Warrell Creek to Nambucca Heads Pacific Highway Upgrade

Annual Ecological Monitoring Report

February 2020 - February 2021

Transport for NSW | April 2021

NSW GOVERNMENT

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Contents

Introduction

This report provides an update on the ecological monitoring outcomes associated with the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade, and covers the period from February 2020 to February 2020. The report has been prepared in accordance with the Warrell Creek to Nambucca Heads Ecological Monitoring Program (Roads and Maritime 2018), for submission to the Department of Planning and Environment and Environment Protection Authority (EPA).

This represents the sixth annual report for the WC2NH project, with Table 1 below highlighting the ecological monitoring reports for the period February 2020 to February 2021.

Table 1 Ecological monitoring reports for the reporting period Feb 20 – Feb 21 included in this annual report.

Species / mitigation monitored	Timing	Reporting
Fauna Underpass	Spring / summer, winter	Year 2 annual report 2020 Year 3 interim report 2021
Giant Barred Frog	Spring, summer and autumn	Year 3 spring 2020 and summer 2021
Yellow-bellied Glider	August to October population monitoring August to January song meter deployment	Year 2 annual report 2020
Microbat roost	Summer, autumn, winter and spring	Year 2 annual report 2020
Threatened Flora	Spring	Year 3 annual report including • Threatened Flora Translocations • In-situ Threatened Plants • Slender Marsdenia and Woolls' Tylophora Habitat Condition
Landscape Monitoring	Quarterly	Year 2 annual report 2020
Road kill	12 weeks following commencement of operation of each stage. Thereafter seasonally	Annual 2020 and Summer 2021 reports
Widened Vegetation Median	Summer/autumn and winter/spring commencing in Year 2 of operation	Year 2 report 2019/2020
Green-thighed frog	Annually based on rainfall events.	Year 2 2019/20 and Year 3 2020/21 reports
Nest Box	Summer / Winter	Year 2 2020 report
Koala	Spring	Year 3 Interim report 2020

Statutory and planning framework

Approval for the Warrell Creek to Urunga Pacific Highway Pacific Highway upgrade was granted by the then Department of Planning & Infrastructure on 19 July 2011 subject to the Minister's Conditions of Approval (CoA) being met. Roads and Maritime has constructed and opened the project in stages. The three main stages of the project are:

- Stage 1 - The Nambucca Heads to Urunga (NH2U) project involved construction of approximately 21.6km of new highway between Nambucca Heads, to the south of Nambucca Heads Interchange, at (Ch19500) and the existing Waterfall Way Interchange at Raleigh, north of Urunga. Stage 1 of the project opened to traffic in July 2016.
- Stage 2 - The Warrell Creek to Nambucca Heads (WC2NH) project involves construction of approximately 19.5km of new highway between the existing Allgomera deviation south of Warrell Creek and extends to the southern extent of the NH2U stage 1. This stage of the project opened to traffic in two parts initially on 19 December 2017 and finally in its entirety on 29 June 2018.

The Warrell Creek to Nambucca Heads Pacific Highway upgrade approval included the requirement to develop an ecological monitoring program:

> *Prior to the commencement of any construction work that will result in the disturbance of any native vegetation, the Proponent shall develop an Ecological Monitoring Program to monitor the effectiveness of the mitigation measures implemented as part of the project. The program shall be developed in consultation with EPA and prepared by a suitably qualified ecologist and shall include but not necessarily be limited to:*
>
> *(a) an adaptive monitoring program to assess the effectiveness of the mitigation measures identified in condition B1 to B6, B7(b), B7(d), B21(c) and B31(b) and allow amendment to the measures if necessary. The monitoring program shall nominate appropriate and justified monitoring periods and performance targets against which effectiveness will be measured. The monitoring shall include operational road kill surveys to assess the effectiveness of fauna crossing and exclusion fencing implemented as part of the project;*
>
> *(b) mechanism for developing additional monitoring protocols to assess the effectiveness of any additional mitigation measures implemented to address additional impacts in the case of design amendments or unexpected threatened species finds during construction (where these additional impacts are generally consistent with the biodiversity impacts identified for the project in the documents listed under condition A1);*
>
> *(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 five successive monitoring periods (i.e. 5 years) after opening of the project to traffic, unless otherwise agreed to by the Director General. The monitoring period may be reduced with the agreement of the Director General in consultation with EPA, depending on the outcomes of the monitoring;*
>
> *(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 will 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 EPA, or as otherwise agreed by those agencies.*
>
> *The Program shall be submitted for the Director General's approval prior to the commencement of any construction work that will result in the disturbance of any native vegetation. Unless otherwise agreed, the Program shall be submitted to the Director General for approval no later than 6 weeks prior to the commencement of any construction that will result in the disturbance of any native vegetation.*

The Warrell Creek to Nambucca Heads ecological monitoring program was approved by the Department of Planning & Environment on 14 March 2018 with a minor change updated by the Department of Planning & Environment independent environmental representative on 1 June 2018

Appendix A Fauna Underpass

Transport
Roads & Maritime
Services

Warrell Creek to Nambucca Heads

Annual Underpass Monitoring Report - Operational Phase, Year Two (2019-2020)

Transport for New South Wales | December 2020

Document Review

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Project team:

Luke Andrews (Field survey, reporting)
Nirvarna Makings (Field survey)
Dr D. Rohweder (Project management, review, Field Survey)
Dr B. Taylor (Field survey)
Nick Priest (Field survey)
Sam Rohweder (Field assistant)
Oscar Taylor (Field assistant)

Report prepared for:

Transport for New South Wales (TfNSW)

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 02 6628 3559 | E david@sandpipereco.com.au

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1. Introduction

In 2015, Transport for NSW (TfNSW), in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages:

- Stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and
- Stage 2b - 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened on 29 June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala, spotted-tailed quoll, grey-headed flying-red fox, yellow-bellied glider, giant barred frog, green-thighed frog ponds, fauna underpasses, vegetated median, road-kill, exclusion fencing, and threatened flora. Sandpiper Ecological Surveys (Sandpiper) was contracted by TfNSW to deliver the WC2NH operational ecological and water quality monitoring program.

The objective of fauna underpass monitoring is "to assess use of underpasses by threatened and common fauna and to assess the effect of exclusion fencing on movement of small mammals, reptiles and frogs" (RMS 2018). Effectiveness of exclusion fence is also assessed in the annual road-kill report (see Sandpiper Ecological 2018, 2019).

The following annual report presents methods and results of the year two operational phase underpass and adjacent habitat surveys. The results are discussed in relation to the potential indicators of success detailed in the WC2NH Ecological Monitoring Program (RMS 2018) and recommendations regarding future monitoring are provided. The potential indicators of success used to assess the performance of the WC2NH underpasses include:

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. No change to densities, distribution, habitat use, and movement patterns compared to baseline population data of target species;
4. Evidence of use by dispersing individuals and different age cohorts;
5. Use by cover-dependent species and species with low mobility;
6. No breaches in fauna exclusion fencing;
7. Low incidences of fauna road strike mortality.

A list of species names for fauna referred to in text and Tables is provided in Appendix A.

1.1 Background

The WC2NH upgrade features 23 fauna underpasses, including 13 box culverts, three pipe culverts and seven bridges. Underpasses targeted for monitoring were specified in the WC2NH Ecological Monitoring Program (EMP; Table 1) and include eleven box culverts and one bridge. Site five includes a dual cell box culvert with one cell designated as a wet passage (for aquatic fauna) and the other as dry passage. The dry cell includes a concrete ledge that provides dry passage for terrestrial fauna. Fauna underpasses were designed to target spotted-tailed quoll (*Dasyurus maculatus*), koala (*Phascolarctos cinereus*) and giant barred frog (*Mixophyes iteratus*). Giant barred frog is known to occur at site 1 (Upper Warrell Creek) only, whilst quoll and koala could occur at sites 2-12. Sites 9/10, and 11/12 consist of corresponding culverts on either side of a vegetated median.

Table 1: Underpasses sampled during operational phase monitoring of the WC2NH upgrade. SQ = spotted-tailed quoll; K = koala; GBF = giant barred frog; * sites consist of dual cells 3x3m box culverts with one cell providing wet passage for aquatic fauna; P/A = presence/absence.

Site	Chainage	Type	Structure	Dimensions	Fauna Furniture (P/A)	Substrate	SQ	K	GBF
1	42500	Combined	Bridge		A	Soil			x
2	55120	Dedicated	Box Culvert	1 x 3000 x 3000	P	Concrete	x	x	
3	56410	Combined	Box Culvert	1 x 2400 x 2400	P	Concrete	x	x	
4	57770	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
5 *	58510	Combined	Box Culvert	2 x 3000 x 3000	A	Concrete	x	x	
6	58560	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
7	59090	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
8	59550	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
9	59750 NB	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	
10	59760 SB	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	
11	60600 NB	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	
12	60610 SB	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest. Eleven underpasses are situated north of the Nambucca River and one (Site 1) is situated at Upper Warrell Creek near the southern extent of the project. Sites four to twelve adjoin Nambucca State Forest and sites two and three adjoin remnant vegetation on private land.

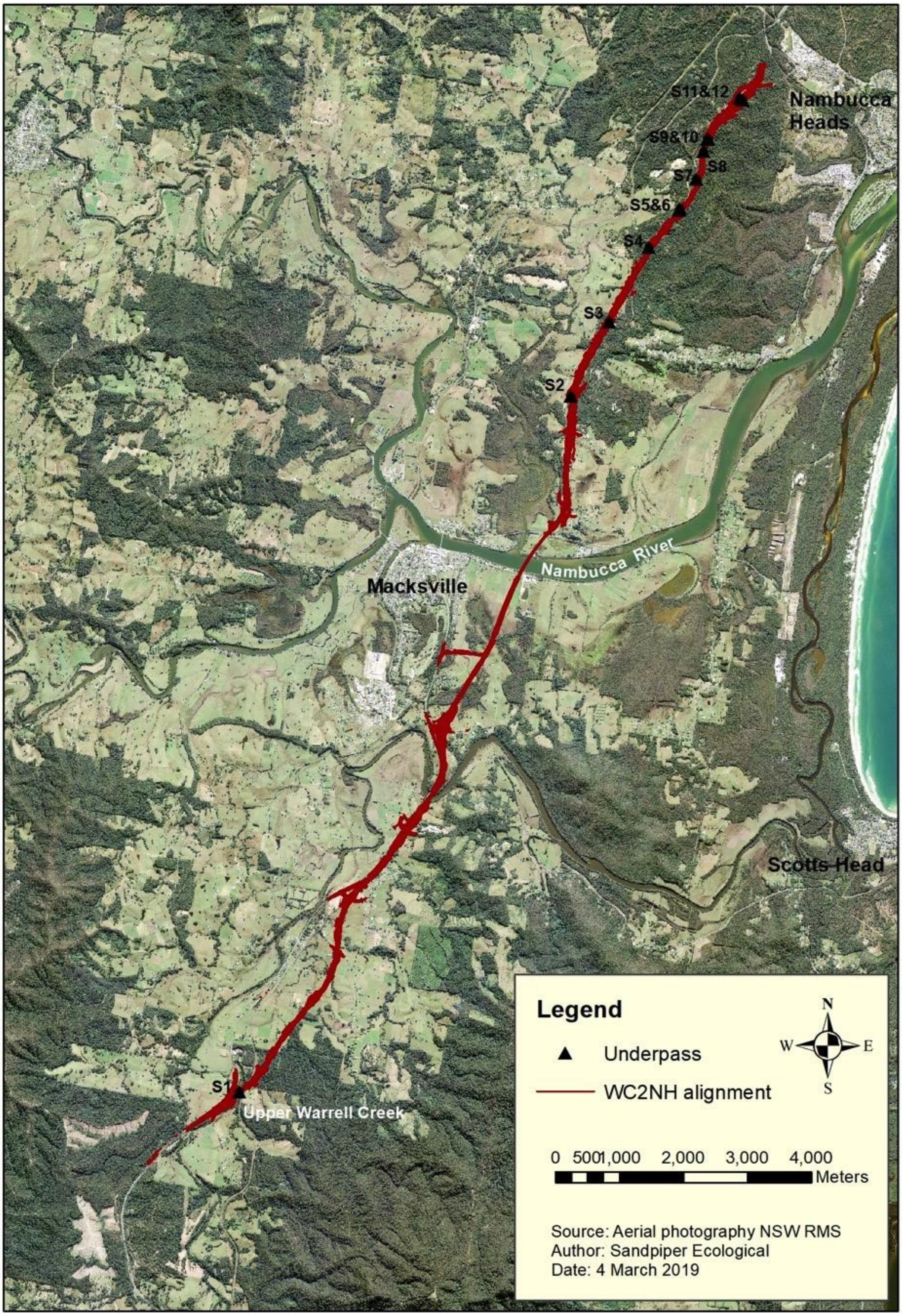

Figure 1: Underpass locations along the WC2NH alignment.

2. Methods

2.1 Timing and weather conditions

Underpass and adjacent habitat surveys were conducted bi-annually between 22 September 2019-28 February 2020 (spring/summer) and 1 June – 1 September 2020 (winter). Dry warm conditions occurred from September 2019 through to January 2020 with a total of 194 mm of rainfall being recorded at the Bureau of Meteorology Bellwood weather station (059150) (Appendix B, Table B1). Warm and wet conditions occurred during February 2020 with the Bellwood station receiving 427 mm (Table 2, Appendix B, Table B1). The winter monitoring period was characterised by cooler and dry conditions (Table 2). Air temperature and relative humidity were collected from Coffs Harbour Airport (station 059151) (Appendix B, Table B1).

Table 2: Summary of weather conditions recorded at Coffs Harbour Airport (station 059151) and Bellwood weather station (059150) during year two operational phase monitoring.

Monitoring period	Total rainfall (mm)	No. rain days	Relative humidity (%)	Max temp range (^{0}C)	Min temp range (^{0}C)
Spring/Summer	665	37	>60% on 90% of days	18.5-35.5	6.7-25
Winter	87	5	>60% on 90% of days	15.9-25.4	2.7-13.3

2.2 Underpasses

2.2.1 Sand pads

Sand pads were installed on 15 October 2019 (spring/summer sample) and 17 June 2020 (winter sample). A 50:50 mix of brickies sand and washed beach sand was used for all sand pads. Two sand pads were installed at each site. In culverts, pads were installed 3-5m from each end, whilst at the bridge (site 1) one pad was installed on each side of Warrell Creek (North and South). Each pad was approximately 50mm deep by 1m wide and extended for the entire culvert width, or for 3m at site 1. At sites with a concrete ledge the pad covered both the floor and ledge (Plate 1). The exception was site 5 where the pad covered the ledge only due to standing water over the culvert floor.

Sand pads were inspected on eight consecutive days across all sites. Rain on 19 June 2020 led to complete or partial wash out of sand pads at sites 3, 5, 8, 9, 10, 11 and 12, with pads reinstalled on 20-21 June. Inspections were conducted by an ecologist and included a systematic scan of each pad searching for fauna tracks. A small torch was used to illuminate the pad, if required. Information recorded included species or fauna group, number of traverses, direction of traverse and pad condition (good, moderate, poor). A complete crossing was recorded when the direction and number of traverses from a species or fauna group was consistent across both pads (east and west) at each site. Incomplete crossings were recorded when the traverse direction and number of track sequences was not consistent across both sand pads. Small fauna exhibit erratic movement making it difficult to accurately determine complete and incomplete crossings. Tracks were identified with reference to Triggs (2004) and advice from senior ecologists. Tracks that could not be identified insitu were photographed and referred to a senior ecologist for identification.

Plate 1. Sand pad being installed in a fauna underpass on the WC2NH upgrade.

2.2.2 Scat and track searches

Each underpass was searched by a senior ecologist and/or ecologist for scats and tracks on two occasions during the spring/summer and winter sample periods. The search involved a slow systematic traverse of each culvert using a hand-held spotlight (Led Lenser P14). Fauna furniture, the culvert floor, and joints were targeted. Areas of accumulated fine sediment were targeted for tracks. Tracks and scats were identified in-situ, with reference to Triggs (2004) and the ecologists experience or photographed and sent to colleagues for identification.

2.2.3 Tile checks

Two roof tiles (300x200) were installed at both ends of underpasses 5m in from the entrance in autumn 2020. These were checked on two occasions during winter sample period.

2.2.4 Cameras

Two motion-activated infra-red cameras (Swift 3C, Swift Enduro or Reconyx HC500) were installed centrally in each culvert, with the exception of site five where one camera was mounted centrally in each cell. At site 1, Reconyx HC500 cameras were initially attached to steel posts, and following theft, were housed in security boxes attached to large boulders. A single camera was installed at approximately 200mm above ground near the water's edge on each side of Upper Warrell Creek (site 1). In total, 24 cameras were installed. In underpasses, both cameras were installed centrally, one on the fauna furniture, and one approximately 300mm above the culvert floor. Cameras were oriented to the east except for site 1 where cameras were oriented perpendicular to the creek on the north and south banks. Cameras at site 10 were re-oriented to the west following a high incidence of false triggers cause by traffic on the southbound carriageway. Swift cameras were set to take 10 seconds of video with no delay between activation. Reconyx cameras were set on time-lapse mode to take a picture at 1-minute intervals between 8 pm and 6 am each day throughout the spring/summer sample period and 6pm to 6am during the winter sample. Time-lapse mode is better suited to targeting frogs and was used successfully to monitor frog pipes on the Sapphire to Woolgoolga Pacific Highway Upgrade (Sandpiper Ecological 2017a, 2018a). Cameras at site 1 were inundated by floodwater on several occasions in February 2020.

During the spring/summer sample period, cameras at sites 1-12 were installed on 8-9 October. Cameras were inspected during the middle of each session to change batteries and SD cards. Following camera checks between 22 October and 18 November, all cameras at sites 1, 2, 3 and 6 (8 cameras) were stolen. Replacement cameras were reinstalled on 28 November at sites 2, 3, 6 and 22 January at site 1. Cameras from sites 2-12 were retrieved on 18 December 2019 following a total sample period of 70-71 days (Table 3). Cameras at site 1 were retrieved on 28 February following a sample period of 49 days (Table 3). Nine of the 24 cameras were active for less than the 60-day minimum sample period, with eight a result of theft and one (site 11 furniture) due to battery failure. Sampling days were further reduced at site 6 (14 days) and site 1 south (14 days) due to camera malfunction and flooding (Table 3). The remaining 15 cameras were active for 70-71 days (Table 3).

During the winter sample period all cameras were installed between 22 and 25 June, except site 1 north, which was installed on 16 July due to replacement of security housing. Checks were conducted on 28 July and all cameras were retrieved on 1 September. Battery failure and camera malfunction reduced sample periods at sites 11 (furniture), 1 (south) and 12 (floor) with all remaining cameras active for the minimum 60 days (Table 3). Overall, the minimum 120 days annual sample period was achieved for 14 of the 24 cameras. Without theft the minimum sample period would have been achieved by 20 of the 24 cameras. Importantly, the total minimum number of camera days required (2880 days) was exceeded during year two operational monitoring (2917 days) (Table 3). Actions proposed to minimise camera malfunction and battery failure are included in the discussion.

Table 3: Camera survey effort during year two operational phase monitoring**.** * = camera stolen; ^ camera flooded

Site	Cam location	Days active		
		Spr/Sum	Winter	Total
1	North	34*^	47	81
	South	34*^	46	80
2	Furniture	20*	61	81
	Floor	34*	71	105
3	Furniture	34*	71	105
	Floor	34*	71	105
4	Furniture	71	71	142
	Floor	71	71	142
5	North	71	71	142
	South	71	71	142
6	Furniture	14*	72	86
	Floor	14*^	72	86
7	Furniture	71	72	143
	Floor	71	72	143
8	Furniture	71	72	143
	Floor	71	72	143
9	Furniture	70	72	142

	Floor	71	72	143
10	Furniture	71	72	143
	Floor	71	72	143
11	Furniture	48	35	83
	Floor	71	72	143
12	Furniture	71	72	143
	Floor	71	37	108
Totals		1330	1587	2917

Image review

Images were uploaded to a computer and viewed using Windows Photo Viewer ©. A senior ecologist or ecologist reviewed all images, with reference to standard field guides (i.e. Menkhorst & Knight 2004; Pizzey & Knight 2007; Van Dyck *et al.* undated).

Fauna were scored making a complete or incomplete crossing:

- A complete crossing was scored when an animal showed directional movement when detected by the centrally mounted camera.
- An incomplete crossing was scored when an animal showed no directional movement (i.e. remained stationary in front of camera) or passed the camera but returned within 10 minutes.

Crossing definitions are consistent with those used at other Pacific Highway monitoring sites (e.g. Sandpiper Ecological 2017b, 2018b, 2019) and crossing structure research programs (e.g. Soanes *et al.* 2015). Further, it represents a conservative approach to identification of complete crossings. Data recorded for each active image included: site, date, time, species, accuracy (definite 90%+ certainty, probable 75-90% certainty, and possible 60-75% certainty), movement direction (east, west, no directional movement (animal stationary, returned), number of images and image numbers. A hierarchical approach was adopted to species identification that included: species, genus or group. Microbats were recorded as presence only due to their transient nature and none reliance on underpasses for thoroughfare.

Data analysis and interpretation

The adequately assess “use of underpasses” from the EMP operation monitoring aim, complete crossings were used as the standard of measure as it encompasses the purpose of fauna underpasses (i.e. A crossings structure that allows fauna to access habitat that has been fragmented by construction of a road or highway). To account for variations in survey effort between sites and years (1 and 2), complete crossings/week and complete crossings/week/underpass were adopted. Birds and microbats were excluded from analysis as they do not require underpasses for thoroughfare.

As seen in dot point five in the potential indicators (see introduction), fauna with low mobility was not defined within the EMP. As such, fauna with low mobility has been assumed to include animals whose movement is generally limited by their size or behaviour. Hence, fauna that exhibit low mobility/cover dependence has been interpreted as frogs, small reptiles (excluding goanna and water dragon), rodents and bandicoots.

A student’s t-test (assuming equal variances) was conducted to compare feral predator activity (cc/week/underpass) between year 1 and year 2 operational monitoring. Sites 11/12 and 9/10 were averaged as they function as a single site and lack independence if treated separately. Site 5 was removed from the analysis due its proximity to site 6 and presence of permanent water, which limits feral predator use. A square root transformation was performed on all data to achieve normality within the dataset.

2.3 Adjacent habitat

2.3.1 Survey design

A total of 18 sites were sampled at the 12 underpasses as part of adjacent habitat surveys. Sample sites were established on each side of an underpass or underpass pair in the case of sites 5/6, 9/10 and 11/12. Adjacent habitat at sites 5 and 6 was sampled as one site as the underpass entrances were located within 50m of each other. Survey effort was reduced at site 3 due to concern about disturbing neighbours. No spotlighting or arboreal Elliott trapping occurred on the west side at site 3 and the diurnal active search was restricted to a small (100m x 30m) triangular shaped remnant of vegetation in the road reserve.

2.3.2 Trapping

Trapping methods applied during the survey included: cage traps, ground Elliott traps (Type A), arboreal Elliott traps (Type B), pitfall traps, and hair funnels. Trapping occurred within a 1ha area immediately adjacent to each culvert entrance and was conducted over three nights at each site. A maximum of 10 sites were sampled concurrently and trapping was conducted between 14 and 20 November 2019 during the spring/summer and 15-21 June during the winter.

Traps were set in a “X” formation with five ground and five arboreal traps set at 20m intervals on one axis and two cage traps and two hair funnels set at 50m spacing on the other axis (Plate 2). A line of three pitfall traps with drift fence was set at the intersection of both lines (Plate 2). Pitfall traps typically followed the contour and were set near fallen logs and dense ground cover. Trap effort is summarised in Table 4.

Plate 2: Example of a pitfall trap line installed during adjacent habitat surveys (L). Setting up traps in adjacent habitat at site 1 (R).

Arboreal traps and ground Elliott traps were baited with a peanut butter, honey and oats mixture. Arboreal traps were installed 1.8m above ground and attached to a bracket. Honey water was sprayed on the trunk above each arboreal trap, and bait was replaced as required. A plastic bag was placed over the end of each trap to provide cover, and a small amount of leaf litter was placed inside the trap. In spring/summer, arboreal traps were set on the western side of trees to provide shelter from the morning sun. Cage traps were set in a sheltered location and alternately baited with either peanut butter, honey and oats, or sardines. A tuna oil and water mix was sprayed around the entrance to cage traps baited with sardines. All traps were checked within four hours of sunrise. In spring/summer cage and Elliott traps were closed following the morning inspection and re-opened in the late afternoon. Pitfall traps were checked in the morning and again in mid-afternoon.

Captured fauna were identified to species or genus, and, where possible, sexed and aged. Fauna were identified with reference to standard field guides (Van Dyck *et al.* 2013; Menkhorst & Knight 2004; Wilson & Swan 2010). Fauna were not marked as the aim of sampling was to determine the range of species present in adjacent habitat.

2.3.3 Diurnal active search

Diurnal active searches were conducted by one or two ecologists and involved a meandering traverse of habitat within 100m of the underpass entrance at each sample site. Surveys involved searching leaf litter, rolling logs, observing reptile habitat (i.e. log piles, rocks, dense leaf litter) and looking for fauna signs such as scats and tracks. Each site was sampled twice during each sample period for a minimum of 30 person minutes/sample. Spring/summer diurnal active searches were conducted between 22 September-21 October 2019 and winter search between 1 June-16 June. A total of 1080 person minutes were spent conducting diurnal active searches (Table 4).

2.3.4 Nocturnal active search

Nocturnal surveys were conducted on each side of each underpass on two non-consecutive nights during the spring/summer and winter sample periods. One or two ecologists conducted spotlight surveys for 60 person minutes per underpass side/sample period (Table 4). Surveys were conducted using hand-held Led Lenser P14 spotlights and involved a meandering traverse of habitat within 200m of the culvert entrance. Fauna were detected by sight and call and identified to species or genus where possible. Spring/summer surveys were conducted between 3 October and 28 November 2019 and winter surveys between 15-17 June. A total of 1080 person minutes were spent conducting nocturnal active searches (Table 4).

2.3.5 Opportunistic records

Opportunistic observations of fauna near culvert entrances made whilst doing other monitoring activities such as koala, giant barred frog and yellow-bellied glider monitoring were recorded. All fauna observed whilst setting up equipment, with exception of birds, were also recorded.

Table 4: Survey effort for sampling adjacent habitat on the WC2NH upgrade. S/S = spring/summer, W = winter, UP = Underpass.

Component	Method / culvert side	No Samples	Total effort
Arboreal Elliott traps	5 x traps @ 20m spacing	3 nights/site	510 trap nights
Ground Elliott traps	5 x Type A Elliott traps @ 20m spacing	3 nights/site	540 trap nights
Cage traps	2 @ 50m spacing	3 nights/site	216 trap nights
Pitfall traps	1 x line of 3 pits with drift fence	3 nights/site	324 trap nights
Hair funnels	2 @ 50m spacing	14 nights/site	504 trap nights
Active diurnal search	30 person minute search at UP entrance	2 sample/site	1080 person minutes
Active nocturnal search	30 person minute search at UP entrance	2 samples/site	1080 person minutes

2.4 Exclusion fence

Two people traversed the entire length of the fauna exclusion fence on foot on 17 June 2020. Sections of exclusion fence inspected included: type 1 chainmesh fence with floppy top feature (18.03km), Type 3 frog fence combined with floppy top (1.32 km) and Type 4 flying-fox fence (1km) fence. The exclusion fence was assessed in relation to condition, structural integrity, overhanging vegetation and vine growth. Any issues were recorded on a datasheet, and the location logged using a hand-held GPS along with a written description of the issue and location.

3. Results

3.1 Underpasses

3.1.1 Camera monitoring

Species diversity and native fauna use

Twenty species and seven fauna groups were confirmed using underpasses during camera monitoring (Table 5). The highest fauna diversity was recorded at site 7 with eighteen species/groups, followed by sites 4, 5 and 10 with fourteen species/groups (Table 5). The lowest diversity was recorded at site 1 with five species/groups (Table 5). Remaining sites recorded between nine and 13 fauna species/groups (Table 5). Six introduced species were recorded including cat, dog, red fox, black rat, house mouse and European hare (Table 5).

