohorts;
3. Use by glider species other than threatened species e.g. sugar glider, greater glider#.

1.2 Scope

In January 2015, Roads and Maritime Services NSW (RMS) contracted Sandpiper Ecological Surveys (Sandpiper) to conduct year one operational phase monitoring of fauna mitigation measures and to assess their effectiveness. Sandpiper was subsequently contracted by RMS to conduct year two and three operational monitoring in October 2015. Year 1 and year 2 monitoring periods have been reported on (Sandpiper 2017a, 2018a).

At the commencement of year 3 (2017) monitoring, Sandpiper's scope was expanded to include underpass exclusion fence monitoring and road mortality monitoring (EMP Section 3.4). The purpose of exclusion fence monitoring is to assess the effectiveness of the fence design in protecting smaller less mobile fauna species such as frogs, reptiles and small mammals from road strike mortality whilst funneling them into the underpass structures. It was determined, in consultation with RMS, that the most effective method to achieve this and to satisfy the intent of the EMP was by use of camera traps, hair funnels active roadside searches and road mortality searches. Exclusion fence monitoring and road mortality monitoring were to occur concurrently with underpass monitoring.

The following report presents results of year three operational phase monitoring conducted during 2017. It includes information on the background, methods, discussion of results and evaluation of mitigation measures against the potential indicators of success detailed in the EMP (BEM 2014). Year three represents the final year of operational phase fauna crossing monitoring.

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 radius of each crossing structure. For the vegetated median, the study area included the vegetated median and habitat within 500m east and west of the highway corridor.

Habitat configuration differed amongst the monitoring sites (Figure 1a&b; Plates 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 of private land 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).

The greater glider *Petauroides volans* was listed as Vulnerable under Commonwealth *Environmental Protection and Biodiversity Conservation Act* 1999 on 25 May 2016, two years after ratification of the S2W EMP (BEM 2014).

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)	
			East side of highway	West side of highway
10720	Moonee	Rope bridge	DOF (8.5 to pole)	DOF/MOF (5 to pole)
11500	Moonee	Fauna underpass	Cl/MOF/DOF (20.5)	MOF/DOF (10.5)
17500	Emerald Beach	Fauna underpass	SF (3.5)	Cl/SF (29.5)
29100-30200	Arrawarra	Vegetated median	SF/MOF/DOF	SF/MOF/DOF
29380	Arrawarra south	Fauna underpass	DOF/MOF (15.8)	DOF/MOF (28.4)
29930	Arrawarra north	Fauna underpass	SF/MOF/DOF (20.8)	SF/MOF/DOF (17.6)
31000	Arrawarra creek	Glide poles	MOF/DOF (23.5)	MOF/DOF (36)


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
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
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 (top). Habitat adjoining rope bridge on the east (middle) and west (bottom) side of the alignment.

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

Plate 3: Habitat adjoining Emerald Beach underpass (ch.17500) on the east (top) and west (bottom) side of the alignment.

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

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

Plate 6: Vegetated median and adjoining habitat at Arrawarra (ch.29100-30200) as viewed along the east/southbound (top) and west/northbound (bottom) side of the alignment. The vegetated median is on the right side of both images. (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 consisted of eleven 1.2m diameter reinforced concrete (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 100mm 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	Dedicated	21.4 (NB) 31.8 (VM) 21.4 (SB)	1 x 3 x 3 1 x 3 x 3
29930	Arrawarra north	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 (top) and from the west entrance (bottom).

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

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

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

3.1.2 Monitoring fauna using underpasses

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 wall opposite the wooden rail, approximately 1.5m above floor level and approximately 2m inside the entrance and facing inwards (Plate 12). Cameras were housed in purpose-built security cases. At the Emerald Beach site, the two cameras were positioned (one each end) looking across the 20m-wide pipe series to attain full coverage of the entrance area (Plate 12). Cameras were only positioned on the east side at Emerald Beach.

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 either side of the pipe series and directed across the entrance area on the east side (right).

A recommendation of the Year 1 monitoring report was to extend the length of the two 8-week seasonal monitoring periods to increase the likelihood of detecting fauna (Sandpiper 2017). Monitoring, therefore, was conducted for 78 days during autumn and 67 days during spring (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 except camera malfunction occurred at Emerald Beach south-east during autumn and reduced active camera days for the period to 43 (Table 3).

Table 3: Fauna underpass camera monitoring periods and days cameras were active. Days Active are for two cameras.

Location	Autumn 2017		Spring 2017	
	Period	Days Active	Period	Days Active
Moonee	3/5 – 21/7/2017	78, 76	29/8 – 3/11/2017	66, 67
Emerald Beach	3/5 – 19/7/2017	76, 43	30/8 – 3/11/2017	65, 65
Arrawarra south	3/5 – 21/7/2017	78, 78	28/8 – 3/11/2017	67, 67
Arrawarra north	3/5 – 21/7/2017	78, 78	28/8 – 3/11/2017	67, 67

3.1.3 Sampling fauna in adjacent habitat

Camera bait stations were installed on both sides of each underpass to sample fauna in adjoining habitat. Two bait stations were positioned at approximately 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 approximately 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 approximately four weeks during the underpass monitoring period. 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 largely caused 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. That site was more open and consequently more vulnerable to vegetation movement caused by wind. A fire in Wedding Bells State Forest during early September consumed the two adjacent habitat cameras on the west side of Arrawarra south underpass.

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 (left) or peanut butter, honey and oats (right).

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

Location	Autumn 2017		Spring 2017	
	Period	Camera days active	Period	Camera days active
Moonee	6/4 – 3/5/2017	27, 27, 9, 0	30/8 – 28/9/2017	29, 25, 30, 29
Emerald Beach	5/4 – 2/5/2017	8, 7, 10, 11	30/8 – 28/9/2017	9, 2, 29, 29
Arrawarra south	5/4 – 3/5/2017	9, 28, 28, 27	31/8 – 26/9/2017	26, 26, burnt, burnt
Arrawarra north	4/4 – 3/5/2017	29, 28, 16, 29	31/8 – 26/9/2017	26, 25, 26, 26

3.1.4 Exclusion fence and road mortality monitoring

A camera (Scoutguard KG680V or Reconyx HC500) was positioned both sides and within 10m of each underpass entrance for a total of 16 cameras. Cameras were either mounted to a standing post or fence post at approximately 100mm above ground level and oriented along the fence (Plate 14). Cameras were deployed for approximately eight weeks in autumn and spring 2018 during underpass camera monitoring (Table 5). Cameras were active for varying number of days during the sampling periods due to false triggering from moving vegetation and some camera malfunction. To offset the loss of some data during autumn 2017, cameras were deployed during autumn 2018 for 4 weeks (Table 5).

Hair funnel sampling was conducted concurrent with autumn and spring fence camera monitoring. A single hair funnel was attached to the exclusion fence approximately 2m in front of each fence camera for a total of 16 funnels. Funnels were baited with peanut butter, honey and oats and left in place for up to four weeks (Table 5). Funnels were retrieved at the end of each period and sent to a hair funnel expert (B. Triggs) for analysis.

Road mortality surveys were conducted on five occasions each during autumn and spring 2017. Surveys entailed slowly walking 200m either side of each underpass (i.e. 400m-long transect) on both sides of the road. Walking transects were performed from behind the guard rail by two ecologists for 30 minutes/survey. Surveys included scanning the road surface and road verge for animal carcasses and actively searching the area between the guard rail and exclusion fence for reptiles and displaced carcasses (Plate 14). The exact location of each carcass was recorded on a data sheet and referred to in subsequent surveys to avoid double-counting.

Table 5: Fence camera monitoring effort. Days active are for 4 cameras per site.

Location	Autumn 2017-18			Spring 2017		
	Period	Camera days active	Days Active (Hair funnels)	Period	Camera days active	Days Active (Hair funnels)
Moonee	6/4 – 3/5/2017, 26/4-23/5/2018	32, 39, 31, 37	21	28/8 – 3/11/2017	40, 33, 67, 51	30
Emerald Beach	5/4 – 3/5/2017 26/4-23/5/2018	34, 11, 12, 13	22	28/8 – 3/11/2017	17, 30, 13, 39	30
Arrawarra south	4/4 – 3/5/2017 26/4-23/5/2018	11, 8, 19, 30	23	28/8 – 3/11/2017	27, 21, 26, 21	30
Arrawarra north	4/4 – 3/5/2017 26/4-23/5/2018	7, 32, 21, 4	23	28/8 – 3/11/2017	64, 15, 14, 14	30

Plate 14: Camera traps and hair funnels were used to monitor exclusion fencing (left). Road mortality searches and active roadside searches were conducted 200m either side of each underpass entrance (right).

3.2 Vegetated median

3.2.1 Design and monitoring methods

Checking of nest boxes, trapping (mark-release-recapture), hair funnels and spotlighting (inc. yellow-bellied glider call playback) were conducted during eight week monitoring periods in summer-autumn and winter-spring 2017. A summary of survey effort and timing for each method is detailed in Table 6.

Table 6: Methods used and survey effort to determine use of vegetated median by gliders.

Method	Summer-Autumn 2017		Winter-Spring 2017		Total Effort
	Period	Effort	Period	Effort	
Nest boxes	15/2 & 6/4/2017	2 checks x 20 boxes	31/8 & 26/9/2017	2 checks x 20 boxes	4 checks
Trapping	3-7/4/2017	4 nights x 30 traps	25-29/9/2017	4 nights x 30 traps	240 trap-nights
Spotlighting & call playback	4/4 & 6/4/2017	2 persons x 2 nights x 3 transects	26/9 & 28/9/2017	2 persons x 2 nights x 3 transects	4 nights
Hair funnels	17/2-3/4/2017	45 nights x 30 funnels	1-25/9/2017	24 nights x 30 funnels	60 funnels

3.2.2 Nest boxes

At the beginning of the 2015 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 15). 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 15). Boxes were spaced at 50m intervals along each transect.

Nest box inspections were conducted at the beginning and end of each monitoring period (Table 6). Two personnel inspected the contents of nest boxes using 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 whereby individuals were removed and placed into cloth bags for processing. Captured gliders were weighed, sexed and breeding status determined. An individual was then issued a numbered ear tag and returned to the box.

Plate 15: Nest box, Elliott trap and hair funnel mounted on a trap-tree (left). Nest boxes were inspected using a purpose built, GoPro camera mounted to an extendable pole (right).

3.2.3 Trapping (Mark-Release-Recapture)

Trapping targeting squirrel and sugar gliders was conducted for four nights during each 8-week monitoring period (Table 6). Ten traps 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 at approximately 5m height (Plate 15). 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. Black plastic was wrapped around the base of each tree to reduce by-catch of brown antechinus (*Antechinus stuartii*) and fawn-footed melomys (*Melomys cervinipes*). Traps were checked at dawn and captured animals were processed as per nest box captures (refer 3.2.2). One hundred and twenty trap-nights were completed during each monitoring period (Table 6).

3.2.4 Hair funnels

Hair funnel sampling was conducted 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 approximately 4m for a total of 30 funnels (Plate 15). 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 45 nights (summer-autumn) and 24 nights (winter-spring) (Table 6).

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 6). Two personnel performed surveys 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 was slung between 3mm wire rope and supported by 10mm wire rope (Plate 16). The bridge spans 86m from pole to pole and rests approximately 9m above road level in the centre of the highway and 10m above ground level at the pole ends. Bridge ends/bulkheads are adjacent to the mid-canopy of dry open forest. Lengths of 25mm diameter silver rope extend from the bulkhead to adjacent trees (Plate 16).

Plate 16: A Reconyx camera mounted to a wooden 'sandwich board' was positioned approximately 2m from each end of the rope bridge to capture moving fauna (left). Slung rope (25mm diam.) was used to link the bulkhead to surrounding trees (right).

3.3.2 Rope bridge - monitoring

Rope bridge monitoring entailed camera surveillance of the rope bridge surface to determine use by arboreal fauna and spotlight and call playback surveys (targeting yellow-bellied gliders) within adjoining habitat to determine the presence of threatened gliders and other arboreal mammals.

Camera monitoring of the rope bridge was continuous during Year 3 and was required to achieve a minimum of 220 days of surveillance during the period March-November. Reconyx SC950 motion-activated infra-red cameras installed at the beginning of Year 1 monitoring were kept operational during the entirety of Year 3 (up to 20 December 2017). Cameras were mounted on 'sandwich' boards and positioned approximately 2m from, and facing, the end of the rope bridge (Plate 16). Cameras were scheduled to turn on at 1700 hours and turn off at 0500 hours eastern standard time (EST). Cameras were set at high sensitivity and programmed to take five 'rapidfire' pictures upon triggering with no delay between triggers. To gain greater insight on glider interactions with the rope bridge, a Scoutguard KG680v camera with video capacity was installed atop each end pole on 9 June 2017. Cameras were positioned approximately 50mm above and directed along the surface of the rope ladder. Scoutguard cameras were scheduled to turn on at 1700 hours and turn off at 0500 hours eastern standard time (EST). Cameras were set at normal sensitivity and programmed to take 15 seconds of video upon triggering with no delay between triggers.

Cameras were checked every 2-3 months via a tree climber to refresh batteries and change memory cards. Both Reconyx cameras were active for 383 days during the extended monitoring period (i.e. 30/11/2016 – 20/12/2017), including 274 days during the March – November period (Table 7). The east Scoutguard camera was active for 169 days, including 149 days during the March – November period. Due to malfunction, the

west Scoutguard camera was only active for one day during the monitoring period.

Spotlighting was performed along a 500m-long transect running parallel to and within 50m of the highway either side of each end of the rope bridge (Figure 1). Spotlight and call playback surveys were conducted as per the method described in section 3.2.5 and conducted on four occasions during the monitoring period (29/8, 31/8, 27/9 and 2/11/2017).

Table 7: Monitoring period start and end dates and number of days active for cameras installed on the rope bridge at Moonee. # = supplementary camera.

Camera Type - position	Start of period	End of period (days)	Days active	Days active Mar-Nov
Reconyx - East	30/11/2016	20/12/2017 (383)	383	274
Reconyx - West	30/11/2016	20/12/2017 (383)	383	274
# Scoutguard – East	9/6/2017	20/12/2017 (194)	169	149
# Scoutguard – West	9/6/2017	20/12/2017 (194)	1	1

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 17). As described in the Year 1 report (Sandpiper 2017), monitoring with cameras was only conducted on the central/median glide pole (Plate 17).

The central glide pole stands 21.5m and the east pole approximately 18m above road level. Both poles are treated hardwood and approximately 500mm diameter at breast height. It includes two arms for gliders to launch from: an upper arm positioned perpendicular to the highway and a lower arm positioned parallel to the highway. Each arm is approximately 3000mm long and 150 x 100mm thick undressed hardwood and are brace-mounted to the pole. The arms are positioned approximately 200mm and 900mm from the pole top. The central pole is 36m from the closest roadside tree to the west and 25m from the east glide pole, which is 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 17).

3.3.4 Glide pole - monitoring

Camera monitoring of the central glide pole was continuous during Year 3 and was required to achieve a minimum 220 days of surveillance during the period March-November. As per year 2, a Scoutguard KG680V IR camera positioned at an end of each pole arm was used for the monitoring. The supplementary Reconyx SC950 cameras positioned at the other end of each pole arm and used during Years 1 and 2 were decommissioned at the start of Year 3 due to their inferior performance compared to the Scoutguard cameras in this monitoring context (refer Sandpiper 2018). Moreover, Scoutguard cameras enabled collection of more informative video footage which wasn't possible with Reconxy SC950 cameras. Removal of the Reconyx cameras also enabled an unobstructed view of each pole arm by the Scoutguard cameras.

Scoutguard cameras were attached to a flat 500mm long metal bar and mounted at an end of each glide pole arm such that each camera was approximately 70mm beyond the end of the glide pole arm (Plate 18). Cameras were set on medium sensitivity and programmed to take 15 seconds of video footage upon triggering. Cameras were scheduled to turn on at 1700 hrs and turn off at 0500hrs EST. Cameras were checked every 2-3 months via a tree climber to refresh batteries and change memory cards.

Scoutguard cameras were active for 270 days (perpendicular cam) and 269 days (parallel cam) during the extended monitoring period (i.e. 30/11/2016 – 20/12/2017), including 180 days (perpendicular cam) and 179 days (parallel cam) during the March – November period (Table 8). Either camera was active for 221 days during the March – November period.

Plate 17: View of the two glide poles at Arrawarra creek looking north. Cameras were installed on the central glide pole positioned between the carriageways (red circle). Solitary Islands Way adjoins the dual carriageway immediately to the east (right of the photo).

Plate 18: Scoutguard KG680V cameras mounted on metal bars & positioned at the end of each pole arm were used for monitoring (left). The upper glide pole arm was perpendicular to the highway (middle) and the lower arm was parallel to the highway (right).

Spotlight surveys and call playback were conducted in forest adjacent to the glide poles to determine the presence of threatened gliders and other arboreal mammals. The two 500m-long roadside transects established in forest either side of the highway at the beginning of year one were spotlighted/call playback on four occasions (i.e. 29/8/2017, 31/8/2017, 27/9/2017, 2/11/2017) during the monitoring period. Spotlight and call playback surveys were conducted as per the method described in Section 3.2.5.

Table 8: Glide pole camera activity periods during Year 3 monitoring. The 375-day monitoring period operated from 30/11/2016 – 20/12/2017.

Camera position	Days active	Days active Mar-Nov	Days either cam active	Days either cam active Mar-Nov
Perpendicular (upper)	280	180	311	221
Parallel (lower)	269	179		

3.4 Data summary and analysis

All images were uploaded to a desk top 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 recorded. A hierarchical approach was adopted to species identification that included: species, genus or group.

Passes 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 were summed for the two cameras for each season. A 'definite' 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. A 'probable' crossing was scored when an animal was recorded making directional movement by one camera only 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. A 'possible' crossing was scored when there was demonstrated exploratory movement at the underpass entrance area or the individual stopped and did not show either strong directional movement or movement that suggests it turned around and exited. An 'unlikely' crossing (referred to as a 'visit') was scored when an individual was observed turning around or returning in <10 minutes or, in the case of the Emerald Beach pipes, was observed moving past the pipe entrance area but not into a pipe. Because cameras at Emerald Beach pipes were only on one side of the underpass, photo sequences were scored as either 'probable', 'possible' or 'unlikely' as per the definitions above. Total crossings for the rope bridge and each underpass were the sum of passes scored as either definite or probable crossings.

Road crossings via the glide pole could not be confirmed from still photographs during year 1 and were inferred based on the reasoning that while an individual may glide to the central pole and return to the same side, it likely represents 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 was consistent with analyses of glide pole monitoring records from the Hume Highway which were supported by radio-tracking data (see Soanes et al. 2015).

After installation of video cameras on glide pole arms during year 2 monitoring, video recordings confirmed road crossings in both directions. To account for the presence of two cameras, video footage of an individual animal recorded by one camera or both concurrently and either separated from other footage by at least 10 minutes or clearly showing a different individual if less than 10 minutes was scored as a 'pass'. Information recorded for each pass, where discernible, included: species, sex, tail tip tone (for sugar gliders), movement type (i.e. explore arm, climb pole, launch east, launch west). For observed glide launches, a Chi-square test for independence was applied to test the choice of either perpendicular/upper arm or parallel/lower arm. The

expected frequency if no choice was exhibited would be 0.5. Each observed glide launch was treated as an independent test.

4. Results

4.1 Underpasses and adjacent habitat

4.1.1 Species in adjacent habitat

Twenty-eight species of vertebrate were detected by cameras in habitat adjoining underpasses (Table 9; Plate 19). Moonee was the most diverse site (19 species) and Arrawarra north the least (11 species). Species diversity was generally similar on each side of an underpass although Moonee recorded a moderate difference (16 spp. versus 9 spp.). More species were recorded during autumn at all sites except Arrawarra north. Long-nosed bandicoot (*Perameles nasuta*), common brushtail possum (*Trichosurus vulpecula*) and swamp wallaby (*Wallabia bicolor*) were recorded at all sites (Plate 19). Squirrel glider (*Petaurus norfolcensis*) was the only threatened species detected in habitat adjacent the underpasses during the monitoring period. Full details of adjacent habitat camera monitoring are provided in Table A1 (Appendix A).

Table 9: Fauna recorded at camera bait stations in habitat adjacent to underpasses during Autumn (A) and Spring (S) survey periods. E = East; W = West; Po = Possible. * = listed as Vulnerable under Biodiversity Conservation Act 2016.

Common Name	*Species Name*	Moonee		Emerald		Arrawarra Sth		Arrawarra Nth	
		E	W	E	W	E	W	E	W
Lace monitor	*Varanus varius*					A	A	S	
Land mullet	*Bellatorius major*		A						
Eastern water dragon	*Intellagama lesueurii*	A		A					
Echidna	*Tachyglossus aculeatus*	A S				S	A	A S	A S
Antechinus spp.	*Antechinus spp.*					A		A	A
Long-nosed bandicoot	*Parameles nasuta*	S	S	A	S	A S	A	A S	S
Northern brown bandicoot	*Isoodon macrourus*			A	S	A	A	S	S
Bandicoot spp.				A	A	A		A S	A
Squirrel glider	*Petaurus norfolcensis**					A			
Short-eared brushtail possum	*Trichosurus caninus*	A							
Common brushtail possun	*Trichosurus vulpecula*	S	A		S	A S	A	S	A S
Brushtail possum spp.		A							
Eastern grey kangaroo	*Macropus giganteus*		S	A S	A S	S			
Red-necked wallaby	*Macropus rufogriseus*	S		A					
Swamp wallaby	*Wallabia bicolor*	A S	A S	A S	S	A S	A	A S	A S
Wallaby spp.					A				A
Fawn-footed Melomys	*Melomys cervinipes*	S							
Water rat (Po)	*Hydromys chrysogaster*					A			
Swamp rat	*Rattus lutreolus*							S	
Bush rat	*Rattus fuscipes*	A	S						
Black rat	*Rattus rattus*	A	A			A		S	
Rodent spp.		A	A	A	A	A		A S	A
Dog	*Canis familiaris*				S		A	A	A
Red fox	*Vulpes vulpes*	A S	A						
Bird sp.				A					
Red-browed finch	*Neochmia temporalis*			A					
Brush turkey	*Alectura lathami*	A S			A S			A	S
Kookaburra	*Dacelo novaeguineae*		S		A				
Noisy pitta	*Pitta versicolor*	A							
Fairy wren sp.	*Malurus sp.*			A					
Eastern Yellow Robin	*Eopsaltria australis*	A							
Russet-tailed Thrush	*Zoothera heinei*	A							
Bar-shouldered Dove	*Geopelia humeralis*	A							
Number of species/side		16	9	9	9	11	7	11	9
Number of species/site		19		13		12		11	
Number of species/season/site (A/S)		14/11		11/7		11/5		8/9	

Plate 19: Species recorded in habitat adjoining fauna underpasses included common brushtail possum (Top Left), echidna (Top Right), bush rat (Middle Left), squirrel glider (Middle Right), swamp wallaby (Bottom Left) and eastern grey kangaroo (Bottom Right).

4.1.2 Species using underpasses

Eight fauna species were confirmed using at least one of the four fauna underpasses during autumn and spring monitoring (Table 10). Three hundred and seventy-five passes and 283 crossings were recorded by the eight cameras. More camera passes were recorded in spring than autumn (229 versus 146) although this was largely attributed to high use of Moonee underpass by red fox (*Vulpes vulpes*) during spring. Moonee was the most frequented underpass with 268 passes and 237 crossings although this was attributed to high use by red fox (Table 10). Emerald Beach and vegetated median north were underpasses most frequented by native fauna (35 and 47 passes respectively) with swamp wallaby (*Wallabia bicolor*) the most frequently detected native

species and detected at all sites (Plate 20). Emerald and Moonee featured the greatest diversity of native species users (4 spp. and 3 spp. respectively) although at Emerald Beach only eastern grey kangaroo (*Macropus giganteus)* were confirmed making crossings (Plate 21).

Four native species/taxa group were recorded making crossings of the underpasses (Table 10; Plate 20 & 21). Swamp wallaby recorded the highest number of underpass crossings amongst native species users, including 24 crossings of the Arrawarra north underpass. Eastern grey kangaroo recorded the next highest number of crossings, including six at the Moonee underpass and three at the Emerald Beach pipes. Long-nosed bandicoot (*Perameles nasuta*) was recorded making one crossing of the Moonee underpass during spring.

At least one species of introduced predator was recorded at each site (Table 10). Red fox and cat (*Felis catus*) were recorded at Moonee and Emerald and dog (*Canis familiaris*) was recorded at the Arrawarra sites. Red fox was recorded making 230 crossings of the Moonee underpass with 69% occurring during spring (Table 10; Plate 22). At least three individuals were identified. On five occasions, red fox was photographed with prey, including eel and a species of rodent. Cat was only detected on three occasions and not confirmed making a crossing of either Moonee or Emerald underpasses. Dogs (up to 2 individuals) were recorded crossing each of the Arrawarra underpasses on two occasions during autumn (Table 10).

Full details of underpass camera monitoring are provided in Table A2 (Appendix A).

Table 10: Species detected and number of camera passes and crossings (passes/crossings) recorded by cameras at each end of fauna underpasses. Aut = Autumn; Spr = Spring.

Common name	*Species name*	Moonee		Emerald Beach		Arrawarra Sth		Arrawarra Nth		Total passes/ crossings
		Aut	Spr	Aut	Spr	Aut	Spr	Aut	Spr	
Bush Turkey	*Alectura lathami*				1/0					1/0
Eastern grey kangaroo	*Macropus giganteus*	6/6	1/0	5/1	23/2	4/2	3/1			42/12
Red-necked Wallaby	*Macropus rufogriseus*				4/0					4/0
Swamp wallaby	*Wallabia bicolor*	3/0	1/0		2/0	7/4	2/2	39/23	1/1	55/30
Wallaby spp.								7/6		7/6
Long-nosed bandicoot	*Perameles nasuta*		1/1							1/1
Red fox	*Vulpes vulpes*	66/53	188/177		1/0					255/230
Dog	*Canis familiarus*					4/2		3/2		7/4
Cat	*Felis catus*	2/0			1/0					3/0
Native fauna passes		9/6	3/1	5/1	30/2	11/6	5/3	46/29	1/1	110/49
Introduced fauna passes		68/53	188/177	0/0	2/0	4/2	0/0	3/2	0/0	265/234
Total Fauna Passes/Crossings		77/59	191/178	5/1	32/2	15/8	5/3	49/31	1/1	375/283

Plate 20: Swamp wallaby captured moving east through the northern Arrawarra underpass (Left and Right).

Plate 21: Photo sequence shows a female eastern grey kangaroo emerging from an eastward crossing of the Emerald Beach pipes.

Plate 22: Moonee underpass featured high use by feral predators including fox (Left) and cat (Right) although crossings were only confirmed for red fox.

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 23% and 50% (Table 11). 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 Emerald Beach (50%) and the least at Arrawarra south (23%). The proportion of native species detected in adjoining habitat and recorded using the respective underpass ranged from 18% at vegetated median south to 33% at Emerald Beach (Table 11). No reptiles detected in adjacent habitat were recorded using the underpasses and neither were several mammal species, including: echidna (*Tachyglossus aculeatus*), *Antechinus* spp., northern brown bandicoot (*Isoodon macrourus*), common and short-eared brushtail possum (*Trichosurus spp.*), squirrel glider (*Petaurus norfolcensis*) and rodents.

Table 11: Species recorded in adjacent habitat and species recorded using underpasses. Data for autumn and spring are pooled. Birds detected in adjoining habitat have been excluded as they are not the target of underpass deployment and were not recorded using underpasses. Adj = adjacent; UP = underpass.

Common Name	*Species Name*	Moonee		Emerald		A'warra Sth		A'warra Nth	
		Adj	UP	Adj	UP	Adj	UP	Adj	UP
Lace monitor	*Varanus varius*					X		X	
Land mullet	*Bellatorius major*								
Eastern water dragon	*Intellagama lesueurii*			X					
Echidna	*Tachyglossus aculeatus*					X		X	
Antechinus spp.	*Antechinus sp.*					X		X	
Long-nosed bandicoot	*Parameles nasuta*	X	X	X		X		X	
Northern brown bandicoot	*Isoodon macrourus*			X		X		X	
Squirrel glider	*Petaurus norfolcensis**					X			
Short-eared brushtail possum	*Trichosurus caninus*	X							
Common brushtail possun	*Trichosurus vulpecula*	X		X		X		X	
Eastern grey kangaroo	*Macropus giganteus*	X	X	X	X	X	X		
Red-necked wallaby	*Macropus rufogriseus*	X		X	X				
Swamp wallaby	*Wallabia bicolor*	X	X	X	X	X	X	X	X
Wallaby spp.				X				X	X
Fawn-footed Melomys	*Melomys cervinipes*	X							
Water rat (Po)	*Hydromys chrysogaster*					X			
Swamp rat	*Rattus lutreolus*							X	
Bush rat	*Rattus fuscipes*	X							
Black rat	*Rattus rattus*	X				X		X	
Rodent spp.		X		X		X		X	
Dog	*Canis familiaris*			X		X	X	X	
Red fox	*Vulpes vulpes*	X	X		X				X
Cat	*Felis catus*		X		X				
Number of species		14	5	10	5	13	3	12	3
Proportion of species in adj habitat using u'pass		36%		50%		23%		25%	
Number of native species		11	3	9	3	11	2	9	2
Proportion of native spp.in adj habitat using u'pass		27%		33%		18%		22%	

4.1.4 Fauna interactions with exclusion fence

A variety of species were detected adjacent the fauna exclusion fence at all four underpass sites (Table 12). Swamp wallaby, eastern grey kangaroo, northern brown bandicoot and black rat were the most commonly detected species (Plate 23). Most animal movements were either along the fence or non-directional (Table 12). On one occasion, an eastern grey kangaroo was observed on the road side of the fence, presumably gaining access through a nearby open gate (Plate 23).

The only through-fence observations made were by black rat and *Antechinus* spp. (probably brown Antechinus). Both species are small enough to easily move through the 45mm chain mesh fencing (Plate 23). Eastern water dragon (Emerald west) was the only reptile detected by the fence cams during the two survey seasons. It was observed moving and making non-directional movement close to the exclusion fence during spring. No photographs featured attempts by this species to move through the fence. Full details of exclusion fence camera monitoring are provided in Table A3 (Appendix A).

Table 12: Species recorded at exclusion fence near underpass entrances and their movements and hair funnel records. NDM = no defined movement; AF = moves along fence; BTR = pass through fence from bush side to roadside; RTB = pass through fence from roadside to bush side. * = observed grazing/moving along roadside of fence. # = hair funnel record.

Common Name	Scientific Name	Autumn (East/West)					Spring (East/West)				
		Hair	NDM	AF	BTR	RTB	Hair	NDM	AF	BTR	RTB
Moonee											
Short-beaked Echidna	*Tachyglossus aculeatus*								1/-		
Cmmn Brushtail Possum	*Trichosurus vulpecula*								-/1		
Nthn Brown Bandicoot	*Isoodon macrourus*			1/-							
Eastern Grey Kangaroo	*Macropus giganteus*			2*/2				3/-	2/-		
Swamp Wallaby	*Wallabia bicolor*		2/4	8/6				10/2	8/2		
Wallaby spp.			1/-								
Black Rat	*Rattus rattus*	-/#	5/-		1/-			-/1	1/-		
Rodent spp.									2/-		
Fox	*Vulpes vulpes*			-/6				-/5	1/2		
TOTAL			**8/4**	**11/14**	**1/0**	**0**		**13/8**	**15/5**	**0**	**0**
Emerald											
Eastern Water Dragon	*Intellagama lesueurii*							-/6	-/1		
Nthn Brown Bandicoot	*Isoodon macrourus*						-/#		-/3		
Bandicoot spp.								-/1			
Eastern Grey Kangaroo	*Macropus giganteus*		2/-	4/-				1/1	2/1		
Red-necked Wallaby	*Macropus rufogriseus*		3/-	1/-							
Swamp Wallaby	*Wallabia bicolor*							3/-	3/1		
Macropod spp.			6/-	2/-							
Black Rat	*Rattus rattus*										1/-
Rodent spp.										1/-	
House Mouse	*Mus musculus*	-/#					#/#				
TOTAL			**11/0**	**7/0**	**0**	**0**		**4/8**	**5/6**	**1/0**	**1/0**
Arrawarra North											
Short-beaked Echidna	*Tachyglossus aculeatus*		1/-	1/-							
Brown antechinus	*Antechinus stuartii*	#/-					#/-				
Antechinus spp.			2/-	3/-	3/-						
Swamp Wallaby	*Wallabia bicolor*		-/1	8/-				1/-	-/1		
Macropod spp.								1/-			
Black Rat	*Rattus rattus*		3/1	2/-	1/-	3/-		1/-	2/-		
House Mouse	*Mus musculus*	-/#					-/#		2/-		
Rodent spp.									1/-		
Fox	*Vulpes vulpes*			3/-					1/-		
TOTAL			**6/2**	**17/0**	**4/0**	**3/0**		**3/0**	**6/1**	**0**	**0**
Arrawarra South											
Brown antechinus	*Antechinus stuartii*	#/#					#/-				
Nthn Brown Bandicoot	*Isoodon macrourus*						-/#		-/10		
Eastern Grey Kangaroo	*Macropus giganteus*								1/-		
Swamp Wallaby	*Wallabia bicolor*			1/-				1/0	-/1		
Macropod spp.								0/1	1/-		
Black Rat	*Rattus rattus*		-/1						-/2	-/3	
House Mouse	*Mus musculus*		1/0				#/#				
Rodent spp.									1/2		
TOTAL			**1/1**	**1/0**	**0**	**0**		**1/1**	**3/15**	**0/3**	**0**

Plate 23: Northern brown bandicoot was observed foraging and moving along the inside of the western exclusion fence at Arrawarra south (top left). On one occasion at Moonee east, an eastern grey kangaroo was observed on the road side of the fence, presumably gaining access through a nearby open gate (top right). Antechinus sp. were observed on several occasions moving through the eastern exclusion fence/drainage flap at Arrawarra north (bottom left & right).

4.1.5 Exclusion fence condition

The roadside floppy-top exclusion fence was generally in good condition except for several breaches. A fallen tree was resting on and across the eastern exclusion fence at Arrawarra north, approximately 20m north of the underpass (Plate 24). The fall had caused only minor damage to the top of the fence, but the position of the tree would enable arboreal fauna to access the roadside. All other fence breaches occurred at the Emerald site.

The western exclusion fence at Emerald was evidently struck by a vehicle approximately 150m north of the underpass. The collision effectively removed 10m of fence (Plate 24). The section of fence sits above a series of 1100mm diameter drainage pipes embedded within a 1800mm high headwall. Despite the loss of this section of fence, the height of the headwall itself would serve as an effective barrier to roadside access by terrestrial fauna.

Open concrete drains occurred at several places along the Emerald west road mortality transect (Plate 25). At these locations, the fence continued over the top of the drain and was not tied in or drainage flaps installed, as per deeper drains at vegetated median north (refer Plate 23). This design created a gap of approximately 150mm at these locations, sufficiently large for small to medium sized vertebrates (e.g. rodents, bandicoots) to

move through. A roadside bandicoot carcass was recorded approximately 30m from one of these drain gaps. It is possible this individual accessed the roadside through this gap. It may also have accessed the roadside via the Emerald Beach interchange 200m to the north or access road openings in the fence on the east side. Two access road fence openings occurred within the eastern road mortality transect at Emerald.

Plate 24: Breaches in the exclusion fence were evident at several locations including Emerald west where a vehicle had collided (top). A fallen tree potentially compromised the fence at vegetated median north east (bottom left).

Plate 25: Concrete drains at a number of places along the Emerald west road mortality transect potentially compromise the fence integrity (bottom right).

4.1.6 Road mortality and fauna in roadside habitat

Fifty-seven vertebrate carcasses representing at least 23 species were recorded during two seasons of road mortality surveys (Table 13; Plate 26). An equivalent number of carcasses were recorded in autumn (n = 29) and spring (n = 28). Moonee (n = 19) and Arrawarra north (n = 18) recorded the most carcasses and Arrawarra south (n = 7) the least. No threatened species carcasses that could be identified to species level were recorded.

Birds were the most frequently recorded taxa group (n = 23) and included at least 10 species. A similar number of carcasses were recorded during autumn (n = 13) and spring (n = 10). The Moonee transects featured the most bird road mortalities (n = 9). Southern boobook *Ninox boobook* (n = 5) was the most frequently recorded species followed by laughing kookaburra *Dacelo novaeguineae* (n = 3). All records were of small to medium sized birds except a single record of an unidentified raptor (i.e. bird of prey).

Mammals were the second most recorded taxa group with 19 records and at least eight species (Table 13). More records occurred during spring (n = 11) compared to autumn (n = 8). Emerald transects featured the most mammal road mortalities (n = 8). It was also the only site where macropod carcasses were recorded and

included two eastern grey kangaroos (*Macropus giganteus)* and one swamp wallaby (*Wallabia bicolor)*. The most frequently recorded species were echidna *Tachyglossus aculeatus* (n = 4) followed by possum spp. (n = 4) and bandicoot spp. (n = 3).

Fourteen reptile carcasses representing at least four species were recorded during road mortality surveys. Equal numbers occurred in autumn and spring (n = 7). Moonee featured the most reptile road mortalities (n = 6). Carpet python was the most commonly recorded species (n = 4). Six snakes could not be identified as only bone fragments remained.

Table 13: Animal carcasses observed on road and road verge during road mortality surveys.

Common Name	Species Name	Moonee		Emerald Beach		A'warra South		A'warra North	
		Aut	Spr	Aut	Spr	Aut	Spr	Aut	Spr
Medium Frog sp.				1					
Bearded Dragon	*Pogona barbata*		1						
Reptile sp.			1						
Carpet Python	*Morelia spilota*	1				1		1	1
Brown Tree Snake	*Boiga irregularis*	1							
Green Tree Snake	*Dendrelaphis punctulatus*	1							
Snake sp.			1			1	1	1	2
Raptor sp.						1			
Bar-shouldered Dove	*Geopelia humeralis*				1				
Southern Boobook	*Ninox boobook*	1		1			1	2	
Dollarbird	*Eurystomus orientalis*		1						
Laughing Kookaburra	*Dacelo novaeguineae*		1			1			1
Fairy Wren sp.			1					1	
Brown thornbill	*Acanthiza pusilla*	1							
Eastern Yellow Robin	*Eopsaltria australis*							1	
Welcome Swallow	*Hirundo neoxena*				1				
Red-browed Finch	*Neochmia temporalis*		2						
Medium Bird spp.								2	
Small Bird spp.		1	1	1					
Short-beaked Echidna	*Tachyglossus aculeatus*		1					2	1
Brown Antechinus	*Antechinus stuartii*				1				
Northern Brown Bandicoot	*Isoodon macrourus*	1							1
Bandicoot spp.				1					
Common Brushtail Possum	*Trichosurus vulpecula*								1
Brushtail Possum spp.				1			1		
Possum sp.		1							
Eastern Grey Kangaroo	*Macropus giganteus*				2				
Swamp Wallaby	*Wallabia bicolor*				1				
Microbat spp.								1	
Rodent spp.		1							
Medium Mammal					1				
Small Mammal					1				
TOTAL		**9**	**10**	**5**	**8**	**4**	**3**	**11**	**7**

Plate 26: At least 23 species of vertebrate were recorded during two seasons of road kill monitoring, including swamp wallaby at Moonee (top left), brown antechinus at Emerald (top right), eastern yellow robin at Arrawarra north (bottom left) and brown tree snake at Moonee (bottom right).

Six species and a total of 13 records of fauna use of roadside habitat were made during road mortality surveys (Table 14). A similar number of observations were made during autumn (n = 6) and spring (n = 7). The highest number of observations occurred at Arrawarra north (n = 5) and Moonee (n = 4). Small skinks (*Lampropholis spp.)* were the most frequently recorded species (n = 8) and were recorded at all sites except Emerald (Table 14). On one occasion a yellow-faced whip-snake (*Demansia psammophis)* was observed basking 4m off the fog line amongst roadside vegetation at Moonee east (Plate 27).

Concurrent records of roadside use and road mortality were evident for two species. Bandicoot spp. diggings in the roadside were detected within 100m of a northern brown bandicoot carcass at Arrawarra north and Macropod spp. scats were detected within 50m of an eastern grey kangaroo carcass at Emerald.

Full details of road mortality and roadside habitat monitoring are provided in Table A4 (Appendix A).

Table 14: Species detected in roadside habitat adjacent exclusion fence during road mortality surveys.

Common Name	*Species Name*	Moonee		Emerald		A'warra Sth		A'warra Nth	
		Aut	Spr	Aut	Spr	Aut	Spr	Aut	Spr
Small skink	*Eulamprus sp.*								1
Skink	*Lampropholis sp.*	2	1			1	1	2	1
Yellow-faced whip snake	*Demansia psammophis*	1							
Red-browed Finch	*Neochmia temporalis*				1				
Bandicoot spp. (diggings)									1
Macropod spp. (scat)					1				
TOTAL		**3**	**1**	**0**	**2**	**1**	**1**	**2**	**3**

Plate 27: A yellow-faced whip-snake was observed at Moonee during autumn road mortality surveys. The individual was basking in roadside habitat on the eastern side of the carriageways.

4.2 Vegetated median

4.2.1 Species detections and highway crossings

Four arboreal mammal species (including three glider species) and three scansorial species were detected by the various methods during the two monitoring seasons at the vegetated median site (Table 15; Plate 28). More records were obtained during autumn (n = 79) than spring (n = 56), largely due to the high number of captures of brown antechinus and fawn-footed Melomys in tree traps targeting gliders (56 captures in autumn compared to 13 captures in spring). The markedly lower spring value was attributed to the loss of all males from the antechinus population in early spring.

Three squirrel gliders *Petaurus norfolcensis* (1 male, 2 female) were captured on five occasions during autumn and three individuals (2 male, 1 female) were captured on eight occasions during spring (Plate 28; Table 16). Overall, six individual squirrel gliders (3 male, 3 female) were captured during year three monitoring. Pouch young were recorded in one female (F6) during autumn and one female (F8) during spring (Table 16). Two squirrel gliders were recaptured from previous years – M1 who was first captured in 2015 and M3 who was first captured in 2016. The female F8 was also first captured in a previous year but could not be reliably identified due to loss of its ear tag.

The location of recaptured individuals confirmed four crossings of the southbound carriageway – two crossings from east forest to median (M5 & F8) and two crossings from median to east forest (F6 & F8). M5 was also

observed completing a glide crossing of the northbound carriageway (median to west forest) after release from a trap on 29/9/2017.

Sugar gliders (*Petaurus breviceps*) were captured in the east forest during autumn (Table 15). All four individuals (2 male, 2 female) were new captures and no highway crossings were confirmed. One of the females showed evidence of previous breeding and the other female was a non-breeding, sub-adult. Nests of either sugar glider or squirrel glider were evident in eight nest boxes on the east side of the alignment and four on the west side in autumn and four boxes on the east side during spring. No individuals were observed in nest boxes during inspections.

Feathertail glider (*Acrobates pygmaeus*) was the other species of glider detected. An individual was observed at the edge of the eastern forest during autumn spotlighting. Distinctive nests of this species were detected in one nest box on the west side during autumn and in a single box on both sides during spring (Table 15). Feathertail glider hair was also detected within one hair funnel in the vegetated median during spring.

A further four non-volant mammal species were detected at the vegetated median site (Table 15). Two species not previously detected at the vegetated median site - eastern pygmy possum (*Cercartetus nanus)* and common dunnart (*Sminthopsis murina)* – were detected from hair funnel samples. Eastern pygmy possum, *listed as Vulnerable under the NSW Biodiversity Conservation Act 2016*, was detected in two hair funnels amongst dry forest with a shrubby understory on the east side during spring. Common dunnart was detected in two hair funnels amongst dry to moist forest on the west side during autumn. Both detections are significant because few records of eastern pygmy possum and common dunnart exist in the locality.

The two other relatively common species detected in arboreal surveys were brown antechinus and fawn-footed Melomys. High numbers of brown antechinus were captured on both sides of the alignment and within the vegetated median during autumn followed by low capture numbers during spring after the male die-off (Table 15; Plate 28). Fawn-footed Melomys were captured in low numbers during autumn on both sides of the alignment and within the median. No individuals were captured during spring but hair was detected in one hair funnel on the west side.

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

Table 15: Arboreal mammals recorded within the vegetated median and/or adjoining habitat. Tx = number of captures in arboreal traps; Sx = number of individuals observed during spotlighting; Nx = number of nest boxes containing nests; Hx = number of records in hair funnels; Pr = probable. ^ = listed as vulnerable on NSW Biodiversity Conservation Act 2016.

Species name	Common Name	Summer-Autumn			Winter-Spring		
		East	Median	West	East	Median	West
Antechinus stuartii	Brown antechinus	H9, T7	H8, T8	H1, T8	H8	H9, T7	H9
Antechinus sp.	Antechinus sp.	N1	H1	N1	N2		N3
Sminthopsis murina	Common dunnart			H2			
Cercartetus nanus	Eastern pygmy possum^				H2		
Petaurus breviceps	Sugar glider	T4, S1					
Petaurus norfolcensis	Squirrel glider^	T3	T2		T4	T4	
Petaurid spp.	Sugar or Squirrel glider	N8		N4	N4		
Acrobates pygmaeus	Feathertail glider	S1		N1	N1	H1	N1
Melomys cervinipes	Fawn-footed melomys	T1	T3	T2, H3			H1
Total Records		**79**			**56**		

Plate 28: Four arboreal and three scansorial mammal species were recorded at the vegetated median site, including the threatened squirrel glider (left), sugar glider (middle) and brown antechinus (right).

Table 16: Squirrel and sugar glider captures and carriageway crossings at the Arrawarra vegetated median. SqG = squirrel glider; SuG = sugar glider; M = male; F = female; py = carrying pouch young; NB = northbound carriageway; SB = southbound carriageway; E = east habitat; M = vegetated median; W = west habitat. * = glide crossing observed after release from a trap.

Trap Location	Date	Species (recapture)	Sex/Id	Carriageway Crossings
Autumn				
M7 trap	4/4/2017	SqG	F6 (py)	
E2-trap	5/4/2017	SqG	F7	
E5-trap	5/4/2017	SqG (session recapture)	F6 (py)	
E7-trap	5/4/2017	SuG	Mb	
E6-trap	6/4/2017	SqG (session recapture)	F6 (py)	Crossed SB carriageway (median > east)
M3 trap	7/4/2017	SqG (recapture)	M1	
E7-trap	7/4/2017	SuG	Mc	
E3-trap	7/4/2017	SuG	Fc	
E3-trap	7/4/2017	SuG	Fd	
Spring				
M2-trap	26/9/2017	SqG (recapture)	M3	
E4-trap	26/9/2017	SqG (recapture)	F8 (py)	
M7-trap	27/9/2017	SqG	M5	
E4-trap	27/9/2017	SqG (session recapture)	F8 (py)	
E4-trap	28/9/2017	SqG (session recapture)	M5	Crossed SB carriageway (median > east)
E6-trap	28/9/2017	SqG (session recapture)	F8 (py)	
M10-trap	29/9/2017	SqG (session recapture)	M5	Crossed SB carriageway (east > median) & crossed NB carriageway (median > west)*
M7 trap	4/4/2017	SqG (session recapture)	F8 (py)	Crossed SB carriageway (east > median)

4.3 Rope bridge and glide pole

4.3.1 Rope bridge and adjacent forest - species detections and highway crossings

Feathertail gliders and sugar gliders were detected on the rope bridge during the year-long monitoring (Table 17). Sugar gliders were detected on three occasions at the east end. On one occasion, an individual was photographed showing strong directional movement towards the east end which suggested a probable eastward crossing (Plate 29). Two of the three detections showed sugar gliders using the edge of the rope bridge and the other occasion the individual moved within the central mesh area. A sugar glider was also observed during spotlighting on one occasion. The individual was spotted at the edge of the west forest, 300m to the north of the rope bridge. The only other arboreal mammal detected during spotlight surveys was a common brushtail possum. It was observed within the east forest, 150m to the south of the rope bridge.

Feathertail gliders were detected on the rope bridge on 10 occasions (Table 17). Most photographs showed an individual exploring both the edge and center of the rope bridge within the field of view. On four occasions an individual exhibited strong directional movement at one camera end. No concurrent images (i.e. photographs captured at both ends within 30 minutes) were recorded but the strong directional movement in each case suggested a probable crossing (Table 17). The strong directional movements occurred both within the center mesh area (two occasions) and the wire edge (two occasions). On one occasion at the west end (2/12/2017), the photo series showed an individual moving swiftly along the edge, stopping approximately 1m from the end and probably gliding off in a northerly direction (Plate 30). No other arboreal mammals or reptiles were recorded on the rope bridge during the monitoring period.

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

Table 17: 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	East cam	West cam	Behaviour (position on bridge)	Crossing likelihood	East forest	West forest
Common brushtail possum				NA	X	
Sugar glider	25/4/17 @0324		Non-directional movement (edge)	Unlikely		X
	2/7/17 @0051		Move east (edge)	Probable		
	28/7/17 @0155		Move west, stop (center)	Possible		
Feathertail glider		28/1/17 @0218	Exploratory east & west movement (edge & center)	Unlikely		
		2/12/17 @0236	Move west & glide off northwards 1m from end (edge)	Probable		
	12/12/17 @0133		Exploratory east & west movement (edge & center)	Unlikely		
	13/12/17 @0231		Move east (center)	Probable		
	15/12/17 @0204		Exploratory east & west movement (edge)	Unlikely		
	17/12/17 @0008		Move east (edge)	Probable		
	17/12/17 @0210		Exploratory east & west movement (edge)	Unlikely		
	17/12/17 @0305		Move west (center)	Probable		
	17/12/17 @2000		Exploratory east & west movement (edge)	Unlikely		
		17/12/17 @2343	Move east, stop, move west (edge)	Unlikely		

Plate 29: Sugar gliders were detected on three occasions at the east end of the rope bridge (left). On one occasion an individual completed a probable eastward crossing (right).

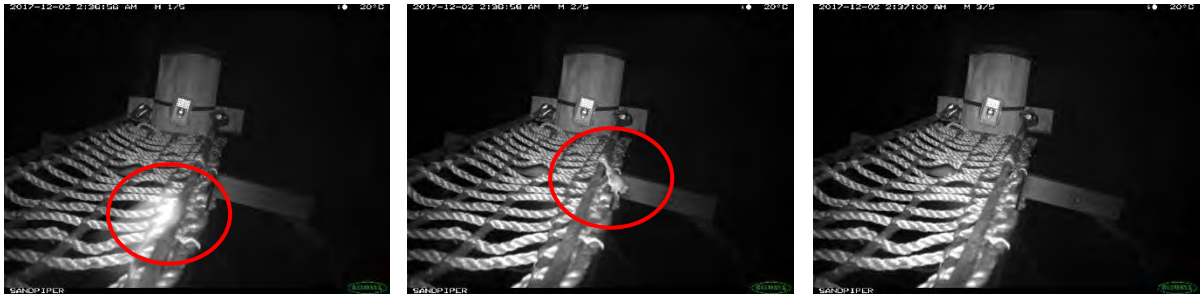

Plate 30: Feathertail glider was detected at either end of the rope bridge on 10 occasions and completed four probable crossings. On one occasion the west camera captured an individual moving towards the west end, stopping 1m from the end and probably gliding off to the north-west, as evident in the three-photo sequence.

4.3.2 Glide poles and adjacent forest - species detections and highway crossings

Cameras positioned on the upper/perpendicular arm and lower/parallel arm of the glide pole recorded 90 passes (2.03 passes/week) during 311 days of active monitoring (Table 18). More passes were recorded by the lower/parallel arm camera (63 passes at 1.64 passes/week) compared with the upper/perpendicular arm camera (43 passes or 1.08 passes/week).

Three species of glider were recorded by pole cameras - squirrel glider, sugar glider and feathertail glider. Squirrel gliders were detected by the lower/parallel arm camera on 10 occasions at a rate of 0.26 passes/week but not by the upper/perpendicular arm camera (Table 18). At least two individuals (a male and female) could be distinguished. The behaviour of individuals was largely exploratory and mostly featured steady movements along the glide pole arm. Squirrel gliders were recorded launching off the lower/parallel arm in an eastward direction on four occasions and westward direction on three occasions (Figure 2; Plate 31). Preference for the lower/parallel arm compared to the upper/perpendicular arm was highly significant (P = 0.008). All glide launches occurred from the inner section of the arm close to the pole (Plate 31).

Sugar gliders were detected on either or both pole arms on 38 occasions (0.86 passes/week) during the monitoring period (Table 18). A greater number of passes were recorded by lower/parallel arm camera (n = 35; 0.91 passes/week) compared with the upper/perpendicular arm cameras (n = 8; 0.2 passes/week). Sugar glider behaviour was largely exploratory and featured both slow and rapid movements along the glide pole arms. On some occasions individuals were observed jumping/climbing higher up the pole from the lower arm. At least three individuals could be identified from images (two females and one male). Sugar gliders were recorded launching into westward glides off the lower/parallel arm on 23 occasions and off the upper/perpendicular arm on four occasions (Figure 2; Plate 31). Preference for gliding from the lower/parallel arm compared to the upper/perpendicular arm was highly significant (P = 0.0003). Launches were made from inner, middle and end of the arm. On two other ooccasions an individual launched into a westward glide from the pole, approximately 400mm above the parallel/lower arm (Plate 32). No eastward glides were recorded.