Native species were recorded making complete crossings (cc) at all underpass sites (Figure 2). Sites 2, 7 and 8 featured the highest use by native species averaging 4.25cc/week, 3.5cc/week and 2.8cc/week respectively (Figure 2). Swamp wallaby (2.3cc/week) and bandicoots (0.95cc/week) were frequently recorded at site 2 while short-eared brushtail possum contributed to the majority of complete crossings at sites 7 (1.71cc/week) and 8 (1.47cc/week) (Table 5). Sites 11 and 12 exhibited the lowest use by native species recording 0.15cc/week and 0.30cc/week (Figure 2).

Macropodidae (swamp wallaby, red-neck wallaby, eastern grey kangaroo, wallaby spp.) was the most frequently recorded native fauna group at a rate of 0.55 cc/week/underpass with detections (herein detections refer to complete crossings) at all sites (Figure 6, Table 5). Of the Macropodidae group swamp wallaby exhibited the highest use of underpasses (complete crossings) followed by red-necked wallaby and eastern grey kangaroo (Table 5). *Trichosurus* spp. (short-eared brushtail possum and common brushtail possum) was recorded at a rate of 0.35cc/week/underpass, Bandicoot spp 0.20cc/week/underpass, reptile (eastern water dragon and lace monitor) 0.19 cc/week/underpass, *Antechinus* spp 0.07cc/week/underpass and Koala 0.02 cc/week/underpass (Figure 6).

Koala was the only threatened species recorded, with complete crossings using the culvert floor recorded at sites 4, 9, and 10 (Table 5 and Figure 2). Koala made seven complete crossings (four east, three west) at site 4 during spring/summer and two complete crossings (one east, one west) during winter (Plate 3). An individual was also recorded making a complete crossing (heading west) through 9 and 10 (split median) during spring/summer (Figure 2, see appendix C Table 1)

Native species use increased from 1.04 ± 1.29 cc/week/underpass during year 1 monitoring to 1.49 ± 2.67 cc/week/underpass during year 2 (Figure 3). Further, in contrast to year 1 native species (1.49 cc/week/underpass) exceeded feral predator use (1.35cc/week/underpass) (Figure 3). Increases in use by Macropodidae spp and Peramelidae spp (Northern brown bandicoot, Long-nosed bandicoot and bandicoot spp.) and *Antechinus* spp largely contributed to increased use of underpasses by native species in year two (Figure 6).

Plate 3: Koala recorded at Site 4, moving west on 1 August 2020.

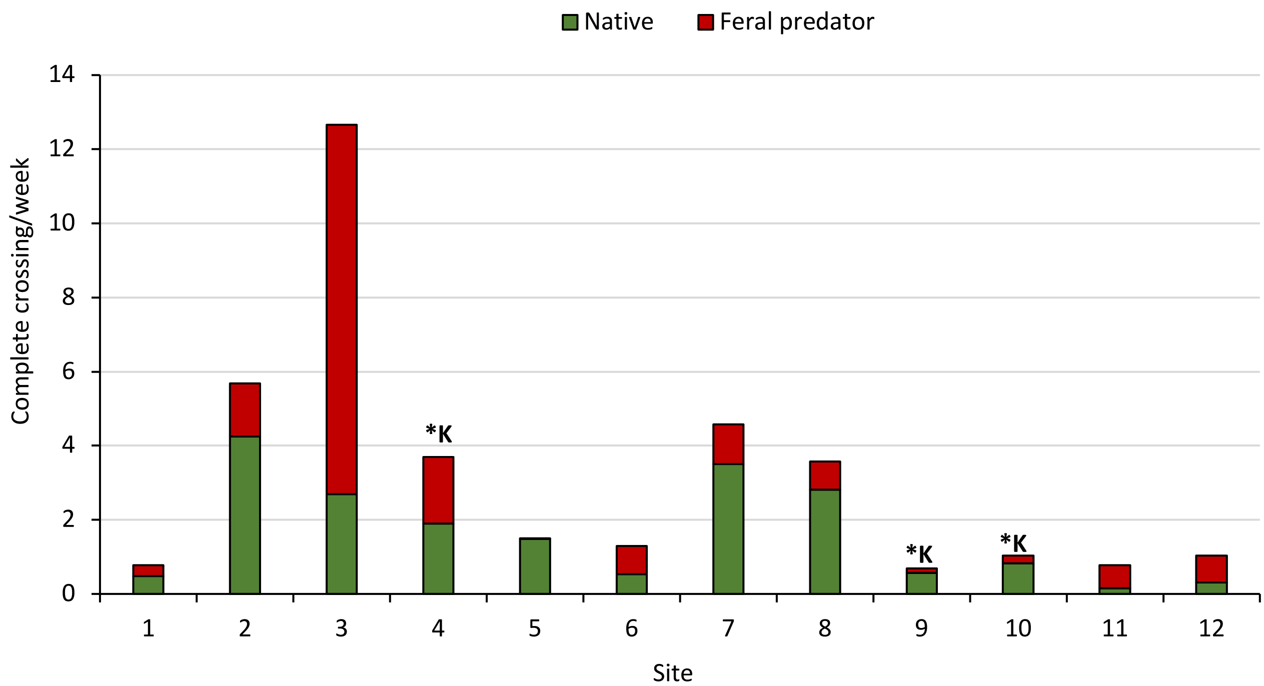

***Table 5:** Survey effort for sampling adjacent habitat on the WC2NH upgrade* *K = indicates complete crossing by koala.

Table 6: Complete crossings/week made by each species/group at each of the 12 underpasses monitored on the WC2NH upgrade during year 2 operational monitoring. Sites 1 and 5 did not contain fauna furniture. [I] = introduced species, Fl = Floor, G = ground (culvert floor). See appendix C, Table C1 for all data.

Species/groups	Site and camera location																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	N	S	FF	G	FF	G	FF	G	N	S	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G
Short-beaked echidna				0.19										0.05										
Antechinus spp			0.23				0.3				0.16		0.17											
Northern brown bandicoot				0.08																0.02				0.11
Long-nosed bandicoot				0.04				0.02	0.02			0.04		0.02				0.02						
Peramelidae spp. (bandicoot)				0.94		0.03		0.39				0.08		0.02				0.07		0.22		0.09		0.14
Koala								0.22										0.02		0.02				
Common brushtail possum								0.02																
Short-eared brushtail possum										0.1	0.04		1.71	0.07	1.47	0.12		0.1		0.07				
Trichosurus spp						0.03		0.05					0.02	0.02	0.24					0.02				
Eastern grey kangaroo						0.17																		
Swamp wallaby	0.3			2.3		0.67		0.2	0.05	0.17		0.12	0.02	0.05		0.12		0.1		0.12		0.03		0.03
Red-necked wallaby						0.23								0.1						0.05				
Wallaby spp				0.3		0.57		0.02						0.15		0.02		0.07		0.07				
Macropod spp				0.15		0.2								0.49										
House mouse*									0.07	0.02								0.02						0.08
Faun-footed melomys							0.02						0.02											
Swamp rat				0.04						0.02														
Bush rat										0.02														
Water rat									0.02	0.79														
Black rat*			0.04				0.02	0.07	0.79	1.6		0.08	0.02	0.02	0.07			0.07		0.12	0.03			0.67
Rodent spp									0.07	0.32	0.04			0.05	0.42						0.03			
Small mammal										0.02				0.02										
Dog*				0.26		1.37		0.12						0.05						0.02		0.09		0.11
Red fox*	0.04	0.04		1.09		0.3		1.13		0.02		0.49		0.91		0.54		0.1		0.07		0.15		0.25
Cat*	0.09	0.13		0.08	0.13	8.17	0.02	0.49				0.28		0.12	0.02	0.2		0.02		0.1	0.03	0.34		0.36
European hare*												0.04				0.07								
Eastern water dragon									0.02	0.07										0.02		0.03		0.03
Lace monitor								0.69		0.07	0.04	0.04		0.17		0.81	0.02	0.1		0.2				
Australian brush turkey																		0.02						
Purple swamphen	0.09	0.04																						
White-browed treecreeper																	0.02							
Welcome swallow					0.73	0.07																		
White faced Heron	0.04																							
Wood duck										0.1														
Species Richness	**5**	**3**	**2**	**11**	**2**	**11**	**4**	**12**	**7**	**13**	**4**	**8**	**6**	**16**	**5**	**7**	**2**	**12**	**0**	**14**	**3**	**6**	**0**	**9**

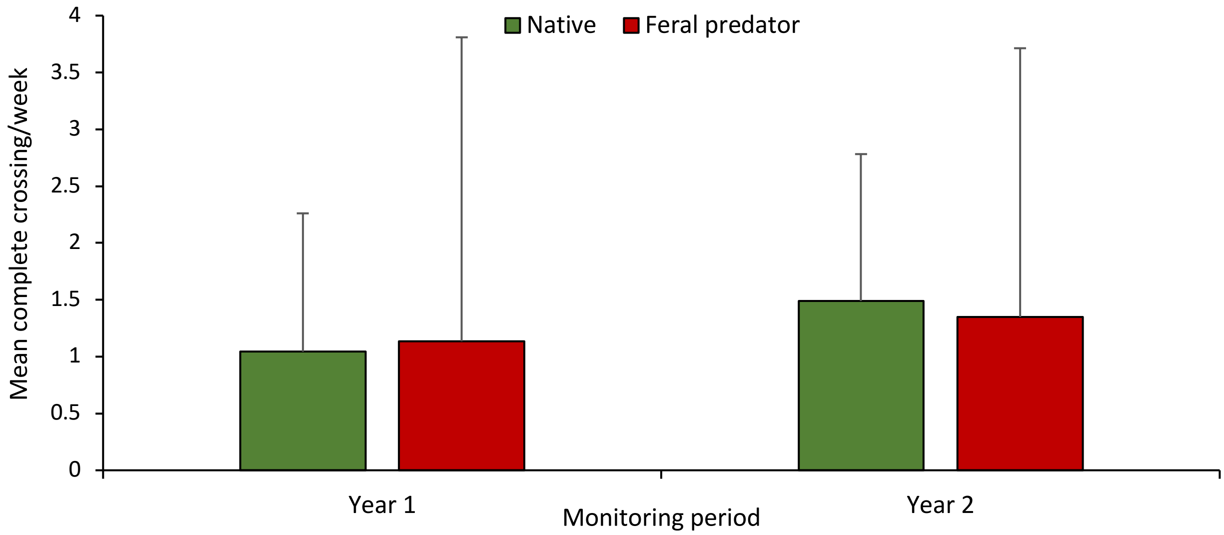

Figure 2: Mean number of complete crossing/week/underpass (+SD) for native and introduced species during year 1 and year 2 monitoring periods (operational).

Feral predator activity

Complete crossings by feral predators were recorded at all sites at an overall rate of 1.34 ± 2.67 cc/week/underpass. This equates to 47% of all complete crossings excluding rodents during year 2 (Figure 2, Figure 3). Feral predator activity was highest at sites 2, 3 and 4 and lowest at sites 5, 9 and 10 (Figure 4). Red fox was recorded at a rate of 0.41 ± 0.39 cc/week/underpass with detections in all underpasses (Figures 5 and 4). Cat (*Felis catus*) recorded 0.84 ± 2.2 cc/week/underpass with detections at all sites except site 5 (Figures 4 and 5). Dog (*Canis lupus familiaris*) exhibited 0.1 ± 0.15 cc/week/underpass and was detected at seven sites (2, 3, 4, 10, 11, 12) (Figures 5 and 4). High use at site 3 can largely be attributed to frequent cat crossings (8.3 cc/week, Figure 4) a majority of which were by 1-2 (distinctive) individuals (Plate 4). Red fox was frequently detected at sites 2 (1.1cc/week), 4 (1.13cc/week) and 7 (0.9cc/week) while dog detections were highest at sites 2 (0.26cc/week) and 3 (1.37cc/week) largely due to two domestic dogs (Figure 4, Plate 4). No instances of predation were recorded in underpasses, although cats carrying prey (rodents) were recorded moving through site 3 on two occasions (see appendix C. Table C1)).

Feral predator use increased from 1.13 ± 2.36 cc/week/underpass during year 1 monitoring to 1.34 ± 2.67 cc/week/underpass during year 2 (Figure 5). While use by cat has remained relatively constant, red fox increased from 0.24 ± 0.45 to 0.41 ± 0.39 cc/week/underpass while dog was recorded at a rate 0.1 ± 0.39 cc/week/underpass with no detections during year 1 monitoring (Figure 5).

Students t-Test comparing mean cc/week/underpass between year 1 and 2 for introduced predators ($P = 0.48$, $n = 12$), foxes ($P = 0.29$, $n = 12$), and cats ($P = 0.85$, $n = 12$) did not identify any statistically significant differences.

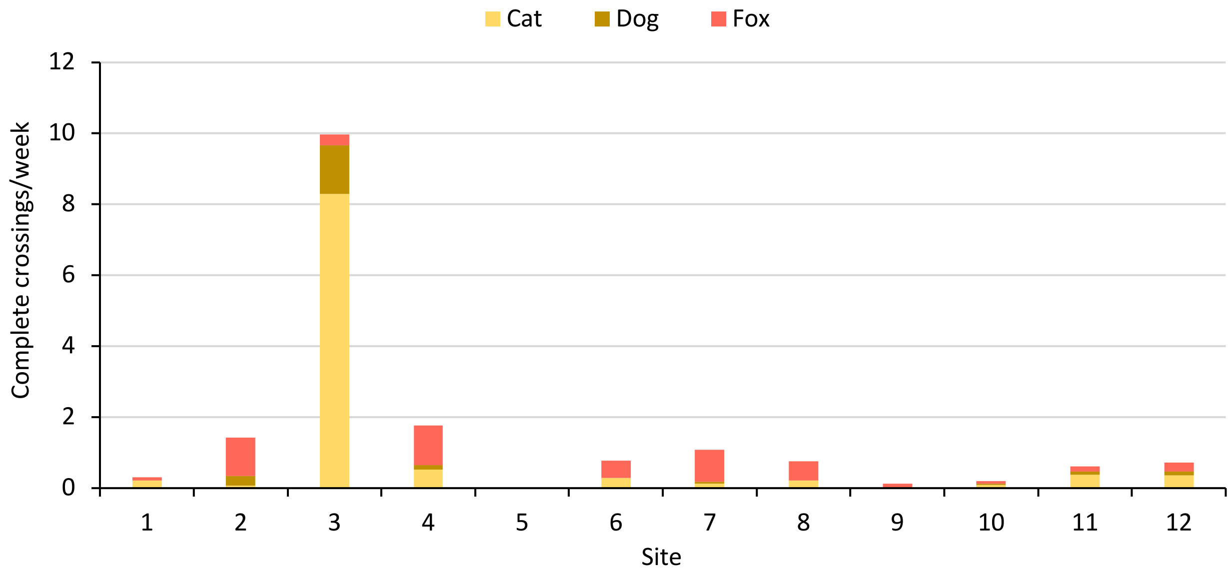

Figure 3: Complete crossings/week by feral predators (cat, red fox, dog) in underpasses during year 2 operational monitoring.

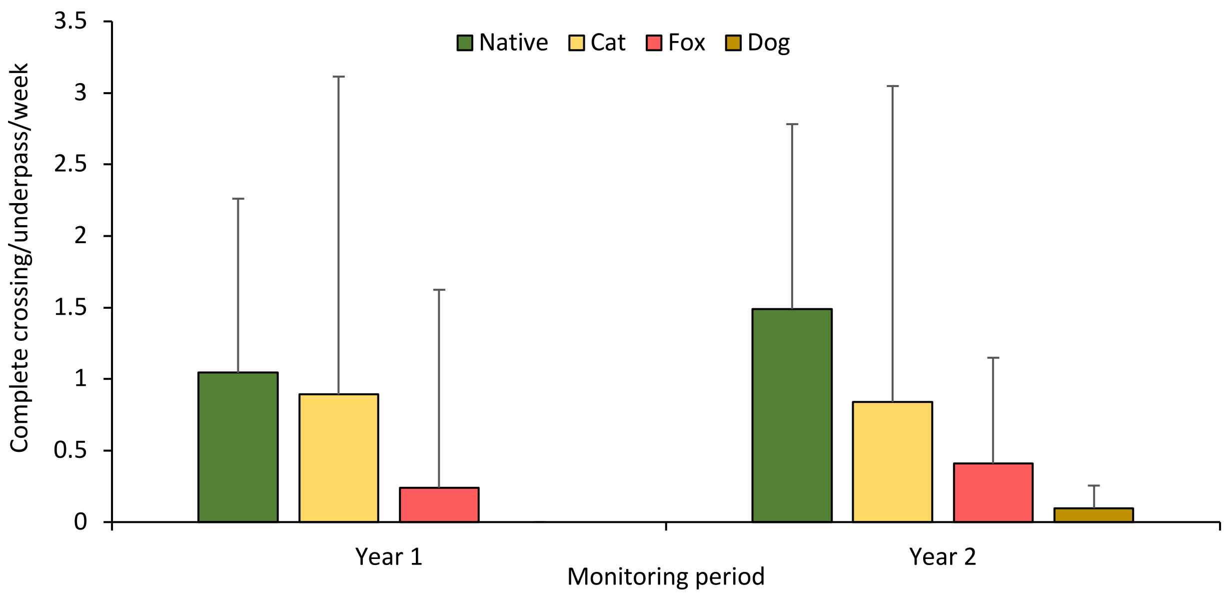

Figure 4. Mean (+SD) number of complete crossing/week/underpass for feral predator species (Cat, Dog, Red fox) during year 1 and year 2 monitoring periods.

Plate 4: Cat individual frequently recorded at site 3 (Top left). Dogs recorded at site 3 (Top right). Feral cat making a complete crossing east at site 7 (Bottom left). Feral dog making a complete crossing east at site 4 (Bottom right).

Use by cover dependent species with low mobility

Fauna with low mobility (see classification in methods) were recorded across all sites with the exception of site 1 (Table 5). In order of use, rodent spp were detected at a rate of 0.43cc/week/underpass, bandicoots 0.20cc/week/underpass and *Antechinus* spp 0.07cc/week/underpass (Figure 6). Rodent species were the most commonly recorded group with confirmed records of introduced black rat (sites 2 and 4-11) house mouse (site 5 and 9), swamp rat (sites 2 and 5), fauna-footed melomys (sites 4 and 7), bush rat (site 5) and water rat (site 5) (Table 5). Bandicoot use was prevalent at site 2 (0.94cc/week) while *Antechinus* spp records were relatively low with complete crossings made on furniture at sites 2, 4, 6 and 7 (Table 5). No cover dependent reptiles or frogs were recorded using underpasses during camera monitoring.

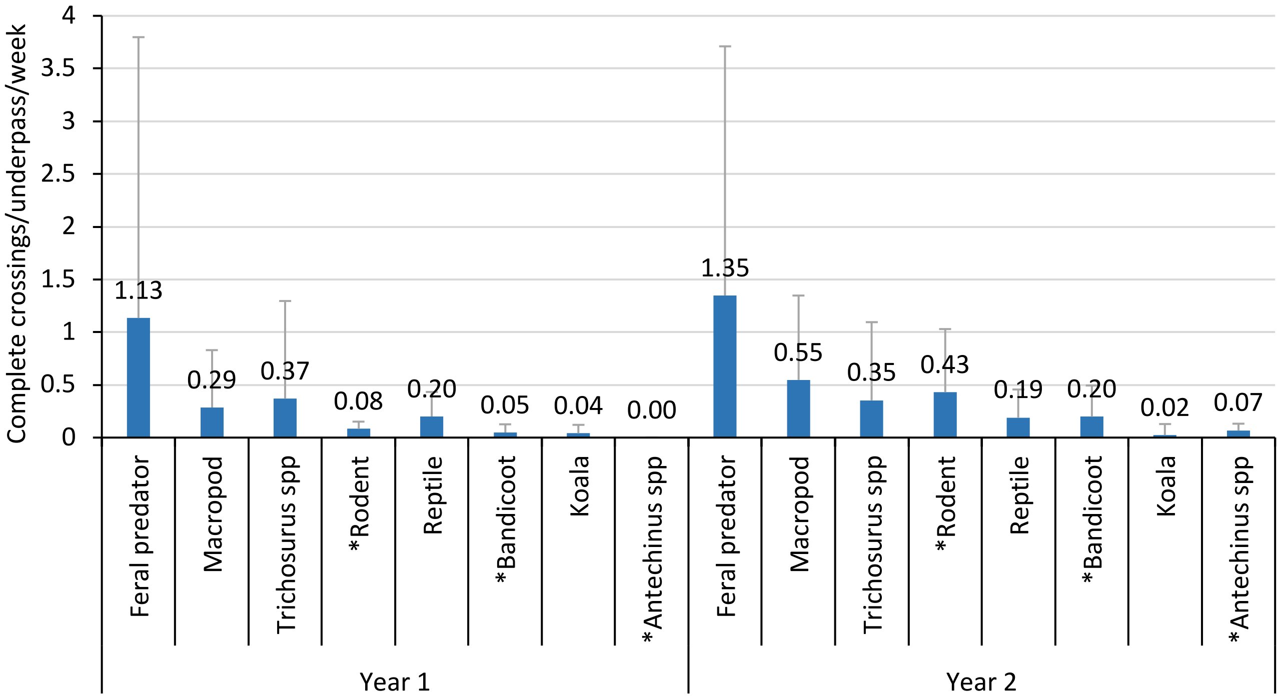

Figure 5: Mean (+SD) number of complete crossings/week/underpass for fauna groups during year 1 and year 2 operational monitoring. *Denotes cover dependent/low mobility species.

Furniture vs Floor

Fauna was recorded using both the culvert floor and furniture during operation phase monitoring (Figure 7). No fauna were recorded using fauna furniture at sites 10 and 12, and sites 1 and 5 did not contain furniture (Table 5). Use of the underpass floor was greater than use of furniture for natives, introduced rodents and feral predators (Figure 7). Furniture use was very low by feral predators, with complete crossings recorded by cat (none for dog or fox) at a rate of 0.02cc/week/underpass (1.2% of all cc by feral predators) (Figure 7, Table 5). Comparatively, 1/3 (31%) of native fauna crossings were completed on fauna furniture at a rate of 0.46cc/week/underpass and the remaining 69% on the culvert floor at a rate of 1cc/week/underpass during year 2 operation (Figure 7). *Trichosurus* spp and *Antechinus* spp, demonstrated preferential use of the fauna furniture accounting for a majority of crossings by native species on the furniture (Table 5, Plate 5). Koalas were recorded using the floor only (Table 5).

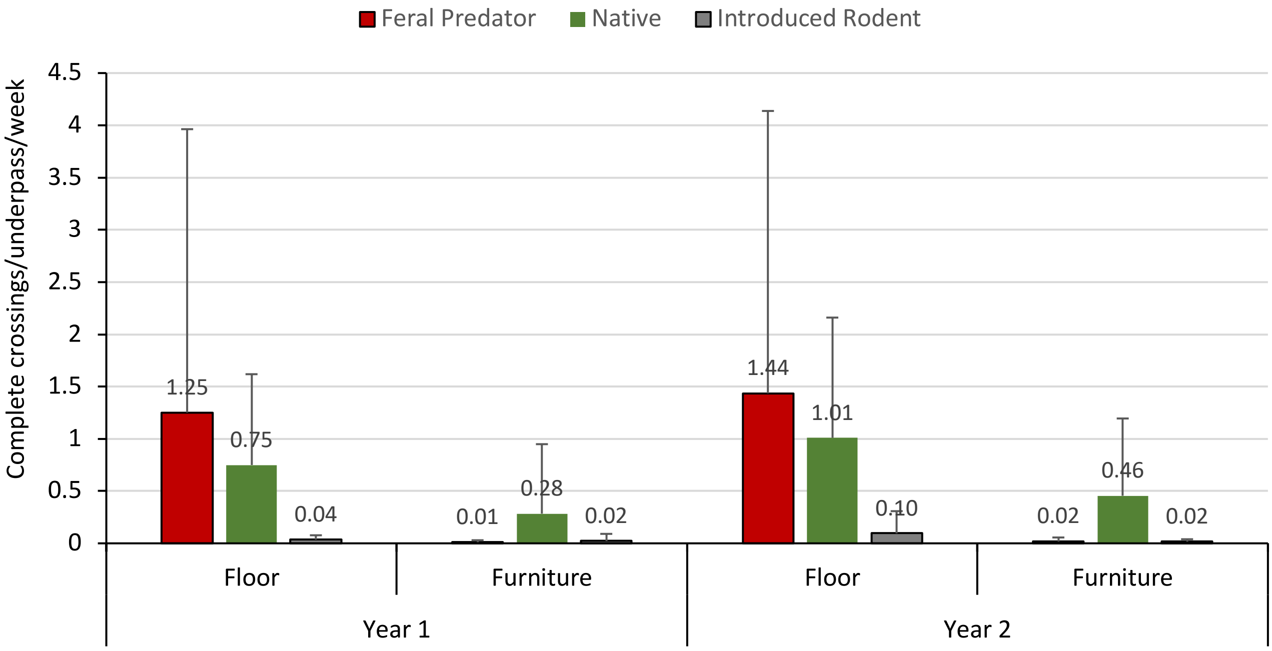

Figure 6: Mean (+SD) number of complete crossings/week/underpass for fauna groups using the culvert floor and furniture during year 1 and year 2 operational monitoring.

Plate 5: Antechinus making a complete crossing west using the fauna furniture at site 6 (Left). Short-eared brushtail possum utilising the fauna furniture at site 8.

3.1.2 Sand pads

Fauna recorded on sand pads largely complimented trends in the underpass camera data. Ten species and fauna groups were recorded on sand pads during monitoring (Appendix C, Table C3). As seen in camera data, species diversity was found to be highest at site 7 (10 species/groups). Rodent spp. was the most commonly recorded fauna group with tracks (incomplete and complete crossings) identified in all underpasses except sites 1 and 8. Koala was recorded making a complete crossing on two occasions at site 4 (Plate 6). Of the smaller fauna groups (small mammals, reptiles and amphibians), a small lizard was reported on one occasion at site 11 and *Antechinus* spp. was reported making three complete crossings at site 2. Sand pad records of feral predators were similar to camera data with cat, dog and red fox confirmed using the underpasses.


Plate 6: Koala tracks (L) recorded on sand pads at Site 4 and Brushtail possum tracks (R) recorded during spring/summer monitoring.

3.1.3 Scat and track searches and tile checks

Ten species, and ten fauna groups were recorded during scat and track surveys during year two monitoring (Appendix C. Table C2). Site 7 and 8 reported the highest diversity of fauna species with ten and nine fauna groups/species respectively (Table 6). Consistent to camera monitoring, sites 1, 11 and 12 report lower fauna diversity with six fauna groups/species or less (Appendix C, Table C2). Tracks or scats of rodents were found in eleven of the twelve culverts and was the most commonly recorded fauna across all sites (Table 6).

Native species/fauna groups were found to be using all culverts (Table 6). Wallaby spp. was recorded at ten sites with lace monitor at seven sites during spring/summer and bandicoot species reported at seven sites each (Table 6). Records of small fauna visitations to the underpasses included *Antechinus* spp. at sites 2,4,6,7, 10, 11 and 12, small and medium reptiles at sites 2, 3, 5 and 8, and a green-tree frog (*Litoria* spp.) scat was recorded at site 10 (Table 6, Appendix C, Table C3). Notably, koala tracks were recorded at site 4 on 28 November and at site 9/10 on 3 October (Appendix C, Table C3).

No fauna was recorded using tiles placed in underpasses.

3.2 Adjacent habitat

Thirty-four species and a further nine fauna groups were recorded in habitat adjoining underpasses (Table 6). The majority of species/groups (28 in total) were detected by diurnal and nocturnal active searches (Table 6, appendix C. Table C4&5). During trapping surveys, a total of 14 species were identified while hair funnels reported a total of seven fauna groups and species (Appendix C, Table C6). Hair funnel analysis identified 6 species/groups using the adjacent habitat (Appendix C, Table C7). Several threatened species were recorded during spotlight surveys of adjacent habitat, including grey-headed flying fox (*Pteropus poliocephalus*) on 17 occasions, koala on the eastern side of site 4 and giant barred frog at site 1 (Appendix C, Table C5).

A total of 66 individuals were captured during the spring/summer survey and 85 individuals during winter (Appendix C, Table C6). Sugar glider, fawn-footed melomys and black rat were captured in arboreal Elliott traps (Plates 7 & 8). Eight species, two mammals, seven reptiles and two frogs were captured in pitfall traps, and five species including brown antechinus, sugar glider, fawn-footed melomys, bush rat and black rat were captured in ground Elliott traps.

During spring/summer trapping, fawn-footed melomys was the most commonly captured species, with 22 individuals, followed by brown antechinus (10 individuals); black rat (five individuals) and bush rat (three individuals). Remaining species and groups reported two individuals or less. Winter capture rates were highest for black rat (21 individuals), fawn-footed melomys (20 individuals), brown antechinus (16 individuals) and bush rat (10) (Appendix C. Table C6).

Table 7: Species of vertebrate recorded during surveys of adjacent habitat in spring/summer 2019. SS = Spring/Summer, W = Winter. * = Threatened species. $_E$= Endangered species. * denotes threatened species; $_I$ = Introduced species.

Species	Active Search		Spotlight		Ground Elliott trap		Arboreal Elliott trap		Cage trap		Pitfall trap		Hair funnel	
	SS	W	SS	W	SS	W	SS	W	SS	W	SS	WW	SS	W
Mammals														
Short-beaked echidna	*			*										
Brown antechinus					*						*			*
Antechinus spp.						*						*	*	
Northern brown bandicoot			*						*	*			*	
Long-nosed bandicoot			*										*	
Peramelidae spp. (bandicoot)	*	*	*											
Sugar glider			*	*	*		*	*						
Acrobates spp				*										
Koala*		*	*											
Short-eared brushtail possum									*	*				
Common brushtail possum														*
Trichosurus spp.													*	*
Common ringtail possum				*										
Wallaby spp.	*	*		*										
Swamp wallaby			*										*	
Macropodidae spp.			*											
Grey-headed flying red fox *			*	*										
Pteropus spp.			*											
Fawn-footed melomys					*	*	*	*				*	*	
Bush rat					*	*							*	*
House mouse [I]						*					*			*
Black rat [I]					*	*	*	*		*			*	*
Red fox [I]	*	*												
Dog		*												
Cat [I]		*	*											

Reptiles														
Burton's legless lizard	*													
Eastern water dragon	*	*	*											
Agamid spp.	*													
Ctenotus spp.		*												
Calyptotis ruficauda		*									*			
Lampropholis delicata											*			
Lampropholis spp.	*	*												
Yellow-faced whipsnake	*													
Dwarf Crowned Snake											*			
Swamp snake														
Blackish blind snake											*			
Black-bellied swamp snake	*										*			
Bandy-bandy			*											
Frogs														
Litoria fallax			*											
Litoria peronii			*											
Litoria tyleri														
Adelotus brevis	*		*											
Limnodynastes peronii			*									*		
Mixophyes iteratus [E]			*											
Crinia signifera		*	*	*										
Pseudophryne coriacea			*								*	*		
Total Nº. Species/groups	**11**	**11**	**20**	**7**	**5**	**5**	**3**	**3**	**2**	**3**	**8**	**4**	**7**	**6**

 

Plate 7: *Calyptotis ruficauda* captured in a pitfall trap (L) and a sugar glider (L) captured in an arboreal Elliott.

Plate 8: A short-eared brushtail possum captured in a cage trap (L) and a fawn-footed melomys captured in a ground Elliot (R) during adjacent habitat trapping.

3.2.1 Species recorded in underpasses and adjacent habitat

During year two monitoring 46 species and fauna groups were recorded in adjacent habitat and 34 in underpasses. Due to duplication between species and fauna groups (e.g. Macropodidae and wallaby spp. includes both red-necked and swamp wallaby) only confirmed species and unique genera have been included in the comparison between underpasses and adjacent habitat. Species that don't rely on underpasses to cross the alignment such as birds, flying-foxes and gliders have also been excluded. With the above exclusions 34 species and genera were confirmed using adjacent habitat and 22 species and genera were recorded using underpasses (Table 7). Red-necked wallaby, swamp rat, water rat, lace monitor, green tree frog were recorded in underpasses only (Table 7). If these species are assumed to also reside in adjacent habitat, the proportion of species in adjacent habitat that utilised underpasses in year two was 56% (Table 7). The proportion of mammals recorded in both adjacent habitat and underpasses was 90%. Green tree frog was the only species of amphibian reported using underpasses, while seven frog species were reported in adjacent habitat (Table 7). Further, of the 14 reptile species/families recorded during monitoring, only two (lace monitor and eastern water dragon) were confirmed using underpasses (Table 7).

Table 8: Species and genera recorded using underpasses and in adjacent habitat during year two monitoring. * denotes threatened species. $_E$= Endangered species; + = species assumed to occur based on presence in underpass.

Species	Adjacent habitat	Underpass
Mammals		
Short-beaked echidna	*	*
Brown antechinus	*	
Antechinus spp.	*	*
Northern brown bandicoot	*	*
Long-nosed bandicoot	*	*
Koala*	*	*
Short-eared brushtail possum	*	*
Common brushtail possum	*	*
Common ringtail possum	*	
Swamp wallaby	*	*
Red-neck wallaby	*	*
Fawn-footed melomys	*	*
Rodent spp.	*	*
Swamp rat	*	*
Water rat	*	*
Bush rat	*	*
House mouse [I]	*	*
Black rat [I]	*	*
Dog [I]	*	*
Red fox [I]	*	*
Cat [I]	*	*
Sub-total mammals	**21**	**19**
Retiles		
Burton's legless lizard	*	
Lace monitor	+	*
Eastern water dragon	*	*
Calyptotis ruficauda	*	
Lampropholis delicata	*	
Ctenotus spp	*	
Yellow-faced whipsnake	*	
Dwarf Crowned Snake	*	
Swamp Snake	*	
Blackish blind snake	*	
Black-bellied swamp snake	*	
Bandy-bandy	*	
Frogs		
Litoria fallax	*	
Litoria peronii	*	
Adelotus brevis	*	
Limnodynastes peronii	*	
Mixophyes iteratus [E]	*	
Crinia signifera	*	
Pseudophryne coriacea	*	
Green tree frog	+	*
Total Nº· Species/genus	**34**	**22**

3.3 Fauna fence and road strike

A total of 30 exclusion fence defects were recorded during the winter fence traverse (see appendix C, Table C8). Fifteen issues were considered minor priority, ten medium priority and four high priority (excluding gate which has since been closed). Minor issues included gaps where drains intersect the fence (8 issues) compromising the function of the exclusion fence and potentially enable fauna to breach the fence. Medium priority issues include instances where branches or trees are overhanging the exclusion fence. Four high priority issues identified included breach underneath the frog fence, substantial vegetation growth over 100m of exclusion fence, a hole dug under the fence and above site 7 where a car had crashed into the exclusion fence (Appendix C, Table C8). An unlocked gate was also found at site 1 which was closed and locked.

No road-kill hot spots were identified adjacent to the underpasses or in sections with exclusion fencing (see road-kill report Sandpiper 2019e). In 2019, nine road-kills were recorded in the fenced area between sites 2 and 12, 66% of which were birds. Three road-kills were reported as small to medium mammals, which should have been excluded by the fence.

4. Discussion

4.1 Low rates of use of fauna underpasses and adjacent habitats by feral predators

Feral predators (combined cat, red fox and dog) recorded complete crossings in underpasses at an overall rate of 1.34 ± 2.67 cc/week/underpass. While what constitutes "low use" is not specified within the WC2NH EMP (RMS 2018), feral predators accounted for 47% of complete crossings with marginally lower rates than recorded for native species (1.49cc/week/underpass). This suggests that feral predators are readily using underpasses to transverse the alignment at a rate that is similar to native fauna.

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; Taylor & Goldingay 2014). It is unknown if feral predators are capturing prey near underpass entrances or simply using underpasses to move through their home range. Given that no instances of predation were recorded, evidence suggests that feral predators are using underpasses to access habitat on both sides of the Pacific Highway. While no instances of predation were observed on camera footage, it is possible that either predation of or avoidance by native species is occurring at monitored underpasses.

Rates of feral predator underpass usage were not consistent throughout the study area. The high usage recorded at site 3 was due to complete crossings by one or two distinctive cats. Previous trapping has failed to capture the individuals, which are likely to be domestic cats from a neighbouring property. Site 2 also recorded relatively high use by fox and cat, which is attributed to the surrounding fragmented agricultural landscape and proximity to site 3. Records of fox were still recorded at all sites (highest at 2, 4, 6, 7, 8) cat 11 sites (highest at 3, 4, 11 and 12) and dog eight sites (highest at 2, 4, 6, 11 and 12). Use of site 4 by dog is of particular concern due to consistent records of koala during both spring/summer and winter 2019/20 and 2018/19 (Sandpiper Ecological 2019).

Despite the absence of statistically significant differences feral predator use increased from a mean of 1.13 ± 2.36 cc/week/underpass in year 1 to 1.34 ± 2.67 cc/week/underpass in year 2. While use by cat has remained relatively constant, red fox increased from 0.24 ± 0.45 to 0.41 ± 0.39 cc/week/underpass (63% increase) and dog increased from nil in year 1 to 0.1 ± 0.39 cc/week/underpass in year 2. These findings suggest that action may be warranted to prevent further increase in feral predator activity, in particular fox and dog. Due to the limited temporal coverage of sampling confirmation of increased activity in year 3 is warranted before control measures are implemented.

4.2 High levels of fauna underpass use by a variety of native species

Native species frequented underpasses at a rate of 1.49cc/week/underpass. A total of 16 native species/genera were recorded making complete crossings. Of the 39 species/genera (includes species recorded in underpasses only) recorded in the adjacent habitat 56% (22 species/genera) were recorded using underpasses. This result is broadly consistent with findings at Sapphire to Woolgoolga (23% to 50%) and slightly higher than the 38% and 42% recorded at NH2U in 2018 and 2019 (Sandpiper Ecological 2018a; 2019d, 2020).

Fauna furniture accounted for 31% of native fauna crossings at a rate of 0.46cc/week/underpass with the remaining 69% on the culvert floor at a rate of 1cc/week/underpass during year 2. *Trichosurus* spp and *Antechinus* spp, demonstrated preferential use of the fauna furniture accounting for the majority of crossings by native species on the furniture. In contrast, feral predators tended to use the culvert floor with only limited use of furniture by cat. Despite no evidence of predation occurring in the underpasses, the furniture is likely to act as a refuge for native fauna, alleviating predation risk and encouraging underpass crossings by native species. These findings demonstrate that fauna furniture is an important feature in underpasses to facilitate complete crossings by some native species and highlight its importance in providing refuge from feral predators. Results are consistent with the findings of Goldingay *et al.* (2017).

Use of underpasses by koalas was consistent across years one and two sampling. Year one monitoring revealed rapid use of underpasses by koalas, with individuals recorded in five culverts. The number of culverts used in year two declined to three with a peak of 0.22 cc/week recorded at Site 4. Koala use of underpasses at WC2NH was quicker than recorded at other nearby sites. The speed of uptake is likely associated with the location of underpasses in relation to home ranges and importance of adjoining habitat.

The results obtained at WC2NH are encouraging and the number of species and frequency of use of the underpasses will likely increase over time (Gagnon *et al.* 2011). Increase in the use of underpasses by macropods, bandicoots and antechinus between year 1 and year 2 monitoring was apparent. However, this may be due to improved conditions during year 2 as year 1 was characterised by drought. Improved vegetation cover will be critical in attracting species with small home ranges, such as the common garden skink, eastern crevice skink and red-tailed skink that were reported using the adjacent habitat. Recent landscape plantings near the entrance of several underpasses will assist in providing such cover. Further, a reduction in the number of feral predators is likely to alleviate predation pressure and lead to increase use of underpasses by native species. To achieve this targeted control may be warranted, particularly at sites regularly used by koalas.

4.3 No change to densities, distribution, habitat use, and movement patterns compared to baseline population data of target species.

The target species for underpass monitoring, as outlined in the project brief, are spotted-tailed quoll, koala and giant barred frog. No spotted-tailed quolls were detected during year two, consistent with baseline monitoring (GeoLink 2014). Spotted-tailed quolls occur in low densities in northern NSW and the absence of records in underpasses is not unexpected.

Koalas occur in low densities in Nambucca State Forest and small numbers of individuals were recorded near the alignment during baseline (1 individual), construction phase (3 individuals), and year one operational phase (3 individuals) surveys (GeoLink 2014; Geolink 2017; Sandpiper Ecological 2019b).

Koalas were recorded using underpasses at sites 4, 9 and 10 during both sand pad and camera monitoring. However, there is no substantive baseline data to confirm if changes in habitat use and movement patterns have occurred. Results to date are encouraging as they suggest that koalas continue to maintain territory on both sides of the alignment.

Giant barred frogs were detected in adjacent habitat at site 1 but not recorded on underpass cameras. Riparian vegetation partially obstructed the camera field of view at site 1 in winter and new camera locations will be selected for year 3 monitoring. Notwithstanding, movement by giant barred frogs at site 1 is likely limited by the sparse riparian vegetation, and low activity in winter. Indeed, sampling giant barred frogs in winter is unlikely to provide useful data. Improved habitat connectivity beneath the Warrell Creek Bridge in conjunction with significant rainfall events and reduced human disturbance may increase giant barred frog movement beneath the highway. Further monitoring is required to confirm if the species can rebound to previous population levels (Sandpiper Ecological 2019c).

4.4 Evidence of use by dispersing individuals and different age cohorts

Accurately confirming age of individuals using underpasses is difficult using surveys methods outlined in the EMP. However, immature short-eared brushtail possums and juvenile swamp wallaby were regularly recorded making complete crossings at sites 2, 7, and 8. Other methods such mark-release-recapture would likely be required to provide definitive proof of use by dispersing individuals and different age cohorts. Such a survey would be expensive and is not warranted.

4.5 Use by cover-dependent species with low mobility

Several cover-dependent species (typically small mammals, small reptiles and frogs) were recorded in adjacent habitat, including eight frog species, three native mammals (brown antechinus, fawn-footed melomys and bush rat) and ten reptile species. Of these, only four (small reptile, antechinus, fawn-footed melomys and bush rat) were recorded using underpasses. Additional, cover dependent, small mammal species recorded in underpasses only were swamp rat, and water rat. Consistent with previous surveys there were limited records of reptiles and amphibians in underpasses. Low occurrence of frogs and reptiles is most likely due to the inability of cameras to detect these species as opposed to avoidance. This shortfall is assisted by the use of sand pads and scat and tracks searches to detect smaller fauna. Sand pads captured tracks of a small reptile at site 12 and scat searches recorded frog scat at Site 10. Further, while the floor tiles installed during winter monitoring did not increase detection of cover dependent species, activity of reptiles and frogs is typically low during winter and improved detection may occur during spring/summer monitoring.

Whilst frogs and reptiles are consistently recorded using underpasses at a low frequency there is substantial evidence that this is due to sampling method and revegetation of culvert entrances rather than avoidance. For example, Sandpiper Ecological (2018c) using time lapse photography recorded four species of frog and eight species of reptile using pipe culverts on the S2W upgrade and both *Litoria barringtonensis* and *L. gracilenta* have been recorded in culverts at Butchers Creek on the WC2Nh upgrade. Use of underpasses by cover dependent species, such as antechinus, is likely to improve as landscape plantings at culvert entrances grow to provide cover between the forest edge and culvert entrance.

4.6 No breaches in fauna exclusion fencing; Low incidences of fauna road strike mortality.

A total of 30 exclusion fence defects were recorded during the winter fence traverse. Gaps were commonly identified where drains intersect the fence (8 issues) compromising the function of the exclusion fence and potentially enabling fauna to breach the fence. Vegetation (vines) was identified on one occasion growing up the fence (Appendix C, Table C8). An unlocked gate was found and subsequently closed upon inspection. Gates have been implicated as a potential cause in the road-kill deaths of koalas on Nambucca Heads to Urunga upgrade (NH2U) and Section 11 of the Woolgoolga to Ballina (W2B) upgrade. In general, the exclusion fence was in good condition. A recent observation of a koala within the road corridor suggests that fauna may push under loose wire beneath gates. This finding suggests that a koala actively seeking to move through the exclusion fence could breach a gate that may appear secure. In that instance TfNSW immediately repaired the loose wire.

No road-kill hot spots were identified adjacent to the underpasses or in sections with exclusion fencing (see Sandpiper 2019e). Nine road-kills were recorded between sites 2 and 12 during 2019, 66% of which were birds. Three were reported as small to medium mammals, which should have been excluded by the fence. Access for these individuals may have been via drains where the metal screen was blocked by sticks.

4.7 Underpass survey effort and methods

Underpass survey effort was compromised due to theft of all cameras at sites 1, 2, 3 and 6 during the spring/summer sample. Battery failure and camera malfunction reduced effort during the winter sample at a small number of sites. Removal of defective cameras and changing camera orientation will be applied to reduce the incidence of false triggers in year three sampling. To reduce the incidence of malfunction and maximise monitoring days, camera operation will in future be checked opportunistically while conducting other work nearby. This will involve checking the infrared flash when passing through the underpasses. Any cameras that do not show an active infrared flash will be inspected more closely.

Records from sand pad checks largely complimented UP camera data. Discerning tracks on sand pads contributes substantially to the inclusion of broad groups such as small reptile and macropod spp. However, sand pads may better detect smaller fauna groups, which can evade camera activation. For instance, a small reptile (site 11) and *Antechinus* spp (site 2) were recorded using the culvert floor without being recorded by the cameras. Further, sand pads have demonstrated moderate persistence in underpass allowing for longer-term monitoring of tracks. This is beneficial when conducting scat and tracks surveys and noting opportunistic records (crossings) that may occur outside of camera or sand pad monitoring periods.

5. Contingency Measures and Recommendations

5.1 Contingency Measures

Contingency measures are summarised in Table 8.

Table 9: Potential problems outlined in the EMP and possible contingency measures. Mitigation measures applicable to the project are addressed in bold text in table below.

Problem	Contingency/Corrective Action	Proposed action
High rates of feral predator activity;	Control program	• Consider need for control programs targeting fox and dog (in particular at site 4). • Discuss alternative methods of cat capture/removal at site 3 with TfNSW
Low levels of native fauna movement and species diversity in underpasses;	Modify habitat structure near underpass entrances and/or modify underpass fauna furniture	Revegetation work has already occurred – no further action required.
No use of underpasses by cover-dependent species or species with low mobility or target threatened species	Modify or add potential groundcover resources	Continue with monitoring of tiles leading into year 3-spring/summer sample.
High rates of fauna road mortality.	Modify exclusion fencing design, location or extent depending on the species and location of mortalities	At this stage of monitoring no modifications to exclusion fence design or extent is recommended.

5.2 Recommendations

Recommendations are summarised in Table 9.

Table 10: Recommendations based on findings from year two operational phase monitoring and response from TfNSW.

Number	Recommendation	Transport for NSW Response
1.	Assess options to control canids at sites regularly used by koalas. The spring/summer year 3 sample should be used to confirm if canid use of underpasses remains high. If monitoring shows high canid activity at key sites (i.e. those used regularly by koala) then TfNSW should consult Local Land Services to identify opportunities to link with other control programs in the locality.	With the assistance of Local Land Services (LLS), TfNSW commenced targeted feral dog baiting and cat trapping in May 2019. Further meetings with LLS have resulted in TfNSW being included as a participant in co-ordinated predator pest baiting programs,

		where LLS has the option to place baits in culverts as part of wider baiting efforts involving other stakeholders. Baiting programs are proposed to take place twice per year at peak predator pest activity times. LLS are aiming to have all stakeholders bait at the same time to maximise impact on predator species including feral dogs, foxes and cats.
2.	Sandpiper Ecological to investigate alternative methods to control cats at sites 2 and 3	Agree and adopted
3.	Continue monitoring of tiles in underpasses during year 3	Agree and adopted
4.	At site 1 (Upper Warrell Creek), undertake an additional 6-8 weeks of camera monitoring in autumn (March/April), commencing in autumn year 3 (2021).	Agree and adopted

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Appendix A – Species list

Table A1: Common and scientific names for all species recorded during year two monitoring at WC2NH. ^ = Threatened species.

Common Name	Scientific Name
Koala^	*Phascolarctos cinereus*
Swamp wallaby	*Wallabia bicolor*
Red-necked wallaby	*Macropus rufogriseus*
Wallaby spp.	
Eastern grey kangaroo	*Macropus giganteus*
	Macropodidae spp.
Short-beaked echidna	*Tachyglossus aculeatus*
Yellow-bellied glider^	*Petaurus australis*
Sugar glider	*Petaurus breviceps*
	Petaurus spp.
Feathertail glider	*Acrobates pygmaeus*
Short-eared brushtail possum	*Trichosurus caninus*
Common brushtail possum	*Trichosurus vulpecula*
Brushtail possum spp.	*Trichosurus spp.*
Common ringtail possum	*Pseudocheirus peregrinus*
Northern brown bandicoot	*Isoodon macrourus*
Long-nosed bandicoot	*Perameles nasuta*
Bandicoot species	*Peramelidae spp.*
Fawn-footed melomys	*Melomys cervinnipes*
	Melomys spp.
Water rat	*Hydromys chrysogaster*
Bush rat	*Rattus fuscipes*
Murid spp.	*Muridae spp.*
Brown antechinus	*Antechinus stuartii*
	Antechinus spp.
Long-nosed potoroo^	*Potorous tridactylus*
Grey-headed flying red fox^	*Pteropus poliocephalus*
Flying red fox spp.	*Pteropus spp.*
Bent-wing spp.	*Miniopterus spp.*
Small mammal spp.	
	Dasyuridae spp.
Eastern crevice skink	*Egernia mcpheii*
Garden skink	*Lampropholis delicata*
Grass skink	*Lampropholis guichenoti*
	Lampropholis spp.
Red-tailed calyptotis	*Calyptotis ruficauda*
Eastern water-skink	*Eulamprus quoyii*
Three-toed skink	*Saiphos equalis*
Skink spp.	*Scincidae spp.*
Coastal carpet python	*Morelia spilota*
Red-bellied black snake	*Pseudechis porphyriacus*
Yellow-faced whipsnake	*Demansia psammophis*
Black-bellied swamp snake	*Hemiaspis signata*
Blackish blind snake	*Anilios nigrescens*
Bandy bandy	*Vermicella annulata*
Coastal carpet python	*Morelia spilota*
Burton's legless lizard	*Lialis burtonis*
Lace monitor	*Varanus varius*
Eastern water dragon	*Intellagama lesueurii*

	Agamid spp.
Freshwater turtle spp.	*Chelidae spp.*
Medium reptile spp.	
Small reptile spp.	
Small snake spp.	
Pacific black duck	*Anas superciliosa*
Pheasant coucal	*Centropus phasianinus*
Intermediate egret	*Ardea intermedia*
Tawny frogmouth	*Podargus strigoides*
Owlet-nightjar	*Aegotheles*
Common Name	Scientific Name
Little eagle^	*Hieraaetus morphnoides*
Eastern osprey^	*Pandion haliaetus*
Glossy Black Cockatoo^	*Calyptorhynchus lathami*
White-throated treecreeper	*Cormobates leucophaea*
Green catbird	*Ailuroedus crassirostris*
Eastern yellow robin	*Eopsaltria australis*
Eastern whipbird	*Psophodes olivaceus*
Water bird spp.	
Medium bird spp.	
Small bird spp.	
Eastern dwarf tree frog	*Litoria fallax*
Tyler's tree frog	*Litoria tyleri*
Red-eyed tree frog	*Litoria chloris*
Green tree frog	*Litoria cerulea*
Dusky toadlet	*Uperolia fusca*
	Uperolia spp.
Tusked frog	*Adelotus brevis*
Common eastern froglet	*Crinia signifera*
Great barred frog	*Mixophyes fasciolatus*
Giant barred frog^	*Mixophyes iteratus*
Striped marsh frog	*Limnodynastes peronii*
Red-backed toadlet	*Pseudophryne coriacea*
Medium frog spp.	
Frog spp.	
Cat	*Felis catus*
Red red fox	*Vulpes vulpes*
Black rat	*Rattus rattus*
European hare	*Lepus europaeus*
House mouse	*Mus musculus*

Appendix B – Weather and climatic conditions

Table B1: Weather during the year 2 monitoring period. Rainfall taken from the BOM weather station at Bellwood (059150). Air temperature, wind and relative humidity collected from Coffs Harbour Airport (station 059151).

Date	MINIMUM Air Temperature (°C)	MAXIMUM Air Temperature (°C)	TOTAL Rain Gauge (mm)	AVERAGE Wind Direction DESCRIPTION	MAXIMUM Wind Speed (km/h)	9am Relative Humidity (%)
22/09/2019	18	26.7	0	SE		64
23/09/2019	16	22	4	SE	26	90
24/09/2019	11.2	20.7	0	SW	30	58
25/09/2019	11.8	22	0	NE	39	61
26/09/2019	14.1	22.7	0	NE	54	89
27/09/2019	10.9	25.3	0	NNE	37	72
28/09/2019	10.4	28.3	0	SSW	57	32
29/09/2019	9.7	21.5	0	NE	35	62
30/09/2019	11.8	22	0	SE	41	73
1/10/2019	13.9	20.7	4	SSE	31	81
2/10/2019	12.1	22.3	0	NE	41	54
3/10/2019	14.2	24.1	0	NE	46	54
4/10/2019	11.7	25.5	0	NE	46	44
5/10/2019	16.7	21.7	0	SW	48	76
6/10/2019	16.6	23.5	0			73
7/10/2019	15.7	28.4	0	NE	41	63
8/10/2019	14.3	22.3	0	SSW	46	96
9/10/2019	9.1	21	0	SSE	50	43
10/10/2019	12.4	20.9	0	SW	44	54
11/10/2019	10.4	19.3	0	ESE	31	82
12/10/2019	11.5	18.5	14	SW	31	83
13/10/2019	12.7	21	6	SW	43	77
14/10/2019	10.2	22.2	7	NE	37	64
15/10/2019	14.7	25.4	0	NE	46	77
16/10/2019	15.3	26.6	0	S	69	65
17/10/2019	18.3	32.8	7	NNW	50	73
18/10/2019	12.1	23.2	0	SSW	31	32
19/10/2019	13	25	0	NNE	33	60
20/10/2019	14.7	22.6	0	SW	54	59
21/10/2019	10.9	22.1	0	SE	28	62
22/10/2019	10	22.8	0	ESE	26	59
23/10/2019	12	24.3	0	NE	44	68

24/10/2019	13.8	25.2	0	NNE	54	57
25/10/2019	14.1	26.3	0	NE	56	56
26/10/2019	18.4	28.7	0	NNE	63	44
27/10/2019	16.5	23.9	0	SW	37	55
28/10/2019	12.5	24.3	0	ESE	28	67

Date	MINIMUM Air Temperature (°C)	MAXIMUM Air Temperature (°C)	TOTAL Rain Gauge (mm)	AVERAGE Wind Direction DESCRIPTION	MAXIMUM Wind Speed (km/h)	9am Relative Humidity (%)
29/10/2019	12.7	24.4	0	NE	44	60
30/10/2019	17.4	26	0	NNE	54	63
31/10/2019	15.9	25	0	NNE	52	61
1/11/2019	17.1	24.9	0	NE	48	58
2/11/2019	17.4	25.4	0	NNE	54	62
3/11/2019	18.9	27.8	0	NNE	72	60
4/11/2019	19.1	28.8	2	N	33	59
5/11/2019	13.9	22	0	S	65	71
6/11/2019	12.4	24.4	3	N	35	48
7/11/2019	10.9	30.2	0	NE	48	34
8/11/2019	12	34.3	0	WSW	44	19
9/11/2019	17.3	22.4	0	S	63	52
10/11/2019	6.7	24.9	0	ENE	33	31
11/11/2019	10.6	23.8	0	NE	41	66
12/11/2019	16.1	30.3	0	NE	54	55
13/11/2019	13.4	23.1	0	S	57	66
14/11/2019	13.3	24.1	0	SE	22	68
15/11/2019	14.7	26.3	0	NNE	48	69
16/11/2019	11.2	24.8	0	SW	41	57
17/11/2019	15.1	24.4	0	WSW	54	73
18/11/2019	14.5	24.4	0	NE	44	69
19/11/2019	16.7	26.5	0	N	39	54
20/11/2019	16.2	25.7	0	SSW	37	57
21/11/2019	17.7	27.6	0	NNE	70	68
22/11/2019	20.6	32	0	NNE	70	42
23/11/2019	20.5	26.1	0	NNE	61	65