Feathertail gliders were detected on either or both glide pole arms on 42 occasions (0.95 passes/week) during the monitoring period (Table 18). A greater number of passes were recorded by the upper/perpendicular arm camera (n = 35; 0.88 passes/week) compared with lower/parallel arm camera (n = 18; 0.47 passes/week). Feathertail glider behaviour was largely exploratory and mostly featured rapid movements along the glide pole arms. Individuals were also often observed jumping/climbing higher up the pole from the lower arm and exploring the top of the pole. It wasn't possible to distinguish different individuals from the video footage, but it is likely that multiple individuals were recorded. Feathertail gliders were recorded launching into glides off the perpendicular/upper arm on 12 occasions (eastward = 2; westward = 10) and off the parallel/lower arm eastward on one occasion (Figure 2; Plate 31). Preference for the upper/perpendicular arm compared to the lower/parallel arm was highly significant (P = 0.002). Glide launches from the upper/perpendicular arm

occurred from the end of the arms whereas glide launches from the lower/parallel arm were from the middle and inner section of the arm.

Spotlight surveys conducted in adjoining forest either side of the alignment recorded a feathertail glider on the west side of the alignment, approximately 80m south of the pole array on 2/11/2017. No gliders were detected in adjoining forest on the east side during surveys.

Full details of glide pole monitoring and adjacent forest spotlight surveys are provided in Table C4-C6 (Appendix C).

Table 18: Number and rate of perpendicular/upper arm and parallel/lower arm camera passes (Arm Passes) for squirrel, sugar and feathertail glider. Both Arm Passes is the sum of records captured concurrently by both cameras (counted as a single record) and those captured by only one camera.

Species	Arm Passes (per active week)		Both Arm Passes (per active week)
	Perpendic/ Upper Arm	Parallel/Lower Arm	
Squirrel glider	0	10 (0.26)	10 (0.23)
Sugar glider	8 (0.20)	35 (0.91)	38 (0.86)
Feathertail glider	35 (0.88)	18 (0.47)	42 (0.95)
TOTAL	43 (1.08)	63 (1.64)	90 (2.03)

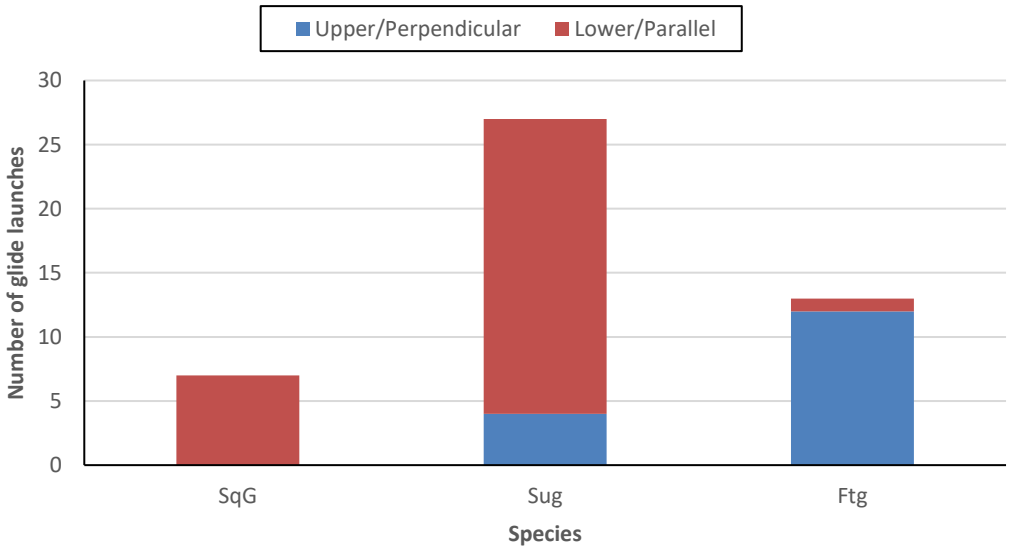

Figure 2. Number of glide launches according to pole arm position/orientation. SqG = squirrel glider, Sug = sugar glider, Ftg = feathertail glider.

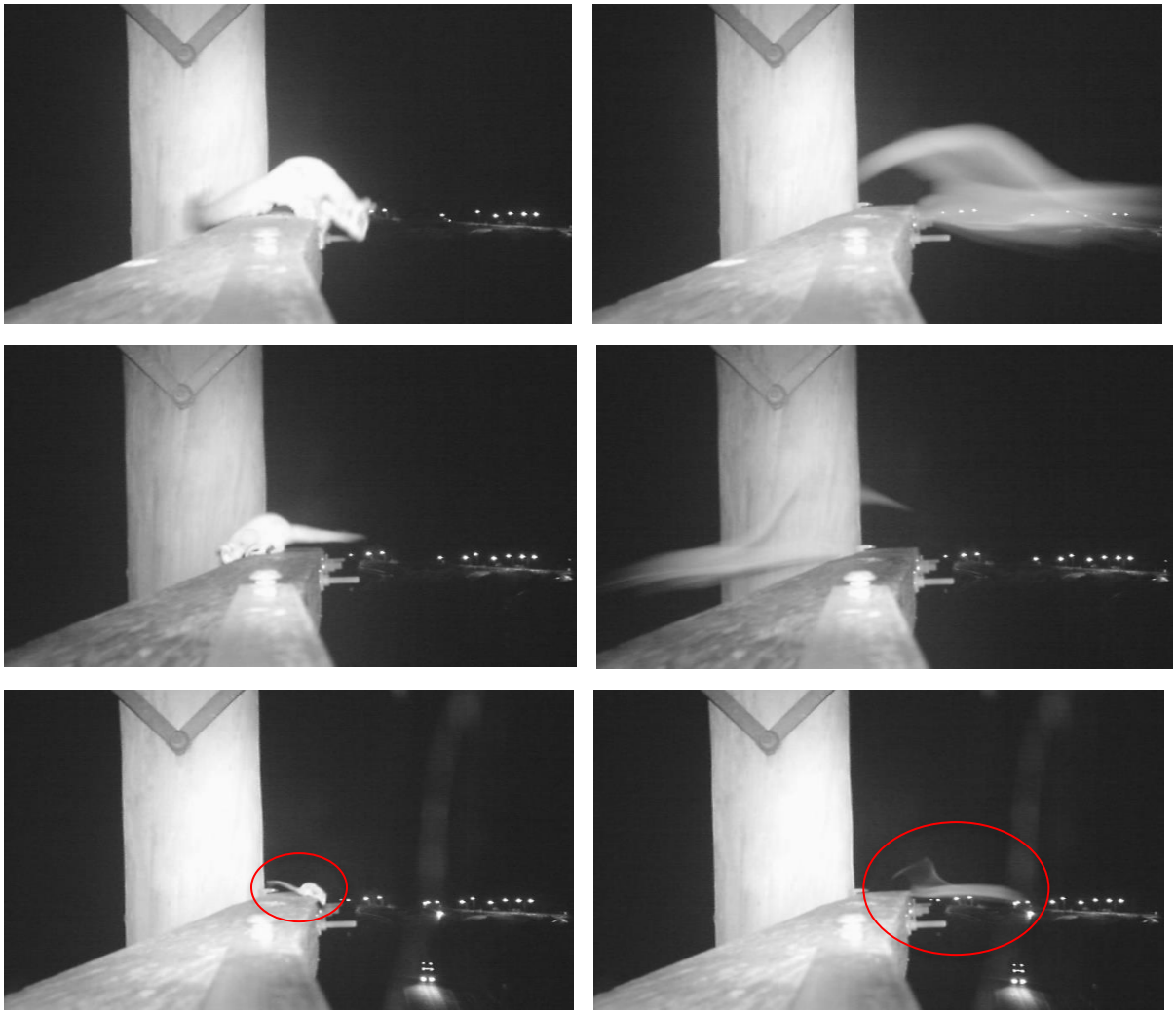

Plate 31: Photo images extracted from video footage of three species of glider launching into glide crossings of the north or southbound carriageway. Top: a squirrel glider launches into an eastward glide across the southbound carriageway from the lower/parallel arm (video captured 4/6/2017 @ 0313hr). Middle: a sugar glider launches into a westward glide across the northbound carriageway from the parallel/lower arm (video captured 14/5/2017 @ 2316hr). Bottom: a feathertail glider launches into an eastward glide across the southbound carriageway from the parallel/lower arm (video captured 3/3/2018 @ 2332hr).

Plate 32: Photo images extracted from video footage of a sugar glider launching into a westward glide from the pole, approximately 400mm above the lower/parallel arm (video captured 17/7/2017 @ 0048hr).

5. Discussion

5.1 Project compliance

5.1.1 Monitoring requirements

Year three fauna mitigation monitoring at S2W satisfied the intent of the EMP and in several cases exceeded its requirements. Some cameras used to survey habitat and fence-lines adjacent to underpasses suffered from false triggering and/or malfunction and two cameras were lost to fire at Arrawarra south. Such constraints are often encountered during terrestrial camera trap surveys. Instances of reduced camera function is not considered to have compromised data quality, particularly as two cameras were positioned in adjacent habitat and along fence-lines either side of the highway at each underpass site to account for such occurrences. The loss of some autumn fence monitoring data due to a back-up system failure was compensated for by additional monitoring during autumn 2018. Cameras in underpasses, on the rope bridge and glide poles functioned well and exceeded the required monitoring period durations.

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. The following sections discuss the results of year 3 monitoring and refer to results of year 1 and 2 (Sandpiper 2017a, 2018a). The three-year monitoring program is then considered against the indicators of success. This is followed by a series of recommendations relevant to the current project and future highway upgrades.

5.2 Species use of underpasses

5.2.1 Native species use of underpasses

Seven native species were confirmed making crossings of one or more underpasses during the three years of monitoring (Sandpiper 2017a, 2018a). Eastern grey kangaroo was recorded making crossings at all sites whereas common brushtail possum, red-necked wallaby and northern brown bandicoot were only recorded making crossings at a single site. Moonee recorded crossings by the most native species (n = 5) with Emerald and Arrawarra south recording the least (n = 3). Most crossings within a single year at a site were fewer than 10 except for lace monitor, eastern grey kangaroo and swamp wallaby (Sandpiper 2017a, 2018a).

The total number of crossings by native species varied considerably across the three years with the fewest occurring during year 1 (n = 27), followed by year 3 (n = 49) and year 2 (n = 215) although the monitoring period was longer in years 2 and 3 (Sandpiper 2017a, 2018a). The higher values in years 2 and 3 was largely attributed to high numbers of crossings by swamp wallaby (Year 2 at Emerald/Arrawarra south; Year 3 at Arrawarra north) and eastern grey kangaroo (Year 2 at Emerald).

The willingness of eastern grey kangaroos to cross the 74.5m-long, 1200mm-diameter RC pipes at Emerald is valuable information as it suggests that drainage pipes of this size and length are viable crossing structures for species as large as an eastern grey kangaroo. Western grey kangaroos have similarly been recorded using a 900mm pipe to cross a highway corridor in Perth (Chachelle *et al.* 2016). These records complement those achieved during concurrent monitoring of dedicated 1050mm RC pipes at Greys Dam where 23 species of vertebrate up to the size of a swamp wallaby were confirmed crossing during two years of monitoring

(Sandpiper 2018b). Clearly, RC pipes provide crossing opportunity for a variety of vertebrate species and are worthy of further investigation at other highway upgrade sites.

The proportion of native species detected in surrounding habitat and using the respective underpass was similar in Year 3 (23 – 50%) compared to Year 2 (22-63%) and Year 1 (14-40%). Typically, the species recorded using underpasses at S2W were those that are not edge-averse and are commonly encountered in fragmented landscapes. Native species detected in adjacent habitat and not recorded using an underpass at any of the four sites during the three years of monitoring (i.e. echidna, *Antechinus* spp., squirrel glider, short-eared brushtail possum, rodents, land mullet and blue-tongued skink) have, except for land mullet, blue-tongued skink and squirrel glider, been recorded using underpasses at other locations (Bond and Jones 2008, Taylor and Goldingay 2003, Sandpiper 2014, 2017b, 2018a) and/or frog pipes at Greys Dam on the S2W upgrade (Sandpiper 2018b). Despite this, most of the native species not recorded using the monitored underpasses prefer more closed habitat and/or are more sensitive to edges (e.g. Connolly-Newman *et al.* 2013). Indeed, the prevalence of grassland adjoining some underpasses, relatively broad gaps between underpass entrances and forest habitat and the lack of vegetative cover near underpass entrances likely contributed to the lack of use by many of these species.

Two other factors may have contributed to lack of recorded use by some native species present in adjoining habitat. Firstly, 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 (Arrawarra south); a relatively long single-cell, dedicated underpass (Moonee); and combined structures (drainage pipe series at Emerald Beach). As such, these different structures/locations may be expected to feature less fauna use, particularly compared to dedicated underpasses positioned close to high quality habitat (e.g. Sandpiper 2010, 2014, 2017b) or the dedicated frog pipe at Greys Dam positioned near a drainage line with thick habitat nearby (Sandpiper 2018b). Underpass monitoring on the Glenugie section of the Pacific Highway upgrade, a site featuring large areas of contiguous forest adjoining underpasses but with equivalent gaps between forest and culvert entrances, identified regular passes by short-beaked echidna, water rat, black rat and red-necked wallaby and occasional passes by *Antechinus* sp. (Sandpiper 2017b). Secondly, the underpass cameras (apart from Emerald pipes) were positioned to try and capture fauna on both the floor of the underpass and the wooden rail. Such positioning may reduce the sensitivity of cameras to detecting fauna movements along the floor. It is therefore possible that some fauna, particularly smaller fauna, evaded detection.

The EMP identified 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 (year one at Moonee east) was the only target species detected near underpasses during the current study. Evidence of brush-tailed phascogale has been recorded during nest box monitoring (Sandpiper Ecological 2016), and eastern pygmy possum was detected (from a hair sample) in dry forest approximately 300m northeast of the Arrawarra south underpass. No threatened species were detected using the subject underpasses during the three years of monitoring. While eastern pygmy possum and common planigale have not been recorded using underpasses, other operational 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, 2017b). Absence or low population densities of these threatened species near the investigated structures would contribute to lack of use as would the fragmented nature of adjacent habitat, lack of cover near entrances, and patchy vegetative links to adjoining forest.

5.2.2 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; Chambers & Bencini 2014; Sandpiper 2014, Taylor & Goldingay 2014, Sandpiper 2017b). Introduced predators (dog, red fox, cat) were present in adjacent habitat at all sites (Table 20) and red fox and dog were recorded making crossings at all sites except Arrawarra north (red

fox) and Emerald (dog). Cats were not confirmed making crossings at any underpass site. Dog crossings were more common at the Arrawarra sites and red fox crossings mostly occurred at Moonee. Emerald and Moonee feature disturbed, fragmented and peri-urbanised landscapes which may be more amenable to red fox compared to the continuous forest context of the vegetated median sites.

The prevalence of red fox at the Moonee underpass is of particular concern. This underpass featured 773 crossings by red fox during the three years of monitoring and included 16 occasions when photographs showed an individual with prey in its mouth. Use of underpasses by red fox with prey has also been reported at Glenugie Pacific Highway upgrade (Sandpiper 2017b). It is unknown if foxes are capturing prey near underpass entrances or simply using underpasses to move between sites. Irrespective, the evidence demonstrates that underpasses enable foxes to readily access habitat on both sides of the Pacific Highway. Construction phase monitoring at Nambucca Heads to Urunga also featured widespread use of recently-constructed underpasses by red fox, cat and dog (Sandpiper 2015b). 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. Predator control at the Moonee site should be considered.

5.2.3 Exclusion fence and fauna road mortality

The roadside floppy-top exclusion fence was generally in good condition except for the few repairable breaches described in Section 4.1.5. However, the open concrete drains which occurred at several places along the Emerald west road mortality transect should be targeted for improvements. The design has created 150mm gaps that small to medium sized fauna could move through and enter the road reserve. It is likely a road-killed bandicoot spp. recorded on the Emerald west road mortality transect had accessed the road through a nearby drain gap.

Fence-line monitoring confirmed that small vertebrates such as rodents and *Antechinus* sp. can breach the chain mesh fence. Frogs or reptiles were not detected breaching the fence although smaller species would be capable of moving through the chain mesh. Most images from the fence monitoring were of medium to large mammals either moving along the fence or showing no directional movement. Exclusion fence monitoring along the Glenugie section of the Pacific Highway upgrade reported similar findings (Sandpiper 2017b).

Road mortality and roadside habitat surveys confirmed likely fence breaches by snakes although all the positively identified species were arboreal and capable of climbing over exclusion fencing (Table 13). Smaller reptiles and frogs were not detected during road mortality surveys though this may be an artefact of the mostly dry and mild conditions experienced during surveys. For example, during a wet evening at the Brunswick Heads bypass section of the Pacific Highway, frogs were observed moving through chain mesh fencing, onto the road surface and being killed in large numbers (Taylor & Goldingay 2003). Small mammal road-kill was only recorded on two occasions (i.e. brown antechinus & rodent sp.) which suggests this cohort are infrequent victims of road mortality despite their presence in roadside habitat and ability to breach the exclusion fence. This has been confirmed in other road mortality studies (see Taylor & Goldingay 2004).

Road mortality of medium to large terrestrial mammals mostly occurred at Emerald and was likely attributable to the numerous fence openings (i.e. Emerald Beach interchange, two side access roads on east side) and gaps (i.e. concrete drains) both within and near the survey transect. The exception to this was short-beaked echidna which was collected on three occasions at Arrawarra north and once at Moonee in areas where the exclusion fence appeared intact. Because they have large home range areas and commonly feature in road mortality surveys (e.g. Taylor & Goldingay 2004), it is conceivable that they enter the roadway through a breach/opening in the fence and move/forage for considerable distances in the roadside before being struck. No threatened species were identified from carcasses during the two seasons of surveys. Despite this, the carcass of a spotted-tail quoll (listed as Vulnerable under the NSW *BC Act 2016*) was reportedly found south of the

southern Moonee interchange in 2016. It's likely the individual entered the road reserve via the interchange area where exclusion fencing is absent. The incident highlights the risk of fauna road incursions in areas where gaps in the fence occur, which are typically at interchanges and side roads.

5.2.4 Indicators of success

1. Low rates of use of fauna underpasses and adjacent habitats by feral predators.
    a. *Feral predators were recorded using underpasses at all sites. Dog crossings were more common at the Arrawarra sites and red fox crossings more common at Moonee. Moonee experienced very high use by red fox.*
    b. How can indicator be achieved or improved? *Targeted feral predator control at Moonee.*
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 ranged between 22% and 63% across the sites and across the three years. This is regarded as moderate use.*
    b. How can indicator be achieved or improved? *Improve level of vegetative cover adjacent underpass entrances and improve vegetative links between entrances and adjoining forest through targeted plantings.*
3. Evidence of use by dispersing individuals and different age cohorts.
    a. *Difficult to determine but likely sub-adult and adult cohorts are using underpasses.*
4. Use by cover-dependent species and species with low mobility.
    a. *Species recorded using underpasses are known to readily access open and fragmented habitat to either forage in or move through. They are also relatively mobile species.*
    b. How can indicator be achieved or improved? *Improve level of vegetative cover adjacent underpass entrances and improve vegetative links between entrances and adjoining forest through targeted plantings.*
5. Low incidence of fauna road strike mortality.
    a. *Low numbers of terrestrial vertebrate carcasses were recorded during road mortality surveys.*
    b. *Instances of medium to large vertebrate road deaths (e.g. bandicoots, macropods) were likely attributed to gaps in the fence created by drainage channels and unfenced side roads and interchanges.*
    c. How can indicator be achieved or improved? *Repair breaches and drainage channel gaps in exclusion fence described in Section 4.1.5.*

5.3 Aerial crossing structures and vegetated median

5.3.1 Vegetated median detections and crossings

Vegetated medians are designed to provide an 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). During the three-year monitoring program at the S2W vegetated median 13 squirrel gliders - five males, eight females (five with pouch young inc. two with pouch young in two consecutive years) - were marked at the vegetated median site. One individual (M1), who was the first squirrel glider capture in Year 1, was recaptured in autumn Year 3.

The mark-recapture records from the trapping program confirmed highway crossings in all four directions by squirrel gliders. That is, the northbound carriageway was crossed from west forest to median on one occasion (1 adult male) and median to west forest on one occasion (1 sub-adult male). The southbound carriageway was crossed east forest to median on three occasions each (2 adult females, 1 sub-adult male) and median to east forest on three occasions (1 adult female, 2 sub-adult male). These results confirm that the vegetated median is enabling movement between and amongst resident squirrel gliders east and west of the highway and that successful breeding is occurring at the site. It is likely that individuals are foraging at times within the median and using it as a stepping stone across the highway. It is unlikely that individuals are residing within the median because there are few hollow bearing trees and limited denning potential.

Sugar gliders (3 male, 4 female, inc. 1 with pouch young) were captured in both the east forest and median and spotlighted in the west forest during the three-year monitoring program. No recaptures occurred but capture in the median confirms a crossing of either the northbound or southbound carriageway. Feathertail gliders were detected in the median (spotlighting, hair funnels), east forest (spotlighting, nest box nests) and west forest (nest box nests). Their presence in the median and results of the glide pole monitoring suggest they can cross 2-lane carriageways. It is plausible that feathertails are denning within the vegetated median.

5.3.2 Rope bridge detections and crossings

Rope bridges enable arboreal mammals to cross two and four lane roads (Goldingay *et al.* 2013; Soanes *et al.* 2015) and are another means of connecting isolated populations (Taylor & Goldingay 2009; van der Ree *et al.* 2010; Taylor & Goldingay 2012). A range of arboreal and scansorial species, including squirrel, sugar and feathertail gliders, common brushtail and common ringtail possums, brush-tailed phascogale and *Antechinus* spp. have been recorded using rope bridges at sites along the Pacific and Hume Highways (Goldingay *et al.* 2013; Soanes *et al.* 2015; Sandpiper 2017b).

At S2W, both feathertail glider and sugar glider were observed on the rope bridge during the three years of monitoring. Feathertail gliders were recorded as completing seven probable crossings and sugar glider one probable crossing which is indicative of very minimal use. Moreover, the probable crossings by feathertail glider should be treated with some caution because the behaviour of feathertail gliders on a rope bridge is typically erratic and exploratory and determining clear, directional movement difficult (see Sandpiper 2017b). The absence of photographs at the other end of the bridge may be 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; Sandpiper Ecological 2017b).

At 86m in length the Moonee rope bridge is one of the longest constructed on the Pacific or Hume Highway's. In comparison, single span, rope bridges at Glenugie range from 55-60m in length, and above road canopy bridges on the Hume Highway from 58 to 86m. The 86m canopy bridge on the Hume Highway has had low use by squirrel glider but regular use by common brushtail and common ringtail possums (Soanes *et al.* 2015). A combination of length, low height above road (9m) and fragmented adjoining forest likely contribute to low use by arboreal fauna of the Moonee structure.

5.3.3 Glide pole detections and crossings

Glide poles are another type of aerial crossing that has also proven effective in enabling feathertail gliders, sugar gliders, squirrel gliders and probably yellow-bellied gliders to cross dual carriageways (Soanes *et al.* 2015; Goldingay et al. 2018; Taylor & Goldingay 2012, 2013). Monitoring of the glide pole in the middle of the carriageways at S2W revealed numerous glide launches to cross the highway including squirrel glider on eight occasions, sugar glider on 38 occasions and feathertail glider on 31 occasions.

The feathertail glider records are particularly significant as there are few reported accounts of their use of highway glide poles. Glide pole monitoring over a three-year period along the Oxley Highway reported detection rates of 0.9-3.6 events/week for sugar glider and 0.3-2.2 events/week for feathertail glider for four roadside glide poles. However, the rates of detection are likely much higher than actual rates of crossing as it was reported that some of the detections would have related to movements within and along the roadside (Goldingay et al. 2018). In contrast, all glide pole detections at S2W have involved crossing of one carriageway.

Video footage of glide launches confirmed crossings in both directions for squirrel glider and feathertail glider. Interestingly, all glide launch records of sugar glider were in a westward direction. Two of these records included individuals launching off the glide pole, approximately 400mm above the lower arm. It may be the case that sugar gliders completed the shorter glide to the east glide pole (i.e. 23.5m compared to a westward glide of 36m to the nearest tree trunk) from the pole below the lower arm and/or from climbing pegs placed at regular intervals for up to 5m below the lower arm (Plate 18).

The glide arm preference demonstrated by each of the three species is informative and emphasises the importance of including both a perpendicular and parallel glide pole arm. Indeed, selecting for the upper/perpendicular arm may have been the only option by which a feathertail glider could achieve the westward glide. That is, the glide angle or decent angle of feathertail gliders is reportedly steeper than squirrel or sugar gliders and averages 32^0 which equates to a glide ratio of 1.6 (Pridmore & Hoffmann 2014; Goldingay & Taylor 2009; Goldingay et al. 2018). This suggests that a feathertail will achieve an average glide distance of 34.4m when gliding from a height of 21.5m. Gliding from the end of the 1.5m-long perpendicular arm shortens the horizontal westward glide distance from 36m to 34.5m – the outer limit of their average glide capacity in this context. Alternatively, feathertail gliders may be landing their westward glides in amongst 4m-high regrowth which was emerging up to 5m closer to the road edge than established trees. Indeed, feathertail gliders are often observed glide-landing onto shrub and regrowth (pers. obs.). The glide scenario for feathertail glider at this site highlights two important points: 1) there is benefit in providing a perpendicular-oriented arm at the top of a glide pole to assist in maximising glide performance; and, 2) glide pole heights and spacing should be informed by calculations to enable safe glide crossings by target species.

Yellow-bellied gliders were not detected on crossing structures or the vegetated median or within adjoining habitat during the monitoring program. During the clearing phase of the S2W upgrade, yellow-bellied gliders were recorded on several occasions in forest over 100m to the west of Arrawarra Creek (glide pole array). More recently they have been recorded on the west of the alignment at Woolgoolga Creek, approximately 4km south of the vegetated median and within Wedding Bells State Forest, approximately 3km north of the Arrawarra glide pole (Sandpiper unpub. data). These records highlight the low population abundance of yellow-bellied gliders in the study area.

5.3.4 Performance indicators

Vegetated median and aerial crossing structures:

1. Evidence of regular use of the median and crossing structures by the target glider species.
    a. *Squirrel glider confirmed using vegetated median and glide pole to cross highway in both directions.*
    b. *No confirmed use of rope bridge by squirrel gliders.*
    c. *No confirmed use of vegetated median or crossing structures by yellow-bellied glider but species not confirmed near crossing structures.*
2. Evidence of use by dispersing individuals and different age cohorts;

   a. *Adult male and female squirrel gliders observed using glide pole and adult and sub-adult males and adult breeding females captured at vegetated median.*

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

   a. *Sugar gliders (male and breeding female) captured in east forest and median and spotlighted in west forests; feathertail glider recorded within and either side of the median; suggests use of median by both species.*

   b. *Sugar glider and feathertail glider recorded making 36 and 31 glide launches respectively from the glide pole to cross highway.*

   c. *Feathertail glider recorded making seven probable crossings and sugar glider one probable crossing of the rope bridge. Erratic nature of feathertail glider behavior constrains the level of confidence.*

6. Recommendations

6.1 Underpasses and exclusion fence

1. 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 during year one.
2. 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. Control should target the pre-breeding period of red fox.
3. Repair breaches to fence and close gaps in drainage channels at Emerald as detailed in Section 4.1.5.