24/11/2019	17.7	25.8	0	NNE	37	75
25/11/2019	20.7	27.3	0	NNE	67	67
26/11/2019	17.7	31.2	0	NNE	61	59
27/11/2019	18.2	24.2	1	S	48	43
28/11/2019	14.6	25.6	0	NE	50	65
29/11/2019	21	27.7	0	NE	61	81
30/11/2019	21.4	30.3	0	SW	72	74
1/12/2019	19.9	27.5	16	NE	35	78
2/12/2019	18.7	31.2	6	WSW	65	56
3/12/2019	12.6	25.8	0	NNE	54	27
4/12/2019	10.5	27.4	0	NNE	43	31
5/12/2019	11.8	30	0	NE	30	44
6/12/2019	11.8	34.1	0	NNE	43	26
7/12/2019	14.3	26.2	0	S	41	55
8/12/2019	13.8	26.8	0	ESE	28	67

Date	MINIMUM Air Temperature (°C)	MAXIMUM Air Temperature (°C)	TOTAL Rain Gauge (mm)	AVERAGE Wind Direction DESCRIPTION	MAXIMUM Wind Speed (km/h)	9am Relative Humidity (%)
9/12/2019	16.4	27.7	0	NE	50	67
10/12/2019	23.3	29.5	0	NNE	57	66
11/12/2019	21.8	24	0	N	54	86
12/12/2019	21	25.8	0	SSW	35	79
13/12/2019	19.3	24	7	SSE	35	95
14/12/2019	19.3	27.2	0	WSW	30	77
15/12/2019	19.2	28.4	0	NNE	37	74
16/12/2019	17.6	28.6	0	S	61	50
17/12/2019	18.3	25.6	0	SW	37	60
18/12/2019	16	25.7	0	ENE	35	56
19/12/2019	19.1	28.7	0	NNE	63	54
20/12/2019	18.8	27.2	0	WSW	35	72
21/12/2019	17.9	27.6	0	NNE	56	67
22/12/2019	21.9	25.5	0	S	57	85
23/12/2019	19.5	27.3	0	WSW	39	65
24/12/2019	21.7	27.4	1	NE	48	79

25/12/2019	20.7	25.9	8	ESE	33	81
26/12/2019	16.9	26.4	4	E	28	93
27/12/2019	16.9	27.4	0	E	31	58
28/12/2019	15	27.8	0	NE	43	53
29/12/2019	18.3	29.3	0	NE	54	55
30/12/2019	20.9	28.8	0	NNE	59	58
31/12/2019	21.6	30	0	NNE	69	55
1/01/2020	22	28.3	0	NNE	67	64
2/01/2020	20.9	28.3	0	NE	46	67
3/01/2020	21.9	28	0	NNE	54	65
4/01/2020	21.5	29.2	0	NNE	63	57
5/01/2020	21.5	28	0	SSW	57	68
6/01/2020	21.5	28.1	0	SSW	35	69
7/01/2020	22.6	29.4	0	NE	44	71
8/01/2020	22.7	30.7	0	NE	56	59
9/01/2020	20.5	30	0	ENE	37	61
10/01/2020	20.1	30.1	0	NNE	67	63
11/01/2020	25	34.5	0	SSE	54	61
12/01/2020	19.2	26.2	3	SSE	41	92
13/01/2020	18.2	27.3	0	S	31	66
14/01/2020	19.2	26.4	0	SW	28	74
15/01/2020	20.5	28.5	0	ENE	26	83
16/01/2020	23.6	30.5	0	NE	54	67
17/01/2020	20.7	24.9	4	NNE	35	83
18/01/2020	20.7	24.4	12	WSW	26	91

Date	MINIMUM Air Temperature (°C)	MAXIMUM Air Temperature (°C)	TOTAL Rain Gauge (mm)	AVERAGE Wind Direction DESCRIPTION	MAXIMUM Wind Speed (km/h)	9am Relative Humidity (%)
19/01/2020	20.5	28.9	85	NNE	41	87
20/01/2020	22.9	33	0	NW	61	66
21/01/2020	22.6	30.7	0	NE	48	62
22/01/2020	21.5	29.7	0	NNE	41	71
23/01/2020	23.6	33.6	0	NNE	63	69
24/01/2020	23.5	31.2	0	NNE	48	80

25/01/2020	21	30.4	0	N	39	77
26/01/2020	23.6	29	0	NNE	59	70
27/01/2020	24.2	29.3	0	NNE	48	65
28/01/2020	23.6	29.6	0	NNE	57	65
29/01/2020	21.3	28.7	0	S	37	76
30/01/2020	23.6	28.8	0	NNE	31	76
31/01/2020	24.6	30	0	NNE	54	63
1/02/2020	23.6	30.8	0	NNE	63	63
2/02/2020	24.1	33.3	0	NE	59	65
3/02/2020	21.5	35.3	10	S	81	73
4/02/2020	20.2	21.8	3	SSW	61	74
5/02/2020	18.9	24.2	0	WSW	26	72
6/02/2020	19.1	25.4	2	E	48	92
7/02/2020	19.3	28.1	69	ENE	43	85
8/02/2020	21.1	25.9	6	SSE	30	92
9/02/2020	21.1	24.3	95	ENE	52	95
10/02/2020	21	28.7	59	NNE	50	88
11/02/2020	20.5	27.1	35	ENE	41	92
12/02/2020	20.6	25.4	32	NE	41	93
13/02/2020	21.5	26.6	42	ESE	35	94
14/02/2020	21	27.2	6	SSW	39	93
15/02/2020	18.6	29	0	NE	28	71
16/02/2020	22.2	26.5	1	S	33	89
17/02/2020	22.4	29.5	0	SW	63	93
18/02/2020	19.1	31.4	13	NE	50	70
19/02/2020	24.4	35.5	0	SSW	39	73
20/02/2020	21	27.8	3	SSE	31	58
21/02/2020	19.9	26.7	0	ESE	28	71
22/02/2020	19.6	25.5	3	WSW	28	92
23/02/2020	18.4	24.6	13	S	22	88
24/02/2020	19.2	24.5	58	SSW	22	95
25/02/2020	19.8	27.7	20	ENE	30	81
26/02/2020	19.7	30.3	0	NNE	44	69

27/02/2020	18.7	28.7	1	SSW	41	76
28/02/2020	19.2	28.6	0	SSW	43	78

Appendix C – Field data

Table C 1: Underpass camera data recorded during spring/summer and winter of year two operational monitoring WC2NH, 2020.

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
12 (west)	G	10/10/2019	0139	Black Rat	Complete	E	Pr	17	
12 (west)	G	10/10/2019	0438	Cat	Complete	W	D	19-20	black cat
12 (west)	G	12/10/2019	2217	house mouse	Complete	E	Pr	28	
12 (west)	G	13/10/2019	2153	Cat	Complete	E	D	29-30	tabby
12 (west)	G	15/10/2019	0201	Black Rat	Complete	E	Pr	42	
12 (west)	G	15/10/2019	2006	Black Rat	Complete	W	D	86	
12 (west)	G	18/10/2019	0306	house mouse	Complete	E	Pr	111	
12 (west)	G	18/10/2019	2332	Black Rat	Complete	E	D	152-153	
12 (west)	G	20/10/2019	1946	Black Rat	Complete	W	D	165	
12 (west)	G	22/10/2019	2327	Black Rat	Complete	E	D	13	
12 (west)	G	5/11/2019	2350	Black Rat	Complete	E	D	23	
12 (west)	G	6/11/2019	1948	Black Rat	Complete	W	D	28	
12 (west)	G	7/11/2019	0047	Cat	Complete	E	D	29	
12 (west)	G	7/11/2019	0447	Black Rat	Complete	E	D	30	
12 (west)	G	7/11/2019	1946	Black Rat	Complete	W	D	35	
12 (west)	G	11/11/2019	2140	Black Rat	Complete	W	Pr	52	
12 (west)	G	12/11/2019	1006	EW dragon	Complete	W	D	53	
12 (west)	G	12/11/2019	1956	Black Rat	Complete	W	D	55	
12 (west)	G	13/11/2019	0022	Black Rat	Complete	E	D	56	
12 (west)	G	17/11/2019	0103	Black Rat	Complete	E	Pr	63	
12 (west)	G	17/11/2019	2200	Black Rat	Complete	W	D	64	
12 (west)	G	17/11/2019	2259	Black Rat	Complete	E	D	65	
12 (west)	G	18/11/2019	2010	Black Rat	Complete	W	D	66	
12 (west)	G	19/11/2019	0148	Black Rat	Complete	E	D	67	
12 (west)	G	26/11/2019	2308	Black Rat	Complete	E	D	9	
12 (west)	G	2/12/2019	0015	Black Rat	Complete	E	D	20	
12 (west)	G	2/12/2019	2049	Black Rat	Complete	E	D	24	
12 (west)	G	6/12/2019	0144	Black Rat	Complete	E	D	34	
12 (west)	G	7/12/2019	0123	Black Rat	Complete	E	D	37-38	
12 (west)	G	14/12/2019	0158	Black Rat	Complete	E	D	45	
12 (west)	G	14/12/2019	2252	Northern brown bandicoot	Complete	E	Pr	46-47	
12 (west)	G	21/06/2020	2103	Cat	Complete	E	D	9-10	Tabby

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
12 (west)	G	24/06/2020	0303	Fox	Incomplete	W-E	D	16-18	
12 (west)	G	25/06/2020	2218	Cat	Complete	E	D	23	Tabby (likely same individual)
12 (west)	G	4/07/2020	2151	Fox	Complete	E	D	24	
12 (west)	G	6/07/2020	0532	Swamp wallaby	Complete	E	D	25	
12 (west)	G	15/07/2020	0042	Fox	Complete	E	D	30	
12 (west)	G	16/07/2020	2204	Bandicoot	Complete	E	D	32	
12 (west)	G	18/07/2020	1928	Cat	Complete	W	D	35	Black cat
12 (west)	G	20/07/2020	0118	Cat	Complete	W	D	36	Tabby
12 (west)	G	16/07/2020	2204	Northern brown bandicoot	Complete	E	D	32	
12 (west)	G	25/07/2020	0032	Bandicoot spp	Complete	E	D	56	
12 (west)	G	26/07/2020	0013	Cat	Complete	W	D	57	black cat
12 (west)	G	26/07/2020	0133	Fox	Complete	W	D	58	
12 (west)	G	28/07/2020	2152	house mouse	Complete	E	D	13	
12 (west)	G	29/07/2020	1906	Cat	Complete	E	D	14	Tabby
12 (west)	G	30/07/2020	1247	Fox	Complete	W	D	15	
12 (west)	G	9/08/2020	2041	Cat	Complete	E	D	16	Tabby
12 (west)	G	12/08/2020	1215	Dog	Incomplete	E-W	D	18-19	Dark Brown
12 (west)	G	12/08/2020	2254	Cat	Complete	W	D	22	Tabby
12 (west)	G	13/08/2020	1009	Dog	Complete	E	D	23	Dark Brown
12 (west)	G	14/08/2020	2317	Northern brown bandicoot	Complete	W	D	26	
12 (west)	G	14/08/2020	2332	Cat	Complete	W	D	27	Black Cat
12 (west)	G	15/08/2020	0158	Northern brown bandicoot	Complete	E	D	28	
12 (west)	G	16/08/2020	2205	Bandicoot spp	Complete	E	D	30	
12 (west)	G	17/08/2020	1942	Bandicoot spp	Complete	W	D	31	
12 (west)	G	17/08/2020	2048	Bandicoot spp	Complete	E	D	32	
12 (west)	G	19/08/2020	0759	Dog	Complete	E	D	33	
12 (west)	G	24/08/2020	1102	Dog	Complete	E	D	34	
12 (west)	G	27/08/2020	2119	Fox	Complete	W	D	40	
12 (west)	G	27/08/2020	2202	Cat	Complete	E	D	41	
12 (west)	G	29/08/2020	0245	Fox	Complete	E	D	43	
12 (west)	G	31/08/2020	0537	Fox	Complete	E	D	44	
12 (west)	G	1/09/2020	0345	Fox	Complete	W	D	45	
11 (East)	FF	17/12/2019	0041	Black Rat	Complete	E	D	61	
11 (East)	FF	24/06/2020	2357	Rodent spp	Complete	E	D	11-23	Several crossings back and forth
11 (East)	FF	26/10/19	0433	Cat	Complete	E	D	69	tabby
11 (East)	G	20/11/2019	nil						
11 (East)	G	10/10/2019	0435	Cat	Complete	W	D	29	black cat

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
11 (East)	G	13/10/2019	2155	Cat	Complete	E	D	32	tabby
11 (East)	G	26/10/2019	0430	Cat	Complete	W	D	37	
11 (East)	G	7/11/2019	0049	Cat	Complete	E	D	84-85	
11 (East)	G	8/11/2019	1545	EW Dragon	Complete	E	Pr	105	
11 (East)	G	29/07/2020	1909	Cat	Complete	E	D	10	Tabby
11 (East)	G	30/07/2020	0246	Fox	Complete	E	D	11	
11 (East)	G	4/08/2020	2033	Cat	Complete	E	D	12-13	Tabby
11 (East)	G	4/08/2020	2039	Cat	Complete	E	D	14	Tabby
11 (East)	G	9/08/2020	2045	Cat	Complete	E	D	16	Tabby
11 (East)	G	12/08/2020	2251	Cat	Complete	E	D	30	Tabby
11 (East)	G	13/08/2020	1010	Dog	Complete	E	D	31	Dark Brown
11 (East)	G	14/08/2020	2318	Cat	Complete	E	D	33	Black Cat
11 (East)	G	15/08/2020	0158	Bandicoot	Complete	E	D	34	
11 (East)	G	16/08/2020	2206	Bandicoot	Complete	E	D	36	
11 (East)	G	17/08/2020	2049	Bandicoot	Complete	E	D	38	
11 (East)	G	19/08/2020	0800	Dog	Complete	E	D	39	Dark Brown
11 (East)	G	24/08/2020	1143	Dog	Complete	E	D	41	Dark Brown
11 (East)	G	27/08/2020	2118	Fox	Complete	W	D	51	
11 (East)	G	27/08/2020	2205	Cat	Complete	E	D	52-54	Tabby
11 (East)	G	29/08/2020	0246	Fox	Complete	E	D	59	
11 (East)	G	31/08/2020	0431	Swamp wallaby	Complete	E	D	61	
11 (East)	G	31/08/2020	0537	Fox	Complete	E	D	62	
11 (East)	G	1/09/2020	0344	Fox	Complete	W	D	63	
10 (west)	FF			Nil (Summer)					
10 (west)	G	26/10/2019	2219	SEBtP	Incomplete	E-W	Pr	41,43-44	
10 (west)	G	27/10/2019	2055	Black Rat	Complete	W	D	45	
10 (west)	G	7/11/2019	0109	SEBtP	Complete	W	Pr	75	
10 (west)	G	25/11/2019	2220	Black Rat	Incomplete	EXM	D	11-14, 16	
10 (west)	G	13/10/2019	2219	cat	Complete	E	D	19	tabby
10 (west)	G	21/10/2019	1314	EW Dragon	Complete	E	Pr	142	
10 (west)	G	21/10/2019	1457	Lace Monitor	Complete	E	D	11	
10 (west)	G	22/10/2019	1321	Lace Monitor	Complete	W	D	24	
10 (west)	G	24/10/2019	2233	Bandicoot spp.	Incomplete	W-E	D	31-32	
10 (west)	G	25/10/2019	1443	Lace Monitor	Complete	E	D	40	
10 (west)	G	28/10/2019	0220	Bandicoot spp	Complete	W	D	42	
10 (west)	G	31/10/2019	0446	Black Rat	Complete	E	D	46	
10 (west)	G	31/10/2019	1254	Lace Monitor	Complete	E	D	47	
10 (west)	G	1/11/2019	2329	Btposs spp	Complete	W	D	49	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
10 (west)	G	7/11/2019	0255	Northern brown bandicoot	Complete	W	Pr	55	
10 (west)	G	8/11/2019	0159	Bandicoot spp	Complete	W	D	58	
10 (west)	G	9/11/2019	0404	Cat	Complete	W	D	61	tabby
10 (west)	G	9/11/2019	2242	Koala	Complete	W	D	63	
10 (west)	G	12/11/2019	0311	Bandicoot spp	Complete	W	D	67	
10 (west)	G	13/11/2019	0139	Bandicoot spp	Complete	W	D	77	
10 (west)	G	16/11/2019	0106	Bandicoot spp	Complete	W	D	80	
10 (west)	G	18/11/2019	1158	Lace Monitor	Complete	W	D	93	
10 (west)	G	19/11/2019	0210	Bandicoot spp	Complete	W	D	94	
10 (west)	G	22/11/2019	0149	Bandicoot spp.	Complete	W	D	15	
10 (west)	G	22/11/2019	0216	Black Rat	Complete	W	D	16	
10 (west)	G	22/11/2019	1559	Lace Monitor	Complete	E	D	19	
10 (west)	G	23/11/2019	0003	Bandicoot spp.	Complete	W	Pr	20	
10 (west)	G	25/11/2019	2252	Black Rat	Complete	EXM	D	31	
10 (west)	G	28/11/2019	1403	Lace Monitor	Complete	E	D	46	
10 (west)	G	4/12/2019	0055	Swamp wallaby	Complete	E	D	110	
10 (west)	G	4/12/2019	0539	Swamp wallaby	Complete	W	Pr	111	
10 (west)	G	4/12/2019	2350	SEBtP	Complete	W	D	112	
10 (west)	G	6/12/2019	1535	Lace Monitor	Complete	E	D	118	
10 (west)	G	22/06/2020	2023	Wallaby spp (probable red-neck)	Complete	W	D	10	
10 (west)	G	23/06/2020	2024	Wallaby spp (probable swamp wallaby)	Complete	W	D	11	
10 (west)	G	24/06/2020	0651	Wallaby spp (probable swamp wallaby)	Complete	E	D	12	
10 (west)	G	24/06/2020	2058	Fox	Complete	E	D	17	
10 (west)	G	28/06/2020	1855	Swamp wallaby	Complete	W	D	18	
10 (west)	G	3/07/2020	1707	Wallaby spp	Complete	E	D	19	
10 (west)	G	5/07/2020	0357	Fox	Complete	E	D	20	
10 (west)	G	5/07/2020	1816	Fox	Incomplete	W-E	D	20	
10 (west)	G	21/07/2020	2316	Cat	Complete	W	D	43	
10 (west)	G	30/07/2020	2228	Red neck Wallaby	Complete	E	D	20	
10 (west)	G	1/08/2020	0643	Wallaby spp	Complete	W	D	21	
10 (west)	G	6/08/2020	2025	Cat	Complete	E	D	23	Tabby
10 (west)	G	16/08/2020	0557	Wallaby spp	Complete	W	D	29	
10 (west)	G	19/08/2020	1741	Dog	Complete	W	D	31	
9 (East)	FF	17/12/2019	1049	Lace Monitor	Complete	W	D	187	
9 (East)	FF	4/12/2019	0653	Treecreeper spp.	Complete	E	Pr	176	
9 (East)	FF			Nil winter part 1					

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
9 (East)	G	17/12/2019	0659	Australian bushturkey	Incomplete	NDM	D	318	
9 (East)	G	13/10/2019	0447	Black Rat	Complete	W	Pr	8	
9 (East)	G	14/10/2019	2049	Black Rat	Complete	E	Pr	24	
9 (East)	G	21/10/2019	1459	Lace Monitor	Complete	E	D	128	
9 (East)	G	22/10/2019	1159	Lace Monitor	Complete	W	D	4-5	
9 (East)	G	22/10/2019	1315	Lace Monitor	Complete	W	D	6	
9 (East)	G	23/10/2019	2306	SEBtP	Complete	E	Pr	9	
9 (East)	G	24/10/2019	2229	Long-nosed bandicoot	Complete	W	Pr	10	
9 (East)	G	24/10/2019	2336	Bandicoot spp	Complete	E	D	11	
9 (East)	G	25/10/2019	0157	SEBtP	Complete	E	D	13-16	
9 (East)	G	29/10/2019	0229	SEBtP	Incomplete	W-E	Pr	19-23	
9 (East)	G	1/11/2019	2101	Bandicoot spp	Complete	E	D	26	
9 (East)	G	9/11/2019	2239	Koala	Complete	W	D	43	
9 (East)	G	21/11/2019	2150	Bandicoot spp.	Complete	E	D	4	
9 (East)	G	22/11/2019	0019	SEBtP	Incomplete	EXM	D	5	
9 (East)	G	2/12/2019	0116	Black Rat	Complete	E	D	40	
9 (East)	G	4/12/2019	0054	Swamp wallaby	Complete	E	Pr	67	
9 (East)	G	4/12/2019	0535	Swamp wallaby	Complete	W	D	68	
9 (East)	G	6/12/2019	1536	Lace Monitor	Complete	E	D	97	MB present
9 (East)	G	21/06/2020	2213	House mouse	Complete	E	D	3	
9 (East)	G	22/06/2020	2024	Wallaby spp	Complete	E	D	11	
9 (East)	G	24/06/2020	2055	Fox	Complete	W	D	18-20	
9 (East)	G	28/06/2020	1855	Wallaby spp.	Complete	E	D	21	
9 (East)	G	3/07/2020	1705	Swamp wallaby	Complete	W	D	29-31	
9 (East)	G	5/07/2020	0356	Fox	Complete	W	D	32	
9 (East)	G	5/07/2020	1814	Fox	Complete	W	D	33	
9 (East)	G	14/07/2020	0140	Cat	Complete	W	D	34-35	Tabby
9 (East)	G	26/07/2020	2036	Fox	Incomplete	W-E	D	131	
9 (East)	G	7/08/2020	1751	Swamp wallaby	Complete	E	D	9	
9 (East)	G	7/08/2020	0158	Wallaby spp	Complete	W	D	10	
8	FF	9/12/2019	0331	cat	Complete	E	D	115	Tabby
8	FF	9/10/2019	0407	SEBtP	Complete	E	Pr	3	
8	FF	9/10/2019	1955	SEBtP	Complete	W	D	14	
8	FF	10/10/2019	0317	2 x SEBtP	Complete	E	Pr	15	2 individuals
8	FF	10/10/2019	0349	SEBtP	Complete	W	D	16	
8	FF	12/10/2019	0445	SEBtP	Complete	E	Pr	28	
8	FF	12/10/2019	2149	SEBtP	Complete	W	D	29	
8	FF	13/10/2019	0235	2 x SEBtP	Complete	E	D	30	2 individuals

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
8	FF	13/10/2019	0401	SEBtP	Complete	E	D	31	
8	FF	13/10/2019	2018	SEBtP	Complete	E	Pr	33	
8	FF	14/10/2019	0027	SEBtP	Complete	W	D	34	
8	FF	14/10/2019	0514	SEBtP	Complete	E	Pr	36	
8	FF	14/10/2019	2022	SEBtP	Complete	W	D	44	
8	FF	15/10/2019	2107	SEBtP	Complete	E	D	57	
8	FF	17/10/2019	0419	SEBtP	Complete	E	D	62	
8	FF	18/10/2019	2055	SEBtP	Complete	E	D	73	
8	FF	19/10/2019	0119	2 x SEBtP	Complete	E	D	74	2 individuals
8	FF	21/10/2019	0046	SEBtP	Complete	E	D	92	
8	FF	21/10/2019	0329	2 x SEBtP	Complete	E	D	93	2 individuals
8	FF	21/10/2019	1927	SEBtP	Complete	E	Pr	101	
8	FF	22/10/2019	2345	SEBtP	Complete	W	D	3	
8	FF	24/10/2019	0133	SEBtP	Complete	W	Pr	6	
8	FF	24/10/2019	0243	SEBtP	Complete	W	Pr	7	
8	FF	24/10/2019	1933	SEBtP	Complete	E	Pr	9	
8	FF	24/10/2019	2232	SEBtP	Complete	E	D	12	
8	FF	25/10/2019	0129	SEBtP	Complete	W	D	13	
8	FF	25/10/2019	0249	2 x SEBtP	Complete	E	D	14	2 individuals
8	FF	27/10/2019	2306	SEBtP	Incomplete	E-W	Pr	21-22	
8	FF	28/10/2019	0118	SEBtP	Complete	W	D	24	
8	FF	30/10/2019	0141	2 x SEBtP	Complete	E	D	30	2 individuals (mother and young)
8	FF	31/10/2019	2348	SEBtP	Complete	E	D	32	
8	FF	1/11/2019	0215	2 x SEBtP	Complete	E	Pr	33	2 individuals (mother and young)
8	FF	1/11/2019	2141	SEBtP	Complete	W	Pr	35	
8	FF	2/11/2019	0004	SEBtP	Complete	W	D	37	
8	FF	4/11/2019	0333	2 x SEBtP	Complete	E	Pr	40	2 individuals (mother and young)
8	FF	6/11/2019	0126	SEBtP	Complete	W	D	43	
8	FF	6/11/2019	0231	2 x SEBtP	Complete	E	D	44	2 individuals (mother and young)
8	FF	10/11/2019	0144	SEBtP	Complete	E	D	51	
8	FF	11/11/2019	0146	2 x SEBtP	Complete	E	D	55	2 individuals (mother and young)
8	FF	14/11/2019	0244	2 x SEBtP	Complete	E	D	61	3 individuals (mother and young)
8	FF	15/11/2019	0127	SEBtP	Complete	E	Pr	62	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
8	FF	15/11/2019	2053	SEBtP	Complete	W	D	66	
8	FF	18/11/2019	0214	2 x SEBtP	Complete	E	D	70	2 individuals (mother and young)
8	FF	19/11/2019	2229	SEBtP	Complete	E	D	76	
8	FF	22/11/2019	0126	2 x SEBtP	Complete	E	D	2	2 individuals (mother and young)
8	FF	22/11/20191	2230	2 x SEBtP	Complete	W	D	5	2 individuals (mother and young)
8	FF	25/11/2019	0335	2 x SEBtP	Complete	E	D	9	2 individuals (mother and young)
8	FF	27/11/2019	0111	SEBtP	Complete	E	D	12	
8	FF	27/11/2019	2218	SEBtP	Complete	E	D	18	
8	FF	28/11/2019	0204	2 x SEBtP	Complete	E	D	19	2 individuals (mother and young)
8	FF	28/11/2019	2244	BtPoss spp	Complete	W	D	24	
8	FF	30/11/2019	0339	2 x SEBtP	Complete	E	D	25	2 individuals (mother and young)
8	FF	30/11/2019	2140	BtPoss spp	Complete	W	D	27	
8	FF	1/12/2019	2311	BtPoss spp	Complete	W	D	30	
8	FF	2/12/2019	0208	SEBtP	Complete	E	D	31-33	
8	FF	4/12/2019	0021	SEBtP	Complete	E	D	52	
8	FF	4/12/2019	0124	BtPoss spp	Complete	W	D	53	
8	FF	5/12/2019	1106	Small bird	Incomplete	NDM	Pr	66	
8	FF	6/12/2019	2155	SEBtP	Complete	E	Pr	73	
8	FF	7/12/2019	0151	SEBtP	Complete	E	D	74	
8	FF	9/12/2019	0250	BtPoss spp	Complete	W	D	84	
8	FF	10/12/2019	0204	BtPoss spp	Complete	W	D	89	
8	FF	10/12/2019	2318	BtPoss spp	Complete	W	Pr	95	
8	FF	11/12/2019	0025	SEBtP	Complete	E	D	96	
8	FF	12/12/2019	2333	SEBtP	Complete	E	D	100	
8	FF	13/12/2019	0218	BtPoss spp	Complete	W	D	101	
8	FF	14/12/2019	2354	SEBtP	Incomplete	W-E	D	102-104	
8	FF	15/12/2019	2337	BtPoss spp	Complete	W	Pr	106	
8	FF	16/12/2019	2329	SEBtP	Complete	E	D	110	
8	FF	17/12/2019	0244	BtPoss spp	Complete	W	Pr	111	
8	FF	17/12/2019	2355	SEBtP	Complete	E	Pr	116	
8	FF	28/06/2020	0209	Black Rat	Complete	E	D	9	
8	FF	28/06/2020	0337	Black Rat	Complete	W	D	10	
8	FF	28/06/2020	2310	Rodent spp	Complete	E	D	11	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
8	FF	29/06/2020	0130	Rodent spp	Complete	E	D	12	Only capture tail
8	FF	29/06/2020	2316	Rodent spp	Complete	E	D	13	
8	FF	30/06/2020	2308	Rodent spp	Complete	E	D	15	
8	FF	3/07/2020	0241	Rodent spp	Complete	E	D	17	
8	FF	4/07/2020	0209	Rodent spp	Complete	E	D	19	
8	FF	4/07/2020	0508	Black Rat	Complete	W	D	20	
8	FF	6/07/2020	0407	Rodent spp	Complete	E	D	22	
8	FF	6/07/2020	1814	Rodent spp	Complete	E	D	24	
8	FF	7/07/2020	1802	Rodent spp	Complete	E	D	26	
8	FF	10/07/2020	1800	Rodent spp	Complete	E	D	30	
8	FF	11/07/2020	2215	Rodent spp	Complete	E	D	32	
8	FF	12/07/2020	2333	Rodent spp	Complete	E	D	34	
8	FF	14/07/2020	2131	Rodent spp	Complete	E	D	36	
8	FF	15/07/2020	2232	Rodent spp	Complete	E	D	38	
8	FF	17/07/2020	0304	Rodent spp	Complete	E	D	43	
8	FF	25/07/2020	2258	Rodent spp	Complete	E	D	52	
8	FF	27/07/2020	0402	Rodent spp	Complete	E	D	54	
8	G	18/12/2019	0039	SEBtP	Complete	E	D	118	MB present
8	G	9/10/2019	1336	Lace Monitor	Complete	E	D	11	
8	G	10/10/2019	2356	SEBtP	Complete	W	Pr	45	
8	G	17/10/2019	2038	SEBtP	Complete	E	D	93	
8	G	19/10/2019	0038	SEBtP	Complete	W	D	101	
8	G	19/10/2019	1224	Lace Monitor	Complete	W	D	108	
8	G	20/10/2019	2245	Cat	Complete	E	D	115	tabby
8	G	21/10/2019	0045	SEBtP	Complete	E	Pr	116	
8	G	22/10/2019	0437	Swamp wallaby	Complete	E	D	126	
8	G	23/10/2019	1037	Lace Monitor	Complete	W	D	7	
8	G	23/10/2019	1452	Lace Monitor	Complete	E	D	8	
8	G	27/10/2019	1324	Lace Monitor	Complete	W	D	28	
8	G	27/10/2019	1524	Lace Monitor	Complete	E	D	30	
8	G	27/10/2019	1612	Lace Monitor	Complete	E	D	31	
8	G	28/10/2019	1128	Lace Monitor	Complete	W	D	40	
8	G	28/10/2019	1504	Lace Monitor	Complete	W	D	41	
8	G	29/10/2019	1002	Lace Monitor	Complete	W	D	48	
8	G	1/11/2019	1010	Lace Monitor	Complete	W	D	58	
8	G	1/11/2019	1450	Lace Monitor	Complete	E	D	60	
8	G	4/11/2019	1425	Lace Monitor	Complete	W	D	69	
8	G	6/11/2019	0956	Lace Monitor	Complete	W	D	75	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
8	G	6/11/2019	1317	Lace Monitor	Incomplete	E-W	D	77-78	
8	G	6/11/2019	1413	Lace Monitor	Complete	E	D	79	
8	G	7/11/2019	1531	Lace Monitor	Complete	E	D	87	
8	G	12/11/2019	1936	Wallaby spp.	Complete	E	D	130	
8	G	13/11/2019	1328	Lace Monitor	Complete	W	D	134	
8	G	15/11/2019	1125	Lace Monitor	Complete	W	D	150	
8	G	15/11/2019	1523	Lace Monitor	Complete	E	D	152	
8	G	17/11/2019	1052	Lace Monitor	Complete	E	D	167-169	
8	G	18/11/2019	1214	Lace Monitor	Complete	W	Pr	182	
8	G	25/11/2019	0606	Swamp wallaby	Complete	W	D	23-24	
8	G	28/11/2019	1148	Lace Monitor	Complete	E	D	41	
8	G	30/11/2019	1014	Lace Monitor	Complete	W	D	56	
8	G	2/12/2019	1155	Lace Monitor	Complete	W	D	62	
8	G	3/12/2019	1450	Lace Monitor	Complete	W	D	72	
8	G	4/12/2019	1148	Lace Monitor	Complete	W	D	82	
8	G	7/12/2019	1316	Lace Monitor	Complete	W	D	152	
8	G	8/12/2019	1115	Lace Monitor	Complete	W	D	159	
8	G	8/12/2019	1439	Lace Monitor	Complete	E	Pr	160	
8	G	9/12/2019	0645	Swamp wallaby	Complete	E	Pr	167	
8	G	9/12/2019	0750	Swamp wallaby	Complete	W	D	173	
8	G	12/12/2019	1445	Lace Monitor	Complete	W	D	181	
8	G	15/12/2019	1141	Lace Monitor	Complete	E	Pr	185	
8	G	17/12/2019	0609	Swamp wallaby	Complete	E	D	208	
8	G	23/06/2020	2245	Fox	Complete	E	D	13	
8	G	24/06/2020	2049	Fox	Complete	E	D	20	
8	G	25/06/2020	2147	Fox	Complete	W	D	22	
8	G	26/06/2020	2244	Fox	Complete	W	D	24	
8	G	27/06/2020	2009	Fox	Incomplete	E-W	D	25	
8	G	27/06/2020	2227	Fox	Complete	E	D	26	
8	G	28/06/2020	0342	Fox	Complete	E	D	27	Injured hind leg
8	G	28/06/2020	2225	Fox	Complete	W	D	28	
8	G	2/07/2020	2219	European Hare	Incomplete	E-W	D	30	
8	G	3/07/2020	0148	European Hare	Complete	E	D	31	
8	G	3/07/2020	0250	European Hare	Complete	W	D	32	
8	G	5/07/2020	0532	Fox	Complete	E	D	33	
8	G	10/07/2020	0136	Fox	Complete	W	D	35	Black socks
8	G	14/07/2020	2345	Fox	Complete	W	D	41	Black socks
8	G	15/07/2020	2206	Fox	Complete	W	D	42	Black socks

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
8	G	21/07/2020	2323	Fox	Complete	W	D	52	Black socks
8	G	24/07/2020	0020	Fox	Complete	E	D	68	
8	G	26/07/2020	0227	Fox	Complete	E	D	69	
8	G	30/07/2020	0253	Cat	Complete	W	D	4	Tabby
8	G	30/07.2020	0329	Fox	Complete	E	D	5	
8	G	31/07/2020	0103	Fox	Complete	W	D	6	
8	G	3/08/2020	0348	Fox	Complete	E	D	7	
8	G	3/08/2020	1857	Cat	Complete	W	D	8	Black Cat
8	G	7/08/2020	0551	Cat	Complete	E	D	9	Black Cat
8	G	7/08/2020	1508	Cat	Complete	W	D	10	Black Cat
8	G	9/08/2020	0328	Fox	Complete	E	D	11	
8	G	12/08/2020	2036	Cat	Complete	E	D	20	Black Cat
8	G	14/08/2020	0755	Cat	Complete	E	D	21	Tabby
8	G	14/08/2020	0759	Cat	Complete	W	D	22	Tabby
8	G	17/08/2020	1849	Fox	Complete	W	D	25	
8	G	18/08/2020	1321	Lace Monitor	Complete	W	D	26	
8	G	20/08/2020	0015	Fox	Complete	E	D	27	
8	G	21/08/2020	0240	Fox	Complete	E	D	28	
7	FF	17/12/2019	1644	Swamp wallaby	Complete	W	D	212-213	
7	FF	9/10/2019	2056	SEBtP	Incomplete	W-E	D	35-39	
7	FF	9/10/2019	2217	SEBtP	Complete	W	D	40-43	
7	FF	9/10/2019	2316	SEBtP	Complete	W	D	44-45	
7	FF	10/10/2019	0116	SEBtP	Complete	E	D	46-47	
7	FF	12/10/2019	2122	2 x SEBtP	Complete	W	D	60	2 individuals (mother and joey)
7	FF	13/10/2019	0305	SEBtP	Incomplete	E-W	D	61-64	
7	FF	20/10/2019	0154	SEBtP	Incomplete	E-W	D	109-108	
7	FF	20/10/2019	0814	SEBtP	Complete	E	D	110	
7	FF	20/10/2019	1942	SEBtP	Incomplete	E-W	D	117-118	
7	FF	20/10/2019	2358	2 x SEBtP	Complete	W	D	119	2 individuals (mother and joey)
7	FF	21/10/2019	0121	SEBtP	Complete	W	D	121	
7	FF	22/10/2019	0133	SEBtP	Complete	W	D	130	
7	FF	22/10/2019	2104	SEBtP	Complete	E	D	2	
7	FF	22/10/2019	2247	SEBtP	Complete	W	D	3	
7	FF	23/10/2019	0021	2 x SEBtP	Complete	E	D	5	2 individuals (mother and joey)
7	FF	23/10/2019	0249	SEBtP	Complete	E	D	7	
7	FF	23/10/2019	1959	SEBtP	Complete	E	D	10	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
7	FF	23/10/2019	2126	SEBtP	Complete	E	D	11	
7	FF	24/10/2019	0419	SEBtP	Complete	W	D	12	
7	FF	24/10/2019	2204	SEBtP	Complete	E	D	13	
7	FF	24/10/2019	2240	SEBtP	Complete	W	D	14	
7	FF	25/10/2019	2253	SEBtP	Complete	E	D	15	
7	FF	27/10/2019	0031	SEBtP	Complete	E	D	16	
7	FF	27/10/2019	0219	2 x SEBtP	Complete	E	D	17	2 individuals (mother and joey)
7	FF	27/10/2019	2047	SEBtP	Complete	E	D	18	
7	FF	27/10/2019	2303	SEBtP	Complete	E	D	19	
7	FF	29/10/2019	2135	SEBtP	Complete	E	D	22	
7	FF	30/10/2019	2109	Antechinus spp	Complete	E	D	25	
7	FF	30/10/2019	2317	2 x SEBtP	Complete	W	D	27	2 individuals (mother and joey)
7	FF	31/10/2019	0107	Antechinus spp	Complete	E	D	28	
7	FF	1/11/2019	0442	Antechinus spp	Complete	E	D	31	
7	FF	2/11/2019	0051	Antechinus spp	Complete	E	D	38	
7	FF	3/11/2019	0035	Antechinus spp	Complete	E	D	42-44	
7	FF	4/11/2019	0208	Black Rat	Complete	E	D	52-53	
7	FF	5/11/2019	0036	2 x SEBtP	Complete	W	D	54	2 individuals (mother and joey)
7	FF	5/11/2019	2102	SEBtP	Complete	E	D	56	
7	FF	6/11/2019	2238	2 x SEBtP	Complete	W	D	58	2 individuals (mother and joey)
7	FF	7/11/2019	0331	Antechinus spp	Complete	E	D	59	
7	FF	8/11/2019	0227	SEBtP	Complete	W	D	64	
7	FF	11/11/2019	2140	SEBtP	Complete	E	D	69	
7	FF	12/11/2019	0055	2 x SEBtP	Complete	W	D	70	2 individuals (mother and joey)
7	FF	13/11/2019	2253	SEBtP	Complete	E	D	77	
7	FF	18/11/2019	2320	2 x SEBtP	Complete	W	D	82	2 individuals (mother and joey)
7	FF	20/11/2019	0111	SEBtP	Complete	E	D	88	
7	FF	20/11/2019	0230	SEBtP	Complete	W	D	89	
7	FF	25/11/2019	2323	2 x SEBtP	Complete	W	D	5	2 individuals (mother and joey)
7	FF	27/11/2019	0339	SEBtP	Complete	E	D	6-7	
7	FF	27/11/2019	2111	SEBtP	Complete	W	D	8	
7	FF	28/11/2019	0124	SEBtP	Complete	W	D	9	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
7	FF	28/11/2019	2034	SEBtP	Complete	E	D	20	
7	FF	28/11/2019	2034	SEBtP	Complete	E	D	21	
7	FF	28/11/2019	2154	SEBtP	Complete	W	D	24-25	
7	FF	28/11/2019	2309	SEBtP	Complete	W	D	27-28	
7	FF	1/12/2019	2107	SEBtP	Complete	E	D	29	
7	FF	6/12/2019	0156	SEBtP	Complete	E	D	47	
7	FF	6/12/2019	2223	SEBtP	Complete	W	D	51	
7	FF	9/12/2019	0338	SEBtP	Complete	E	D	58-59	
7	FF	9/12/2019	2140	SEBtP	Complete	W	D	60	
7	FF	9/12/2019	2231	SEBtP	Complete	E	D	61-62	
7	FF	10/12/2019	0438	SEBtP	Complete	E	D	63	
7	FF	10/12/2019	2303	SEBtP	Complete	W	D	69	
7	FF	11/12/2019	0332	SEBtP	Complete	E	D	70	
7	FF	11/12/2019	2046	SEBtP	Complete	W	Pr	72	
7	FF	13/12/2019	0423	SEBtP	Complete	E	D	76	
7	FF	13/12/2019	2354	BtPoss spp	Complete	W	D	77	
7	FF	14/12/2019	0429	SEBtP	Complete	W	D	78	
7	FF	14/12/2019	2139	SEBtP	Complete	W	D	80	
7	FF	15/12/2019	0431	SEBtP	Complete	E	D	82	
7	FF	12/07/2020	2127	Antechinus spp	Complete	E	D	11	
7	FF	13/07/2020	2022	Short-eared brushtail possum	Incomplete	W	D	12-13	
7	FF	19/07/2020	2148	Short-eared brushtail possum	Complete	E	D	18-19	
7	FF	20/07/2020	006	Short-eared brushtail possum	Complete	E	D	20	
7	FF	1/08/2020	2110	Short-eared brushtail possum	Complete	E	D	9-11	
7	FF	1/08/2020	2214	Short-eared brushtail possum	Complete	W	D	12-13	
7	FF	9/08/2020	2214	Short-eared brushtail possum	Complete	E	D	14-15	
7	FF	15/08/2020	0536	FF Melomys	Complete	E	Pr		
7	FF	18/08/2020	2104	Short-eared brushtail possum	Complete	W	D	18	
7	FF	27/08/2020	2028	Short-eared brushtail possum	Complete	E	D	23-24	
7	FF	1/09/2020	0113	Short-eared brushtail possum	Complete	W	D	25	
7	G	15/12/2019	2132	SEBtP	Complete	W	D	85	
7	G	9/10/2019	1046	Lace Monitor	Complete	W	Pr	12	
7	G	9/10/2019	2053	SEBtP	Complete	E	D	23	
7	G	10/10/2019	0702	Macropod spp	Complete	E	D	25	
7	G	10/10/2019	2233	Wallaby spp	Complete	W	D	31	
7	G	14/10/2019	0618	Macropod spp	Complete	E	D	34	
7	G	17/101/19	0616	Macropod spp	Complete	E	D	35	
7	G	17/10/2019	1147	Brush turkey	Complete	E	Pr	55	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
7	G	18/10/2019	0017	Red-necked wallaby	Complete	W	Pr	63	
7	G	19/10/2019	2237	Red-necked wallaby	Complete	W	Pr	79	
7	G	20/10/2019	1947	SEBtP	Complete	E	Pr	90	
7	G	21/10/2019	0015	Fox	Complete	E	Pr	91	
7	G	22/10/2019	0333	Macropod spp	Complete	E	Pr	97	
7	G	2210/19	0423	Macropod spp	Complete	E	D	98	
7	G	22/10/2019	1821	Echidna	Complete	W	D	5	
7	G	22/10/2019	2139	Macropod spp	Complete	W	D	6	
7	G	29/10/2019	0513	Macropod spp	Complete	E	Pr	24	
7	G	30/10/2019	0025	Red-necked wallaby	Complete	W	D	25-27	
7	G	1/11/2019	2037	BtPoss spp	Complete	E	D	28	
7	G	3/11/2019	0956	Macropod spp	Complete	E	D	29	
7	G	6/11/2019	0719	Macropod spp	Complete	E	D	32	
7	G	6/11/2019	1201	Lace Monitor	Complete	W	Pr	33	
7	G	7/11/2019	2038	Red-necked wallaby	Complete	W	D	36	
7	G	8/11/2019	2031	Macropod spp	Complete	E	D	46	
7	G	10/11/2019	0521	Macropod spp	Complete	E	D	48	
7	G	13/11/2019	0431	Macropod spp	Complete	E	D	56	
7	G	15/11/2019	0508	Macropod spp	Complete	E	D	61	
7	G	18/11/2019	0328	Macropod spp	Complete	E	D	72	
7	G	21/11/2019	0557	Wallaby spp.	Complete	E	D	7	
7	G	22/11/2019	2248	Black Rat	Incomplete	EXM	D	10-13	
7	G	23/11/2019	0131	Echidna	Complete	W	D	14	
7	G	23/11/2019	0525	Macropod spp	Complete	E	D	15	
7	G	26/11/2019	0002	Bandicoot spp.	Complete	W	D	19	
7	G	26/11/2019	0855	Macropod spp	Complete	E	D	20	
7	G	27/11/2019	0624	Macropod spp	Complete	E	D	22	
7	G	27/11/2019	1126	Lace Monitor	Complete	W	D	26	
7	G	28/11/2019	0820	Macropod spp	Complete	E	D	29	
7	G	29/11/2019	1414	Lace Monitor	Complete	W	D	36	
7	G	2/12/2019	0503	Macropod spp	Complete	E	Pr	40	
7	G	3/12/2019	0044	Long-nosed bandicoot	Complete	E	D	52	
7	G	4/12/2019	0921	Lace Monitor	Complete	E	D	62	
7	G	8/12/2019	0528	Macropod spp	Complete	E	D	101	
7	G	8/12/2019	0955	Lace Monitor	Complete	E	D	103	
7	G	15/12/2019	2213	Swamp wallaby	Complete	W	D	128	
7	G	17/12/2019	0015	Cat	Complete	E	Pr	139	tabby
7	G	22/06/2020	2212	Short-eared brushtail possum	Complete	E	D	6	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
7	G	23/06/2020	0001	Short-eared brushtail possum	Complete	E	D	7	
7	G	23/06/2020	2139	Short-eared brushtail possum	Complete	E	D	9	
7	G	26/06/2020	2031	Fox	Complete	E	D	16	
7	G	27/06/2020	0300	Fox	Complete	E	D	17	
7	G	28/06/2020	0039	Fox	Complete	E	D	19	
7	G	28/06/2020	0653	Fox	Complete	E	D	20	
7	G	29/06/2020	0143	Fox	Complete	E	D	23	
7	G	29/06/2020	0620	Fox	Complete	E	D	25	
7	G	30/06/2020	0310	Fox	Complete	W	D	26	x2
7	G	4/07/2020	0053	Fox	Complete	W	Pr	28	
7	G	4/07/2020	0150	Short-eared brushtail possum	Complete	W	Pr	29	
7	G	5/07/2020	0103	wallaby spp	Complete	E	D	30	
7	G	5/07/2020	1859	Fox	Complete	E	D	32	
7	G	6/07/2020	0459	Fox	Complete	E	D	33	
7	G	7/07/2020	2217	Fox	Complete	W	D	34	
7	G	10/07/2020	0001	Fox	Complete	E	D	35	
7	G	13/07/2020	0304	fox	Complete	e	d	38	
7	G	15/07/2020	2222	Fox	Complete	E	D	43	
7	G	17/07/2020	2317	Cat	Complete	E	D	45	
7	G	19/07/2020	2249	Short-eared brushtail possum	Complete	W	D	47	
7	G	25/07/2020	2238	Rodent spp	Complete	E	D	49	
7	G	26/07/2020	2324	Fox	Complete	E	D	51	
7	G	27/07/2020	1633	Wallaby spp	Complete	W	D	52	
7	G	27/07/2020	1634	Wallaby spp	Complete	W	D	53	
7	G	27/07/2020	1712	Wallaby spp	Complete	E	D	54	
7	G	27/07/2020	2247	Fox	Complete	E	D	55	
7	G	29/07/2020	1208	Fox	Complete	E	D	5	
7	G	29/07/2020	2207	Cat	Complete	E	D	6	Tabby
7	G	31/07/2020	2056	Cat	Complete	E	D	7	Tabby
7	G	1/08/2020	05050	Fox	Complete	E	D	9	
7	G	5/08/2020	05050	Fox	Complete	E	D	10	
7	G	6/08/2020	0138	Cat	Complete	E	D	11	
7	G	7/08/2020	0027	Dog	Complete	E	D	12	
7	G	8/08/2020	1807	Fox	Complete	E	D	13	
7	G	11/08/2020	1253	Dog	Complete	W	D	15	
7	G	15/08/2020	1933	Fox	Complete	E	D	16	
7	G	15/08/2020	2344	Rodent spp	Complete	E	D	17	
7	G	16/08/2020	1938	Fox	Complete	E	D	18	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
7	G	17/08/2020	0108	Fox	Complete	E	D	19	
7	G	19/08/2020	1409	Fox	Complete	W	D	20-21	
7	G	19/08/2020	1758	Fox	Complete	E	D	22	
7	G	21/08/2020	0050	Fox	Complete	E	D	22	
7	G	22/08/2020	1338	Fox	Complete	E	D	25	
7	G	23/08/2020	1712	Swamp wallaby	Incomplete	E-W	D	30-31	
7	G	24/08/2020	0524	Fox	Complete	E	D	32	
7	G	25/08/2020	0652	Fox	Complete	E	D	35	
7	G	25/08/2020	1822	Fox	Complete	E	D	36	
7	G	26/08/2020	0123	Fox	Complete	E	D	37	
7	G	26/08/2020	1206	Lace Monitor	Complete	E	D	39	
7	G	28/08/2020	2341	Fox	Complete	E	D	40	
7	G	29/08/2020	0208	Short-eared brushtail possum	Complete	W	D	41	
7	G	29/08/2020	1055	Fox	Complete	E	D	42	
7	G	29/08/2020	1125	Fox	Complete	E	D	42	
7	G	31/08/2020	00167	Fox	Complete	E	D	43	
7	G	31/08/2020	0417	Small mammal	Complete	E	D	44	
6	FF	17/12/2019	0218	SEBtP	Complete	W	D	140	
6	FF	19/10/2019	1233	Lace Monitor	Complete	E		136-139	
6	FF	13/07/2020	0819	Rodent spp	Incomplete	NDM	D	59-63	
6	FF	4/08/2020	1936	Microbat spp	Present	NDM	D	97-98	Microbat sitting on furniture
6	FF	28/08/1010	0118	Antechinus spp	Complete	E	D	115-123	
6	FF	30/08/2020	1831	Antechinus spp	Complete	E	D	130-131	
6	FF	31/08/2020	1950	Antechinus spp	Complete	E	D	133-134	
6	FF	31/08/2020	2016	Antechinus spp	Complete	E	D	135-136	
6	FF								
6	FF								
6	G	20/10/2019	No fauna photos taken, only photos of camera retrieval - maybe camera malfunction				Pr		
6	G	14/10/2019	0421	Swamp wallaby	Incomplete	E-W	D	47	
6	G	19/10/2019	1115	Lace Monitor	Complete	EXM	D	106-167	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
6	G	19/10/2019	2146	Black Rat	Complete	E	Pr	173	
6	G	21/10/2019	2317	Black Rat	Complete	W		180	
6	G	23/06/2020	0559	Fox	Complete	E	D	7-9	
6	G	25/06/2020	0457	Fox	Complete	E	D	28-30	
6	G	25/06/2020	0829	Fox	Complete	E	D	31-33	
6	G	27/06/2020	2223	Fox	Complete	E	D	58-60	
6	G	30/06/2020	1143	Cat	Complete	E	D	112-114	x 2
6	G	5/07/2020	0631	Fox	Complete	E	D	160-162	
6	G	6/07/2020	0013	Swamp wallaby	Complete	W	D	169-178	
6	G	6/07/2020	0851	cat	Complete	E	D	181-183	
6	G	16/07/2020	0907	Fox	Complete	E	D	220-222	
6	G	17/07/2020	0600	Fox	Complete	W	D	223-224	
6	G	17/07/2020	0625	Swamp Wallaby	Complete	W	D	226-228	
6	G	19/07/2020	2208	Cat	Complete	E	D	229-231	Kitten
6	G	21/07/2020	0941	Cat	Complete	E	D	238-240	Kitten
6	G	26/07/2020	0829	Cat	Complete	E	D	247-249	Tabby
6	G	27/07/2020	0203	Bandicoot spp	Complete	E	D	250-252	
6	G	28/07/2020	0534	Fox	Complete	E	D	253-255	
6	G	28/07/2020	1734	Fox	Complete	W	D	235-237	
6	G	2/08/2020	0023	European Hare	Complete	E	D	238-242	
6	G	10/08/2020	1825	Fox	complete	w	d	265-267	
6	G	10/08/2020	2153	bandicoot spp	Complete	E	D	268-270	
6	G	10/08/2020	2238	Long-nosed bandicoot	Complete	W	D	270-273	
6	G	13/08/2020	0249	Cat	Complete	E	D	275-279	Tabby
6	G	18/08/2020	0507	Fox	Complete	E	D	292-294	
6	G	31/08/2020	0244	Fox	Complete	E	D	328-331	
5	North	20/10/2019	No photos taken - camera malfunction				D		
5	North	9/10/2019	2033	Black Rat	Complete	E	Pr	22	
5	North	17/10/2019	1956	house mouse	Complete	E	D	48	
5	North	21/10/2019	2112	Black Rat	Incomplete	NDM	D	60	
5	North	22/10/2019	2035	Rodent spp	Complete	E	Pr	4	
5	North	23/10/2019	2102	Black Rat	Complete	E	D	11	
5	North	23/10/2019	2158	Rodent spp	Complete	E	Pr	14	
5	North	23/10/2019	2224	Black Rat	Complete	E	D	16	
5	North	24/10/2019	0302	Rodent spp	Complete	E	Pr	18	
5	North	24/10/2019	2122	Black Rat	Complete	E	Pr	21	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
5	North	24/10/2019	2159	Black Rat	Incomplete	E-W	Pr	22	
5	North	25/10/2019	1503	EW dragon	Complete	W	D	26	
5	North	25/10/2019	2130	Black Rat	Incomplete	NDM	Pr	29	
5	North	25/10/2019	2148	Black Rat	Complete	E	D	32	
5	North	26/10/2019	2037	Black Rat	Incomplete	EXM	D	37,39	
5	North	26/10/2019	2119	Black Rat	Complete	W	D	40	
5	North	29/10/2019	2312	Black Rat	Complete	E	Pr	67	
5	North	1/11/2019	2019	Black Rat	Complete	E	D	73	
5	North	1/11/2019	2043	Black Rat	Complete	E	D	75	
5	North	1/11/2019	2249	Black Rat	Complete	W-E	Pr	79-81	
5	North	2/11/2019	2004	Black Rat	Complete	E	Pr	83	
5	North	4/11/2019	0254	Black Rat	Complete	E	D	88	
5	North	4/11/2019	0414	Black Rat	Complete	W	D	89	
5	North	4/11/2019	0441	Black Rat	Complete	E	D	90	
5	North	12/11/2019	1327	Swamp wallaby	Incomplete	NDM	D	137	
5	North	13/11/2019	0241	Swamp wallaby	Complete	E	Pr	138	
5	North	14/11/2019	2137	Black Rat	Incomplete	NDM	D	149	
5	North	16/11/2019	2035	Black Rat	Complete	E	D	175-176	
5	North	18/11/2019	2045	Black Rat	Complete	E	D	227-228	
5	North	22/11/2019	0303	Black Rat	Complete	E	D	36	
5	North	23/11/2019	0026	Long-nosed bandicoot	Complete	W	D	48	
5	North	23/11/2019	2058	Black Rat	Complete	E	Pr	62	
5	North	26/11/2019	2354	Black Rat	Complete	E	D	79	
5	North	15/12/2019	2307	Black Rat	Complete	E	D	336	
5	North	15/12/2019	2327	Black Rat	Complete	W	D	338	
5	North	16/12/2019	0044	Black Rat	Complete	E	D	339	
5	North	16/12/2019	0240	Black Rat	Complete	E	Pr	341	
5	North	16/12/2019	0503	Black Rat	Complete	E	D	343	
5	North	16/12/2019	0518	house mouse	Complete	E	Pr	345	
5	North	16/12/2019	2116	Black Rat	Complete	E	D	364	
5	North	16/12/2019	2310	house mouse	Complete	E	D	366	
5	North	17/12/2019	2149	Black Rat	Complete	E	D	391	
5	North	14/07/2020	2103	Black Rat	Incomplete	E-W	D	19-20	
5	North	26/07/2020	2341	Water Rat	Complete	E	D	22	
5	South	18/12/2019	0125	Black Rat	Complete	W	D	393	
5	South	8/10/2019	2055	Black Rat	Complete	E	D	16	
5	South	8/10/2019	2236	Black Rat	Complete	W	Pr	17	
5	South	8/10/2019	2326	Black Rat	Complete	E	Pr	18	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
5	South	9/10/2019	2021	Black Rat	Complete	E	D	63, 65	
5	South	10/10/2019	2131	Black Rat	Complete	E	Pr	76	
5	South	12/10/2019	0008	Water rat	Complete	E	Pr	88	
5	South	12/10/2019	2257	Water rat	Complete	E	D	93	
5	South	14/10/2019	2208	Water rat	Complete	W	D	105	
5	South	14/10/2019	2307	Water rat	Complete	E	D	106	
5	South	15/10/2019	0150	Water rat	Complete	E	D	107	
5	South	16/10/2019	2333	Water rat	Complete	E	Pr	117	
5	South	20/10/2019	0009	Black Rat	Complete	E	D	138	
5	South	20/10/2019	0243	Fox	Incomplete	E-W	D	139-140	
5	South	21/10/2019	2118	Black Rat	Incomplete	E-W	D	177-178	
5	South	21/10/2019	2135	Black Rat	Complete	W	D	179	
5	South	21/10/2019	2138	Black Rat	Incomplete	EXM	D	180-183	
5	South	21/10/2019	2153	Black Rat	Complete	E	D	184	
5	South	22/10/2019	2025	Black Rat	Incomplete	E-W	Pr	9-10	
5	South	23/10/2019	0211	Black Rat	Complete	E	Pr	11	
5	South	24/10/2019	0116	Black Rat	Complete	E	Pr	17	
5	South	24/10/2019	1958	Black Rat	Complete	E	D	18	
5	South	25/10/2019	0034	Black Rat	Complete	E	Pr	20	
5	South	25/10/2019	2036	Black Rat	Complete	E	D	26	
5	South	25/10/2019	2154	Rodent spp	Complete	E	D	27	
5	South	25/10/2019	2314	Rodent spp	Complete	E	Pr	29	
5	South	26/10/2019	0128	Black Rat	Complete	E	Pr	30	
5	South	26/10/2019	0204	Black Rat	Incomplete	E-W	Pr	31-32	
5	South	26/10/2019	2105	Black Rat	Complete	E	Pr	35	
5	South	26/10/2019	2242	Black Rat	Incomplete	NDM	D	36	
5	South	26/10/2019	2359	Water rat	Complete	E	Pr	39	
5	South	27/10/2019	0458	Black Rat	Complete	E	Pr	40	
5	South	27/10/2019	2012	Black Rat	Complete	E	D	46	
5	South	27/10/2019	2051	Rodent spp	Complete	E	Pr	48	
5	South	27/10/2019	2158	Black Rat	Complete	E	Pr	49	
5	South	28/10/2019	0507	Black Rat	Incomplete	NDM	Pr	50	
5	South	28/10/2019	1936	Black Rat	Complete	E	Pr	60	
5	South	28/10/2019	2341	Water rat	Complete	W	D	62	
5	South	29/10/2019	0141	Black Rat	Complete	W	Pr	63-64	
5	South	29/10/2019	2109	Black Rat	Complete	E	D	81	
5	South	29/10/2019	2250	Black Rat	Complete	W	D	82	
5	South	30/10/2019	0039	Rodent spp	Complete	E	Pr	84	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
5	South	30/10/2019	0149	Black Rat	Complete	E	Pr	86	
5	South	30/10/2019	2027	Black Rat	Complete	E	Pr	96	
5	South	30/10/2019	2134	Black Rat	Complete	E	Pr	97	
5	South	31/10/2019	2158	Black Rat	Complete	E	D	116	
5	South	1/11/2019	0308	Black Rat	Complete	W	Pr	117	
5	South	1/11/2019	2143	Black Rat	Complete	E	D	126	
5	South	1/11/2019	2301	Black Rat	Complete	W	D	128	
5	South	2/11/2019	0354	Rodent spp	Complete	E	D	129	
5	South	3/11/2019	0244	Rodent spp	Complete	E	D	137	
5	South	3/11/2019	2233	Water rat	Complete	W	D	139	
5	South	4/11/2019	0346	Rodent spp	Complete	E	D	140	
5	South	4/11/2019	1445	EW dragon	Incomplete	NDM	Pr	147	
5	South	4/11/2019	2322	Black Rat	Complete	E	D	148	
5	South	4/11/2019	2342	Black Rat	Complete	W	D	149	
5	South	6/11/2019	0025	Rodent spp	Complete	E	Pr	157	
5	South	6/11/2019	2045	SEBtP x 2	Complete	E	Pr	165	Mother and joey
5	South	6/11/2019	2112	SEBtP x 3	Complete	W	D	166	Mother and joey
5	South	6/11/2019	2250	Black Rat	Complete	W	D	167	
5	South	6/11/2019	2314	Black Rat	Complete	E	D	168	
5	South	7/11/2019	0242	Rodent spp	Complete	E	D	169	
5	South	8/11/2019	0025	Black Rat	Complete	E	D	182	
5	South	8/11/2019	0445	Black Rat	Complete	W	D	183	
5	South	8/11/2019	2052	Black Rat	Complete	W	Pr	197	
5	South	9/11/2019	0054	Black Rat	Complete	E	D	199	
5	South	9/11/2019	0133	Black Rat	Incomplete	W-E	Pr	200,202	
5	South	9/11/2019	0433	Black Rat	Complete	W	D	203	
5	South	10/11/2019	0124	Rodent spp	Complete	E	Pr	209-210	
5	South	11/11/2019	0248	Black Rat	Complete	W	Pr	230	
5	South	11/11/2019	0440	Black Rat	Complete	W	D	231	
5	South	12/11/2019	0427	Rodent spp	Complete	E	Pr	232	
5	South	12/11/2019	0801	Swamp wallaby	Complete	E	D	234	
5	South	12/11/2019	1239	Lace Monitor	Complete	W	D	237	
5	South	12/11/2019	1748	Swamp wallaby	Complete	E	D	239-242	
5	South	14/11/2019	1506	Swamp wallaby	Complete	W	D	261-262	
5	South	15/11/2019	1401	Lace Monitor	Complete	E	Pr	277	
5	South	15/11/2019	1705	Swamp wallaby	Incomplete	E-W	D	278-279	
5	South	15/11/2019	2047	Rodent spp	Complete	E	D	280	
5	South	15/11/2019	2201	Black Rat	Complete	W	D	281	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
5	South	15/11/2019	2319	Black Rat	Complete	W	D	282	
5	South	17/11/2019	2109	Small mammal	Complete	E	Pr	306	
5	South	17/11/2019	2342	Black Rat	Complete	E	Pr	307	
5	South	18/11/2019	0532	Swamp wallaby	Complete	E	D	310	
5	South	19/11/2019	1142	Lace Monitor	Complete	W	Pr	368	
5	South	19/11/2019	1945	Black Rat	Complete	E	Pr	369	
5	South	20/11/2019	0028	Black Rat	Complete	E	Pr	371	
5	South	20/11/2019	1951	Black Rat	Complete	E	D	8	
5	South	21/11/2019	1131	EW dragon	Complete	W	D	29	
5	South	21/11/2019	2327	Black Rat	Complete	W	D	30	
5	South	22/11/2019	0414	Black Rat	Complete	W	D	31	
5	South	22/11/2019	2121	Black Rat	Complete	E	D	71	
5	South	22/11/2019	2211	Black Rat	Incomplete	EXM	D	72-75	
5	South	24/11/2019	0153	Black Rat	Incomplete	W	Po	90	
5	South	24/11/2019	2306	Swamp rat	Complete	E	Pr	109	
5	South	25/11/2019	2246	Black Rat	Complete	E	D	120	
5	South	26/11/2019	2318	Black Rat	Complete	W	D	147	
5	South	27/11/2019	0001	Black Rat	Complete	E	D	148	
5	South	27/11/2019	0204	Black Rat	Complete	W	D	149-150	
5	South	2/12/2019	0052	Black Rat	Incomplete	E-W	D	231-233	
5	South	3/12/2019	1427	EW dragon	Complete	E	D	280	
5	South	9/12/2019	0039	Bush rat	Complete	W	Pr	394	
5	South	9/12/2019	0523	Swamp wallaby	Complete	E	Pr	395	
5	South	9/12/2019	0728	Swamp wallaby	Complete	E	Po	407	
5	South	11/12/2019	0422	Water rat	Complete	E	D	422	
5	South	16/12/2019	0120	house mouse	Incomplete	EXM	D	443-444	
5	South	17/12/2019	2217	Black Rat	Complete	W	D	473	
5	South	5/06/2020	2211	Water Rat	Complete	E	D	20	
5	South	10/06/2020	0315	Water Rat	Complete	E	D	21-22	
5	South	10/06/2020	0411	Water Rat	Incomplete	E-W	D	23-26	
5	South	15/06/2020	2007	Water Rat	Complete	E	D	27	
5	South	16/06/2020	0323	Water Rat	Complete	E	D	29-31	
5	South	17/06/2020	0406	Water Rat	Complete	W	D	32	
5	South	18/06/2020	0350	Water Rat	Complete	W	D	33	
5	South	18/06/2020	2011	Water Rat	Incomplete	EXM	D	35	
5	South	19/06/2020	0354	Water Rat	Complete	W	D	36-37	
5	South	20/06/2020	2307	Water Rat	Complete	E	D	38-40	
5	South	21/06/2020	0408	Water Rat	Complete	W	D	41	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
5	South	21/06/2020	1855	Water Rat	Complete	E	D	42	
5	South	22/06/2020	0325	Water Rat	Complete	W	D	44	
5	South	23/06/2020	2218	Water Rat	Complete	E	D	45	
5	South	24/06/2020	2156	Water Rat	Complete	W	D	46	
5	South	1/07/2020	2209	Water Rat	Complete	W	D	47	
5	South	7/07/2020	0606	Wood duck	Complete	W	D	7	x 2
5	South	7/07/2020	0716	Wood duck	Complete	E	D	8-10	
5	South	8/07/2020	1019	Wood duck	Complete	E	D	11-13	x 2
5	South	9/07/2020	1732	Water rat	Complete	E	D	14	
5	South	11/07/2020	0315	Water rat	Complete	E	D	15	
5	South	14/0/2020	0417	Water rat	Complete	E	D	16	
5	South	16/07/2020	0447	Water rat	Complete	E	D	17	
5	South	17/07/2020	1458	Rodent spp	Complete	E	D	18	
5	South	24/07/2020	0343	Water rat	Complete	E	D	19	
5	South	26/02/2020	1811	Water rat	Complete	E	D	22	
5	South	26/07/2020	2257	Microbat spp	Present	NDM	D	23-25	
4	FF	18/12/2019	0437	Black Rat	Complete	W	D	474-475	
4	FF	1/07/2020	0625	Microbat spp	Present	NDM	D	6	
4	FF	1/07/2020	2338	Cat	Complete	W	D	9	
4	FF	13/07/2020	0625	Microbat spp	Present	NDM	D	11	
4	FF	17/07/2020	2104	Antechinus spp	Complete	E	D	12-14	
4	FF	23/07/2020	2104	Antechinus spp	Complete	E	D	16	
4	FF	29/07/2020	2336	Antechinus spp	Complete	E	D	9	
4	FF	3/08/2020	1836	Antechinus spp	Complete	E	D	10	
4	FF	9/08/2020	2339	Antechinus spp	Complete	E	D	11	
4	FF	10/08/2020	1821	Antechinus spp	Complete	E	D	12	
4	FF	11/08/2020	1823	Antechinus spp	Complete	E	D	14	
4	FF	14/08/2020	0254	Antechinus spp	Complete	E	D	16	
4	FF	14/08/2020	2055	Antechinus spp	Complete	E	D	17	
4	FF	17/08/2020	0045	Antechinus spp	Complete	E	D	19	
4	FF	17/08/2020	1910	Antechinus spp	Complete	E	D	19	
4	FF	18/08/2020	2334	Antechinus spp	Complete	E	D	22	
4	FF	24/08/2020	0114	Rodent spp (probable FF)	Complete	E	D	23	
4	G	11/12/2019	1028	Lace Monitor	Complete	E	D	39	MB present
4	G	14/10/12019	0145	cat	Complete	E	D	33	Tabby
4	G	14/10/2019	0200	Fox	Complete	E	D	34	
4	G	16/10/2019	2253	Black Rat	Complete	E	D	48	
4	G	19/10/2019	0234	Koala	Complete	E	D	68	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
4	G	20/10/2019	1242	Lace Monitor	Complete	W	D	90	
4	G	21/10/2019	2227	Koala	Complete	W	D	95	
4	G	22/10/2019	2055	cat	Complete	W	D	4	tabby
4	G	23/10/2019	1217	Lace Monitor	Complete	E	D	6	
4	G	25/10/2019	1113	Lace Monitor	Complete	E	D	12	
4	G	28/10/2019	1203	Lace Monitor	Complete	W	D	17	
4	G	29/10/2019	1156	Lace Monitor	Complete	E	D	18	
4	G	29/10/2019	2227	Black Rat	Complete	E	D	19	
4	G	30/10/2019	1227	Lace Monitor	Complete	W	D	20	
4	G	1/11/2019	0956	Lace Monitor	Complete	E	D	21	
4	G	1/11/2019	1521	Lace Monitor	Complete	W	D	23	
4	G	3/11/2019	1007	Lace Monitor	Complete	E	D	27	
4	G	3/11/2019	1354	Lace Monitor	Complete	W	D	30	
4	G	9/11/2019	0959	Lace Monitor	Complete	E	D	47	
4	G	9/11/2019	1505	Lace Monitor	Complete	W	D	48	
4	G	13/11/2019	0825	Cat	Complete	E	D	65	
4	G	13/11/2019	1944	Cat	Complete	W	D	66	
4	G	15/11/2019	0104	Koala	Complete	E	D	67	
4	G	15/11/2019	1255	Lace Monitor	Complete	E	D	73-74	
4	G	16/11/2019	1402	Lace Monitor	Complete	E	D	77	
4	G	18/11/2019	1223	Lace Monitor	Complete	W	Pr	85	
4	G	19/11/2019	0431	Swamp wallaby	Complete	W	D	86-87	
4	G	19/11/2019	1052	Lace Monitor	Complete	E	D	89	
4	G	20/11/2019	0502	Cat	Complete	E		91	
4	G	20/11/2019 to 18/12/2019 period (Camera date record malfunction)					D		
4	G	21/11/2019	1925	cat	Complete	E	D	5	Tabby
4	G	6/01/2015	2152	Koala	Complete	E	D	6	
4	G	7/01/2015	1121	Lace Monitor	Complete	W	D	10	
4	G	10/01/2015	2017	Koala	Complete	W	D	12	
4	G	10/01/2015	2052	cat	Complete	E	Pr	13	
4	G	11/01/2015	1853	Black Rat	Complete	E	D	16	
4	G	12/01/2015	1854	Koala	Complete	E	D	20	
4	G	14/01/2015	1003	Lace Monitor	Complete	W	D	37	
4	G	18/01/2015	0616	Lace Monitor	Complete	W	D	45	
4	G	20/01/2015	0514	Lace Monitor	Complete	E	D	53	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
4	G	20/01/2015	0624	Lace Monitor	Complete	W	Pr	54	
4	G	23/01/2015	0936	Lace Monitor	Complete	W	D	88	
4	G	26/01/2015	1056	Lace Monitor	Complete	W	D	93	
4	G	27/01/2015	1014	Lace Monitor	Complete	W	D	99	
4	G	29/01/2015	1945	Cat	Complete	E	D	106	Tabby
4	G	30/01/2015	2130	Koala	Complete	W	D	107	
4	G	31/01/2015	0414	cat	Complete	E	D	108	Tabby
4	G	31/01/2015	0918	Lace Monitor	Complete	W	D	118	
4	G	22/06/2020	2040	Fox	Complete	W	D	3-7	Eats chicken thighs left
4	G	23/06/2020	0541	Fox	Complete	E	D	8	
4	G	24/06/2020	0103	Fox	Complete	W	D	9	
4	G	24/06/2020	0443	Fox	Complete	E	D	10-12	
4	G	25/06/2020	0206	Fox	Complete	E	D	17	
4	G	25/05/2020	2138	Fox	Complete	W	D	18	
4	G	26/05/2020	2037	Fox	Complete	E	D	20	Running
4	G	26/05/2020	2057	Fox	Complete	W	D	21	Running
4	G	27/05/2020	0006	Fox	Complete	E	D	23	Running
4	G	27/05/2020	0457	Fox	Complete	E	D	25	
4	G	27/05/2020	1026	Fox	Complete	W	D	26	
4	G	27/05/2020	1126	Fox	Complete	E	D	27	
4	G	27/06/2020	1926	Cat	Complete	W	D	28	Spotted
4	G	28/06/2020	0529	Fox	Complete	E	D	29	
4	G	29/06/2020	0444	Cat	Complete	E	D	30	Dark paws and tail
4	G	30/06/2020	0134	Cat	Complete	W	D	32	Spotted
4	G	30/06/2020	2217	Cat	Complete	E	D	35	
4	G	1/07/2020	0448	Fox	Complete	E	D	36	
4	G	1/07/2020	1941	Fox	Complete	E	D	39	
4	G	1/07/2020	2338	Cat	Complete	E	D	40	Dark paws and tail
4	G	3/07/2020	0731	Dog	Complete	E	D	42-45	
4	G	3/07/2020	1754	Fox	Complete	W	D	46	
4	G	3/07/2020	1828	Fox	Complete	W	D	47	
4	G	6/07/2020	1756	Bandicoot spp	Complete	E	D	49	
4	G	7/07/2020	0304	Fox	Complete	E	D	51	
4	G	7/07/2020	2023	Fox	Complete	E	D	52	
4	G	10/07/2020	1915	Cat	Complete	W	D	53	Spotted
4	G	11/07/2020	1949	Bandicoot spp	Complete	E	D	54	
4	G	12/07/2020	0422	Fox	Complete	W	D	55	
4	G	14/07/2020	0456	Fox	Complete	E	D	56	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
4	G	14/07/2020	0553	Fox	Complete	W	D	57	
4	G	14/07/2020	1800	Fox	Complete	W	D	59	
4	G	15/07/2020	0615	Fox	Complete	E	D	60	
4	G	17/07/2020	0616	Fox	Complete	E	D	62	
4	G	17/07/2020	0616	Fox	Complete	W	D	62	
4	G	18/07/2020	0520	Cat	Complete	E	D	64	
4	G	20/07/2020	2142	Bandicoot spp.	Complete	E	D	66	
4	G	21/07/2020	1920	Bandicoot spp.	Complete	E	D	67	
4	G	24/07/2020	0741	Fox	Complete	E	D	68	
4	G	25/07/2020	0000	Bandicoot spp.	Complete	E	D	69	
4	G	26/07/2020	2314	Bandicoot spp.	Complete	E	D	71	
4	G	27/07/2020	2113	Bandicoot spp.	Complete	E	D	72	
4	G	29/07/2020	0049	cat	Complete	E	D	9	
4	G	29/07/2020	1800	Fox	Complete	E	D	10	
4	G	29/07/2020	2156	Bandicoot spp	C	E	D	11	
4	G	30/07/2020	0539	Cat	Complete	E	D	12	
4	G	30/07/2020	1540	Dog	C	E	D	13	
4	G	30/07/2020	1636	Fox	Complete	W	D	14	
4	G	30/07/2020	2317	Bandicoot	C	E	D	16	
4	G	1/08/2020	0102	Koala	Complete	W	D	17	
4	G	1/08/2020	0342	Koala	Complete	E	D	18	
4	G	1/08/2020	1751	Bandicoot spp	Complete	E	D	19	
4	G	1/08/2020	1916	Fox	Complete	E	D	20	
4	G	1/08/2020	1934	Fox	Complete	E	D	21	
4	G	2/08/2020	1816	Fox	Complete	E	D	22	
4	G	3/08/2020	1704	Fox	Complete	E	D	23	
4	G	4/08/2020	1816	Bandicoot spp	Complete	E	D	24	
4	G	4/08/2020	2022	Cat	Complete	E	D	25	
4	G	5/08/2020	1819	Fox	Complete	W	D	26	
4	G	7/08/2020	1817	Fox	Complete	W	D	27	
4	G	9/08/2020	1841	Fox	Complete	W	D	28	
4	G	9/08/2020	2149	Common brushtail possum	Complete	E	D	29	
4	G	10/08/2020	1950	Bandicoot spp	C	E	D	31	
4	G	11/08/2020	2025	Bandicoot spp	C	E	D	32	
4	G	11/08/2020	2035	Long nosed bandicoot	C	W	D	33	
4	G	13/08/2020	1825	Fox	C	W	D	36	
4	G	13/08/2020	1939	Bandicoot spp	C	E	D	37	
4	G	14/08/2020	1836	Bandicoot spp	C	E	D	38	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
4	G	14/08/2020	218	Bandicoot spp	C	E	D	40	
4	G	15/08/2020	2046	Cat	C	W	D	44	
4	G	16/08/2002	2030	Fox	C	W	D	45	
4	G	16/08/2020	2038	Fox	C	W	D	46	
4	G	16/08/2020	2110	Fox	C	E	D	47	
4	G	17/08/2020	0251	Fox	C	W	D	48	
4	G	18/08/2020	0252	Fox	C	W	D	50	
4	G	22/08/2020	1359	Dog	C	E	D	51	Black white on chest
4	G	22/08/2020	1400	Dog	C	W	D	53	Black white on chest
4	G	25/08/2020	2207	BtPoss spp	C	E	D	59	
4	G	25/08/2020	2225	BtPoss spp	C	E	D	60	
4	G	25/08/2020	2302	Swamp Wallaby	C	W	D	61	
4	G	25/08/2020	2302	Swamp Wallaby	C	W	D	62	
4	G	26/08/2020	1227	Lace Monitor	C	W	D	63	
4	G	26/08/2020	1925	Swamp Wallaby	C	W	D	65	
4	G	27/08/2020	0537	Swamp Wallaby	C	E	D	68	
4	G	27/08/2020	0551	Swamp Wallaby	C	E	D	69	
4	G	29/08/2020	1446	Lace Monitor	C	E	D	70	
4	G	29/08/2020	1813	Fox	C	W	D	71	
4	G	29/08/2020	1907	Wallaby spp.	C	W	D	72	
4	G	30/08/3030	1917	Dog	C	E	D	74	Black
4	G	31/08/2020	1245	Fox	C	W	D	75	
4	G	31/08/2020	1824	Fox	C	E	D	76	
4	G	1/09/2020	0443	Swamp Wallaby	C	W	D	77	
4	G	1/09/2020	0453	Swamp Wallaby	C	W	D	79	
3	FF	31/01/2015	1617	cat	Complete	W	D	119	Tabby
3	FF	9/10/2019	1013	Welcome swallow	Incomplete	EXM	Pr	8-10	2 individuals
3	FF	9/10/2019	1147	Welcome swallow	Incomplete	EXM	D	13	
3	FF	14/10/2019	0417	Cat	Complete	W	Pr	22	Black, white paws
3	FF	14/10/2019	1002	Welcome swallow	Incomplete	EXM	D	24-26	
3	FF	15/10/2019	1059	Welcome swallow	Incomplete	EXM	Pr	32-33	2 individuals
3	FF	16/10/2019	0952	Welcome swallow	Incomplete	EXM	Pr	49-50	
3	FF	16/10/2019	1052	Welcome swallow	Incomplete	EXM	Pr	51-52	
3	FF	17/10/2019	0817	Welcome swallow	Incomplete	EXM	Pr	70	2 individuals
3	FF	17/10/2019	1026	Welcome swallow	Incomplete	EXM	Pr	81	
3	FF	17/10/2019	1251	Welcome swallow	Incomplete	EXM	Pr	91	
3	FF	17/10/2019	1426	Welcome swallow	Incomplete	EXM	Pr	95, 97	
3	FF	17/10/2019	1527	Welcome swallow	Incomplete	EXM	Pr	103	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
3	FF	17/10/2019	1705	Welcome swallow	Incomplete	EXM	Pr	108	
3	FF	18/10/2019	1604	Welcome swallow	Incomplete	EXM	Pr	133	
3	FF	18/10/2019	1350	Welcome swallow	Incomplete	EXM	Pr	144	
3	FF	19/10/2019	1408	Welcome swallow	Incomplete	EXM	Pr	146	
3	FF	21/10/2019	1020	Welcome swallow	Incomplete	EXM	Pr	157-159	2 individuals
3	FF	29/11/2019	1048	Welcome swallow	Incomplete	EXM	D	10-11	
3	FF	1/12/2019	1453	cat	Complete	E	Pr	18	Black, white paws
3	FF	1/12/2019	1826	Welcome swallow	Incomplete	EXM	D	20	
3	FF	25/06/2020	2336	Microbat spp	Present	EXM	D	8	
3	FF	28/06/2020	2012	Cat	Incomplete	E-W	D	19-20	White socks - Grey
3	G	5/12/2019	0705	cat	Complete	E	D	52	Black, white paws
3	G	9/10/2019	0529	Cat	Complete	E	D	55	Black, white paws
3	G	10/10/2019	0146	Cat	Complete	W	D	65-69	Black, white paws
3	G	10/10/2019	0542	Cat	Complete	W	D	71	Black, white paws
3	G	10/10/2019	0722	Cat	Complete	E	Pr	72	Black, white paws
3	G	10/10/2019	2037	Fox	Complete	E	Pr	76	
3	G	11/10/2019	0547	Wallaby spp.	Complete	E	Pr	77	
3	G	11/10/2019	0623	Wallaby spp.	Complete	E	D	78	
3	G	11/10/2019	0834	Wallaby spp.	Complete	W	D	80	
3	G	11/10/2019	1331	Cat	Complete	W	D	81	Black, white paws
3	G	11/10/2019	1401	Cat	Complete	E	D	82	Black, white paws (With killed rodent spp.)
3	G	12/10/2019	0412	Cat	Complete	W	D	83	Black, white paws
3	G	12/10/2019	0442	Cat	Complete	E	D	84	Black, white paws
3	G	12/10/2019	0545	Cat	Complete	W	D	85	Black, white paws
3	G	12/10/2019	0629	Cat	Complete	E	D	86	Black, white paws
3	G	12/10/2019	1351	Cat	Complete	W	D	87	Black, white paws
3	G	12/10/2019	1438	Cat	Complete	W	D	88	Black, white paws
3	G	12/10/2019	1542	Cat	Complete	E	D	89	Black, white paws
3	G	12/10/2019	1545	Cat	Complete	E	D	90	Black, white paws
3	G	13/10/2019	0410	Cat	Complete	W	D	91	Black, white paws
3	G	13/10/2019	0607	Cat	Complete	E	Po	92	Black, white paws
3	G	13/10/2019	0930	Macropod	Complete	W	D	93	
3	G	13/10/2019	2232	Fox	Complete	E	D	94	
3	G	13/10/2019	2322	Cat	Complete	W	D	95	Black, white paws
3	G	14/10/2019	0542	Cat	Complete	W	D	97	Black, white paws
3	G	14/10/2019	0633	Cat	Complete	E	D	102	Black, white paws (With killed rodent