6.2 Aerial crossing structures and vegetated median

1. Ensure tall, roadside trees are retained at the vegetated median, including edge trees within the median and those along the edge of the east and west forest.
2. Ensure tall, roadside trees are retained (both sides of the alignment) and patches of regenerating roadside vegetation (west side of alignment) at the Arrawarra glide pole site.

6.3 Future highway upgrade projects

1. Rope bridges should be installed at upper canopy level to improve accessibility for arboreal fauna.
2. Rope bridges should be a minimum of 12m above road level at their lowest point.
3. Rope bridge ends should be positioned as close to the adjacent canopy as practicable and no more than 5m from the canopy.
4. Glide pole heights and spacing must be informed by calculations to enable safe road crossings by target species.
5. Glide poles should include two 3m-long arms, orientated at 90^0 to each other, near the top of the glide pole.
6. Glide pole installation should ensure that the upper arm is orientated perpendicular to the road to maximise glide distance.
7. Disturbance should be minimised where practicable around entrances 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.

8. 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 – Adjacent habitat camera monitoring data

Table A1: Fauna recorded by camera traps in habitat adjacent to underpasses during autumn and spring 2017. Accuracy/Likelihood: D = Definite; Pr = Probable; Po = Possible.

Camera/Site	Date	Time	Species	Confidence	Pic no./s	Comments
Moonee ES	30/08/2017	2343	Fawn-footed Melomys	Pr	1-21	
	31/08/2017	2339	Red-necked Wallaby	Po	22-23	
	1/09/2017	1853	Fawn-footed Melomys	Pr	28-30	
	2/09/2017	119	Fawn-footed Melomys	Pr	31	
	25/09/2017	725	Bush Turkey	D	34-36	
Moonee EN	31/08/2017	1811	Swamp Wallaby	Pr	43-79	
	2/09/2017	223	Brushtail Possum	Pr	109-114	
	2/09/2017	1559	Swamp Wallaby	D	115-135	
	3/09/2017	1904	Swamp Wallaby	Pr	139-162	
	5/09/2017	1541	Bush Turkey	Pr	169-171	
	6/09/2017	214	Fox	D	172-177	
	6/09/2017	315	Brushtail Possum	D	178-198	
	6/09/2017	2038	Swamp Wallaby	Pr	199-237	
	7/09/2017	119	Swamp Wallaby	D	238-270	
	7/09/2017	2334	Swamp Wallaby	D	280-306	
	8/09/2017	118	Swamp Wallaby	Po	307-309	hopping past in background
	8/09/2017	141	Swamp Wallaby	Pr	310-324	
	9/09/2017	0032	Swamp Wallaby	Pr	328-330	
	9/09/2017	250	Brushtail Possum	D	334-360	x2
	10/09/2017	858	Bush Turkey	D	394-396	
	10/09/2017	2033	Swamp Wallaby	D	397-399	
	11/09/2017	2028	Brushtail Possum	D	400-405	
	12/09/2017	808	Bush Turkey	D	406-408	
	13/09/2017	1814	Swamp Wallaby	Pr	409-411	

Camera/Site	Date	Time	Species	Confidence	Pic no./s	Comments
	14/09/2017	347	Brushtail Possum	D	415-417	
	15/09/2017	138	Brushtail Possum	Pr	624-627	
	16/09/2017	2230	Swamp Wallaby	D	637-645	
	17/09/2017	2010	Long-nosed Bandicoo	D	646-648	
	17/09/2017	2158	Swamp Wallaby	Po	649-654	
	18/09/2017	158	Swamp Wallaby	Pr	664-669	
	18/09/2017	2005	Long-nosed Bandicoo	Po	676-678	
	19/09/2017	2204	Fox	Po	685-686	
	20/09/2017	350	Brushtail Possum	D	688-690	
	20/09/2017	1146	Echidna	D	694-699	
	21/09/2017	458	Fox	D	706-723	
Moonee WN	3/09/2017	2140	Swamp Wallaby	D	31-39	
	4/09/2017	1947	Swamp Wallaby	D	40-48	
	8/09/2017	2311	Swamp Wallaby	D	52-67	
	9/09/2017	1809	Swamp Wallaby	D	70-85	
	23/09/2017	513	Eastern Grey Kangaroo	D	88-90	
Moonee WS	30/08/2017	2343	Bush Rat	D	1-3	
	31/08/2017	325	Bush Rat	D	4-15	
	31/08/2017	1953	Bush Rat	D	16-21	
	31/08/2017	2339	Swamp Wallaby	D	22-23	
	1/09/2017	1853	Bush Rat	D	28-30	
	2/09/2017	119	Black Rat	D	31-33	
	4/09/2017	237	Bush Rat	D	34-36	
	4/09/2017	1912	Swamp Wallaby	D	37	
	6/09/2017	1257	Swamp Wallaby	D	40-43	
	18/09/2017	2128	Long-nosed Bandicoo	D	46-48	
	22/09/2017	1707	Kookaburra	D	49-51	
	26/09/2017	1830	Swamp Wallaby	D	52-58	
	28/09/2017	824	Swamp Wallaby	D	61-84	
Emerald ES	1/09/2017	1829	Eastern Grey Kangaroo	D	1250	

Camera/Site	Date	Time	Species	Confidence	Pic no./s	Comments
Emerald EN	3/09/2017	2123	Swamp Wallaby	D	10-15	
	4/09/2017	302	Swamp Wallaby	D	19-21	
	6/09/2017	422	Eastern Grey Kangaroo	D	679-699	
	7/09/2017	154	Eastern Grey Kangaroo	Pr	1141-1146	
	8/09/2017	443	Swamp Wallaby	D	1630-1632	
	9/09/2017	1524	Eastern Grey Kangaroo	D	2884-2886	
Emerald WN	31/08/2017	805	Eastern Grey Kangaroo	D	7-18	
	31/08/2017	2055	Eastern Grey Kangaroo	D	19-30	
	2/09/2017	219	Common Brushtail Possum	D	34-36	
	2/09/2017	351	Northern Brown Bandicoot	D	37-75	
	3/09/2017	224	Northern Brown Bandicoot	D	76-86	
	3/09/2017	2140	Eastern Grey Kangaroo	D	88-96	
	4/09/2017	321	Northern Brown Bandicoot	D	97-135	
	4/09/2017	538	Eastern Grey Kangaroo	D	136-138	
	5/09/2017	341	Northern Brown Bandicoot	D	142-150	
	6/09/2017	1906	Northern Brown Bandicoot	D	151-154	
	7/09/2017	124	Northern Brown Bandicoot	D	157-162	
	7/09/2017	635	Eastern Grey Kangaroo	D	163-165	
	7/09/2017	1202	Dog	D	166-168	
	7/09/2017	1928	Northern Brown Bandicoot	D	169-171	
	8/09/2017	525	Swamp Wallaby	D	172-181	
	8/09/2017	2350	Dog	D	184-185	
	9/09/2017	1902	Northern Brown Bandicoot	D	187-189	
	10/09/2017	1536	Dogs	D	190-192	x3 1 adult 2 puppies
	12/09/2017	134	Northern Brown Bandicoot	D	193-204	
	14/09/2017	1910	Northern Brown Bandicoot	D	205-206	
	15/09/2017	631	Dog	D	208-213	x2 adults
	15/09/2017	1558	Dog	D	217-237	x2 puppies
	15/09/2017	1912	Northern Brown Bandicoot	D	238-240	
	15/09/2017	2341	Northern Brown Bandicoot	D	241-246	

Camera/Site	Date	Time	Species	Confidence	Pic no./s	Comments
	18/09/2017	1636	Bush Turkey	D	247-255	
	20/09/2017	107	Eastern Grey Kangaroo	D	256-257	
	23/09/2017	1252	Common Brushtail Possum	D	259-261	
	23/09/2017	1305	Bush Turkey	D	262-267	
Emerald WS	30/08/2017	2120	Common Brushtail Possum	D	4-42	
	31/08/2017	2228	Eastern Grey Kangaroo	D	44-93	
	31/08/2017	2320	Common Brushtail Possum	D	94-114	
	3/09/2017	1943	Northern Brown Bandicoot	D	115-118	
	5/09/2017	157	Northern Brown Bandicoot	D	121-129	
	5/09/2017	225	Northern Brown Bandicoot	D	130-132	
	6/09/2017	510	Northern Brown Bandicoot	D	133-135	
	6/09/2017	2014	Northern Brown Bandicoot	D	136-141	
	7/09/2017	105	Northern Brown Bandicoot	D	142-144	
	10/09/2017	2323	Northern Brown Bandicoot	D	148-150	
	13/09/2017	231	Northern Brown Bandicoot	D	151-156	
	13/09/2017	526	Swamp Wallaby	D	157-158	
	14/09/2017	2201	Long-nosed Bandicoo	D	160-174	
	18/09/2017	2229	Northern Brown Bandicoot	D	178-180	
	21/09/2017	1920	Common Brushtail Possum	D	181-189	
	26/09/2017	2004	Northern Brown Bandicoot	D	190-198	
	27/09/2017	1609	Dog	D	199-210	
A'warra EN	nil	nil	nil	nil	nil	
A'warra ES	31/08/2017	2142	Swamp Wallaby	D	11-16	
	1/09/2017	206	Northern Brown Bandicoot	D	17-28	
	2/09/2017	744	Swamp Wallaby	Pr	32-35	
	3/09/2017	237	Northern Brown Bandicoot	D	38-55	
	4/09/2017	104	Swamp rat	Pr	62-67	
	4/09/2017	1010	Goanna	D	71-88	
	4/09/2017	2156	Swamp Wallaby	D	92-103	
	5/09/2017	402	Northern Brown Bandicoot	D	107-244	

Camera/Site	Date	Time	Species	Confidence	Pic no./s	Comments
	6/09/2017	1221	Goanna	D	254-256	
	6/09/2017	1809	Northern Brown Bandicoot	D	257-265	
	8/09/2017	455	Swamp Wallaby	D	267-280	
	8/09/2017	1842	Northern Brown Bandicoot	D	281-283	
	8/09/2017	1922	Echidna	D	284-286	
	9/09/2017	1739	Echidna	D	290-292	
	9/09/2017	2122	Rodent sp.	Pr	293-295	
	11/09/2017	2021	Bandicoot sp.	Pr	308-310	
	11/09/2017	2343	Swamp Wallaby	D	311-325	
	12/09/2017	857	Swamp Wallaby	D	329-331	
	12/09/2017	1338	Goanna	D	335-340	
	13/09/2017	139	Northern Brown Bandicoot	D	341-343	
	13/09/2017	1937	Northern Brown Bandicoot	Pr	347-348	
	17/09/2017	2316	Northern Brown Bandicoot	Pr	377-379	
	18/09/2017	100	Northern Brown Bandicoot	Pr	380-382	
	18/09/2017	2213	Northern Brown Bandicoot	D	395-397	
	19/09/2017	236	Black Rat	Pr	398-400	
	21/09/2017	412	Long-nosed Bandicoo	D	419-421	
	23/09/2017	1841	Common Brushtail Possum	D	449-451	
	25/09/2017	2238	Swamp Wallaby	D	458-472	
	25/09/2017	2336	Northern Brown Bandicoot	Pr	473-475	
A'warra WN	31/08/2017	2302	Common Brushtail Possum	D	22-24	
	2/09/2017	1836	Swamp Wallaby	D	25-30	
	8/09/2017	2302	Common Brushtail Possum	D	31-33	
	11/09/2017	247	Echidna	D	34-36	
	15/09/2017	2338	Swamp Wallaby	D	37-54	
	16/09/2017	224	Common Brushtail Possum	D	55-60	
	18/09/2017	1829	Swamp Wallaby	D	61-84	
	19/09/2017	213	Echidna	D	85-96	
A'warra WS	1/09/2017	111	Common Brushtail Possum	D	7-9	

Camera/Site	Date	Time	Species	Confidence	Pic no./s	Comments
	7/09/2017	2435	Common Brushtail Possum	D	10-12	
	7/09/2017	611	Bush Turkey	D	13-15	
	11/09/2017	2142	Northern Brown Bandicoot	D	16-18	
	12/09/2017	1206	Northern Brown Bandicoot	D	19-22	
	12/09/2017	116	Long-nosed Bandicoo	D	25-33	
	13/09/2017	544	Swamp Wallaby	D	34-48	
A'warra EN	15/09/2017	2336	Common Brushtail Possum	D	7-9	
	21/09/2017	655	Swamp Wallaby	D	10-48	
	24/09/2017	705	Eastern Grey Kangaroo	D	49-57	
	26/09/2017	105	Long-nosed Bandicoo	D	58-60	
A'warra ES	5/09/2017	1638	Swamp Wallaby	D	10-24	
	13/09/2017	2131	Long-nosed Bandicoo	D	25-33	
	23/09/2017	119	Echidna	D	34-36	

Appendix A – Underpass camera monitoring data

Table A2: Fauna recorded by camera traps in underpasses during autumn and spring 2017. Accuracy/Likelihood: D = Definite; Pr = Probable; Po = Possible.

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
Moonee Bch East							Moonee Bch West							
8/5/17	2007	Fox	D	E	86-92	Pr								
8/5/17	2108	Fox	D	E	96-99	Pr								
8/5/17	2122	Fox	D	W	101-105	Pr								
9/5/17	2000	Fox	D	W	106-110	Po								
							10/5/17	122	Fox	D	W	36-37	Po	
10/5/17	2020	Fox	D	E	111	Pr								
10/5/17	2040	Fox	D	E	116-118	Pr								
11/5/17	144	Fox	D	E	121	Pr								
11/5/17	224	Fox	D	E	126-130	Pr								
11/5/17	2049	Fox	D	E	131-133	Pr								
11/5/17	2338	Fox	D	E	136-139	Pr								
							12/5/17	125	Fox	D	W	41-43	Pr	
15/5/17	612	EG Kangaroo x 3	D	W	141-200	Pr								
15/5/17	704	EG Kangaroo	D	W	201-205	Pr								
							15/7/17	712	EG Kangaroo	D	E	46-50	Pr	
15/5/17	725	EG Kangaroo	D	W	206-211	Pr								
							18/5/17	1556	Swamp Wallaby	D	ETE	51-66	No	
18/5/17	2132	Fox	D	E	216-219	Pr								

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
19/5/17	503	Fox	D	E	221	Pr								
							19/5/17	2123	Fox	D	ETE	71-85	No	
20/5/17	2125	Fox	D	E	226-230	Pr								
24/5/17	2125	Fox	D	E	231-233	Pr								
25/5/17	923	Cat	D	NDM	236-240	Un								
25/5/17	945	Cat	D	W then E	241-254	Un								
26/5/17	1523	Fox x 2	D	W	256-264	Pr	26/5/17	1526	Fox	D	NDM	86-90	Pr	High likelihood of a crossing
							26/5/17	1545	Fox	D	W	91-94	Pr	
							27/5/17	859	Fox	D	E	96-100	Pr	
							28/5/17	220	Fox	D	NDM	101-105	Po	
							28/5/17	1006	Fox	D	W	106-107	Pr	
							29/5/17	1050	Fox	D	W	111	Po	
							29/5/17	1103	Fox	D	W then E	116-125	No	
							29/5/17	1445	Fox	D	W	126-129	Pr	
							30/5/17	1026	Fox	D	W	131-132	Pr	
							30/5/17	1224	Fox	D	W	136-140	Pr	
							30/5/17	1317	Fox	D	E	141-145	Pr	
							31/5/17	1003	Fox	D	E	146-150	Pr	
							2/6/17	124	Fox	D	W	171-174	Pr	
							3/6/17	1904	Fox	D	W	176-178	Pr	
							7/6/17	919	Fox	D	E	181-185	Pr	
							8/6/17	1022	Fox	D	W	186-187	Pr	
							8/6/17	1331	Fox	D	E	191-195	Pr	
							9/6/17	1038	Fox	D	E	216-220	Pr	
							13/6/17	1857	Fox	D	W	221-224	Pr	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							13/6/17	1956	Fox	D	E	226-230	Pr	
							13/6/17	2038	Fox	D	W	231-233	Pr	
							19/6/17	124	Fox	D	W	236-239	Pr	
							19/6/17	2228	Fox	D	W	241-244	Pr	
							20/6/17	102	Fox	D	W	246-249	Pr	
							20/6/17	324	Fox	D	NDM	251-255	Po	
							20/6/17	453	Fox	D	W	256-260	Pr	
							20/6/17	740	Fox	D	W	261-263	Pr	
							20/6/17	810	Fox	D	E	266-270	Pr	
							22/6/17	1146	Fox	D	W	271-273	Pr	
							22/6/17	1244	Fox	D	E	276-280	Pr	
							24/6/17	211	Swamp Wallaby	D	NDM	281-285	Po	
							24/6/17	328	Swamp Wallaby	D	NDM	286-290	Po	
							24/6/17	1358	Person (walker)	D	W	291-293	D	
							25/6/17	1524	Motorbike x 2	D	W then E	296-335	D	
							27/6/17	2055	Fox	D	E	336-340	Pr	
							28/6/17	1816	Fox	D	W	341-343	Pr	
							30/6/17	238	Fox	D	NDM	346-350	Pr	
							4/7/17	146	Fox	D	NDM	351-355	Po	
							4/7/17	2322	Fox	D	E	356-360	Po	
							11/7/17	2140	Fox	D	W	361-362	Pr	
							11/7/17	2144	Fox	D	NDM	366-370	Pr	
							12/7/17	0025	Fox	D	W	371-373	Pr	
							12/7/17	435	Fox	D	NDM	376-380	Pr	
							15/7/17	107	Fox	D	W	381-383	Pr	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							15/7/17	1212	Fox	D	W	386-387	Pr	
							16/7/17	1324	Fox	D	E then stops	391-395	Po	
							16/7/17	2206	Fox	D	W	396-398	Pr	
							17/7/17	1059	Fox	D	W	401-403	Pr	
							18/7/17	547	Fox	D	W	406-410	Pr	
							18/7/17	2007	Fox	D	NDM	411-415	Po	
							19/7/17	1021	Fox	D	W	416-417	Pr	
							6/9/2017	306	Fox	D	E	7261-7263	Pr	
7/9/2017	1515	human	D	W then E	67-88	Unlikely								
9/9/2017	1625	human	D	W then E	91-99	Unlikely								
							14/9/2017	131	Fox	D	W	7906-7907	Pr	
							14/9/2017	232	Fox	D	E	7909-7911	Pr	
							14/9/2017	2302	Fox	D	E	7912-7914	Pr	
16/9/2017	735	Eastern Grey Kangaroo	D	W then E	100-105	Unlikely								
							17/9/2017	0023	Fox	D	E	8407-8409	Pr	
							17/9/2017	350	Fox	D	E	8539-8541	Pr	
17/9/2017	853	human	D	W then E	106-114	Definite	17/9/2017	854	human	D	W then E	8704-8709	D	
27/10/2017	1023	Fox	D	W	229-231	Pr								
							28/9/2017	1803	Fox	D	W	21-23	Pr	
							28/9/2017	1856	Fox	D	E	26-30	Pr	
							29/9/2017	1206	Fox	D	W	31-31	Pr	
							29/9/2017	1249	Fox	D	W	36-41	Pr	
							30/9/2017	2013	Fox	D	E then W	46-54	Unlikely	
							1/10/2017	2136	Fox	D	W	56-60	Pr	
							2/10/2017	1900	Fox	D	W	61-64	Pr	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							3/10/2017	102	Fox	D	W	66-68	Pr	
							3/10/17	2111	Fox	D	W	71-73	Pr	
							3/10/17	2156	Fox	D	E	76-80	Pr	
							4/10/2017	1858	Fox	D	W	81-85	Pr	
							4/10/2017	2030	Fox	D	E then W	86-98	unlikely	
							4/10/2017	2059	Fox	D	W	101-103	Pr	
							4/10/2017	2206	Fox	D	W	106-107	Pr	
							4/10/2017	2249	Fox	D	E	111-115	Pr	
							5/10/2017	1715	Fox	D	W	116-118	Pr	
							5/10/2017	1744	Fox	D	E	121-125	Pr	
							6/10/2017	134	Fox	D	W	126-134	Pr	2x fox heading west
							6/10/2017	226	Fox	D	W	136-138	Pr	
							6/10/2017	301	Fox	D	E	141-145	Pr	
							6/10/2017	2026	Fox	D	W	151-152	Pr	
							6/10/2017	2046	Fox	D	E	156-160	Pr	
							6/10/2017	2056	Fox	D	E	161-165	Pr	
							6/10/2017	2216	Fox	D	E then W	166-177	Unlikely	
							7/10/2017	140	Fox	D	W	181-184	Pr	
							7/10/2017	186	Fox	D	E then W	186-194	Unlikely	turns arounds, looks at camera and leaves via W entrance
							7/10/2017	223	Fox	D	E	196-200	Pr	
							7/10/2017	2016	Fox	D	W	201-202	Pr	
							7/10/2017	2054	Fox	D	E	206-210	Pr	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							7/10/2017	2211	Fox	D	W	211-213	Pr	
							7/10/2017	2339	Fox	D	E	216-220	Pr	
							8/10/2017	219	Fox	D	E	221-225	Pr	
							8/10/2017	344	Fox	D	W	226-227	Pr	
							8/10/2017	1330	Fox	D	W	231-232	Pr	
							8/10/2017	1402	Fox	D	E	236-240	Pr	
							8/10/2017	1559	Fox	D	W	241-242	Pr	
							8/10/2017	1647	Fox	D	E	246-250	Pr	
							8/10/2017	1944	Fox	D	W	251-252	Pr	
							8/10/2017	2006	Fox	D	W	256-258	Pr	
							8/10/2017	2049	Fox	D	E	261-265	Pr	
							8/10/2017	2143	Fox	D	W	266	Pr	
							8/10/2017	2230	Fox	D	E	271-273	Pr	
							8/10/2017	2239	Fox	D	E	276-280	Pr	turns around and looks at camera
							9/10/2017	322	Fox	D	W	281-283	Pr	
							9/10/2017	1818	Fox	D	W	286-288	Pr	
							9/10/2017	1855	Fox	D	E	291-295	Pr	prey in mouth, eel? Fish?
							9/10/2017	1910	Fox	D	W	296-298	Pr	
							9/10/2017	2013	Fox	D	E	301-305	Pr	
							9/10/2017	2210	Fox	D	W	306-307	Pr	
							9/10/2017	2225	Fox	D	W	311	Pr	
							9/10/2017	2241	Long nosed Bandicoot	D	E	316-320	Pr	
							9/10/2017	2302	Fox	D	E	321-325	Pr	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							10/10/2017	211	Fox	D	W	326-328	Pr	
							10/10/2017	252	Fox	D	E	331-333	Pr	
							10/10/2017	2117	Fox	D	W	336-337	Pr	
							10/10/2017	2155	Fox	D	E	341-345	Pr	
							10/10/2017	2353	Fox	D	W	346-347	Pr	
							11/10/2017	0014	Fox	D	W	351	Pr	
							11/10/2017	0032	Fox	D	E	356-360	Pr	
							11/10/2017	0044	Fox	D	E	361-365	Pr	
							11/10/2017	2118	Fox	D	W	366-371	Pr	
							11/10/2017	2215	Fox	D	E	376-380	Pr	
							12/10/2017	0026	Fox	D	W	381-382	Pr	
							12/10/2017	106	Fox	D	E	386-390	Pr	
							12/10/2017	257	Fox	D	W	391	Pr	
							12/10/2017	330	Fox	D	E	396-400	Pr	
							12/10/2017	1853	Fox	D	W	401	Pr	
							12/10/2017	1959	Fox	D	E	406-410	Pr	
							12/10/2017	2156	Fox	D	W	411	Pr	
							12/10/2017	2231	Fox	D	W	416-418	Pr	
							12/10/2017	2244	Fox	D	E	421-425	Pr	
							13/10/2017	311	Fox	D	W	426	Pr	
							13/10/2017	350	Fox	D	E	431-435	Pr	
							13/10/2017	2032	Fox	D	W	436-438	Pr	
							13/10/2017	2122	Fox	D	E	441-445	Pr	
							13/10/2017	2126	Fox	D	E	446-450	Pr	
							13/10/2017	2141	Fox	D	E	451-455	Pr	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							13/10/2017	2222	Fox	D	E	456-460	Pr	Turns around and looks at camera
							14/10/2017	1248	Fox	D	W	461-463	Pr	
							14/10/2017	147	Fox	D	W	466-468	Pr	
							14/10/2017	232	Fox	D	E	471-475	Pr	
							14/10/2017	2049	Fox	D	E then W	476-482	Unlikely	
							14/10/2017	2054	Fox	D	W	486-488	Pr	
							14/10/2017	2058	Fox	D	W then E	491-500	Pr	
							14/10/2017	2304	Fox	D	W	501-507	Pr	
							14/10/2017	2344	Fox	D	E	511-515	Pr	
							15/10/2017	1830	Fox	D	W	516-517	Pr	
							15/10/2017	1910	Fox	D	E	521-525	Pr	
							16/10/2017	427	Fox	D	W	536-537	Pr	
							16/10/2017	459	Fox	D	E	541-545	Pr	
							16/10/2017	2151	Fox	D	E	551-555	Pr	
							16/10/2017	2254	Fox	D	W	556-559	Pr	
							16/10/2017	2338	Fox	D	E	561-565	Pr	
							17/10/2017	158	Fox	D	W	571-573	Pr	
							17/10/2017	2100	Fox	D	W	586	Pr	
							17/10/2017	2144	Fox	D	E	591-595	Pr	
							17/10/2017	2152	Fox	D	W	596-598	Pr	
							17/10/2017	2157	Fox	D	W	601-603	Pr	
							17/10/2017	2234	Fox	D	E	606-610	Pr	
							18/10/2017	223	Fox	D	E	611-615	Pr	Prey in mouth. Eel??
							18/10/2017	429	Fox	D	E	616-620	Pr	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							18/10/2017	1903	Fox	D	W then E	621-630	Pr	
							18/10/2017	1917	Fox	D	W	631-634	Pr	
							18/10/2017	2205	Fox	D	W then E	636-645	Pr	
							18/10/2017	2246	Fox	D	E	646-650	Pr	
							18/10/2017	2349	Fox	D	W	651-652	Pr	
							19/10/2017	120	Fox	D	W	656-658	Pr	
							19/10/2017	232	Fox	D	W	661-662	Pr	
							19/10/2017	259	Fox	D	E	666-670	Pr	
							19/10/2017	2003	Fox	D	W	671	Pr	
							19/10/2017	2303	Fox	D	W	676-677	Pr	
							19/10/2017	2345	Fox	D	E	681-685	Pr	
							20/10/2017	0040	Fox	D	E then W	686-693	unlikely	
							20/10/2017	204	Fox	D	W	696-700	Pr	
							20/10/2017	250	Fox	D	E	701-705	Pr	
							20/10/2017	2010	Fox	D	W	706	Pr	
							20/10/2017	2115	Fox	D	W	711-712	Pr	
							20/10/2017	2203	Fox	D	W	716	Pr	
							21/10/2017	238	Fox	D	E then W	721-728	Pr	
							21/10/2017	1953	Fox	D	W	731-732	Pr	
							21/10/2017	2207	Fox	D	W	736-737	Pr	
							22/10/2017	0016	Fox	D	W	741-743	Pr	
							22/10/2017	156	Fox	D	W	746-748	Pr	
							22/10/2017	1614	Fox	D	W	751-752	Pr	
							22/10/2017	1656	Fox	D	E	756-760	Pr	
							22/10/2017	2024	Fox	D	E then W	761-770	Unlikely	
							22/10/2017	2239	Fox	D	E	771-775	Pr	
							23/10/2017	239	Fox	D	W	776-778	Pr	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							23/10/2017	331	Fox	D	E	781-785	Pr	
							23/10/2017	1334	Fox	D	W	786-788	Pr	
							23/10/2017	1408	Fox	D	E	791-795	Pr	
							24/10/2017	928	Fox	D	W	796-798	Pr	
							24/10/2017	1008	Fox	D	E	801-805	Pr	
							24/10/2017	2005	Fox	D	W	806-808	Pr	
							24/10/2017	2052	Fox	D	E	811-815	Pr	
							24/10/2017	2204	Fox	D	W	816-817	Pr	
							25/10/2017	1201	Fox	D	W	821-822	Pr	
							25/10/2017	1251	Fox	D	E	826-830	Pr	
							25/10/2017	2206	Fox	D	W	831-832	Pr	
							25/10/2017	2315	Fox	D	W	836-837	Pr	
							26/10/2017	0017	Fox	D	W	841-842	Pr	
							26/10/2017	0048	Fox	D	E	846-850	Pr	
							26/10/2017	303	Fox	D	W	851-854	Pr	
							26/10/2017	328	Fox	D	E	856-860	Pr	Carrying prey
							26/10/2017	332	Fox	D	W then E then W	861-880	Pr	Probably crossed east to west
							26/10/2017	412	Fox	D	E	881-885	Pr	
							26/10/2017	517	Swamp Wallaby	D	E then W	886-892	Unlikely	
							26/10/2017	2107	Fox	D	W	896	Pr	
							27/10/2017	136	Fox	D	W	901-905	Pr	
							27/10/2017	237	Fox	D	E	906-910	Pr	
							27/10/2017	300	Fox	D	W	911-915	Pr	
							27/10/2017	342	Fox	D	E	916-920	Pr	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							27/10/2017	1024	Fox	D	W	921-922	Pr	
							27/10/2017	1113	Fox	D	E	926-930	Pr	
							27/10/2017	2307	Fox	D	W	931-932	Pr	
							27/10/2017	2337	Fox	D	E	936-940	Pr	
							28/10/2017	1108	Fox	D	W	941	Pr	
							28/10/2017	1208	Fox	D	E	946-950	Pr	carrying prey, lizard sp.
							28/10/2017	2027	Fox	D	W	951	Po	
							28/10/2017	2049	Fox	D	W	956-958	Pr	
							28/10/2017	2329	Fox	D	W	961-962	Pr	
							29/10/2017	0004	Fox	D	E	966-970	Pr	
							29/10/2017	2126	Fox	D	W	971	Po	
							29/10/2017	2154	Fox	D	W	976-977	Pr	
							29/10/2017	2224	Fox	D	E	981-985	Pr	
							30/10/2017	108	Fox	D	W	991-993	Pr	
							30/10/2017	205	Fox	D	E	996-1000	Pr	carrying prey, rodent sp.
							30/10/2017	1327	Fox	D	W	1001-1106	Pr	
							30/10/2017	1430	Fox	D	E	1011-1015	Pr	
							30/10/2017	2049	Fox	D	W	1016-1018	Pr	
							30/10/2017	2117	Fox	D	E	1021-1025	Pr	
							30/10/2017	2336	Fox	D	W	1026-1029	Pr	
							31/10/2017	1434	Fox	D	W	1031-1033	Pr	
							31/10/2017	1506	Fox	D	E	1036-1040	Pr	
							1/11/2017	1740	Fox	D	W	1041-1042	Pr	
							1/11/2017	2114	Fox	D	E	1046-1050	Pr	
							2/11/2017	1000	Fox	D	W	1051-1053	Pr	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							2/11/2017	1050	Fox	D	E	1056-1060	Pr	
							2/11/2017	1908	Fox	D	E then W	1061-1067	Unlikely	
							2/11/2017	2159	Fox	D	W	1071	Po	
							2/11/2017	2227	Fox	D	E	1076-1080	Pr	
Emerald Bch East-North							**Emerald Bch East-South**							
6/5/17	532	EG Kangaroo	D	Exit	56-79	D								
23/5/17	652	EG Kangaroo	D	Explore	81/105	Po								
							15/6/17	521	EG Kangaroo	D	Grazing	66-75	Un	
4/7/17	609	EG Kangaroo	D	Explore	176-200	Po								
							4/9/2017	1912	EG Kangaroo	D	NDM	43-60	Unlikely	
6/9/2017	201	EG Kangaroo	D	NDM	61-63	unlikely	6/9/2017	220	EG Kangaroo	D	NDM	61-123	Unlikely	
9/9/2017	140	EG Kangaroo	D	NDM	64-138	unlikely								
9/9/2017	1549	EG Kangaroo	D	Exit	139-156	Pr								
							9/9/2017	1603	EG Kangaroo	D	NDM	124-156	unlikely	
							9/9/2017	1642	EG Kangaroo	D	NDM	157-162	unlikely	
							10/9/2017	2132	Fox	D	NDM	163-165	unlikely	
12/9/2017	517	EG Kangaroo	D	NDM	157-194	unlikely								
							13/9/2017	2011	EG Kangaroo	D	NDM	166-171	unlikely	
14/9/2017	2104	EG Kangaroo	D	Exit	196-237	Pr								

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							14/9/2017	2122	Swamp Wallaby	D	NDM	172-174	unlikely	
							15/9/2017	2240	EG Kangaroo	D	NDM	175-204	unlikely	
							17/9/2017	2239	Swamp Wallaby	D	NDM	205-216	unlikely	
							21/9/2017	316	red-necked Wallaby	D	NDM	217-231	unlikely	
							26/9/2017	123	red-necked Wallaby	D	NDM	232-240	unlikely	
							26/9/2017	407	EG Kangaroo	D	NDM	241-309	Unlikely	
							26/9/2017	1951	EG Kangaroo	D	NDM	310-327	unlikely	
							28/9/2017	1701	Bush Turkey	D	NDM	19-21	unlikely	
1/10/2017	110	EG Kangaroo	D	NDM	16-36	unlikely								
1/10/2017	209	EG Kangaroo	D	NDM	37-54	unlikely								
							3/10/2017	1733	EG Kangaroo	D	NDM	22-33	unlikely	
4/10/2017	334	red-necked Wallaby	D	NDM	55-75	unlikely								
							4/10/2017	2309	EG Kangaroo	D	NDM	34-126	unlikely	
							6/10/2017	2042	EG Kangaroo	D	NDM	127-144	unlikely	
							7/10/2017	1757	EG Kangaroo	D	NDM	148-153	unlikely	
7/10/2017	1817	EG Kangaroo	D	NDM	76-90	unlikely								
							18/10/2017	1355	EG Kangaroo	D	NDM	154-168	unlikely	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
							21/10/2017	2013	EG Kangaroo	D	NDM	169-186	unlikely	
24/10/2017	941	EG Kangaroo	D	S then N	91-102	unlikely								
							27/10/2017	1203	Cat	D	NDM	187-189	unlikely	
1/11/2017	345	red-necked Wallaby	D	NDM	103-111	unlikely								
2/11/2017	524	EG Kangaroo	D	NDM	112-138	unlikely								
Arrawarra South-East							Arrawarra South-West							
							7/5/17	758	Swamp Wallaby	Pr	E	86-90	Pr	
7/5/17	824	Swamp Wallaby	Pr	W	86-90	Pr								
11/5/17	1721	Swamp Wallaby	D	NDM	91-95	Po								
							15/5/17	503	Dog	D	Enter/exit	91-95	No	
11/6/17	928	Swamp Wallaby	Pr	NDM	136-140	Po								
							19/6/17	1051	Dog	E	E	141-145	Pr	
27/6/17	933	Dog	D	E	141-144	D	27/6/17	931	Dog	D	E	146-150	D	
9/7/17	747	Swamp Wallaby	Pr	W	146-150	Pr								
9/7/17	1707	Swamp Wallaby	Pr	E	151	D	9/7/17	1702	Swamp Wallaby	D	E	156-160	D	
20/7/17	857	EG Kangaroo x 2	D	W	156-180	D	20/7/17	857	EG Kangaroo x 2	D	W	161-164	D	
10/9/2017	1056	Human - motorbike	D	E then S	100-103	D	10/9/2017	1056	Human - motorbike	D	S	109-111	D	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
13/9/2017	939	Swamp Wallaby x2	D	E	106-108	D								
16/9/2017	712	EG Kangaroo x2	D	E	109-120	Po								
28/10/2017	1653	EG Kangaroo	D	E	268-270	Pr								
Arrawarra North-East							Arrawarra North-West							
							18/5/17	918	Swamp Wallaby	Pr	W	31	Pr	
25/5/17	937	Wallaby sp.	D	W	66-70	Pr								
28/5/17	243	Wallaby sp.	D	W	71-74	Pr								
28/5/17	1027	Wallaby sp.	D	W	76-80	Pr								
31/5/17	808	Wallaby sp.	D	W	81-85	Pr								
31/5/17	958	Wallaby sp.	D	W	86-90	Pr	31/5/17	1003	Swamp Wallaby	D	W	41	D	
31/5/17	1012	Wallaby sp.	D	E	91-92	Pr								
31/5/17	1154	Swamp Wallaby	D	Enter/exit	96-108	No								
31/5/17	1428	Wallaby sp.	D	W	111-115	Po								
							31/5/17	1509	Swamp Wallaby	Po	NDM	46	Po	
2/6/17	1015	Wallaby sp.	D	E	116	Pr								
3/6/17	1648	Wallaby sp.	D	E	141	Pr	3/6/17	1645	Swamp Wallaby	D	E	81-85	D	
6/6/17	1116	Swamp Wallaby	D	E	146	Pr	6/6/17	1105	Swamp Wallaby	D	E	86-90	D	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
7/6/17	834	Swamp Wallaby	Pr	W	151-155	Pr								
							8/6/17	1005	Swamp Wallaby	D	E	106-110	Pr	
8/6/17	1631	Swamp Wallaby	Pr	W	166-170	Pr								
15/6/17	819	Swamp Wallaby	D	W	171-180	Pr								
20/6/17	2159	Swamp Wallaby	D	NDM	181-185	Po								
22/6/17	951	Swamp Wallaby	D	E	186-188	D	22/6/17	950	Swamp Wallaby	D	E	111-115	D	
24/6/17	1347	Swamp Wallaby	Pr	W	191-195	Pr								
25/6/17	2109	Swamp Wallaby	Po	NDM	196	Po								
26/6/17	813	Swamp Wallaby	D	NDM	201-205	Po								
							27/6/17	849	Swamp Wallaby	Pr	E	116-120	Pr	
27/6/17	959	Swamp Wallaby	D	W	206-210	D	27/6/17	1004	Swamp Wallaby	D	W	121-123	D	
27/6/17	1356	Dog	D	W	211-220	Pr	27/6/17	1358	Dog	D	W	126-128	D	
29/6/17	728	Swamp Wallaby	Pr	W	221-225	Pr								
1/7/17	1624	Swamp Wallaby	Pr	W	226-230	Pr								
1/7/17	2020	Swamp Wallaby	D	E	231-234	Pr								
3/7/17	1002	Swamp Wallaby	D	NDM	236-245	D	3/7/17	956	Swamp Wallaby	D	E	131-135	D	
3/7/17	1214	Swamp Wallaby	D	W	246-250	D	3/7/17	1218	Swamp Wallaby	D	NDM	136-140	D	

Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Date	Time	Species	Accu- racy	Movement	Pic No.	Crossing Likelihood	Comments
5/7/17	840	Swamp Wallaby	Pr	W	251-255	Pr								
8/7/17	1009	Swamp Wallaby	Pr	W	256-260	Pr								
							8/7/17	1014	Swamp Wallaby	Pr	E	142	Pr	
							9/7/17	806	Swamp Wallaby	D	NDM	146-150	Po	
11/7/17	1718	Swamp Wallaby	D	NDM	261-265	Po								
12/7/17	857	Swamp Wallaby	D	E	266	D	12/7/17	855	Swamp Wallaby	D	E	151-155	D	
20/7/17	2330	Swamp Wallaby	D	W	271-279	Pr								
20/7/17	2356	Swamp Wallaby	Pr	W	281-285	Pr								
21/7/17	251	Swamp Wallaby	Pr	NDM	286	Po								
							9/9/2017	820	Swamp Wallaby	D	W	94-96	Pr	

Appendix A – Exclusion fence camera monitoring data

Table A3: Fauna recorded by camera traps positioned on exclusion fence adjacent to monitored underpasses during autumn 2017 & 2018 and spring 2017. Accuracy/Likelihood: D = Definite; Pr = Probable; Po = Possible. NDM = no defined movement; AF = moves along fence; AR = approaches and retreats; RTB = pass through fence from roadside to bush side; BTR = pass through fence from bush side to roadside.

Camera/Site	Date	Time	Species	Confidence	Movement	Pic no./s	Comments
Moonee ESS	6/04/2013	208	Wallaby sp.	D	NDM	155-157	
	6/04/2013	637	Yellow-throated scrubwren	Pr	NDM	161-163	
	7/04/2013	349	Northern brown bandicoot	D	AF	1112-1119	S to N
	1/09/2017	452	Rodent sp.	Pr	AF	1219-1221	
	29/09/2017	242	Swamp wallaby	Pr	NDM	127-132	grazing
	20/09/2017	2247	Swamp wallaby	D	AF	1117-1170	grazing
	2/10/2017	131	Swamp wallaby	Po	NDM	1189-1191	
	4/10/2017	213	Eastern grey kangaroo	D	NDM	1201-1218	grazing
	8/10/2017	2215	Fox	D	AF	2236-2238	
	10/10/2017	0045	Swamp wallaby	D	AF	2614-2643	grazing
	11/10/2017	0025	Swamp wallaby	D	NDM	3556-3597	grazing
	18/10/2017	0001	Swamp wallaby	D	AF	4408-4452	grazing
	18/10/2017	2100	Swamp wallaby	D	AF	4471-4500	grazing
	19/10/2017	313	Swamp wallaby	D	AF	4501-4509	grazing
	2/05/2018	1801	Swamp Wallaby	D	NDM	25-30	grazing
	3/05/2018	1057	Fairy Wren spp.	D	RTB	31-33	
	5/05/2018	0433	Eastern grey kangaroo	D	AF	40-54	grazing
	6/05/2018	2144	Swamp wallaby	D	AF	73-93	grazing
	8/05/2018	1923	Black Rat	D	BTR	94-99	Climbs fence
	11/05/2018	1426	Red-browed finch	D	NDM	106-114	
	11/05/2018	2323	Black Rat	D	NDM	121-132	Climbs fence
	16/05/2018	0324	Black Rat	D	NDM	166-168	Climbs fence

	17/05/2018	0246	Black Rat	D	NDM	175-184	Climbs fence
	18/05/2018	1246	Fairy Wren spp.	D	RTB	184-186	
	18/05/2018	1830	Black Rat	Pr	NDM	187-192	Climbs fence
	19/05/2018	0322	Swamp Wallaby	D	AF	193-207	Grazing
	20/05/2018	1222	Eastern grey kangaroo	D	AF	214-216	On road side of fence
	20/05/2018	1614	Large-billed Scrubwren	D	RTB	217-219	
	20/05/2018	2000	Black rat	Pr	NDM	223-231	Climbs fence
	21/05/2018	1521	Red-browed finch	D	NDM	240-243	
Moonee ES	6/04/2013	2354	Swamp wallaby	Pr	NDM	416-418	
	29/08/2017	835	Swamp wallaby	Pr	NDM	1-3	
	2/09/2017	940	Swamp wallaby	Pr	NDM	2713-2739	
	4/09/2017	1344	Swamp wallaby	D	AR	4141-4245	approaches fence then retreats, grazes on grass nearby
	5/09/2017	940	Swamp wallaby	Pr	NDM	4999-5028	grazing
	28/09/2017	2021	Swamp wallaby	D	AR	175-195	
	30/09/2017	417	Black Rat	Pr	AR	1306-1308	Poked head through fence road to bush side
	3/10/2017	1723	Eastern grey kangaroo	Pr	NDM	1327-1329	
	7/10/2017	1249	Eastern grey kangaroo	D	AF	2008-2040	grazing
	8/10/2017	131	Swamp wallaby	D	AF	2044-2061	grazing
	9/10/2017	636	Eastern grey kangaroo	D	NDM	2074-2097	grazing, group of 4-5 nearby
	9/10/2017	1343	Echidna	D	AF	2281-2283	
	15/10/2017	103	Swamp wallaby	D	AF	2659-2670	grazing
	18/10/2017	2023	Swamp wallaby	D	NDM	2725-2739	grazing
	22/10/2017	1940	Swamp wallaby	D	NDM	3340-3363	grazing
	24/10/2017	2344	Eastern grey kangaroo	D	AF	3712-3780	grazing
	26/10/2017	2138	Swamp wallaby	D	NDM	3994-4002	grazing
	2/11/2017	2233	Swamp wallaby	Pr	NDM	5287-5289	grazing
	1/05/2018	1556	White-browed Scrubwren	D	RTB	757-759	
	2/05/2018	1838	Swamp Wallaby	D	AF	766-768	
	3/05/2018	1249	Red-browed Finch	D	NDM	790-792	

	5/05/2018	2344	Swamp wallaby	D	AF	1037-1044	
	8/05/2018	0000	Swamp Wallaby	Pr	AF	1138-1140	
	9/05/2018	1308	Fairy Wren spp.	D	BTR	1180-1182	
	10/05/2018	1455	Red-browed finch	D	RTB	1195-1200	
	12/05/2018	0316	Swamp Wallaby	D	AF	1231-1236	
	12/05/2018	1515	Red-browed finch	D	RTB	1309-1311	
	13/05/2018	0042	Swamp wallaby	D	AF	1312-1329	
	17/05/2018	2020	Swamp Wallaby	D	AF	2101-2103	
	19/05/2018	2206	Eastern grey kangaroo	D	AF	2212-2217	
	21/05/2018	1202	Red-browed finch				
Moonee WS	11/04/2013	1053	Swamp wallaby	D	AF	10-24	N to S
	20/04/2013	1634	Swamp wallaby	D	NDM	25-30	
	23/04/2013	2051	Red fox	D	AF	31-33	S to N
	25/04/2013	1709	Swamp wallaby	D	NDM	34-36	
	25/04/2013	1728	Swamp wallaby	D	AF	37-42	S to N
	28/04/2013	159	Red fox	Pr	AF	43-45	S to N
	28/04/2013	247	Red fox	D	AF	46-48	S to N
	29/04/2013	2123	Swamp wallaby	D	AF	49-57	S to N
	5/09/2017	2347	Swamp wallaby	D	AF	28-51	grazing
	8/09/2017	0051	Swamp wallaby	D	NDM	58-69	grazing
	14/09/2017	2058	Fox	D	NDM	79-82	
	27/09/2017	130	Swamp wallaby	D	NDM	85-133	grazing
	27/09/2017	2238	Fox	D	NDM	136-138	
	1/10/2017	2134	Fox	D	NDM	4-6	
	5/10/2017	2027	Fox	D	NDM	7-12	
Moonee WN	12/04/2013	543	Swamp wallaby	D	NDM	7-21	
	14/04/2013	131	Red fox	D	AF	22-27	S to N
	21/04/2013	739	Swamp wallaby	D	AF	28-36	N to S
	24/04/2013	1628	Swamp wallaby	D	NDM	37-42	
	24/04/2013	1123	Red fox	D	AR	43-45	
	25/04/2013	1749	Swamp wallaby	D	AF	46-54	S to N
	27/04/2013	Red fox	Red fox	D	AF	55-57	N to S

	6/09/2017	2032	Black Rat	Pr	NDM	7-9	
	9/09/2017	2142	Swamp wallaby	D	NDM	10-69	grazing
	11/09/2017	2311	Fox	D	AF	70-78	
	8/10/2017	311	Swamp wallaby	D	AF	82-129	grazing
	18/10/2017	2222	Common Brushtail possum	Pr	AF	130-132	
	2/11/2017	1906	Fox	D	AF	133-135	
	29/04/2018	0243	Swamp wallaby	D	AF	7-18	
Emerald ES	5/04/2013	2348	Red necked wallaby	Pr	NDM	92-97	
	7/04/2013	1642	Brown thornbill	Po	NDM	161-162	
	7/04/2013	2120	Red necked wallaby	Pr	AF	167-178	
	9/04/2013	122	Red necked wallaby	Pr	NDM	215-220	
	10/04/2013	803	Small bird sp.	D	NDM	272-273	
	10/04/2013	1301	Small bird sp.	D	NDM	422-424	
	11/04/2013	1246	Small bird sp.	D	NDM	515-517	
	12/04/2013	222	Macropod sp.	D	AF	530-532	
	12/04/2013	544	Macropod sp.	Pr	NDM	533-535	
	12/04/2013	1452	Red-browed finch	Po	NDM	575-577	
	14/04/2013	949	Red-browed finch	D	NDM	707-709	
	15/04/2013	303	Macropod sp.	D	NDM	884-889	
	16/04/2013	1708	Eastern grey kangaroo	D	AF	947-952	x3
	19/04/2013	1336	Eastern grey kangaroo	D	AF	983-993	x2
	19/04/2013	1342	Eastern grey kangaroo	D	NDM	995-1007	
	24/04/2013	1652	Red-necked wallaby	Pr	NDM	1085-1090	
	25/04/2013	0047	Macropod sp.	Po	AR	1091-1095	
	25/04/2013	0048	Eastern grey kangaroo	D	AF	1100-1114	
	25/04/2013	545	Unid			1119	

	28/04/2013	517	Macropod sp.	D	NDM	1148-1150	
	3/09/2017	2005	Eastern grey kangaroo	D	AR	85-99	
	4/09/2017	254	Black rat	Pr	RTB	112-114	
	6/09/2017	1938	Rodent sp.	Pr	BTR	1564-1569	Climbing fence
	27/09/2017	2101	Swamp wallaby	Pr	NDM	1-3	
	5/10/2017	112	Eastern grey kangaroo	D	AF	46-60	grazing
	2/05/2018	0122	Eastern grey kangaroo	D	AF	4-39	Grazing
	3/05/2018	1508	Fairy Wren spp.	D	RTB	40-42	
	4/05/2018	0333	Eastern grey kangaroo	D	NDM	43-45	
Emerald EN	7/04/2013	757	Crow	Pr		276	
	8/04/2013	1803	Macropod sp.	D	NDM	522-524	
	9/04/2013	1848	Macropod sp.	Pr	NDM	699-704	
	13/04/2013	2033	Wallaby sp.	D	NDM	1695-1697	
	9/09/2017	313	Swamp wallaby	Pr	AF	3678-3680	2 x grazing near fence, one approaches fence
	13/09/2017	1814	Swamp wallaby	Pr	NDM	6219-6230	grazing near fence
	5/10/2017	2228	Swamp wallaby	D	AF	2482-2505	grazing
	6/10/2017	0030	Swamp wallaby	D	NDM	2509-2511	grazing
	8/10/2017	0051	Swamp wallaby	D	AF	2788-2799	grazing
	10/11/2017	0005	Eastern grey kangaroo	D	NDM	3733-3735	
			Camera Stolen				
Emerald WS	6/04/2013	1550	Superb fairy wren	D	AF	1470-1471	Flying, male
	6/04/2013	1614	Small bird sp.	D	NDM	1484-1486	
	7/04/2013	1555	Superb fairy wren	D	NDM	1849	Female
	30/09/2017	1253	Eastern grey kangaroo	D	AF	2548-2571	grazing
	30/09/2017	2344	Swamp wallaby	D	AF	2575-2580	
	2/10/2017	643	Eastern grey kangaroo	D	NDM	2614-2727	grazing
	7/05/2018	1633	Fairy Wren spp.	D	RTB	829-831	
	9/05/2018	1506	Fairy Wren spp.	D	BTR	883-885	
Emerald WN	9/04/2013	1615	Superb fairy wren	D	NDM	260-262	Female
	31/08/2017	1127	Eastern water dragon	D	NDM	320-388	
	28/09/2017	1929	Bandicoot sp.	Pr	NDM	614-615	
	28/09/2017	2143	Northern brown bandicoot	Pr	AR	619-621	approaches fence
	29/09/2017	900	Eastern water dragon	D	NDM	622-627	
	29/09/2017	942	Eastern water dragon	D	NDM	640-642	
	1/10/2017	1128	Eastern water dragon	D	NDM	1330-1332	

	3/10/2017	2055	Northern brown bandicoot	D	AF	1456-1461	
	4/10/2017	1701	Eastern water dragon	D	AR	1906-1908	
	5/10/2017	933	Eastern water dragon	D	NDM	1948-1959	
	5/10/2017	1111	Eastern water dragon	D	NDM	2236-2238	
	5/10/2017	2049	Northern brown bandicoot	Pr	AR	3386-3390	
A'warra EN	3/04/2013	2300	Antichinus sp.	Pr	AF	19-37	
	4/04/2013	2300	Black rat	Pr	NDM	64-66	
	4/04/2013	2300	Black rat	Pr	BTR	70-78	
	4/04/2013	2300	Antichinus sp.	Po	AF	79-81	
	4/04/2013	2300	Black rat	D	AR	82-87	
	4/04/2013	1100	Superb fairy wren	Pr	NDM	97-99	On road side of fence
	6/04/2013	2300	Antichinus sp.	Po	AF	109-111	
	6/04/2013	2300	Antichinus sp.	Po	BTR	112-113	
	6/04/2013	2300	Black rat	D	NDM	115-117	
	8/04/2013	2300	Black rat	D	RTB	129-144	
	9/04/2013	2300	Antichinus sp.	Po	NDM	151-153	Po RTB
	13/04/2013	2300	Antichinus sp.	Pr	NDM	172	
	14/04/2013	2300	Black rat	D	RTB	175-177	
	15/04/2013	2300	Black rat	D	AF	196-198	
	16/04/2013	2300	Echidna	D	NDM	205-207	
	16/04/2013	2300	Black rat	D	RTB	211-216	Po BTR again?
	16/04/2013	2300	Antichinus sp.	Po	BTR	217-219	
	19/04/2013	2300	Antichinus sp.	Pr	BTR	232-234	
	19/04/2013	2300	Black rat	D	NDM	235-240	
	1/09/2017	415	Swamp wallaby	D	NDM	788-790	grazing
	30/08/2017	133	Black Rat	D	NDM	13-15	
	11/09/2017	2058	Black Rat	D	AF	16-18	Could have come through fence from road side
	21/09/2017	222	Black Rat	D	AF	19-21	Could have come through fence from road side
	21/09/2017	2019	House Mouse	Pr	AF	22-24	
	23/09/2017	1947	House Mouse	Pr	AF	25-27	
A'warra ES	Nil						