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
									spp.)
3	G	14/10/2019	0658	Cat	Complete	E	D	103	Black, white paws
3	G	14/10/2019	1828	EG kangaroo	Complete	W	D	104-106	
3	G	14/10/2019	2035	Cat	Complete	W	D	107	Black, white paws
3	G	14/10/2019	2227	Cat	Complete	E	D	108	Black, white paws
3	G	15/10/2019	0103	Cat	Complete	W	D	109	Black, white paws
3	G	15/10/2019	0143	Cat	Complete	E	D	110	Black, white paws
3	G	15/10/2019	0228	Cat	Complete	W	D	111-115	Black, white paws, and throat
3	G	15/10/2019	0320	Cat	Complete	E	D	116	Black, white paws
3	G	15/10/2019	0436	Fox	Complete	W	Pr	118-120	
3	G	15/10/2019	0453	EG kangaroo	Complete	E	D	121	
3	G	15/10/2019	0553	Cat	Complete	W	D	122	
3	G	15/10/2019	0605	Fox	Complete	E	Pr	123	
3	G	15/10/2019	0625	EG kangaroo	Complete	E	D	124-125	
3	G	15/10/2019	0629	Cat	Complete	E	Pr	126	Black, white paws
3	G	15/10/2019	2020	Wallaby spp.	Complete	W	D	131-132	
3	G	16/10/2019	0458	Cat	Complete	W	Pr	136	Black, white paws
3	G	16/10/2019	0533	EG kangaroo	Complete	E	Pr	137-138	
3	G	16/10/2019	0537	EG kangaroo	Complete	W	D	139	
3	G	17/10/2019	0207	Fox	Complete	W	D	145	
3	G	17/10/2019	1413	Cat	Complete	W	D	156-159	Black, white paws, and throat
3	G	17/10/2019	1454	Cat	Complete	E	D	160	
3	G	17/10/2019	1538	Cat	Complete	W	D	161	
3	G	17/10/2019	1542	Cat	Complete	E	D	163	
3	G	17/10/2019	1549	Cat	Complete	E	D	164	
3	G	18/10/2019	0522	Fox	Complete	E	D	165	
3	G	18/10/2019	1012	Cat	Incomplete	NDM	Pr	177-178	
3	G	18/10/2019	1138	Welcome swallow	Incomplete	EXM	D	187-189	
3	G	18/10/2019	1209	Welcome swallow	Incomplete	EXM	Pr	192-193	
3	G	18/10/2019	1911	Swamp wallaby	Complete	W	D	202-206	
3	G	18/10/2019	2053	Cat	Complete	W	D	210	Black, white paws
3	G	19/10/2019	0142	Fox	Complete	W	D	211	
3	G	19/10/2019	0222	Fox	Complete	E	D	212	
3	G	19/10/2019	0331	Cat	Complete	W	D	213	Black, white paws, and throat
3	G	19/10/2019	0356	Cat	Complete	W	D	214	Black, white paws
3	G	19/10/2019	0401	Cat	Complete	E	D	215	Black, white paws