	1/10/2017	211	Macropod sp.	D	NDM	421-426	
	1/10/2017	2055	rodent sp.	Pr	AF	430-432	
	28/4/18	2203	Swamp Wallaby	D	AF	196-201	Moves towards culvert
	4/5/18	1931	Swamp Wallaby	Pr	AF	406-408	
	5/5/18	0852	Swamp Wallaby	D	AF	409-411	
	7/5/18	0557	Swamp Wallaby	D	AF	535-538	Moves away from culvert
	9/5/18	0124	Swamp Wallaby	D	AF	550-555	
	9/5/18	2340	Fox	Pr	AF	562-564	Moves towards culvert
	11/5/18	0315	Swamp Wallaby	Pr	AF	607-610	
	12/5/18	0725	Swamp Wallaby	D	AF	684-669	
	20/5/18	0135	Fox	D	AF	1030-1032	
	20/5/18	0135	Fox	D	AF	1033-1035	
	20/5/18	1642	Swamp wallaby	D	AF	1039-1040	
A'warra WN	nil						
A'warra WS	3/04/2013	2300	Black rat	D	NDM	9-14	Climbing small tree
	4/04/2013	2300	Swamp wallaby	D	NDM	396-404	
	1/10/2017	120	Swamp wallaby	D	AF	2038-2064	approaches fence grazing
A'warra EN	14/04/2013	238	Swamp wallaby	Pr	AR	1891-1899	
A'warra ES	9/09/2017	1847	Wallaby sp.	Pr	AF	1234-1239	moving along fence towards camera
	28/09/2017	2023	Rodent sp.	Pr	AF	184-186	moving along fence
	4/10/2017	1325	fairy wren sp.	D	RTB	583-585	moves through fence
	17/10/2018	718	Eastern Grey Kangaroo	Pr	AF	586-588	moves along fence but at a fair distance
	6/10/2017	910	Swamp Wallaby	D	NDM	724-726	grazing
	11/05/2018	1648	Tawny Grassbird	D	RTB	1960-1962	
	19/05/2018	1945	House Mouse	Pr	NDM	3021-3022	climbs fence
A'warra WN	4/04/2013	58	Black rat	Pr	NDM	605-607	Climbing fence
	2/09/2017	1822	Northern Brown Bandicoot	D	AF	4-12	
	3/09/2017	2018	Northern Brown Bandicoot	D	AR	16-21	

	4/09/2017	2028	Northern Brown Bandicoot	D	AR	22-27	
	6/09/2017	236	Northern Brown Bandicoot	D	AR	28-33	
	7/09/2017	15	Northern Brown Bandicoot	D	AR	34-45	
	8/09/2017	1836	Northern Brown Bandicoot	D	AR	45-48	
	10/09/2017	2113	rodent sp.	Pr	AF	52-54	
A'warra WS	29/08/2017	125	Macropod sp.	Po	NDM	7-8	
	29/08/2017	2354	Black Rat	Pr	BTR?	24-53	appears to pass though pipe
	30/08/2017	145	Swamp Wallaby	D	AF	54-62	grazing near fence
	30/08/2017	208	Black Rat	Pr	BTR?	63-68	appears to pass though pipe
	1/09/2017	413	Black Rat	Pr	AF	90-92	
	2/09/2017	0002	Northern Brown Bandicoot	D	AR	96-128	Approached pipe and puts head inside
	2/09/2017	235	Black Rat	Pr	AF	129-131	
	2/09/2017	1816	Northern Brown Bandicoot	D	AR	132-137	Approached pipe and puts head inside
	3/09/2017	231	Rodent sp.	Pr	RTB	141-143	sitting in entrance of pipe
	4/09/2017	2022	Northern Brown Bandicoot	D	AR	150-152	Approached pipe and puts head inside
	5/09/2017	2052	Black Rat	Pr	AR	234-239	
	12/09/2017	2332	Northern Brown Bandicoot	D	AR	246-251	Approached pipe and puts head inside
	3/10/2017	415	Black Rat	Pr	AF	262-264	

Appendix A – Road mortality and roadside habitat monitoring data

Table A4: Results of road mortality and roadside habitat fauna surveys conducted at underpass monitoring sites during autumn and spring 2017. Accuracy/Likelihood: D = Definite; Pr = Probable; Po = Possible.

Side	Date	Observers	Start	End	Road kill	Location	Cleared	Fauna	Notes	Fence conditions	Weather
Moonee East	6/4/17	BT,SR	1235	1304	sm. bird sp.	10N, 3EoFL	Y	Nil	Fence>Fog Line(FL) ?		Warm, showers
					Sthn boobook	100S, 2EoFL	Y				
	28/4/17	BT/SR	1210	1236	Nil			Nil			Mild, occ. shower, windy
	8/5/17	NP/SR	1501	1533	S.Boobook	10S, 7EofFL	Y	Lampropholis sp	Same as last survey, moved by mower? Very dissecated		
					Poss. Kookaburra	30N, 5EofFL	Y		Just skull found		
	24/5/17	BT/NP	955	1022	Nil			Y-f whip snake (3EoFL); Lamprapholis sp.			Fine, mild, 23-25C
	8/6/17	BT/GM	1511	1539	NB b'coot	30s,1EoFL	Y	Nil	Service Rd west side		Fine, cloudy , 18-20
					Brown thornbill	110s, 3EoFL	Y				
	30/8/17	GM/SR	1540	1610	Nil			Nil			
	28/9/17	BT/SR	1051	1120	Nil					Good	Fine, windy, cloudy, 24deg

	18/12/17	NP	1240	1340	Dollar bird	70s, 4.5EofFL	Y	Nil	Only wings found	Good	Hot and windy (30plus deg)
					Juv Fairy Wren sp.	20n, 2.5EofFlL	Y	Nil			
Moonee West	6/4/17	BT,SR	1426	1459	Carpet python	100S, 3WoFL	Y	Nil	Fence>FL ?		Warm, showers
					Br tree snake	110S, 1WoFL	Y				Mild, occ. shower, windy
	28/4/17	BT/SR	1241	1308	Nil			Nil			
	8/5/17	NP/SR	1540	1615	Gr tree Snake	150N, 3WoFL	Y	Nil			Mild, cloudy
	24/5/17	BT/NP	1025	1052	Rodent sp.	50N, 2WoFL	Y	Lampropholis sp			Fine, 23-25C
	8/6/17	BT/GM	1440	1509	Nil			Nil			Fine, cloudy , 18-20
	29/8/17	NP	1605	1705	Kookaburra	5s1EoFL (median)	N	Nil	Busy traffic		Fine, 16
	28/9/17	BT/SR	1020	1048	Bearded dragon	100nLane	Y			Good	Fine, windy, cloudy, 24deg
	26/10/2017	BT/SR	1138	1205	Snake sp	170N, 3WoFL	Y	Nil			Fine, 25-30
	3/11/2017	BT/OT	1005	1029	Nil			Lamprapholis sp			Fine 20-26
	18/12/17	NP	1240	1340	RB Finch	100N, 4WofFL	Y	Nil			Hot and windy

					RB Finch	40N, 3WofFL	Y	Nil			
					Reptile sp.	40N, 3WofFL	Y	Nil	Only vertebrae found		
					Echidna	20N, 1WofFL	Y	Nil			
					Small bird	90S, 4WofFL	Y	Nil	Only down feathers found		
Emerald East	5/4/17	BT,SR	1458	1529	Nil			Nil	Fence>FL:23-30m, inc. service road		Warm, showers
	28/4/17	BT/SR	1051	1118	Nil			Nil	Many side Rd access fence openings		Mild, occ. shower, windy
	8/5/17	NP/SR	1344	1414	Nil			Nil			Mild, cloudy.
	24/5/17	BT/NP	1058	1125	Nil			Nil			Fine, 23-25C
	8/6/17	BT/GM	1609	1640	Nil			Nil			Fine, cloudy , 18-20
	30/8/17	NP	1525	1625	Brown Antechinus	130s, 3EoFL	Y	Macropod scat			Fine, 19
					Med mammal sp	40s, 2EoFL	Y	(Gate open)			
					BS Dove	35s, 0.5WoFL (median)	Y				
	27/9/17	BT/SR	1122	1150	Est Grey Kroo	160n, 1WoFL	Y		Carcass in median	Good	Fine, windy, cloudy, 21deg
	26/10/2017	BT/SR	1039	1104	Nil			Nil			Fine, 25-30
	3/11/2017	BT/OT	1107	1131	Nil			Nil			Fine 20-26
	18/12/17	NP	1350	1450	Nil			Nil			

Emerald West	5/4/17	BT,SR	1622	1654	Br-tail possum sp.	150N, 1WoFL	Y	Nil	Fence>FL:9-11m	Fence pushed over oppo r-k, drains through fence open at base up to 300mm	Warm, showers
	28/4/17	BT/SR	1125	1152	Bandicoot sp	20n, 3WoFL	Y	Nil		Incomplete cut in fence 50s	Mild, occ. shower, windy
	8/5/17	NP/SR	1418	1452	S. Boobook	60N, 5WofFL	Y	RN Wallaby at park spot, 150noTran	Very old, dissecated	Incomplete cut in fence 50s	Mild, cloudy
					Med Frog sp.	160S, 3WofFL	Y				
	24/5/17	BT/NP	1127	1155	Bird sp	180s, 2WoFL	Y	Nil			Fine, 23-25C
	8/6/17	BT/GM	1642	1711	Nil			Nil			Fine, cloudy , 18-20
	30/8/17	NP	1420	1520	Small mammal sp	100s, 2EoFL	N	RB Finch	On roadway		Fine, 20
					EG Kangaroo	400n, 3woFL	N		Stuck behind fence?		
	27/9/17	BT/SR	1155	1222	Swamp wallaby	190s, 4WoFL	Y		Smudge remains	Good	Fine, windy, cloudy, 21deg
	26/10/2017	BT/SR	1106	1131	Welcome swallow	160s, 3WoFL	Y	Nil			Fine, 25-30
	3/11/2017	BT/OT	1134	1201	Nil			Nil			Fine 20-26
	18/12/17	NP	1350	1450	Nil			Nil			
A'warra South East	5/4/17	BT/SR	847	918	Nil			Nil	Fence>FL ?		Warm, showers
	28/4/17	BT/SR	950	1015	Nil			Nil			Mild, occ. shower, windy

	4/5/17	BT/NP	945	1012	Nil			Lamprapholis sp			Mild, cloudy rain <24hr
	24/5/17	BT/NP	1355	1424	Nil			Nil			Fine, mild
	7/6/17	BT/GM	1432	1500	Nil			Nil			Fine, cloudy , 15-17
	31/8/17	NP/GM	900	930	Nil			Nil			Fine 16
	27/9/17	BT/SR	855	922	Nil			Nil		Good	Fine, windy, cloudy, 22deg
	26/10/2017	BT/SR	1254	1321	Nil			Nil			Fine, 25-30
	3/11/2017	BT/OT	751	816	Boobook	200s,1EoFL	Y	Lamprapholis sp			Fine 20-26
	18/12/17	GM/MJ	1230	1430	Nil						
A'warra South West	5/4/17	BT,SR	710	741	Carpet python	50S, 3WoFL	Y	Nil	Fence>FL:6-20		Warm, showers
	28/4/17	BT/SR	1322	1350	Nil			Nil			Mild, occ. shower, windy
	4/5/17	BT/NP	1047	1111	Kookaburra (skull)	150s, 1WoFL	Y	Nil			Mild, cloudy rain <24hr
	24/5/17	BT/NP	1216	1245	Snake sp.	180n, 2EoFL	Y	Nil	Snake adjacent median		Fine, 23-25C
					Raptor sp.	160s, 2EoFL	Y		Raptor adjacent median		
	7/6/17	BT/GM	1604	1628	Nil			Nil			Fine, cloudy , 15-17
	31/8/17	NP/SR	1045	1115	Med Snake sp.	100s, 3WoFL	N	Nil			
	27/9/17	BT/SR	1026	1052	Nil					Good	Fine, windy, cloudy, 22deg

	26/10/2017	BT/SR	1421	1448	Nil	20n, mid road	N	Nil	Only a smudge of fur		Fine, 25-30
	3/11/2017	BT/OT	921	948	B-tail possum sp.			Nil			Fine 20-26
	18/12/17	GM/MJ	1230	1430	Nil						
A'warra North East	6/4/17	BT,SR	910	943	Boobook (SOR. 28/4)	180N, 1WoFL	N	Nil	Fence>FL ?	Tree fall on fence 20N, no fence damage, road access for arboreals	Warm, showers
	28/4/17	BT/SR	1020	1048	Est. y robin	150s, 1EoFL	Y	Nil			Mild, occ. shower, windy
					Fairy wren sp.	90s, 3EoFL	Y				
	4/5/17	BT/NP	1017	1042	Nil			Lamprapholis sp			Mild, cloudy rain <24hr
	24/5/17	BT/NP	1323	1351	Nil			Lamprapholis sp			Fine, 23-25C
	7/6/17	BT/GM	1506	1529	Nil			Nil			Fine, cloudy , 15-17
	31/8/17	NP/SR	935	1005	Small snake	190s, 4EoFL	Y	Bandicoot digging at top of batter			
					Kookaburra	15s, 5EoF	Y	Log over fence			
					carpet Python	5NP, 3EoFL	Y				

	27/9/17	BT/SR	925	950	Nil			Eulamprus sp.		Good	Fine, windy, cloudy, 22deg
	26/10/2017	BT/SR	1323	1349	Nil			Nil			Fine, 25-30
	3/11/2017	BT/OT	821	848	Nil			Lamprapholis sp			Fine 20-26
	18/12/17	GM/MJ	1230	1430	Nil						
A'warra North West	5/4/17	BT,SR	752	825	Echidna	100N, 2WoFL	Y	Nil	Fence>FL:6-20		Warm, showers
					Carpet python	30S, 2WoFL	Y				
	28/4/17	BT/SR	1352	1420	Echidna	150s, 3WoFL	Y	Nil			Mild, occ. shower, windy
	4/5/17	BT/NP	1044	1110	Boobook?	200n, 2EoFL	Y	Nil			Mild, cloudy rain <24hr
	24/5/17	BT/NP	1249	1320	Microbat sp	10n,2WoFL; 6EoF	Y	Nil			Fine, 23-25C
					Snake sp	180s, 1EoFL	Y		Snake adjacent median		
					Med. Bird sp.	190s, 1.5EoFL	Y		Bird adjacent median		
	7/6/17	BT/GM	1533	1559	Med. Bird sp.	170, 1EoFL	Y	Nil	Bird adjacent median		Fine, cloudy , 15-17
	31/8/17	NP/SR	1010	1040	NB Bandicoot	90s, 3WoFL in drain	Y	Nil			
	27/9/17	BT/SR	952	1020	Snake	150n, 3EoFL	Y		CBtP on road, 50n of N end (cleared, smudge)	Good	Fine, windy, cloudy, 22deg
					CBtP	80n, 1WoFL	Y				
	26/10/2017	BT/SR	1351	1418	Echidna	180s,2EoFL	Y	Nil			Fine, 25-30

	3/11/2017	BT/OT	850	918	Nil			Nil			Fine 20-26
	18/12/17	GM/MJ	1230	1430	Nil						

Appendix B – Vegetated median data

Table B1: Squirrel and sugar glider trap captures during 2017. SqG = squirrel glider; SuG = sugar glider; recap = recapture

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
M7 trap	4/4/2017	SqG	F6-500/L-red	335	100	235	F	B	Slight	Cream	2xPY(30mm)	
E2-trap	5/4/2017	SqG	F7-504/L-white	285	100	185	F	A-B	Slight	Cream	Nil	Pouch stretched
E5-trap	5/4/2017	SqG (S-recap)	F6-500/L-red	360	135	225	F	B	Slight	Cream	2xPY(30mm), broken R-hand claw	Crossed: med>E
E7-trap	5/4/2017	SuG	Mb-517/L	160	30	130	M	B-C	Slight-mod	Grey		
E6-trap	6/4/2017	SqG (S-recap)	F6				F					
M3 trap	7/4/2017	SqG (recap)	M1	360	110	250	M	C	Mod	Cream	Nil secs	
E7-trap	7/4/2017	SuG	Mc-506/R-green	220	100	120	M	B	Mod	Cream	Secretons	
E3-trap	7/4/2017	SuG	Fc-501/L-green	200	110	90	F	B	Slight	Cream	Non-parous	
E3-trap	7/4/2017	SuG	Fd-518/L	195	100	95	F	A	Slight	White	Nullliparous	
M2-trap	26/9/2017	SqG (recap)	M3	299	110	189	M	C	Mod	Cr-yellow	Secretions	
E4-trap	26/9/2017	SqG (recap)	F8 (2ripEars)	285	110	175	F	B	Mod	Cr	1xPY (10mm)	
M7-trap	27/9/2017	SqG	M5-519/R			153	M	A-B	Slight	W-cr	Nil sec	
E4-trap	27/9/2017	SqG (S-recap)	F8 (2ripEars)				F					
E4-trap	28/9/2017	SqG (S-recap)	M5				M					Crossed: med>E
E6-trap	28/9/2017	SqG (S-recap)	F8 (2ripEars)				F					
M10-trap	29/9/2017	SqG (S-recap)	M5	255			M					Crossed: E>med; glided Med>W after release; 45-50m, launch 15m high from P b'wood

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
M7-trap	29/9/2017	SqG (S-recap)	F8 (2ripEars)				F					Crossed: E>med

Appendix B – Vegetated median data

Table B2: Other species captures during vegetated median trapping in 2016. F-f = Fawn-footed; Br = Brown.

Location	Date	Species (recapture)	In bag wt	Bag wt	Net wt	Sex	Breeding status
W1trap	4/4/2017	Br A'chinus	47	27	20	M	
W3 trap	4/4/2017	Br A'chinus	57	25	32	M	
M9 trap	4/4/2017	Br A'chinus			30	F	
M8 trap	4/4/2017	F-f melomys	122	30	92	M	
M5 trap	4/4/2017	Br A'chinus			30,20	F,M	
E5 trap	4/4/2017	Br A'chinus	60	30	30	F	
E9 trap	4/4/2017	Br A'chinus			20	F	
E10 trap	4/4/2017	Br A'chinus	55	29	26	F	
W1 trap	5/4/2017	Br A'chinus			30,20	M,F	
W2-trap	5/4/2017	Br A'chinus	58	40	38	M	
W7-trap	5/4/2017	F-f melomys	110	50	60	M	
M9 trap	5/4/2017	Br A'chinus	68	51	17	M	
E8-trap	5/4/2017	Br A'chinus	85	55	30	M	
E9-trap	5/4/2017	Br A'chinus	80	62	18	F	
E9-trap	5/4/2017	Br A'chinus	70	42	28	?	
W1 trap	6/4/2017	Br A'chinus				F	
W3 trap	6/4/2017	Br A'chinus				M	
M9 trap	6/4/2017	Br A'chinus				M	
M7-trap	6/4/2017	F-f melomys	170	55	115	M	
M6 trap	6/4/2017	Br A'chinus				Mx2	
M5 trap	6/4/2017	Br A'chinus				M	
M1 trap	6/4/2017	Br A'chinus				M	
E9-trap	6/4/2017	Br A'chinus				F	

Location	Date	Species (recapture)	In bag wt	Bag wt	Net wt	Sex	Breeding status
W1 trap	7/4/2017	Br A'chinus					
W3 trap	7/4/2017	Br A'chinus				M	
W7 trap	7/4/2017	F-f melomys				M	
M9-trap	7/4/2017	Br A'chinus				M	
M7- trap	7/4/2017	F-f melomys				F	
E9- trap	7/4/2017	F-f melomys				M	
M6-trap	26/9/2017	Br A'chinus				F	5xPY
M1-trap	26/9/2017	Br A'chinus				F	4+PY
M6-trap	27/9/2017	Br A'chinus			32	F	5xPY
M1-trap	27/9/2017	Br A'chinus			25	F	4+PY
M6-trap	28/9/2017	Br A'chinus			33	F	5xPY
M1-trap	28/9/2017	Br A'chinus				F	4+PY
M1-trap	29/9/2017	Br A'chinus				F	4+PY

Appendix B – Vegetated median data

Table B3: Nest box inspection data summer/autumn 2017.

Nest Box ID	Inspect date	Fauna	Signs	Condition	Inspect date	Fauna	Signs	Condition
East 1	15/2/17	Nil	Old euc leaf nest (Pet (pr));	Good	6/4/2017	Nil	Old leaf nest,	Good
East 2	15/2/17	Nil	Old euc leaf nest (Pet (pr));	Good	6/4/2017	Nil	Old scattered leaf nest	Good
East 3	15/2/17	Nil	Old euc leaf nest (Pet (pr));	Good	6/4/2017	Nil	Old leaf nest	Good
East 4	15/2/17	Nil	Old euc leaf nest (Pet (pr));	Good	6/4/2017	Nil	Old scattered leaf nest	Good
East 5	15/2/17	Nil	Mod Old euc leaf nest (Pet (pr));	Good	6/4/2017	Nil	Leaf nest, some fresh leaves	Good
East 6	15/2/17	Nil	Old euc leaf nest (Pet (pr));	Good	6/4/2017	Nil	Partial leaf nest	Good
East 7	15/2/17	Nil	Old euc leaf nest (Pet (pr));	Good	6/4/2017	Nil	Old leaf nest	Good
East 8	15/2/17	Nil	Old euc leaf nest (Pet (pr));	Good	6/4/2017	Nil	Old leaf nest, poss recent use	Good
East 9	15/2/17	Nil	Old euc leaf nest & latrine (Ant (pr))	Good	6/4/2017	Nil	Old leaf nest, latrine cnr, old Euro beehive	Good
East 10	15/2/17	Old lvs/bark & white ants	Major termite damage	Major termite damage	6/4/2017	Nil	Nil, termites	Major termite damage
West 1	15/2/17	Nil	Black ants	Good	6/4/2017	Nil	Ni, ants	Good
West 2	15/2/17	Nil	Black ants	Good	6/4/2017	Nil	Nil, ants	Good
West 3	15/2/17	Nil	Black ants	Good	6/4/2017	Nil	Nil, ants	Good
West 4	15/2/17	Nil	Old Euc leaf nest(Pet (pr)), black ants	Good	6/4/2017	Nil	Nil, ants	Good
West 5	15/2/17	Nil	Black ants	Good	6/4/2017	Nil	Nil, ants	Good
West 6	15/2/17	Nil	fresh euc lvs (Pet(pr))	Good	6/4/2017	Nil	Old leaf nest	Good
West 7	15/2/17	Nil	Old euc leaf nest & latrine (A'chinus (pr))	Good	6/4/2017	Nil	Old leaf nest	Good
West 8	15/2/17	Nil	Old Euc leaf nest(Pet (pr))	Good	6/4/2017	Nil	Old leaf nest	Good
West 9	15/2/17	Nil	Abandoned Black ant nest	Good	6/4/2017	Nil	Nil, ants	Good
West 10	15/2/17	Nil	Old flouncy euc leaf nest (FtG (pr))	Good	6/4/2017	Nil	Old leaf nest, ants	Good

Appendix B – Vegetated median data

Table B4: Nest box inspection data spring 2017.

Nest Box ID	Inspect date	Fauna	Signs	Condition	Inspect date	Fauna	Signs	Condition
East 1	31/8/17	Nil	Old leaf nest	Good	26/9/2017	Nil	Old Pet. leaf nest,	Good
East 2	31/8/17	Nil	Old leaf nest	Good	26/9/2017	Nil	Old Pet. leaf nest,	Good
East 3	31/8/17	Nil	Old leaf nest, latrine cnr, ants	Good	26/9/2017	Nil	Old leaf nest, latrine cnr ; Achinus (pr)	Good
East 4	31/8/17	Nil	Old leaf nest	Good	26/9/2017	Nil	Old Pet. leaf nest,	Good
East 5	31/8/17	Nil	Old leaf nest	Good	26/9/2017	Nil	Old Pet. leaf nest,	Good
East 6	31/8/17	Nil	Few leaves	Good	26/9/2017	Nil	Few scattered lvs	Good
East 7	31/8/17	Nil	Old leaf nest,	Good	26/9/2017	Nil	Old leaf nest,	Good
East 8	31/8/17	Nil	Freshish globular leaf nest , FtG (pr)	Good	26/9/2017	Nil	Freshish globular leaf nest , FtG (pr)	Good
East 9	31/8/17	Nil	Old messy leaf nest, old Euro beehive	Good	26/9/2017	Nil	Old leaf nest, latrine cnr ; Achinus (pr)	Good
East 10	31/8/17	Nil	Nil	Severe termite damage	26/9/2017	Nil	Nil	Severe termite damage
West 1	31/8/17	Nil	Nil - ants	Good	26/9/2017	Nil	Ants	Good
West 2	31/8/17	Nil	Nil -ants	Good	26/9/2017	Nil	Ants	Good
West 3	31/8/17	Nil	Nil - ants	Good	26/9/2017	Nil	Ants	Good
West 4	31/8/17	Nil	Nil - ants	Good	26/9/2017	Nil	Ants	Good
West 5	31/8/17	Nil	Nil - ants	Good	26/9/2017	Nil	Ants	Good
West 6	31/8/17	Nil?	Fresh leaf on old leaf nest, some bark strips (Antech -Pr)	Good	26/9/2017	Nil	Fresh leaf on old leaf nest, some bark strips (Antech -Pr)	Good
West 7	31/8/17	Nil?	Old leaf nest, latrine cnr ; Achinus (pr)	Good	26/9/2017	Nil	Old leaf nest, latrine cnr ; Achinus (pr)	Good
West 8	31/8/17	Nil?	Old leaf nest, latrine cnr ; Achinus (pr)	Good	26/9/2017	Nil	Old leaf nest, latrine cnr ; Achinus (pr)	Good
West 9	31/8/17	Nil?	Nil - ants	Good	26/9/2017	Nil	Ants	Good
West 10	31/8/17	Nil	Old messy leaf nest	Good	31/8/17	Nil	Old flouncy leaf nest, FtG (pr)	Good

Appendix B – Vegetated median data

Table B5: Hair funnel sampling data for summer-autumn and winter-spring 2017.

Funnel id	Autumn 2017			Spring 2017		
	Install Date	Collect date	Fauna	Install Date	Collect date	Fauna
East 1	17/2/2017	3/4/2017	sm. Dasyurid (pr)	1/9/2017	25/9/2017	A. stuartii
East 2	17/2/2017	3/4/2017	Antechinus stuartii	1/9/2017	25/9/2017	A. stuartii
East 3	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	Cercartetus nanus
East 4	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
East 5	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	C. nanus
East 6	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
East 7	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
East 8	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
East 9	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
East 10	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
Median 1	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
Median 2	17/2/2017	3/4/2017	A. stuartii (Pr)	1/9/2017	25/9/2017	A. stuartii (Pr)
Median 3	17/2/2017	3/4/2017	A. stuartii (Pr)	1/9/2017	25/9/2017	A. stuartii
Median 4	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
Median 5	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
Median 6	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
Median 7	17/2/2017	3/4/2017	sm. Dasyurid (pr)	1/9/2017	25/9/2017	A. stuartii
Median 8	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
Median 9	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
Median 10	17/2/2017	3/4/2017	Antechinus sp. (pr)	1/9/2017	25/9/2017	Acrobates pygmeus
West 1	17/2/2017	3/4/2017	A. stuartii	1/9/2017	25/9/2017	A. stuartii
West 2	17/2/2017	3/4/2017	Melomys cervinipes	1/9/2017	25/9/2017	A. stuartii
West 3	17/2/2017	3/4/2017	M. cervinipes	1/9/2017	25/9/2017	A. stuartii
West 4	17/2/2017	3/4/2017	sm. Dasyurid (pr)	1/9/2017	25/9/2017	M. cervinipes

Funnel id	Autumn 2017			Spring 2017		
	Install Date	Collect date	Fauna	Install Date	Collect date	Fauna
West 5	17/2/2017	3/4/2017	M. cervinipes	1/9/2017	25/9/2017	A. stuartii
West 6	17/2/2017	3/4/2017	Sminthopsis murina	1/9/2017	25/9/2017	A. stuartii
West 7	17/2/2017	3/4/2017	S. murina	1/9/2017	25/9/2017	A. stuartii
West 8	17/2/2017	3/4/2017	small dasyurid - tail hairs	1/9/2017	25/9/2017	A. stuartii
West 9	17/2/2017	3/4/2017	Melomys sp. (pr)	1/9/2017	25/9/2017	A. stuartii
West 10	17/2/2017	3/4/2017	Isoodon macrourus	1/9/2017	25/9/2017	A. stuartii

Appendix B – Vegetated median data

Table B6: Spotlight effort and detections for summer-autumn and winter-spring 2017. SuG = sugar glider; FtG = feathertail glider. SE = saw eyeshine; SM = saw movement.

Site	Date	Observ ers	Start Time	Finish Time	Species	Comments	Flowering	Moon	Wind	Rain	Visibility	Air Temp	Humidity
East	4/4/2017	NP/GM	1946	2017	Nil		Mel. quin	1/4	MLB	Showers	DS	18.8	92.3
	6/4/2017	NP/GM	1930	2000	SuG	SE@200m10e	Mel. quin	1/4	Msb	Light shower	DS	19	84.5
	26/9/2017	BT/SR	1941	2016	Nil		Twood	1/4	Msb	Nil	DS	15.2	80
	28/9/2017	BT/SR	1825	1852	Nil		Twood	1/4	Msb	Nil	DS	24	48
Median	4/4/2017	NP/GM	1820	1900	Nil		Mel. quin	1/4	MLB	Light showers	DS	18.8	92.3
	6/4/2017	NP/GM	1855	1925	Nil		Mel. quin	1/4	Still	Light showers	DS	19.2	83
	26/9/2017	BT/SR	1825	1853	Nil		Twood	1/4	Msb	Nil	DS	18.9	63
	28/9/2017	BT/SR	1901	1930	Nil		Twood	1/4	Msb	Nil	DS	24	48
West	4/4/2017	NP/GM	1905	1940	Nil		Mel. quin	1/4	MLB	Nil	DS	18.9	91
	6/4/2017	NP/GM	1820	1852	FTG	sm@400m5W	Mel. quin	1/4	Nil	Nil	DS	19.7	82.8
	26/9/2017	BT/SR	1859	1930	Nil		Twood	1/4	Msb	Nil	DS	18.9	63
	28/9/2017	BT/SR	1937	2006	Nil		Twood	1/4	Msb	Nil	DS	21	64

Appendix C – Rope bridge and glide pole data

Table C1: Rope bridge camera monitoring survey effort.

Survey period (days)	Cam Type	East cam				West cam			
		Pics	Days active	Batteries	Comments	Pics	Days active	Battery %	Comments
30/11 - 17/2/17 (79)	Reco	96	79	66% (L>L)	No change; time ok;	15	79	16% (L>L)	No change; time ok;
17/2 - 20/12/17 (304)	Reco	135p	304	0	taken down	15	304	0	Unable to check Reco cams 9/6/17 & 30/8 due to RMS access safety restrictions.
9/6 - 30/8/17 (82)	SG	692v	66	0%(A>A)		0	0	SD not installed properly	SG installed top of poles; Video=10sec; Sens=normal; (GREG checked: 9/6 & 30/8)
30/8- 20/12/17 (112)	SG	9754p	103	0	taken down	599v	1	0	SG changed to Pics (NICK collected cams 20/12); Vid every minute for West cam.

Appendix C – Rope bridge and glide pole data

Table C2: Rope bridge camera monitoring detections. NDM = No Directional Movement; ME = move east; MW = move west.

Date	Time	Species	Accu-racy	Movement	Bridge sctn	Cam tyoe	Pic No.	Time	Species	Accu-racy	Movement	Bridge sctn	Cam type	Pic No.	Crossing Likelihood	Comments
East								West								
27/1/17								218	Feathertail glider	D	ME, MW, exit	center & edge	Reco	1-10	Unlikely	
24/4/17	324	Sugar glider	D	NDM	Edge	Reco	16-20								Unlikely	
1/7/17	0051	Sugar glider	D	ME	Edge	Reco	23-25								Prob	
27/7/17	155	Sugar glider	D	MW, stopped	Centre	SG	317v								Poss	stops at camera and explores, video then ends
1/12/17								236	Feathertail glider	D	Move west & glide off northwards 1m from end (edge)	Edge	Reco	2	Prob	
11/12/17	133	Feathertail glider	D	MW, ME	Centre & edge	Reco	91-100								Unlikely	
12/12/2017	231	Feathertail glider	D	ME	Centre	Reco	121-126								Prob	
14/12/2017	204	Feathertail glider	D	explore	Edge	Reco	102-105								Unlikely	
16/12/2017	0008	Feathertail glider	D	ME	Edge	Reco	112-115								Prob	
16/12/2017	210	Feathertail glider	D	MW ME	Edge	Reco	116-120								Unlikely	ME then on platform holding up rope W of camera
16/12/2017	305	Feathertail glider	D	MW	center	Reco	121-30								Prob	
16/12/2017								2343	Feathertail glider	D	ME, MW	Edge	Reco	13-15	Unlikely	
16/12/2017	2000	Feathertail glider	D	explore	Edge	Reco	131-135								Unlikely	

Appendix C – Rope bridge and glide pole data

Table C3: Rope bridge and glide pole spotlight survey effort and detections. SuG = sugar glider; FtG = feathertail glider. CBTP = common brushtail possum. SE = saw eyeshine; SM = saw movement.

Site	Date	Observers	Start Time	Finish Time	Species	Comments	Flowering	Moon	Wind	Rain	Visibility	Air Temp	Humidity
Rope-e	29/8/17	GM/SR	2000	2035	Nil		Nil	2/4	Msb	Nil	Some detail seen	10.1	83
	31/8/17	GM/SR	1817	1850	1xCBTP	SE@150s15w	Nil	2/4	mlb	Nil	Some detail	16.9	54
	27/9/17	BT/SR	1832	1858	Nil		Bbutt, Tallow	1/4	MLB	Nil	Detail	20.5	65
	1/11/13	BT/OT	1944	2013	Nil			1/4	Msb	Nil	Detail	18.8	84
Rope-w	29/8/17	GM/SR	2045	2120	Nil		Iron bark, Stringybark, blackbutt.	2/4	Nil	Nil	Some detail seen	10.4	85
	31/8/17	GM/SR	1905	1940	Nil		Ironbark, Stringybark, blackbutt.	2/4	mlb	nil	Some detail	15.7	53
	27/9/17	BT/SR	1911	1942	SuG	SE300n10w	Bbutt, Tallow	1/4	MLB	Nil	Detail	20.5	65
	1/11/13	BT/OT	2026	2052	Nil		Twood	1/4	Msb	Nil	Detail	18.8	84
Pole-e	29/8/17	GM/SR	1820	1900	Nil		Nil	2/4	Msb	Nil	Some detail seen	12.1	70
	31/8/17	GM/SR	2040	2110	Nil		Nil	2/4	Mlb	Nil	Some detail	13.5	59
	27/9/17	BT/SR	2010	2038	Nil		B'butt	1/4	MLB	Nil	Detail	20.5	67
	1/11/13	BT/OT	2106	2132	Nil			1/4	Msb	Nil	Detail	18.8	84
Pole-w	29/8/17	GM/SR	1910	1940	Nil		Bbutt	2/4	Msb	Nil	Some detail seen	11.2	78
	31/8/17	GM/SR	2005	2035	Nil		B'butt	2/4	mlb	Nil	Some detail	13.9	57
	27/9/17	BT/SR	2048	2120	Nil		B'butt	1/4	MLB	Nil	Detail	20.5	67
	1/11/13	BT/OT	2138	2205	FtG	SM 80s	Twood	1/4	Msb	Nil	Detail	18.8	84

Appendix C – Rope bridge and glide pole data

Table C4: Glide pole camera monitoring effort. A camera was positioned at the end of the upper/perpendicular arm and lower/parallel arm. Reco = Reconyx SC950; SG = Scoutguard KG680v

Survey period (days)	Camera Type	Upper Arm (Reco: face west; SG: face east)				Lower Arm (Reco: face south; SG: face north)			
		Pics	Days active	Battery %	Comments	Pics	Days active	Battery %	Comments
30/11 - 17/2/17 (79)	Reco	10	2	0%	Time ok. Took down	60	79	99%	Took down cams
	SG	151v	79	2/3 (A>A)	Time ok; no change; 8g>8g	69v	79	2/3 (A>A)	Time ok. No change; 8G >8G
17/2 - 9/6/17 (102)	SG	75v	102	2/3 (A>A)	Time ok; no change; 8g>8g	181v	102	1/3 (A>A)	Time ok. No change; 8G >8G
9/6 - 30/8/17 (82)	SG	82v	51	0/3 (A>A)	Time ok; no change; 8g>8g	40v	82	1/3 (A>A)	Time ok. No change; 8G >8G
30/8-20/12/17(112)	SG	690v	48	0	taken down	423v	6	0	Took down cams

Appendix C – Rope bridge and glide pole data

Table C5: Glide pole camera monitoring detections. A camera was positioned at the end of the upper/perpendicular and lower/parallel arm. D = Definite; Pr = Probable; Po = Possible. Reco = Reconyx SC950; SG = Scoutguard KG680v.

Date	Upper Arm E-W (SG faces E; Reco faces W)					Lower Arm N-S (Reco faces South; SG faces Nth)				
	Time	**Species**	**Accu-racy**	**Movement**	**Pic No.**	**Time**	**Species**	**Accu-racy**	**Movement**	**Pic No.**
2/12/16	2406	Feathertail glider	D	explore	p.6-15 (Reco)					
2/12/16	0106	Feathertail glider	D	glide west off end	v-1					
3/12/16	o123	Feathertail glider	D	glide west off end	v-2					
4/12/16	2342	Feathertail glider	D	glide west off end	V-3					
8/12/16	o228	Feathertail glider	D	glide west off end	V-5					
10/12/16	o107	Feathertail glider	D	explore arm & cam	v-6,7	106	Feathertail Glider	D	explore arm	v.4
14/12/16						304	Feathertail Glider	D	explore arm and pole, climbs up pole	v.5
15/12/16	2213	Feathertail glider	D	glide west off end	V-9					
18/12/16	2116	feathertail glider	D	explore arm	v-10					
20/12/16						2148	Sugar glider (F?; Tip+)	D	explore arm	v.6
22/12/16						2209	feathertail glider	D	explore arm	v.8
23/12/16	2302	feathertail glider	D	explore arm/camera	v-11-13					
24/12/16	o145	feathertail glider	D	explore; glide west off end	v.14-17	143	Feathertail Glider	D	explores arm an pole, climbs up pole	v.9
24/12/16						204	Feathertail Glider	D	explore arm, north end	v.10
25/12/16	2213	Feathertail glider	D	explore arm	v.31	2210	Feathertail Glider	D	explore arm	v.11
25/12/16	2308	Feathertail glider	D	explore arm	v.32-38					
28/12/16	2434	feathertail glider	D	explore arm	v.41-43					
28/12/16	o245	feathertail glider	D	explore arm; glide EAST off end	v.44-46	241	Feathertail Glider	D	explores arm and pole, climbs pole	v12-13

Date	Upper Arm E-W (SG faces E; Reco faces W)					Lower Arm N-S (Reco faces South; SG faces Nth)				
	Time	**Species**	**Accu-racy**	**Movement**	**Pic No.**	**Time**	**Species**	**Accu-racy**	**Movement**	**Pic No.**
29/12/16	2054	feathertail glider	D	glide WEST off arm end	v.52	2054	Feathertail Glider	D	explore arm and pole, climbs up pole	v.17
30/12/16	2246	feathertail glider	D	explore arm	v.54	2244	Feathertail Glider	D	explore arm, north end	v.22
30/12/16	2357	feathertail glider	D	explore arm, glide WEST off arm end	v.55-56				explore arm, north end	v.23
1/1/17	125	feathertail glider	D	explore arm	v.62-64	123	Feathertail Glider	D		
2/1/17	233	feathertail glider	D	explore arm	v.66					
3/1/17	2321	feathertail glider	D	explore arm	v.76-77					
8/1/17	208	feathertail glider	D	explore arm, jumps down to lower arm	v.78					
9/1/17	246	feathertail glider	D	explore arm	v.79					
17/1/17	2303	feathertail glider	D	explore arm	v.96					
26/1/17						0022	Feathertail Glider	D	explore arm	v.32
28/1/17	2345	feathertail glider	D	explore arm	v.109-110					
30/1/17	0005	feathertail glider	D	explore arm	v.111	0015	Feathertail Glider	D	explore arm	v.33
30/1/17	0058	feathertail glider	D	explore arm	v.112	0059	Feathertail Glider	D	explores arm and pole, climbs pole	v.34
1/2/17	2145	feathertail glider	D	explore pole	v.113					
3/2/17	239	feathertail glider	D	explore arm and pole	v.117					
5/2/17						137	Sugar glider (?; Tip-)	D	explores arm, glide WEST off mid arm	v.44-45
6/2/17	41	feathertail glider	D	explore arm and pole	v.118-120	039	Feathertail Glider	D	explores arm and pole, climbs pole	v.46-48
7/2/17	111	feathertail glider	D	glide WEST off arm end	v.121					
7/2/17	317	sugar glider (M; Tip-]	D	explore arm	v.122-123					
21/2/17	153	sugar glider [F;Tip+)	D	explore pole/arm, glide WEST off arm end	v.23-27	149	sugar glider (M?; Tip-)	D	explores arm	v.20-27
26/2/17	0011	feathertail glider	D	explore arm, glide off EAST end	v.36					

Date	Upper Arm E-W (SG faces E; Reco faces W)					Lower Arm N-S (Reco faces South; SG faces Nth)				
	Time	**Species**	**Accu-racy**	**Movement**	**Pic No.**	**Time**	**Species**	**Accu-racy**	**Movement**	**Pic No.**
3/3/17						2332	Feathertail Glider	D	explores arm, glide EAST off mid arm	v.39
8/3/17						440	Feathertail Glider	D	explores arm	v.48
25/3/17	2342	feathertail glider	D	explore arm	v.46-47	2341	Feathertail Glider	D	explores arm and pole, climbs pole	v.104
26/3/17						2352	Sugar Glider (F; tip?)	D	explores arm	v.105-106
29/3/17						0000	Feathertail Glider	D	explores arm	v.107
12/4/17	1950	sugar glider	D	explore arm	v. 69					
20/4/17	0014	sugar glider (?; Tip-)	D	glide WEST off mid arm	v.70	0012	sugar glider [?; ?]	D	explores arm	v.143
21/4/17						0013	sugar glider (M?; Tip-)	D	explores arm, glide WEST	v.145
23/4/17	404	sugar glider (?; Tip-)	D	glide WEST off arm end	v.71	403	sugar glider (?; Tip-)	D	explores arm and pole, climbs pole	v.147
24/4/17						158	squirrel glider (?)	D	explores arm	v.148
24/4/17						318	sugar glider (M?; Tip-)	D	explores arm	v.149
28/4/17						207	sugar glider (M?; Tip-)	D	explores arm, glide WEST off mid arm	v.150
28/4/17						235	squirrel glider (?)	D	glide WEST off mid arm	v.151
30/4/17						331	sugar glider (M?; Tip-)	D	glide WEST off mid arm	v.160
3/5/17						358	sugar glider (F?; tip+?)	D	glide WEST off mid arm	v.161
4/5/17	357	sugar glider	D	explore arm (?; ?)	v.72	356	sugar glider (M?; Tip-)	D	explores arm	v.162
9/5/17						438	sugar glider (F?; Tip-)	D	explores arm	v.165-166
10/5/17	2146	sugar glider	D	explore arm east end (?; Tip-]	v.73					
14/5/17						2316	Sugar glider (?; Tip-)	D	glide WEST off mid arm	v.168
26/5/17						208	sugar glider (?; Tip-)	D	glide WEST off mid arm	v.169

Date	Upper Arm E-W (SG faces E; Reco faces W)					Lower Arm N-S (Reco faces South; SG faces Nth)				
	Time	**Species**	**Accu-racy**	**Movement**	**Pic No.**	**Time**	**Species**	**Accu-racy**	**Movement**	**Pic No.**
29/5/17						2124	sugar glider (F?; Tip-)	D	glide WEST off mid arm	v.170
1/6/17						2205	sugar glider (?; ?)	D	glide WEST off mid arm	v.171
3/6/17						438	sugar glider (?; ?)	D	glide WEST off mid arm	v.172
4/6/17						240	sugar glider (M; Tip-)	D	glide WEST off mid arm	v.173
4/6/17						312	squirrel glider (M)	D	explores arm, glide EAST off mid arm	v.174-178
4/6/17						407	sugar glider (M; Tip-)	D	glide WEST off mid arm	v.179
5/6/17	339	sugar glider	D	glide WEST off arm end (?; Tip-]	v.75	339	sugar glider (F?; Tip-)	D	explores arm and pole, climbs pole	v.180
6/6/17						434	sugar glider (M; Tip-)	D	glide WEST off mid arm	v.181
21/6/17						2056	squirrel glider (M)	D	glide WEST off mid arm	v.3
24/6/17						0050	sugar glider (M?; Tip-)	D	glide WEST off mid arm	v.4
25/6/17						303	sugar glider (M; Tip-)	D	glide WEST off mid arm	v.5
26/6/17						418	sugar glider (?; ?)	D	glide WEST off mid arm	v.6
28/6/17						427	sugar glider (M?; ?)	D	explore	v.7
1/7/17						517	sugar glider (?; ?)	D	glide WEST off mid arm	v.8
2/7/17						432	sugar glider (M?; ?)	D	glide WEST off mid arm	v.10
3/7/17						448	sugar glider (?; ?)	D	glide WEST off mid arm	v.11
5/7/17						454	sugar glider (?; Tip+)	D	explore, glide WEST off mid arm	v.12-13
14/7/17						208	sugar glider (?; ?)	D	explore pole, glide WEST off pole	v.14
16/7/17						2006	squirrel glider (?)	D	explores arm	v.15-16
17/7/17						0048	sugar glider (M?; Tip-)	D	explores arm/pole, glide WEST off pole	v.17
21/7/17						2240	sugar glider (?; ?)	D	glide WEST off mid arm	v.18

Date	Upper Arm E-W (SG faces E; Reco faces W)					Lower Arm N-S (Reco faces South; SG faces Nth)				
	Time	**Species**	**Accu-racy**	**Movement**	**Pic No.**	**Time**	**Species**	**Accu-racy**	**Movement**	**Pic No.**
25/7/17						318	sugar glider (M?; Tip-)	D	glide WEST off mid arm	v.19
27/7/17	2031	feathertail glider	D	explore arm	v.24-25					
9/8/17						2044	sugar glider (?; ?)	D	explores arm	v.20
14/8/17						2051	squirrel glider (F?)	D	explores arm	v.28
15/8/17						0023	squirrel glider (M)	D	explores arm, glide EAST off mid arm	v.29-32
21/8/17						248	squirrel glider (M)	D	explores arm, glide EAST off mid arm	v.34-35
27/8/17						145	squirrel glider (M)	D	explores arm, glide EAST off mid arm	v.39
30/8/17						103	squirrel glider (M)	D	explores arm, glide WEST off mid arm	v.40
12/9/17	1914	feathertail glider	D	glide WEST off arm end	v.397					
18/9/17	2202	feathertail glider	D	explore arm and pole	v.541-546					
25/9/17	309	feathertail glider	D	explore arm	v.596					

Appendix C Threatened Flora

Pacific Highway Sapphire to Woolgoolga Upgrade
Threatened Flora Monitoring Year 7 Annual Report

Prepared for NSW Roads and Maritime Services

Peter Richards

November 2018

This report, **Pacific Highway Sapphire to Woolgoolga Upgrade Threatened Flora Monitoring Year 7 Annual Report**, was prepared for NSW Roads and Maritime Services in accordance with the NSW *Environmental Planning and Assessment Act* 1979, the NSW *Threatened Species Conservation Act* 1995 and the Commonwealth *Environmental Protection and Biodiversity Conservation Act* 1999. The author of this report is Peter Richards, Consultant Ecologist, whose qualifications are B.Sc. (UNE). Any opinion expressed in this report is the professional, objective opinion of the author.

May 2018

Title Page image: Translocated Rusty Plum tree showing vigorous new growth. Translocation Area 2, Wedding Bells State Forest, April 2018. Image taken by Peter Richards, April 2018.

TABLES

FIGURES

GLOSSARY

TERM	MEANING
ANPC	Australian Network for Plant Conservation
EP&A Act	*NSW Environmental Planning and Assessment Act* 1979
In situ	Latin term meaning 'in the original place'. In this report, refers to threatened plants that are being protected where they were found
LGA	Local Government Area
MCoA	Minister's Conditions of Approval
NSW EPA	NSW Environmental Protection Agency
NSW OEH	NSW Office of Environment and Heritage
RMS	NSW Roads and Maritime Services
S2W	Sapphire to Woolgoolga Pacific Highway Upgrade Project
S2W ERG	Sapphire to Woolgoolga Environmental Reference Group
TA	Translocation Area
TSC Act	*NSW Threatened Species Conservation Act* 1995

INTRODUCTION

Background

The Sapphire to Woolgoolga Pacific Highway Upgrade project (S2W) is a 25 km-long section of the Pacific Highway upgrade located entirely within the Coffs Harbour Local Government Area (LGA). Translocation of three threatened plant species directly impacted by the project was undertaken, with the aim of salvaging impacted individuals and establishing new, self-sustaining populations at alternative sites to compensate for the habitat and/or plants lost due to the highway development (Ecos Environmental 2010, 2011). The three translocated plant species are:

- *Lindsaea incisa*, a small ground fern, listed as Endangered under the NSW *Threatened Species Conservation Act 1995* (TSC Act);
- *Marsdenia longiloba* (Slender Marsdenia), a slender vine, listed as Endangered under the TSC Act; and
- *Niemeyera whitei* (Rusty Plum), a medium-sized rainforest tree, listed as Vulnerable under the TSC Act.

In addition to the translocated specimens, individuals of the same three species were recorded at various sites within the S2W project boundary, along with individuals of the threatened plant *Quassia* sp. B. These plants were not directly impacted by the construction works and have been protected *in situ* within areas of native vegetation adjacent to the S2W alignment. Figure 1 shows the location of the three translocation areas and the sites supporting *in situ* threatened flora species. Figure 2 shows the same sites in relation to the route of the new S2W alignment.

In accordance with the Minister's Conditions of Approval (MCoA) for the S2W Flora Translocation Plan (Ecos Environmental 2010), an annual monitoring report is to be prepared, addressing the following matters:

- Background and description of the translocation project;
- A description of translocation methods;
- A description of monitoring methods;
- An analysis of monitoring data on a species by species basis;
- An assessment of causes of plant mortality;
- An accurate record of the plants transplanted and propagated;
- A description of the population enhancement program;
- Evaluate the short-term success of the translocation in accordance with ANPC Guidelines for the Translocation of Threatened Plants in Australia (Vallee *et al.* 2004).
- An evaluation of the methods and cost-effectiveness of the translocation project; and
- Work plan for monitoring, maintenance and management of the translocation site over the next twelve months.

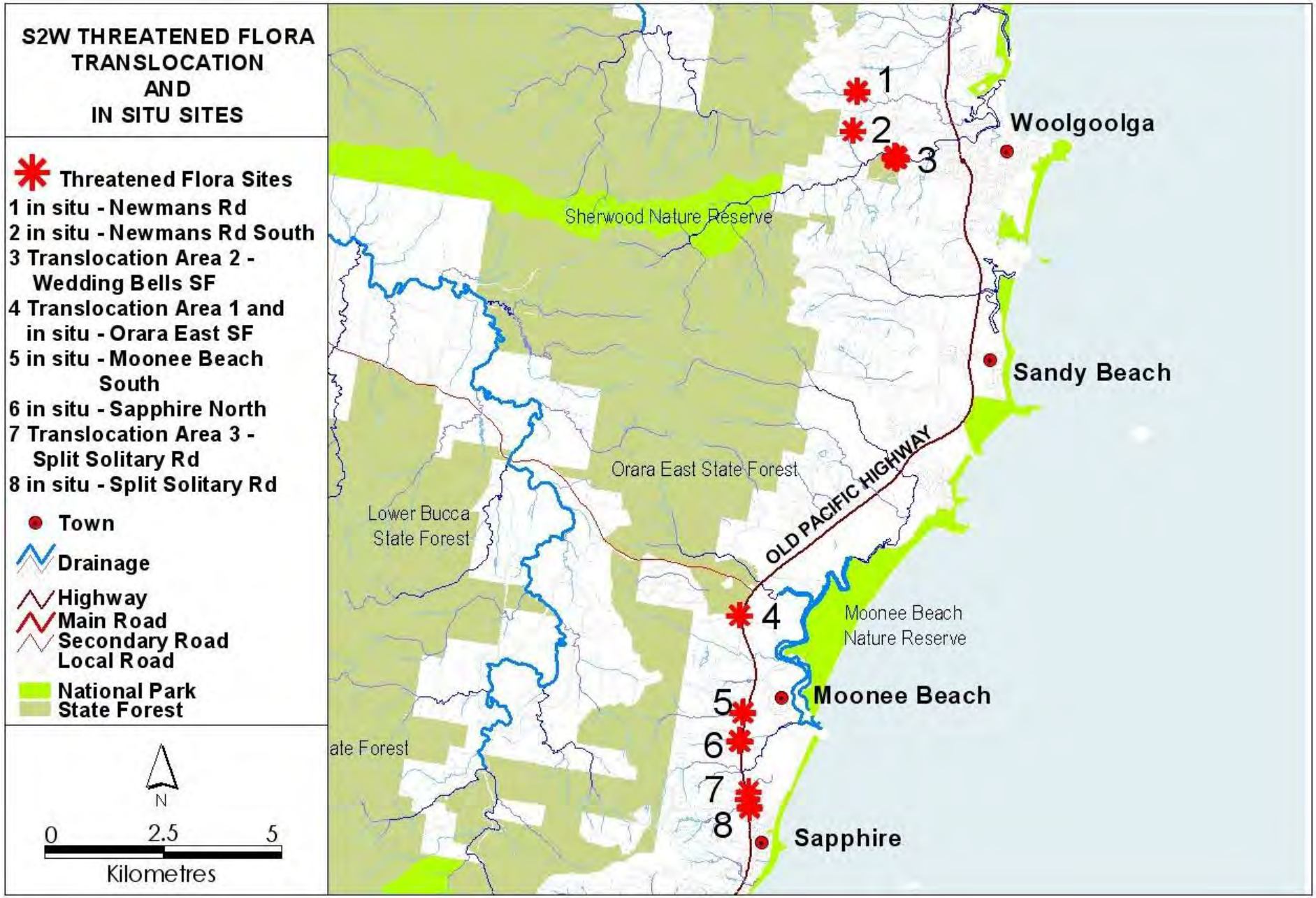

Figure 1: Location of S2W Threatened Flora Translocation Areas and in situ Threatened Flora sites.