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
3	G	19/10/2019	0415	Cat	Complete	W	Pr	216	Black, white paws
3	G	19/10/2019	0508	Swamp wallaby	Complete	E	D	217-219	
3	G	19/10/2019	0618	Cat	Complete	E	Pr	221	Black, white paws
3	G	19/10/2019	2001	Wallaby spp.	Complete	W	D	230	
3	G	20/10/2019	0511	Macropod spp.	Complete	E	Pr	231	
3	G	20/10/2019	1752	Swamp wallaby	Complete	W	D	240-241	
3	G	20/10/2019	2202	Cat	Complete	W	D	242	Black, white paws
3	G	21/10/2019	0514	Swamp wallaby	Complete	E	D	243-245	
3	G	21/10/2019	0519	Cat	Complete	E	D	246	Black, white paws
3	G	21/10/2019	0804	Cat	Complete	W	D	247	Black, white paws
3	G	21/10/2019	0814	Cat	Complete	E	D	248	Black, white paws, (with killed rodent spp.)
3	G	21/10/2019	1302	Cat	Complete	W	D	249	Black, white paws, and throat
3	G	21/10/2019	1307	Cat	Complete	E	D	250	Black, white paws
3	G	21/10/2019	1331	Cat	Complete	W	D	251	Black, white paws, and throat
3	G	21/10/2019	1558	Cat	Complete	E	D	252	Black, white paws
3	G	21/10/2019	2313	Cat	Complete	E	D	257	Black, white paws
3	G	22/10/2019	0446	Cat	Complete	W	D	258	Black, white paws, and throat
3	G	22/10/2019	0644	Cat	Complete	E	D	259	Black, white paws
3	G	22/10/2019	0704	Macropod spp.	Complete	E	D	260	
3	G	22/10/2019	0836	Cat	Complete	E	D	262	Black, white paws
3	G	22/10/2019	1107	Cat	Complete	W	D	265	Black, white paws, and throat
3	G	22/10/2019	1146	Cat	Complete	E	D	266	Black, white paws
3	G	28/11/2019	2018	Cat	Complete	E	D	12	Black, white paws
3	G	30/11/2019	2240	Cat	Complete	EXM	Po	22-30	Black, white paws
3	G	1/12/2019	0435	Fox	Complete	W	D	33	
3	G	1/12/2019	0507	Wallaby spp.	Complete	E	Pr	34	
3	G	1/12/2019	1231	Cat	Complete	W	Pr	38	
3	G	1/12/2019	2302	Swamp wallaby	Complete	W	D	40-41	
3	G	2/12/2019	2121	Cat	Complete	E	D	43-51	Tabby
3	G	2/12/2019	2250	Cat	Complete	W	D	52-54	Black, white paws
3	G	3/12/2019	0347	Cat	Complete	EXM	Pr	55-58	
3	G	3/12/2019	0517	Wallaby spp.	Complete	E	D	61	
3	G	3/12/2019	2041	Swamp wallaby	Complete	W	D	78	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
3	G	4/12/2019	0101	Cat	Complete	W	D	79	Black, white paws
3	G	4/12/2019	0517	Wallaby spp.	Complete	E	D	81	
3	G	4/12/2019	1831	Cat	Complete	E	D	94	Black, white paws
3	G	5/12/2019	0308	Cat	Complete	W	D	95	Black, white paws, and throat
3	G	6/12/2019	0235	Cat	Complete	W	D	103-104	Black, white paws, and throat
3	G	6/12/2019	2237	Swamp wallaby	Complete	W	Po	135	
3	G	7/12/2019	0227	Cat	Complete	W	D	136	Tabby
3	G	7/12/2019	0530	Cat	Complete	E	Pr	138	Black, white paws
3	G	8/12/2019	0450	Macropod spp.	Complete	E	D	150	
3	G	8/12/2019	0613	Cat	Complete	EXM	Po	153-154	Black, white paws, and throat
3	G	8/12/2019	1700	Swamp wallaby	Complete	E	Po	156	
3	G	9/12/2019	0508	Macropod spp.	Complete	E	Pr	158	
3	G	9/12/2019	1728	Swamp wallaby	Complete	E	D	161	
3	G	9/12/2019	2227	Cat	Complete	E	D	162-163	
3	G	10/12/2019	0648	Swamp wallaby	Complete	E	D	165	
3	G	10/12/2019	0743	Swamp wallaby	Complete	W	D	166	
3	G	10/12/2019	2224	Macropod spp.	Complete	E	D	176	
3	G	11/12/2019	1701	Swamp wallaby	Complete	E	D	177	
3	G	12/12/2019	0109	Cat	Complete	E	D	178	Black, white paws, and throat
3	G	12/12/2019	2130	Cat	Complete	W	D	179-181	Black, white paws, and throat
3	G	12/12/2019	2351	Cat	Complete	W	D	182	Black, white paws, and throat
3	G	13/12/2019	0054	Swamp wallaby	Complete	W	Pr	183	
3	G	13/12/2019	0622	Wallaby spp.	Complete	W	Pr	184	
3	G	13/12/2019	0645	Wallaby spp.	Complete	E	Pr	185	
3	G	14/12/2019	2017	Wallaby spp.	Complete	E	D	187	
3	G	14/12/2019	2210	Cat	Complete	W	D	188	Black, white paws, and throat
3	G	15/12/2019	0043	Cat	Complete	E	D	189	Black, white paws
3	G	17/12/2019	2112	Swamp wallaby	Complete	W	Pr	194-195	
3	G	18/12/2019	0228	Cat	Complete	W	D	196	
3	G	18/12/2019	0451	Cat	Complete	E	D	197	
3	G	21/06/2020	1837	Cat	Complete	W	D	5-6	Larger Grey - white socks

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
3	G	21/06/2020	1904	Cat	Complete	W	D	7	Smaller grey - white socks
3	G	21/06/2020	1837	Cat	Complete	E	D	8	Larger Grey - white socks carrying Prey (probable Rodent)
3	G	21/06/2020	2026	Cat	Complete	E	D	9	Tabby
3	G	21/06/2020	1904	Cat	Complete	W	D	10-11	Smaller grey - white socks investigates cage
3	G	22/06/2020	0355	Red-necked wallaby	Complete	E	D	12-13	
3	G	22/06/2020	1838	Cat	Complete	W	D	22-25	White socks - Grey
3	G	23/06/2020	1839	Cat	Complete	E	D	26-77	White socks - Grey feeding on drumsticks
3	G	23/06/2020	0522	Wallaby spp.	Complete	E	D	78	
3	G	23/06/2020	0658	Dogs	Incomplete	W-E	D	79-94	x 2 (kelpie crosses - collars)
3	G	23/06/2020	1842	Cat	Complete	E	D	96-97	
3	G	23/06/2020	1853	Red-necked wallaby	Complete	W	D	98-100	
3	G	23/06/2020	1930	Cat	Complete	W	D	101	
3	G	23/06/2020	2022	Cat	Complete	W	D	102-105	
3	G	23/06/2020	2024	Cat	Complete	E	D	106	
3	G	23/06/2020	2149	Cat	Complete	E	D	107	
3	G	23/06/2020	2301	Cat	Complete	W	D	108	
3	G	24/06/2020	0017	Cat	Complete	W	D	109	
3	G	24/06/2020	0442	Cat	Complete	E	D	112	
3	G	24/06/2020	1528	Cat	Complete	E	D	116	
3	G	24/06/2020	1609	Red-necked wallaby	Complete	W	D	117	
3	G	24/06/2020	1652	Cat	Complete	E	D	118	
3	G	24/06/2020	1923	Cat	Complete	E	D	119	
3	G	24/06/2020	2243	Cat	Complete	E	D	121	
3	G	24/06/2020	0029	Cat	Complete	E	D	121	Carrying prey (Probable Large Rodent)
3	G	25/06/2020	0630	Dog	Complete	W	D	124-129	x 2 (kelpie crosses - collars)
3	G	25/06/2020	1226	Cat	Complete	W	D	138	
3	G	25/06/2020	1324	Cat	Complete	E	D	139	
3	G	25/06/2020	2343	Cat	Complete	E	D	144	
3	G	26/06/2020	0621	Dog	Complete	W	D	145-146	x 2 (kelpie crosses - collars)

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
3	G	26/06/2020	0634	Dog	Complete	E	D	148	x 2 (kelpie crosses - collars)
3	G	26/06/2020	0719	Dog	Complete	W	D	149	x 2 (kelpie crosses - collars)
3	G	26/06/2020	0727	Dog	Complete	E	D	150	x 2 (kelpie crosses - collars)
3	G	27/06/2020	1918	Cat	Complete	W	D	157	
3	G	27/06/2020	1918	Cat	Complete	W	D	158	
3	G	27/06/2020	2105	Cat	Complete	E	D	157	
3	G	27/06/2020	0258	Cat	Complete	E	D	158	
3	G	27/06/2020	2231	Cat	Complete	E	D	164	
3	G	27/06/2020	2256	Cat	Complete	E	D	165	Carry prey
3	G	28/06/2020	0630	Dog	Complete	W	D	166	x 2 (kelpie crosses - collars)
3	G	28/06/2020	0641	Dog	Complete	E	D	166	
3	G	28/06/2020	2217	Cat	Complete	W	D	170	
3	G	29/06/2020	0046	Cat	C	E	D	171	
3	G	29/06/2020	0451	Cat	C	E	D	173	
3	G	29/06/2020	1409	Cat	C	E	D	178	
3	G	29/06/2020	1704	Cat	C	E	D	178	
3	G	28/07/2020	1904	Cat	Complete	W	D	5	Fat tabby or ginger
3	G	28/07/2020	1914	Cat	Complete	W	D	6	Black with white socks
3	G	28/07/2020	2041	Cat	Complete	E	D	7-8	Black with white socks
3	G	28/07/2020	2102	Cat	Complete	W	D	9	Black with white socks
3	G	28/07/2020	2117	Cat	Complete	W	D	10	Fat tabby or ginger
3	G	28/07/2020	2208	Cat	Complete	E	D	11	Fat tabby or ginger
3	G	28/07/2020	2317	Cat	Complete	W	D	12	Fat tabby or ginger
3	G	29/07/2020	0036	Cat	Complete	E	D	13	Fat tabby or ginger
3	G	29/07/2020	0059	Cat	Complete	W	D	14	Fat tabby or ginger
3	G	29/07/2020	0135	Cat	Complete	E	D	15-16	Black with white socks
3	G	29/07/2020	0446	Cat	Complete	E	D	17	Fat tabby or ginger
3	G	29/07/2020	1105	Cat	Complete	W	D	18	Black with white socks
3	G	29/07/2020	1719	Cat	Complete	E	D	20	Black with white socks
3	G	29/07/2020	1845	Cat	Complete	E	D	21	Black with white socks
3	G	29/07/2020	1922	Cat	Complete	W	D	22	
3	G	29/07/2020	2113	Cat	Complete	E	D	23	Fat tabby or ginger
3	G	30/07/2020	0048	Cat	Complete	W	D	24	Fat tabby or ginger
3	G	30/07/2020	0241	Cat	Complete	W	D	25	Black with white socks
3	G	30/07/2020	0336	Cat	Complete	E	D	26	Fat tabby or ginger

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
3	G	30/07/2020	1733	Cat	Complete	E	D	27	Black with white socks
3	G	30/07/2020	2236	Cat	Incomplete	WE	D	28-29	
3	G	31/07/2020	0130	Cat	Complete	W	D	30	Black with white socks
3	G	31/07/2020	0149	Cat	Complete	E	D	31	Black with white socks
3	G	31/07/2020	0443	Cat	Complete	E	D	35	Fat tabby or ginger
3	G	31/07/2020	0829	Cat	Complete	E	D	36	Black with white socks
3	G	31/07/2020	1332	Cat	Complete	W	D	37	Black with white socks
3	G	31/07/2020	1620	Cat	Complete	E	D	38	Black with white socks
3	G	31/07/2020	2030	Cat	Complete	E	D	40	Black with white socks
3	G	1/08/2020	0124	Cat	Complete	W	D	41	
3	G	1/08/2020	0357	Cat	Complete	W	D	42	Black with white socks
3	G	1/08/2020	0409	Cat	Incomplete	EW	D	43-45	Black with white socks
3	G	1/08/2020	0433	Cat	Complete	E	D	46	Black with white socks
3	G	1/08/2020	0501	Cat	Incomplete	WE	D	47-48	Black with white socks
3	G	1/08/2020	0644	Dog	Incomplete	EXM	D	50	
3	G	1/08/2020	1744	Swamp wallaby	Complete	W	D	52	
3	G	1/08/2020	1843	Cat	Complete	E	D	54	Black with white socks
3	G	2/08/2020	0234	Cat	Incomplete	WE	D	55-56	Black with white socks
3	G	2/08/2020	0356	Swamp wallaby	Complete	E	D	57	
3	G	2/08/2020	0705	Dogs	Incomplete	WE	D	58-59	2 x kelpies
3	G	2/08/2020	1206	Cat	Complete	W	D	60	Black with white socks
3	G	2/08/2020	2157	Cat	Complete	E	D	61	Black with white socks
3	G	3/08/2020	0538	Cat	Complete	E	D	62	Black with white socks
3	G	3/08/2020	2353	Cat	Complete	W	D	63	Black with white socks
3	G	4/08/2020	0648	Dogs	Incomplete	WE	D	64-67	2 x kelpies
3	G	4/08/2020	0801	Cat	Complete	E	D	68	Black with white socks
3	G	5/08/2020	0003	Cat	Complete	W	D	69	Black with white socks
3	G	5/08/2020	0434	Cat	Complete	E	D	70-72	Black with white socks
3	G	5/08/2020	0704	Dogs	Incomplete	WE	D	74-75	2 x kelpies
3	G	5/08/2020	0749	Cat	Complete	E	D	77	Black with white socks
3	G	5/08/2020	1538	Cat	Complete	W	D	78	Black with white socks
3	G	5/08/2020	1708	Cat	Complete	E	D	79	Black with white socks
3	G	5/08/2020	1730	Cat	Complete	W	D	80	
3	G	5/08/2020	2152	Cat	Complete	E	D	84	Black with white socks
3	G	6/08/2020	0639	Dogs	Incomplete	EW	D	85-86	2 x kelpies
3	G	6/08/2020	0823	Cat	Complete	E	D	87	Black with white socks
3	G	6/08/2020	1202	Cat	Complete	W	D	88	Black with white socks
3	G	6/08/2020	1603	Cat	Complete	E	D	89-91	Black with white socks

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
3	G	6/08/2020	1657	Cat	Complete	E	D	92	Black with white socks
3	G	6/08/2020	1812	Cat	Complete	E	D	93	Black with white socks
3	G	6/08/2020	1949	Cat	Complete	E	D	94	
3	G	6/08/2020	2255	Cat	Complete	E	D	97	
3	G	7/08/2020	0739	Dogs	Incomplete	EW	D	98-100	2 x kelpies
3	G	7/08/2020	1043	Cat	Incomplete	EW	D	102-103	Black with white socks
3	G	7/08/2020	1357	Cat	Complete	E	D	104	Black with white socks
3	G	7/08/2020	1923	Cat	Complete	W	D	105	
3	G	7/08/2020	1939	Cat	Complete	E	D	107	Black with white socks
3	G	7/08/2020	2136	Cat	Complete	E	D	108	Black with white socks
3	G	8/08/2020	0654	Dogs	Incomplete	WE	D	109-112	2 x kelpies
3	G	8/08/2020	1503	Swamp wallaby	Complete	W	Pr	113	
3	G	8/08/2020	2120	Cat	Complete	W	D	115	
3	G	8/08/2020	2301	Cat	Complete	E	D	116	
3	G	8/08/2020	2327	Wallaby spp.	Complete	E	D	117	
3	G	9/08/2020	0003	Cat	Complete	W	D	118	
3	G	9/08/2020	0409	Wallaby spp.	Complete	W	D	119	
3	G	9/08/2020	0658	Dogs	Incomplete	WE	D	120-121	2 x kelpies
3	G	9/08/2020	0708	Cat	Complete	E	D	122	
3	G	9/08/2020	1855	Cat	Complete	W	D	123	
3	G	9/08/2020	1959	Cat	Complete	E	D	124	
3	G	9/08/2020	2331	Cat	Complete	E	D	125	
3	G	10/08/2020	2001	Cat	Complete	W	D	126	
3	G	10/08/2020	2148	Cat	Complete	E	D	127	
3	G	11/08/2020	1357	Cat	Complete	W	D	128	
3	G	11/08/2020	1441	Cat	Complete	E	D	129	
3	G	11/08/2020	1856	Bandicoot spp	Complete	E	Pr	130	
3	G	12/08/2020	1946	Cat	Complete	W	D	131	
3	G	13/08/2020	0130	Cat	Complete	E	D	132	
3	G	14/08/2020	0025	BtPoss spp	Complete	E	D	133	
3	G	14/08/2020	0510	Cat	Complete	E	D	135	
3	G	15/08/2020	0504	Cat	Complete	W	D	136	
3	G	15/08/2020	0719	Cat	Complete	E	D	137	
3	G	15/08/2020	1845	Cat	Complete	W	Pr	138	
3	G	15/08/2020	1906	Cat	Complete	W	D	139	
3	G	15/08/2020	1944	Cat	Complete	E	D	140	
3	G	15/08/2020	2041	Cat	Complete	E	D	141-145	
3	G	15/08/2020	2340	Cat	Complete	W	D	146	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
3	G	16/08/2020	0144	Cat	Complete	W	D	147	
3	G	16/08/2020	0508	Cat	Complete	E	D	148-149	
3	G	16/08/2020	0546	Cat	Complete	W	D	150	
3	G	16/08/2020	0709	Dogs	Incomplete	WE	D	151-153	2 x kelpies
3	G	16/08/2020	1719	Cat	Complete	E	D	154	
3	G	16/08/2020	1922	Cat	Complete	W	D	156	
3	G	16/08/2020	2228	Cat	Complete	E	D	157	
3	G	16/08/2020	2302	Cat	Complete	W	D	158	
3	G	17/08/2020	0040	Cat	Complete	W	D	159	
3	G	17/08/2020	0202	Cat	Complete	E	D	160	
3	G	17/08/2020	0340	Wallaby spp.	Complete	E	D	161	
3	G	17/08/2020	0438	Wallaby spp.	Complete	E	D	162	
3	G	17/08/2020	0532	Cat	Complete	E	D	163	
3	G	17/08/2020	0846	Cat	Complete	W	D	164	
3	G	17/08/2020	1809	Cat	Complete	E	D	165	
3	G	17/08/2020	2139	Cat	Complete	W	D	166	
3	G	17/08/2020	2254	Cat	Incomplete	WE	D	167-68	
3	G	18/08/2020	0254	Red-necked wallaby	Complete	W	D	169-170	
3	G	18/08/2020	0936	Cat	Incomplete	EW	D	171-72	
3	G	18/08/2020	1631	Cat	Complete	E	D	173	
3	G	18/08/2020	1959	Cat	Complete	W	D	174	
3	G	18/08/2020	2142	Cat	Complete	E	D	175	
3	G	19/08/2020	0604	Dogs	Incomplete	WE	D	176-178	2 x kelpies
3	G	20/08/2020	0152	Cat	Complete	W	D	179	
3	G	20/08/2020	0306	Cat	Complete	E	D	180	
3	G	20/08/2020	0624	Cat	Complete	W	D	181	
3	G	20/08/2020	0646	Cat	Complete	E	D	182	
3	G	20/08/2020	2111	Cat	Complete	E	D	184	
3	G	21/08/2020	0713	Dogs	Incomplete	WE	D	186-187	2 x kelpies
3	G	21/08/2020	0727	Cat	Complete	E	D	188	
3	G	21/08/2020	0906	Cat	Complete	E	D	190	
3	G	21/08/2020	1510	Cat	Incomplete	WE	D	192-3	
3	G	21/08/2020	1709	Cat	Complete	E	D	194	
3	G	21/08/2020	2138	Cat	Complete	E	D	196	
3	G	22/08/2020	0522	Wallaby spp.	Complete	E	D	197	
3	G	22/08/2020	0533	Cat	Complete	W	D	198	
3	G	22/08/2020	1341	Dog	Complete	W	D	200	
3	G	22/08/2020	1532	Cat	Complete	E	D	201	Black with white socks