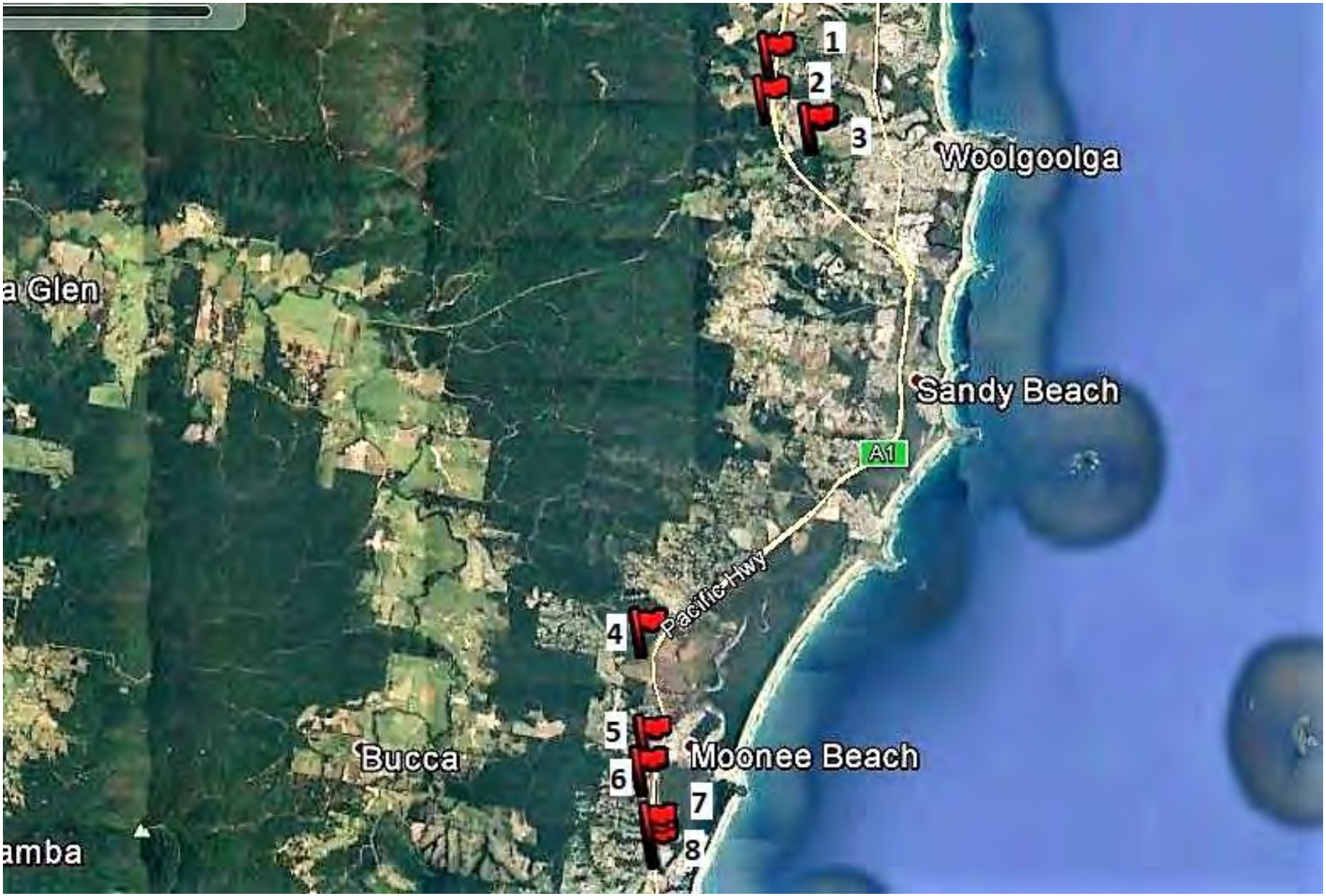

Figure 2: Location of S2W Threatened Flora Translocation Areas and in situ Threatened Flora sites in relation to the S2W upgrade route.

Annual Monitoring Reports

Implementation of the flora translocation program and monitoring of translocated and *in situ* flora is based on the S2W Threatened Flora Translocation Plan (Ecos Environmental 2010) and the approved S2W Ecological Monitoring Program (Benchmark Environmental Management 2009). The first annual monitoring report (Ecos Environmental 2011) covered the period up to June 2011; the second annual reports (Ecos Environmental 2012a & b) provide results up to October 2012 and the third annual report (Richards 2013) accounts for the period up to October 2013.

The results in the third annual report (Richards 2013) revealed that most translocated Slender Marsdenia plants in Translocation Area 2 (TA2) had died back, and many Slender Marsdenia plants protected *in situ* had also died back or were in poor condition. This prompted the approval regulator, the NSW Environment Protection Authority (EPA), to seek further information regarding the possible mortality of the translocated Marsdenia plants. It was suggested by the author that, rather than survey the sites in late spring at the peak of the seasonal dry period, a survey of all translocated and *in situ* plants be undertaken in early autumn 2014, after late spring and summer rains. This proposal was accepted by EPA, and an interim report (Richards 2014a) recorded a general improvement in the condition and number of plants of all target species, including an increase in the number of live translocated Slender Marsdenia recorded at TA2. All data collected in March 2014 were also presented in the fourth annual report (Richards 2014b) which was submitted in November 2014. The fifth annual report (Richards 2016) marked the commencement of the operational phase of S2W, with oversight of ongoing environmental monitoring and maintenance the responsibility of RMS.

The sixth annual monitoring report (Richards 2017) provided results and recommendations arising from the continued monitoring of translocated and *in situ* threatened flora undertaken in March 2017. Furthermore, the Year 6 report provided an evaluation of:

- The short-term success of the S2W flora translocation program,
- the translocation methods employed and their cost-effectiveness, and
- the need for ongoing monitoring of the S2W flora translocation and *in situ* sites.

The Year 6 evaluation of the need for ongoing monitoring of the S2W flora translocation and *in situ* sites is presented below in Table 1. The sites where further monitoring and/or weed control are required are highlighted by orange shading.

Table 1: Year 6 annual report (Richards 2017) evaluation of the need for further monitoring of S2W threatened flora sites.

Site	Method	Future Monitoring	Comments
Newmans Road	In situ	No further monitoring	Weeds at low levels, site relatively secure
Newmans Road South	In situ	No further monitoring	Weeds at low levels on site. Continue exotic grass control in adjacent road reserve to enhance native regeneration
TA2 Wedding Bells SF	Translocation	Further monitoring required	Weeds continue to seriously threaten this site; Slender Marsdenia requires ongoing monitoring
TA1 Orara East SF	Translocation	No further monitoring	Lindsaea incisa transplants approaching natural cover and condition; weed-free site
Orara East SF	In situ	No further monitoring	Continue exotic grass control in adjacent road reserve
Moonee South	In situ	No further monitoring	All in situ species appear healthy and secure
Sapphire North	In situ	No further monitoring	Quassia plants healthy and secure; weeds at low levels
TA3 Split Solitary Road	Translocation	Further monitoring required	Weeds and native climbers encumbering Rusty Plums; weed control required
Split Solitary Road	In situ	No further monitoring	Slender Marsdenia plants healthy, secure. Continue weed control at this site

In addition to the above evaluation, the following detailed recommendations for weed control at specific sites were provided in the Year 6 report:

Wedding Bells SF / TA2

1. Continuation of a twice-yearly weed control program, targeting infestations of Broad-leaf Paspalum, Mysore Thorn (a Class 3 Noxious Weed), Coral Tree, Blue Billygoat Weed and Lantana (a Class 4 Noxious Weed). The next program should be undertaken in early December 2017.
2. Discuss with Forestry Corporation NSW the possibility of implementing a weed eradication program in areas of Wedding Bells State Forest adjoining TA2. Target weeds are Mysore Thorn and Coral Tree. Other target species include Lantana and Winter Senna.

Split Solitary Road / TA3

3. Continue an annual weed control program at Split Solitary Road *in situ* site. To be undertaken by a bush regeneration team that is familiar with Slender Marsdenia or has been trained to recognise the species by an experienced botanist. Target species are Lantana, Winter Senna and Camphor Laurel.
4. Undertake weed control and selective pruning in TA3, as the two Rusty Plum transplants are being encroached upon by Winter Senna and native vines (Morinda) and trees.

Orara East SF / TA1 and Newmans Road South

5. Continue targeted control of exotic grasses in road reserves adjacent to Orara East State Forest (TA1 and *L. incisa in situ* site) and Newmans Road South *in situ* site to reduce competition and promote regeneration of native shrubs and trees at both sites. Target species are Rhodes Grass, Setaria and Giant Paspalum. After consultation with CCBR during the March 2017 control program, control effort should be increased to one person for two hours at each site twice yearly.

This current report describes the implementation of the Year 6 recommendations for ongoing monitoring of Slender Marsdenia transplants at TA2, Rusty Plum transplants at TA3, and the weed control actions undertaken at TA2, Split Solitary Road/TA3, TA1 and Newmans Road South.

METHODS

Monitoring of plants at TA2 and TA3 was undertaken on 6th April 2018. Weed control was undertaken on 6th-7th April and 10th–11th May 2018.

Monitoring Plants

The methods employed to monitor the translocated plants and the plants protected *in situ* are described in detail in Ecos Environmental (2010) and the approved S2W Ecological Monitoring Program (Benchmark Environmental Management 2009). Since only translocated Slender Marsdenia at TA2 and Rusty Plums at TA3 now require monitoring, the methods of monitoring and evaluating those species are summarised below.

Plants targeted for translocation were each given a unique field identification code on labelled flagging tape. The labelled flagging was attached directly to each plant, or to wallaby cages protecting individual plants (Rusty Plum enhancement plantings and Slender Marsdenia transplants). The locality of each plant was recorded using GPS, and maps prepared showing the location of plants in each Translocation Area.

Translocated plants were assessed every three months for the first year, at six-monthly intervals for the following two years, then annually for the duration of the monitoring program. Table 2 lists the information recorded during each monitoring survey.

Table 2: Data recorded for all translocated and in situ plants during the S2W flora monitoring program.
x = data recorded for this species; t = recorded only for translocated specimens. *See below for description of general condition classes.

Data recorded	Slender Marsdenia	Rusty Plum
Species name	x	x
Unique id code	x	x
Translocation type, date	t	t
Place of origin	t	t
Condition when planted	t	t
Initial height	x	x
No. of stems, diameter	x	x
Bark condition		x
Insect grazing	x	x
Mammal grazing	x	x
Evidence of recruitment	x	x
Date	x	x
Location	x	x
General condition*	x	x
Height	x	x
Leaf condition	x	x
No. of leaves	x	
Flowers / fruits	x	x
Length of new shoots		x
Evidence of disease	x	x

Condition Scores

The monitoring surveys recorded a general plant condition score on a scale of 0 to 5, where 0 is dead or died back and 5 is excellent. These condition scores may be defined for each species as follows:

Slender Marsdenia and Rusty Plum condition classes:
0 = dead / died back; 1 = leafless and no sign of re-shooting; 2 = pruned foliage retained, or small amount of re-shooting after defoliating, or foliage sparse/discoloured; 3 = vigorous re-shooting; 4 = crown recovering, foliage healthy; 5 = crown recovered, growing actively, and/or flowering or seeding recorded.

A leaf condition score was recorded for Rusty Plum (the number of leaves present on Slender Marsdenia plants was recorded, rather than leaf condition). This score was also on a scale of 0 to 5, where 0 is dead and 5 is excellent.

Slender Marsdenia – dead plants

The question of when a Slender Marsdenia plant should be considered dead is especially relevant to translocated individuals, as it is vital to determine outright success or failure of translocation efforts to inform future proposals that might include translocation as a mitigation measure. In on-site discussions with members of the S2W Environmental Reference Group (ERG) in February 2014, an arbitrary criterion was agreed whereby if no above-ground material is recorded on an individual Slender Marsdenia plant for four consecutive years then that plant is to be considered dead.

Weed Control

Since 2012, bush regeneration and weed control works have been undertaken in some of the S2W translocation and in-situ flora sites by Coffs Coast Bush Regeneration Group (now operating as New Earth Regeneration). New Earth was once again engaged to undertake the weed control actions described in this report. Control methods employed by New Earth include:

- Spot-spraying or wicking of target species such as Broad-leaved Paspalum *P. mandiocanum*, Blue Billygoat Weed *Ageratum houstonianum*, Setaria *S. sphacelata* and Rhodes Grass *Chloris gayana*;
- Hand-pulling small seedlings of Mysore Thorn *Caesalpinia decapetala*, Coral Tree *Erythrina X sykesii*, Lantana *L. camara* and Winter Senna *S. pendula* var. *glabrata*;
- Cut and paint on larger plants of Mysore Thorn and Lantana.

Table 3 below outlines the weed control effort undertaken at each site.

Table 3: Weed control effort employed at each site.

Weed Control Site	Site effort
Recommendation 1. TA 2 (Wedding Bells State Forest).	1 day x 2 people x 2 visits (4 person days)
Recommendations 3 & 4. Split Solitary Road *in situ* Site and TA3.	1 day x 2 people x 1 visit (2 person days)
Recommendation 5. Road Reserves adjacent to TA 1 (Orara East State Forest) and Newmans Road South *in situ* Site.	4 hours x 1 person x 2 visits (1 person day)

RESULTS

Monitoring Plants

Slender Marsdenia

Of the eight Slender Marsdenia translocated into TA2 in 2001, two (25% of plants) were recorded with aerial stems during this survey (Figure 3). This is the same result as last year. Both plants were healthy, albeit of reduced stature and with fewer leaves than last survey. However, progressive regeneration of the natural vegetation at the site appears to be increasingly shading the Slender Marsdenia plants.

Figure 3: Slender Marsdenia transplant ML4 at TA2, April 2018

Two other plants, ML1 and ML2, were not observed this survey, but are potentially still alive, in accordance with the definition agreed with the S2W ERG. Monitoring results for 2011 to 2018 for Slender Marsdenia transplants in TA2 are provided in Table 4 below.

Table 4: Slender Marsdenia transplants in TA2 - monitoring results 2011 – 2018. Plants shaded in orange were last recorded with aerial growth over four years ago and are considered to have died.

Transplant No.	Height, no. of leaves pre-transplant March 2011	Height, no. of leaves May 2011	Height, no. of leaves Oct 2012	Height, no. of leaves Oct 2013	Height, no. of leaves Mar 2014	Height, no. of leaves Oct-Nov 2014	Height, no. of leaves Feb – Mar 2016	Height, no. of leaves in Mar 2017	Height, no. of leaves in April 2018
ML1	100cm, 16 leaves	25cm, 5 leaves	28cm, 2 leaves	died back	110cm, 12 leaves	140cm, 12 leaves	died back	died back	died back
ML2	40cm, 6 leaves	80cm, 3 leaves	died back	died back	5cm, 3 leaves	30cm, 4 leaves	died back	died back	died back
ML3	50cm, 8 leaves	120cm, 7 leaves	died back	died back	died back	died back	died back	Dead	
ML4	10cm, 6 leaves	130cm, 2 leaves	died back, base green	died back	died back	died back	died back	0.8m, 23 lvs	0.8m, 7 lvs
ML5	150cm, 25 leaves	130cm, 8 leaves	died back, base green	died back	died back	died back	died back	Dead	
ML6	rhizome	10cm, 4 leaves	180cm, 16 leaves actively growing	230cm, 9 leaves	200cm, 2 leaves	240cm, 16 leaves	240cm, 18 leaves	2m, 19lvs	1.8m, 13 lvs
ML7	rhizome	130cm, 11 leaves	died back	died back	died back	died back	died back	Dead	
ML8	rhizome	8cm, 3 leaves	died back	died back	died back	died back	died back	Dead	

Rusty Plum

By 2014 two of the four Rusty Plums translocated into TA3 had died. At the time of the current survey, the remaining two Rusty Plums, NW130 and NW126, persist at the site (Table 5), with condition scores of 2 (Figure 4) and 3 (Figure 5) respectively, and little or no growth over the past two surveys, due largely to very dry conditions and the plants being overgrown by other, mostly native, small trees and vines.

Table 5: Rusty Plum individuals transplanted to TA3 showing height and diameter at breast height (dbh) before transplanting, and height and condition from November 2014 to April 2018.

Site	Id No.	Height before transplanting in 2011	Cond Nov 2014	Height Feb 2016	Cond Feb 2016	Height Mar 2017	Cond Mar 2017	Height Apr 2018	Cond Apr 2018
TA3	NW128	6m	Dead	-	-	-	-	-	-
	NW129	7m	Dead	-	-	-	-	-	-
	NW130	5m	2	1.6m	3	1.1m	3	1.2m	2
	NW126	1.8m	3	1.1m	3	1.2m	3	1.2m	3

Figure 4: Rusty Plum transplant NW130 at TA3 showing poor condition and limited growth.

Figure 5: Rusty Plum transplant NW126 at TA3, showing small amount of new growth and unhealthy older foliage, April 2018.

Weed Control

TA2 (Wedding Bells State Forest)

New Earth undertook a total of four person days weed control works in TA2, where the target weed species continue to recruit into the site from surrounding infestations (Figure 6).

Figure 6: Brent Hely of New Earth Regeneration cuts and paints a young Coral Tree at TA2.

During assessment of the translocated Slender Marsdenia plants in TA2, an evaluation of the overall site indicated that regeneration has greatly benefited from ongoing weed control. A natural overstorey is gradually re-establishing across the site, with a reduced density of understorey weeds the result of an increase in canopy shading (Figure 7). However, where the canopy is yet to recover, heavy infestations of target weeds remain.

Figure 7: Assisted regeneration in TA2 is proving successful; April 2018.

The translocated Rusty Plums and the Rusty Plum enhancement plantings in TA2 are generally in excellent condition. The enhancement plantings have grown significantly since the original wire wallaby guards were replaced by larger tree guards (Figure 8).

Figure 8: Rusty Plum planting P16 in TA2, over 2m high, was 1.4m high one year ago.

TA3 (Split Solitary Road)

Native and non-native vines and small trees were carefully cut away from the two surviving Rusty Plum transplants at TA3 to increase light levels and reduce competition (Figure 9).

Figure 9: Rusty Plum NW130 at TA3 after removal of encroaching vegetation, May 2018 (image courtesy of New Earth Regeneration).

Split Solitary Road in situ site

Careful hand-weeding, spot-spraying, or cutting and painting of Lantana, Winter Senna, Camphor Laurel, Umbrella Tree (*Schefflera* sp.), Ground Asparagus (*Asparagus aethiopicus*) and Cocos Palm (*Syagrus romanzoffiana*) juveniles was undertaken within this in situ Slender Marsdenia site (Figure 10). Non-native plants that supported Slender Marsdenia vines were not treated.

Figure 10: Split Solitary Road in situ Slender Marsdenia site after careful weeding May 2018 (image courtesy of New Earth Regeneration).

Road Reserves at TA1 (Orara East SF) and Newmans Road South in situ site

Dense swards of robust exotic grasses, such as Setaria, Vasey Grass and Rhodes Grass, have hindered native regeneration within the road reserves adjacent to these two S2W flora sites. New Earth made two visits to each site this season and targeted these grass species, along with other weeds such as Ragweed (*Ambrosia artemisiifolia*), to reduce competition and encourage natural regeneration. It was apparent at both sites that previous weed control treatments had been effective, with a notable surge in recruitment of native shrub and tree species since the last treatment (Figure 11 to Figure 14).

Figure 11: Brent Hely treating road reserve weeds at TA1 April 2018.

Figure 12: View of natural regeneration in road reserve adjacent to Lindsaea incisa in-situ population, Orara East SF, April 2018.

Figure 13: Brent Hely spot-spraying exotic grasses in road reserve adjacent to Newmans Road South in-situ site.

Figure 14: North end of Newmans Road South in-situ site showing extent of natural regeneration April - May 2018.

DISCUSSION

Monitoring Plants

Slender Marsdenia

The Slender Marsdenia transplants in TA2 show a slight decline in condition since the previous survey. Regeneration of the native vegetation within TA2 will inevitably shade out both remaining plants. In his Year 6 monitoring report, Richards (2017) considered that the translocation of Slender Marsdenia had failed with a 25% survival rate since 2011. If the remaining two plants that were not bearing aerial stems this year do reappear, then the survival rate would be 50%, but this is considered highly unlikely given the encroachment of a dense native canopy across the site. A very tall Flooded Gum wet sclerophyll forest with a tall, closed rainforest mid-stratum is regenerating at TA2. This vegetation type is too heavily shaded in the understorey to support Slender Marsdenia, which is recorded most often in moist or wet sclerophyll open forest on upper to lower sheltered slopes, on the ecotone between wet and dry sclerophyll forest or the ecotone between sclerophyll forest and rainforest in gullies (Commonwealth of Australia 2008; Ecos Environmental 2010; author's personal observations). The author has observed Slender Marsdenia within rainforest or heavily shaded sites on very few occasions.

Rusty Plum

The Rusty Plum transplants in TA3 have also declined in condition since last year, due mainly to overtopping by a variety of vigorous native and non-native vines, shrubs and trees, but also possibly due to the very dry winter-spring periods experienced in the past two years. As noted previously, two transplanted Rusty Plums have already died at this site. The two plants that died were located on the uppermost part of the site and probably succumbed to exposure and loss of soil moisture. The surviving plants, if kept free of competing vegetation, are in more sheltered positions and stand a better chance of surviving.

Weed Control

The current program of weed control is succeeding in its objectives of minimising infestations of weed species within specific translocation areas and in situ sites, and of reducing competition from exotic species in regenerating road reserves adjacent to two sites. However, the recruitment of weed species into TA2 will continue while the infestations of mature, seed-producing Mysore Thorn and Coral Tree persist on the land adjacent to TA2 in Wedding Bells State Forest. This situation requires a cooperative weed management effort with NSW Forestry Corporation, as detailed in recommendation 2 in last year's report (Richards 2017):

"Discuss with Forestry Corporation NSW the possibility of implementing a weed eradication program in areas of Wedding Bells State Forest adjoining TA2. Target weeds are Mysore Thorn and Coral Tree. Other target species include Lantana and Winter Senna."

This recommendation has not yet been implemented. Failure to take prompt action threatens TA2 with re-infestation by Mysore Thorn and Coral Tree. Re-infestation by these species would quickly transform the regenerating native vegetation within TA2 into an impenetrable weed thicket, much as the site was prior to preparation as a receival site for Rusty Plum and Slender Marsdenia.

RECOMMENDATIONS

The following recommendations are a repeat of those provided in the Year 6 report (Richards 2017). Further, the recommendations are consistent with the ten-year operational phase monitoring commitment for in-situ threatened fauna and translocation areas detailed in the EMP (BEM 2014).

Table 6 below summarises the recommendations for ongoing flora monitoring and weed control at each specific S2W flora site.

Table 6: Summary of recommendations for ongoing monitoring and weed control.

Site	Method	Future Monitoring	Weed Control
Newmans Road South	In situ	No further monitoring	Continue control of exotic grasses and other weeds in adjacent road reserve to facilitate native regeneration. Evaluate the need for further treatments after next visit.
TA2 Wedding Bells SF	Translocation	Slender Marsdenia requires ongoing monitoring	Continue weed control regime as weeds continue to seriously threaten this site. Control program targeting weed infestation adjacent to TA2 is required.
Orara East SF	In situ	No further monitoring	Continue control of exotic grasses and other weeds in adjacent road reserve to facilitate native regeneration. Evaluate the need for further treatments after next visit.
TA3 Split Solitary Road	Translocation	Further monitoring of Rusty Plums required	Continue control of weeds and native climbers encumbering Rusty Plums. Evaluate the need for further treatments after next visit
Split Solitary Road	In situ	No further monitoring	Continue weed control at this site, avoiding Slender Marsdenia plants. Evaluate the need for further treatments after next visit.

Recommended Work Program

Weed Control – Wedding Bells SF / TA2

1. Continuation of a twice-yearly weed control program, targeting infestations of Broad-leaf Paspalum, Mysore Thorn (a Class 3 Noxious Weed), Coral Tree, Blue Billygoat Weed and Lantana (a Class 4 Noxious Weed).
2. Undertake, with Forestry Corporation NSW, a cooperative weed eradication program in areas of Wedding Bells State Forest adjoining TA2. Target weeds are Mysore Thorn and Coral Tree. Other target species include Lantana and Winter Senna. This action requires prompt implementation to reduce the current level of recruitment of weeds into TA2.

Weed Control – Split Solitary Road / TA3

3. Continue an annual weed control program at Split Solitary Road *in situ* site. To be undertaken by a bush regeneration team that is familiar with Slender Marsdenia or has been trained to recognise the species by an experienced botanist. Target species are Lantana, Winter Senna and Camphor Laurel.
4. Undertake weed control and selective pruning in TA3, as the two Rusty Plum transplants are being encroached upon by Winter Senna and native vines (Morinda) and trees.

Protective plantings – Orara East SF / TA1 and Newmans Road South

5. Continue targeted control of exotic grasses in road reserves adjacent to Orara East State Forest (TA1 and *L. incisa in situ* site) and Newmans Road South *in situ* site to reduce competition and promote regeneration of native shrubs and trees at both sites. Target species are Rhodes Grass, Setaria and Giant Paspalum.

The weed control effort described in Table 3 should be repeated next season.

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