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
3	G	22/08/2020	2352	Cat	Complete	W	D	202	Fat tabby or ginger
3	G	23/08/2020	0015	Cat	Complete	E	D	203	Fat tabby or ginger
3	G	23/08/2020	0537	Cat	Complete	E	D	204	Black with white socks
3	G	23/08/2020	0713	Red-necked wallaby	Complete	E	Pr	206	Joey in pouch
3	G	23/08/2020	0723	Dogs	Complete	W	D	207,209-211	2 x kelpies
3	G	23/08/2020	1415	Cat	Complete	W	D	212	Black with white socks
3	G	23/08/2020	1804	Cat	Complete	E	D	213	Black with white socks
3	G	23/08/2020	1837	Red-necked wallaby	Complete	W	D	214	Joey in pouch
3	G	23/08/2020	1900	Swamp wallaby	Complete	W	D	215-216	
3	G	24/08/2020	0116	Swamp wallaby	Complete	E	Pr	217	
3	G	25/08/2020	0207	Cat	Complete	W	D	230	
3	G	25/08/2020	0645	Cat	Complete	E	D	232	Black with white socks
3	G	25/08/2020	1209	Cat	Incomplete	WE	D	234-235	Black with white socks
3	G	27/08/2020	1322	Cat	Incomplete	WE	D	236-237	Black with white socks
3	G	28/08/2020	1236	Cat	Complete	W	D	238	
3	G	28/08/2020	1623	Cat	Complete	E	D	239	
3	G	29/08/2020	0021	Swamp wallaby	Complete	E	D	241	
3	G	29/08/2020	0631	Cat	Complete	W	D	242-243	
3	G	29/08/2020	1538	Cat	Complete	W	D	244	
3	G	29/08/2020	1833	Cat	Complete	E	D	245	
3	G	29/08/2020	2254	Red-necked wallaby	Complete	E	D	246	
3	G	30/08/2020	1010	Cat	Complete	W	D	249	
3	G	30/08/2020	1032	Cat	Complete	E	D	250	
3	G	30/08/2020	2304	Cat	Complete	W	D	251	
3	G	30/08/2020	2329	Cat	Incomplete	EW	D	252-253	
3	G	31/08/2020	0405	Cat	Incomplete	WE	D	254-255	
3	G	31/08/2020	0657	Dogs	Incomplete	WE	D	256-258	2 x kelpies
3	G	31/08/2020	0804	Cat	Complete	E	D	259	
3	G	31/08/2020	1138	Cat	Complete	W	D	260	
3	G	31/08/2020	1824	Cat	Complete	E	D	261	
3	G	1/09/2020	0205	Cat	Complete	W	D	262	
3	G	1/09/2020	0359	Cat	Complete	E	D	263	
2	FF	18/12/2019	0458	Macropod spp.	Complete	E		198	
2	FF	24/06/2020	0301	Black Rat	Complete	W	D	10-15	
2	FF	11/07/2020	0813	Antechinus spp	Complete	E	D	76-106	
2	FF	21/08/2020	0321	Antechinus spp	C	E	D	22-33	
2	FF	24/08/2020	2321	Antechinus spp	C	W	D	34-35	
2	FF	27/08/2020	0132	Antechinus spp	C	W	D	43-45	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
2	FF	28/08/2020	0321	Antechinus spp	Incomplete	E-W	D	51-52	
2	FF	28/08/2020	2047	Antechinus spp	C	W	D	59-63	
2	FF	No pics							MB present
2	G	28/11/2019	Nil fauna				D		
2	G	8/10/2019	1943	Fox	Complete	W	D	2	
2	G	8/10/2019	2021	Cat	Complete	E	Pr	3	Black, white paws
2	G	9/10/2019	0431	Wallaby spp.	Complete	W	Pr	4	
2	G	10/10/2019	0102	Swamp wallaby	Complete	W	D	11	
2	G	10/10/2019	0312	Swamp wallaby	Complete	E	D	12	
2	G	10/10/2019	0329	Swamp wallaby	Complete	E	D	13-14	
2	G	10/10/2019	0343	Swamp wallaby	Complete	E	D	15-16	
2	G	13/10/2019	0154	Fox	Complete	E	D	27	
2	G	13/10/2019	2244	Fox	Incomplete	E-W	D	29-31	
2	G	14/10/2019	0358	Fox	Complete	E	D	33	
2	G	14/10/2019	1937	Fox	Complete	W	D	34	
2	G	15/10/2019	0002	Fox	Complete	W	D	35	
2	G	15/10/2019	0102	Fox	Complete	E	Po	36	
2	G	15/10/2019	1936	Swamp rat	Complete	E	D	41	
2	G	16/10/2019	2246	Fox	Incomplete	W-E	D	45-47	
2	G	17/10/2019	0342	Fox	Complete	E	D	48	
2	G	17/10/2019	2040	Fox	Complete	W	D	52	
2	G	18/10/2019	2353	Fox	Complete	E	D	60	
2	G	19/10/2019	0245	Fox	Complete	E	D	63	
2	G	19/10/2019	0456	Fox	Complete	E	D	64	
2	G	19/10/2019	2016	Fox	Complete	E-W	D	73	
2	G	19/10/2019	2028	Fox	Complete	W	D	74	
2	G	19/10/2019	2102	Fox	Complete	W	D	75	
2	G	20/10/2019	0322	Fox	Complete	E	D	76	
2	G	20/10/2019	2118	Fox	Incomplete	W-E	D	84-86	
2	G	21/10/2019	0330	Fox	Complete	W	D	87	
2	G	21/10/2019	0517	Fox	Complete	E	D	89	
2	G	21/10/2019	1927	Swamp wallaby	Complete	W	D	94	
2	G	21/10/2019	2014	Fox	Complete	W	D	96	
2	G	21/10/2019	2101	Fox	Complete	W	D	97	
2	G	22/10/2019	0417	Fox	Complete	E	D	99	
2	G	22/10/2019	0450	Swamp wallaby	Complete	E	Pr	100	
2	G	22/10/2019	0521	Fox	Complete	E	D	101	
2	G	22/10/2019	0544	Swamp wallaby	Complete	E	D	102	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
2	G	30/11/2019	0422	Macropod spp.	Complete	E	D	84	
2	G	1/12/2019	0249	Fox	Complete	E	D	90	
2	G	1/12/2019	0800	Macropod spp.	Complete	E	D	91	
2	G	2/12/2019	2353	Fox	Complete	E	Pr	138	
2	G	4/12/2019	2021	Swamp wallaby	Complete	E	D	236	
2	G	4/12/2019	2032	Swamp wallaby	Complete	W	D	237	
2	G	5/12/2019	0508	Swamp wallaby	Complete	E	D	238	
2	G	6/12/2019	0407	Swamp wallaby	Complete	E	D	313	
2	G	7/12/2019	0326	Swamp wallaby	Complete	E	D	416	
2	G	7/12/2019	2130	Swamp wallaby	Complete	E	D	441	
2	G	8/12/2019	0009	Fox	Complete	E	D	442	
2	G	8/12/2019	1624	Dog	Complete	E	D	465	No collar visible, relatively skinny
2	G	8/12/2019	2005	Macropod spp.	Incomplete	W-E	Pr	467	
2	G	9/12/2019	0409	Swamp wallaby	Complete	E	Pr	468	
2	G	10/12/2019	2028	Swamp wallaby	Complete	E	D	589	
2	G	11/12/2019	0453	Echidna	Complete	E	Po	591	
2	G	12/12/2019	0050	Swamp wallaby	Complete	E	D	674	
2	G	12/12/2019	0233	Swamp wallaby	Complete	E	D	676	
2	G	12/12/2019	2139	Swamp wallaby	Complete	E	D	733	
2	G	13/12/2019	0346	Swamp wallaby	Complete	E	Pr	735-737, 739	
2	G	14/12/2019	2021	Swamp wallaby	Complete	E	D	765	
2	G	15/12/2019	0035	Dog	Complete	E	D	769	
2	G	15/12/2019	0159	Swamp wallaby	Complete	E	D	770	
2	G	15/12/2019	0407	Swamp wallaby	Complete	W	D	771-772	
2	G	16/12/2019	2315	Fox	Complete	E	D	850	
2	G	23/06/2020	0428	Swamp Wallaby	Complete	E	D	43	
2	G	23/06/2020	0527	Swamp wallaby	Complete	E	D	44	
2	G	23/06/2020	1916	Swamp wallaby	Complete	E	D	114-117	
2	G	23/06/2020	1931	Wallaby	Incomplete	E-W	D	119	
2	G	23/06/2020	2139	Swamp wallaby	Incomplete	NDM	D	124-127	
2	G	23/06/2020	2152	Swamp wallaby	Complete	W	D	128-129	
2	G	26/06/2020	220	Fox	Complete	E	D	220	
2	G	28/06/2020	275	Swamp Wallaby	Complete	E	D	275	
2	G	28/06/2020	2343	Bandicoot spp	Complete	E	D	295	
2	G	29/06/2020	0725	Wallaby spp.	Complete	E	D	297	
2	G	29/06/2020	1457	Swamp wallaby	C	W	D	316-317	
2	G	30/06/2020	0527	Wallaby spp.	C	E	D	320	
2	G	30/06/2020	0613	Swamp Wallaby	C	E	D	321	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
2	G	1/07/2020	1926	Swamp Wallaby	C	W	D	400	
2	G	2/07/2020	0051	Swamp Wallaby	C	E	D	404	
2	G	3/07/2020	0516	Wallaby spp.	C	E	D	444	
2	G	5/07/2020	0043	Wallaby spp.	Incomplete	E	D	497	
2	G	29/07/2020	0547	Swamp wallaby	C	E	D	25	
2	G	29/07/2020	0613	Swamp wallaby	C	W	D	26	
2	G	30/07/2020	0713	Cat	C	E	D	47	Grey white socks
2	G	31/07/2020	0444	Swamp wallaby	C	E	D	80	
2	G	31/07/2020	0558	Swamp wallaby	C	E	D	81	
2	G	1/08/2020	0500	Swamp wallaby	C	E	D	82	
2	G	1/08/2020	0500	Dog	C	E	D	83	Kelpie from site 3
2	G	1/08/2020	1837	Swamp Wallaby	C	W	D	141	Carrying young
2	G	2/08/2020	1804	Bandicoot spp.	C	E	D	181	
2	G	3/08/2020	0416	Swamp wallaby	C	E	D	183	
2	G	3/08/2020	0529	Swamp wallaby	C	E	D	184	
2	G	3/08/2020	1536	Dog	C	E	D	202	Black Dog white chest
2	G	3/08/2020	1544	Dog	C	E	D	205	
2	G	3/08/2020	1900	Bandicoot spp.	C	E	D	208	
2	G	3/08/2020	1910	Northern brown bandicoot	C	E	D	209	
2	G	4/08/2020	1805	Wallaby spp.	C	W	D	235	
2	G	5/08/2020	0552	Swamp wallaby	C	E	D	239	
2	G	9/08/2020	0546	Swamp Wallaby	C	E	D	366	
2	G	9/08/2020	1752	Swamp Wallaby	C	E	D	393	
2	G	10/08/2020	0510	Swamp wallaby	C	E	D	395	x 2
2	G	10/08/2020	1850	Bandicoot spp.	C	E	D	414	
2	G	10/08/2020	1958	Bandicoot spp.	C	E	D	416	
2	G	11/08/2020	0024	Echidna	C	E	D	417	
2	G	11/08/2020	1800	Swamp wallaby	C	E	D	452	
2	G	12/08/2020	0522	Swamp wallaby	C	E	D	454	
2	G	12/08/2020	0524	Swamp wallaby	C	E	D	455	
2	G	12/08/2020	1757	Bandicoot spp.	c	e	d	478	
2	G	12/08/2020	2220	Bandicoot spp.	C	E	D	481	
2	G	13/08/2020	0559	Swamp Wallaby	C	E	D	482	
2	G	13/08/2020	2337	Swamp wallaby	C	E	D	521	
2	G	14/08/2020	0435	Swamp Wallaby	Incomplete	E-W	D	522	X 2
2	G	14/08/2020	0450	Swamp Wallaby	Complete	E-W	D	522	X 2
2	G	14/08/2020	1748	Bandicoot spp.	C	E	D	541	
2	G	14/08/2020	1821	Bandicoot spp.	C	E	D	542	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
2	G	14/08/2020	2103	Bandicoot spp.	C	E	D	546	
2	G	14/08/2020	2321	Bandicoot spp.	C	E	D	549	
2	G	15/08/2020	0606	Swamp Wallaby	C	E	D	551	
2	G	15/08/2020	12:08	Dog	C	W	D	552	Black white chest
2	G	15/08/2020	1705	Dog	C	E	D	579	Black white chest
2	G	15/08/2020	1749	Long-nosed bandicoot	C	E	D	580	
2	G	15/08/2020	1916	Bandicoot spp.	C	E	D	584	
2	G	16/08/2020	0343	Swamp wallaby	C	E	D	590	
2	G	16/08/2020	1755	Bandicoot spp.	C	E	D	623	
2	G	16/08/2020	1806	Bandicoot spp	C	E	D	624	
2	G	16/08/2020	1911	Bandicoot spp	C	E	D	629	
2	G	16/08/2020	1922	Bandicoot spp	C	E	D	630	
2	G	16/08/2020	1922	Bandicoot spp	C	E	D	633	
2	G	16/08/2002	2230	Bandicoot spp	C	E	D	635	
2	G	17/08/2020	0012	Northern brown bandicoot	C	E	D	638-639	
2	G	17/08/2020	0219	Bandicoot spp	C	E	D	641	
2	G	17/08/2020	1757	Bandicoot spp	C	E	D	682	
2	G	17/08/2020	1929	Bandicoot spp	C	E	D	686	
2	G	17/08/2020	2227	Echidna	C	W	D	687	
2	G	18/08/2020	0242	Swamp wallaby	C	E	D	689	x 2 with juvenile
2	G	18/08/2020	0355	Bandicoot	C	E	D	690	
2	G	18/08/2020	1752	Bandicoot spp	C	E	D	725	
2	G	19/08/2020	0428	Swamp Wallaby	C	E	D	730	
2	G	19/08/2020	1849	Bandicoot spp	C	E	D	783	
2	G	20/08/2020	1850	Bandicoot spp	C	E	D	784	
2	G	20/08/2020	0301	Echidna	C	W	D	789	
2	G	20/08/2020	0301	Echidna	C	E	D	789	
2	G	20/08/2020	2228	Swamp wallaby	C	E	D	835	
2	G	21/08/2020	0238	Wallaby spp.	C	E	D	838	
2	G	21/08/2020	0239	Swamp wallaby	C	E	D	839	
1	North	18/12/2019	0112	Cat	Incomplete	W-E	D	922-923	Tabby
1	North	27/02/2020	0611	Swamp Wallaby	Complete	W	D	2740-2778	
1	North	8/02/2020	0555	White faced Heron	Complete	E	D	9337-9339	
1	North	8/02/2020	0916	Purple Swamp-hen	Incomplete	W-E	D	9340-9348	
1	North	17/02/2020	0759	Purple Swamp-hen x 3	Incomplete	E-W		4228-4252	1 complete in background
1	North	7/08/2020	0403	Swamp wallaby	Complete	W	D	7652	

Site	Side	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Pic/vid No.	Comments
1	North	12/08/2020	0223	Swamp wallaby	C	E	D	1294-1296	
1	North	12/08/2020	0624	Cat	C	W	D	1538-1539	Black cat
1	North	17/07/2020	1007	Swamp wallaby	C	E	D	1254-1258	
1	North	20/07/2020	1217	Fox	C	E	D	3070	
1	North	16/08/2020	0106	Swamp wallaby	C	E	D	4343-4355	
1	North	16/08/2020	0409	Swamp wallaby	C	W	D	4554-4557	
1	North	18/08/2020	0455	Swamp Wallaby	C	E	D	6165-6167	
1	South	22/10/2019	Nil fauna				D		Camera stolen replaced in Jan 20
1	South	22/10/2019	Nil fauna						Camera stolen replaced in Jan 20
1	South	5/07/2020	0714	Cat	Complete	E	E	8035-8039	
1	South	6/07/2020	0322	Cat	Complete	E	E	8534-835	
1	South	9/08/2020	0913	Cat	Complete	E	D	9434-9441	
1	South	9/07/2020	0703	Purple Swamp-hen	Complete	W	D	11093	
1	South	5/07/2020	1201	Fox	Complete	W	D	15358	

Table C 2: Scat and track data recorded during spring/summer (ss) and winter (w) during year two of operational phase monitoring WC2NH, 2020.

Species/Group	Site																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W
Short-beaked echidna															*									
Antechinus spp.			*				*				*		*						*		*		*	
Peramelidae spp. (bandicoot)			*	*				*	*				*		*		*		*				*	
Koala*							*										*		*					
Trichosurus spp.				*									*	*										
Swamp wallaby													*											
Wallaby spp.	*		*	*	*	*	*		*	*	*		*		*			*		*				
Macropod spp.	*			*											*									
Microbat spp.							*																	
House mouse		*												*				*						

Rodent spp.		*	*		*	*	*	*	*	*	*	*	*	*	*		*	*	*	*				*
Dog				*							*	*					*							
Red fox [I]	*		*	*	*	*		*	*	*	*	*	*	*		*		*		*		*		*
Cat [I]			*		*	*		*	*				*			*			*			*	*	*
Lace monitor					*		*				*		*		*		*		*					
Medium lizard			*						*						*									
Small reptile					*				*															
Litoria spp.																			*					
Welcome swallow					*																			
Bird spp.																	*							
Total no. Species/groups	3	2	7	6	7	4	6	4	7	3	6	3	9	4	7	2	6	4	7	3	1	2	3	3

Table C 3: Sand pad data recorded over 8 nights during spring/summer (ss) and winter (w) during year two of operational phase monitoring WC2NH, 2020.

Species/group	1		2		3		4		5		6		7		8		9		10		11		12	
	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W
Short-beaked echidna			*										*											
Antechinus spp.			*																					
Peramelidae spp. (bandicoot)				*			*	*							*									
Koala*							*																	
Trichosurus spp.			*	*									*	*	*		*							
Swamp wallaby													*											
Red neck wallaby					*																			
Wallaby spp.			*	*	*	*				*			*					*		*				
Macropod spp.	*			*																				

House mouse[I]		*												*				*						
Rodent spp.		*	*	*		*	*	*	*	*	*	*		*			*	*	*	*	*		*	*
Dog[I]											*	*				*								
Red fox [I]	*		*	*	*	*		*		*				*		*		*		*		*		*
Cat [I]		*			*	*	*	*					*		*	*						*		
Lace monitor											*		*		*		*		*					
Waterbird spp.	*																							
Lampropholis spp.																					*			
Medium reptile							*		*		*						*							
Australian brush turkey													*											
Total species/group	3	3	6	6	4	4	5	4	2	3	4	2	7	4	4	3	4	4	2	3	2	2	1	2

Table C 4: Nocturnal (spotlighting) adjacent habitat surveys conducted during spring/summer and winter during year two of operational phase monitoring WC2NH, 2020.

Location	Side	Date	Obs. No.	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	Humidity	Comment
11&12	E	15/06/20	1	LA	1859	1929	Wallaby spp (Heard)	Nil	Nil	Good	13.2	91	
	W	15/06/20	1	LA	1933	2003	SuG Sm	Nil	Nil	Good	13.2	91	
	E	17/06/20	2	DR	1750	1820	Nil	MSB	Nil	Good	14	77	
	W	17/06/20	2	LA	1750	1820	Nil	MSB	Nil	Good	14	77	
9&10	E	15/06/2020	1	BT	1908	1938	Common ringtail possum	Nil	Nil	Good	17	70	
	W	15/06/2021	1	DR	1908	1938	GHFF	Nil	Nil	Good	17	70	
	E	17/6/20	2	BT	1903	1932	ONj	MSB	NIL	GOOD	11.5	84	
	W	17/6/20	2	BT	1829	1900	Nil	MSB	NIL	GOOD	11.5	84	
8	E	15/06/2020	1	BT	1945	2015	Nil	Nil	Nil	Good	17	70	
	W	15/06/2021	1	DR	1945	2015		Nil	Nil	Good	17	70	
	E	17/6/20	2	BT	2009	2040	Nil	MSB	NIL	GOOD	10.6	89	
	W	17/6/20	2	BT	1936	2005	Nil	MSB	NIL	GOOD	10.6	89	
7	E	15/06/20	1	LA	2006	2036	Crinia signifera	Nil	Nil	Good	12.8	93	
	W	15/06/20	1	LA	2037	2107	Nil	Nil	Nil	Good	12.8	93	
	E	17/06/20	2	DR	1824	1854	Nil	MSB	Nil	Good	14	77	
	W	17/06/20	2	LA	1824	1854	Nil	MSB	Nil	Good	14	77	
5&6	E	15/06/2020	1	BT	2020	2050	Nil	Nil	Nil	Good	17	70	
	W	15/06/2020	1	DR	2020	2050	Crinia signifera	Nil	Nil	Good	17	70	
	E	17/06/2020	2	DR	1917	1947	Nil	MSB	Nil	Good	12.8	79	
	W	17/06/2020	2	LA	1917	1947	Nil	MSB	Nil	Good	12.8	79	
4	E	16/06/2020	1	BT	1836	1906	FtG	Nil	Nil	Good	13.8	84	
	W	16/06/2020	1	LA	1836	1906	nil	Nil	Nil	Good	13.8	84	
	E	19/06/20	2	DR	1832	1902	nil	MSB	NIL	Good	11.5	84	
	W	19/06/20	2	LA	1832	1902	nil	MSB	NIL	Good	11.5	84	
3 (E only)	E	15/06/20	1	LA	2112	2142	Nil	Nil	Nil	Good	12.8	93	
	E	17/06/2020	2	DR/LA	2008	2038	Wallaby (bouncing)	MSB	Nil	Good	12.8	79	
2	E	15/06/20	1	DR	2105	2140	Sb echidna, Cr. signifera, GHFF	Nil	Nil	Good	17	70	

	W	15/06/20	1	BT	2105	2140	SuG, Cr. signifera	Nil	Nil	Good	17	70	
	E	17/06/20	2	LA	2046	2116	GhFF	MSB	Nil	Good	14	77	
	W	17/06/20	2	DR	2046	2116	nil	MSB	Nil	Good	14	15	
1	E	16/06/2020	1	BT	1745	1815	nil	Nil	Nil	Good	14.9	84	
	W	16/06/2020	1	LA	1745	1815	nil	Nil	Nil	Good	14.9	84	
	E	19/06/20	2	DR	1748	1818	Nil	Nil	Nil	Good	15.6	68	
	W	19/06/20	2	LA	1748	1818	Crinia signifera	Nil	Nil	Good	15.6	68	
11&12	E	3/10/19	1	NM/BT	2210	2225	GHFF, P. coriacea	Nil	Nil	Good	14.9	84	
	W	3/10/19	1	NM/BT	2152	2207	GHFF	Nil	Nil	Good	14.9	84	
	E	27/11/19	2	LA	2120	2150	GHFF, A. brevis						
	W	27/11/19	2	DR	2120	2150	GHFF, SuG,						
9&10	E	3/10/19	1	NM/BT	2110	2125	GHFF, P.coriacea, A.brevis	Nil	Nil	Good	16.1	79	
	W	3/10/19	1	NM/BT	2128	2143	P.coriacea, GHFF	Nil	Nil	Good	16.1	79	
	E	27/11/19	2	LA	2200	2230	Swamp wallaby, GHFF						
	W	27/11/19	2	DR	2200	2230	GHFF						
8	E	21/10/19	1	NM/LA	2142	2157	GHFF	Nil	Nil	Good	14.2	83	
	W	21/10/19	1	NM/LA	2125	2140	GHFF	Nil	Nil	Good	14.2	83	
	E	28/11/19	2	LA	2000	2030	GHFF						
	W	28/11/19	2	DR	2000	2030	GHFF						
7	E	21/10/19	1	NM/LA	2045	2100	A.brevis, C.signifera, Limnodynastes peronii, GHFF	Nil	Nil	Good	14.2	83	
	W	21/10/19	1	NM/LA	2102	2117	A. Brevis, SuG SE, prob bandicoot HM, GHFF	Nil	Nil	Good	14.2	83	
	E	28/11/19	2	LA	2040	2110	Bandy bandy, GHFF, Adelotus brevis	Nil					
	W	28/11/19	2	DR	2040	2110	GHFF	Nil					
5&6	E	18/10/19	1	NP/NM	2025	2040	GHFF, Lit. peronii, Lit. fallax, A brevis	Nil	Nil	Good	16.2	65	
	W	18/10/19	1	NP/NM	2040	2055	Lit. tyleri, P. Coriacea	Nil	Nil	Good	16.2	65	
	E	28/11/19	2	LA	2120	2150	Lit. fallax, Lit. peroni, Lim. peroni, GHFF	Nil	V. Light	Good	22	77	
	W	28/11/19	2	DR	2120	2150	GHFF, Sw. Wallaby, Lit. peroni	Nil					
4	E	21/10/19	1	NM/LA	2005	2020	GHFF, Limnodynastes peronii	Nil	Nil	Good	16.4	71	
	W	21/10/19	1	NM/LA	2021	2036	GHFF, SuG hc	Nil	Nil	Good	16.4	71	

	E	28/11/19	2	LA	2200	2230	GHFF, koala (sub-adult)	Nil	V. Light	Mod	22	78	
	W	28/11/19	2	DR	2200	2230	GHFF						
3 (E only)	E	18/10/19	1	NP/NM	2005	2020	Cat, LN Bandicoot, Macropod spp.	Nil	Nil	Good	16.5	60	
	E	21/10/19	2	NM/LA	1935	1950	GHFF, Frog spp, cat, Wallaby spp	Nil	Nil	Good	16.4	71	
	E	28/11/19	3	DR/LA	1050	1105	Nil	Nil	Light	Mod	22	78	
2	E	18/10/19	1	NP/NM	1930	1945	C. signifera	Nil	Nil	Good	16.7	56	
	W	18/10/19	1	NP/NM	1945	2000	Nil	Nil	Nil	Good	16.7	56	
	E	28/11/19	2	LA	2315	2345	Nil	Nil	Light	Mod	22	80	
	W	28/11/19	2	DR	2315	2345	GHFF						
1	E	16/10/19	1	NP/NM	2015	2030	Lit fallax						
	W	16/10/19	1	NP/NM	2000	2015	M iteratus, water dragon, small mammal spp., ad brevis						
	E	27/11/19	2	LA	2018	2048	Lit fllax, ff sp						
	W	27/11/19	2	DR	2018	2048	Ad brevis , lit fallax, northern brown, ff sp, swamp wallaby						

Table C 5: Diurnal adjacent habitat surveys conducted during spring/summer and winter during year two of operational phase monitoring WC2NH, 2020.

Site	Date	Side	Survey No.	Observers	Start Time	Finish Time	Wind	Rain	Visibility	Air Temp	Humidity	Species (no. of individuals / behaviour)	Signs (scats/tracks etc)	Comments
11&12	1/06/20	W	1	LA	11:50	0:20	Nil	Nil	Good	20.8	59	Lampropholis spp		
	1/06/20	E	1	LA	1221	1251	Nil	Nil	Good	20.8	59	Wallaby (scat)		
	16/6/20	W	2	BT	958	1027	MSB	Nil	Good	17.6	71	Lampropholis spp.		
	16/6/20	E	2	BT	1031	1100	MSB	Nil	Good	18.1	68	Lampropholis spp.; Saiphos equalis	B'coot diggings	
9&10	1/06/20	W	1	LA	1255	1325	Nil	Nil	Good	22.1	59	Wallaby (scat)		
	1/06/20	E	1	LA	1330	14:00	Nil	Nil	Good	23.8	53	Wallaby (scat)		
	16/6/20	W	2	BT	1120	1150	MSB	Nil	Good	19.1	64	Nil	B'coot diggings	
	16/6/20	E	2	BT	1154	1223	MSB	Nil	Good	19.1	64	Lampropholis spp.		
8	1/06/20	W	1	LA	1406	1446	Nil	Nil	Good	23.8	53	Bandicoot diggings		
	1/06/20	E	1	LA	1448	1516	Nil	Nil	Good	23.8	53	Cat (tracks), Lampropholis x1, Wallaby scat,		
	16/6/20	W	2	BT	1245	1315	MSB	Nil	Good	19	67	Nil		
	16/6/20	E	2	BT	1318	1347	MSB	Nil	Good	19	67	Nil		
7	5/06/20	W	1	LA	11:15	11:45	Nil	Light	Good	19.2	54	Wallaby (scat), Old koala scat		
	1/06/19	E	1	LA	1523	1553	Nil	Nil	Good	21.9	53	Calyptotis ruficauda, Bandicoot diggings		
	16/6/20	W	2	BT/LA	1356	1411	MSB	Nil	Good	19.6	70	Nil		
	16/6/20	E	2	BT/LA	1415	1430	MSB	Nil	Good	19.6	70	L.delicata		
5&6		W	1	LA	11:51	12:21	Nil	Light	Good	19.2	54	Calyptotis ruficauda, Bandicoot diggings		
		E	1	LA	12:24	12:54	Nil	Light	Good	19.2	54	Bandicoot diggings		
	16/6/20	W	2	BT/LA	1436	1451	MSB	Nil	Good	19.6	70	Nil		
	16/6/20	E	2	BT/LA	1453	1509	MSB	Nil	Good	19.6	70	Nil		
4		W	1	LA	13:04	13:34	Nil	Light	Good	19.2	54	Calyptotis ruficauda		
		E	1	LA	13:35	14:05	Nil	Light	Good	19.2	54	Nil		
	17/6/20	W	2	BT	1436	1451	MSB	Nil	Good	19.1	62	Nil	B'coot diggings	
	17/6/20	E	2	LA	1140	1210	MSB	Nil	Good	19.1	62	Rodent scats		
3	17/6/20	E	1	DR	1010	1040	MSB	Nil	Good	NR	NR	Nil		
	17/6/20	W	1	DR	945	1005	MSB	Nil	Good	NR	NR	Nil		
	20/6/20	E	2	LA	1115	1145	Nil	Nil	Good	18	60	Nil		
	20/6/20	W	2	DR	1115	1145	Nil	Nil	Good	18	60	Crinia signifera		
2	16/6/20	E	1	DR	1430	1500	MSB	Nil	Good	19.6	70	C. ruficauda x1, Lampropholis spp. x1, Ctenotus spp x1,	Swamp wallaby (scat)	
	16/6/20	W	1	DR	1505	1530	MSB	Nil	Good	19.6	70	Nil		
	20/06/2020	E	2	LA	1121	1151	Nil	Nil	Good	17.7	58	Crinia signifera, Lampropholis spp.		
	20/06/2020	W	2	DR	1121	1151	Nil	Nil	Good	17.7	58	Nil		
1	1/06/20	W	1	LA	1003	1033	Nil	Nil	Good	18.1	63	EW dragon x2, Lampropholis spp x 1, Btp (scat), Wallaby (track)		

	1/06/20	E	1	LA	1035	1105	Nil	Nil	Good	18.1	63	Lampropholis spp., Fox (scat), Dog (tracks)		
	20/06/2020	E	2	DR	1035	1105	Nil	Nil	Good	17.7	58	Nil		
	20/06/2020	W	2	LA	1035	1105	Nil	Nil	Good	17.7	58	Water dragon, Crinia signifera		
11&12	22/9/19	W	D1	NM	845	915	Msb	Nil	Good	19	82	Lampropholis spp.	OBS	
	22/9/19	E	D1	NM/NP	915	930	MSB	Nil	Good	19	82	Lampropholis spp., A. brevis, Wallaby scat, bandicoot diggings	Obs	
	1/10/19	W	D2	NP	1445	1515	Nil	Nil	Good	21	79	Wallaby scat		
	1/10/19	E	D2	NP	1515	1545	Nil	Nil	Good	21	79	Lampropholis spp., Wallaby scat		
9&10	3/10/19	W	D1	NP	11:00	11:30	RL	Nil	Good	21.5	68	Lampropholis spp., small mammal nest (melomys?), Bandicoot diggings		
	3/10/19	E	D1	NP	11:30	12:00	RL	Nil	Good	21.5	68	Echidna diggings		
	15/10/19	W	D2	Nm/La	9:30	9:45	Nil	Nil	Good	22.1	75	Lampropholis spp		
	15/10/19	E	D2	Nm/La	9:50	10:05	Nil	Nil	Good	22.1	75	Bandicoot diggings, Lampropholis spp, Wallaby scat		
8	3/10/19	W	D1	NP	12:05	1235	RL	Nil	Good	23	65	Lampropholis spp, Echidna diggings, Wallaby scat		
	3/10/19	E	D1	NP	1235	1305	RL	Nil	Good	23	65	Lampropholis spp.		
	Incidental											Swamp snake		
	15/10/19	W	D2	NM/LA	1010	1025	Nil	Nil	Good	22.7	75	Lampropholis spp, bearded dragon		
	15/10/19	E	D2	NM/LA	1030	1045	Nil	Nil	Good	22.7	75	Lampropholis spp, Wallaby scat		
	16/10/19	W	D3	LA	12:02	1232	Msb	Nil	Good	25.8	67	Yellow faced whipsnake, lace Monitor, Lampropholis spp, Bandicoot diggings		
	16/10/19	E	D3	LA			Msb	Nil	Good	25.8	67	Wallaby scat		
7	4/10/19	W	D1	NP	945	1015	RL	Nil	Good	23	61	Wallaby scat, bandicoot diggings		
	4/10/19	E	D1	NP	1015	1045	RL	Nil	Good	23	61	Echidna diggings, Wallaby scat		
	16/10/19	W	D2	LA	1245	1300	Msb	Nil	Good	24.9	69	Lampropholis spp multiple		
	16/10/19	E	D2	LA	1315	1330	Msb	Nil	Good	24.9	69	Lampropholis spp multiple, bandicoot diggings, Wallaby scat		
5&6	Incidental											Burtons legless lizard		
	16/10/19	W	D1	NP/NM	1025	1040	Nil	Nil	Good	29	49	Lampropholis spp, Wallaby scat, bandicoot digging		
	16/10/19	E	D1	NP/NM	1040	1055	Nil	Nil	Good	29	49	Lampropholis spp., Wallaby scat, bandicoot & echidna diggings		
	18/10/19	W	D2	NM	1200	1230	MSB	Nil	Good	22	27	Lampropholis spp multiple, bandicoot diggings		
	18/10/19	E	D2	NM	1235	1305	MSB	Nil	Good	22	27	Wallaby scat, Lampropholis spp multiple		
4	16/10/19	W	D1	NM	1105	1135	Nil	Nil	Good	25.5	66	Lampropholis spp., Wallaby scat, bandicoot & echidna diggings		
	16/10/19	E	D1	NP	1105	1135	Nil	Nil	Good	25.5	66	Lampropholis spp., Wallaby scat,		

												bandicoot & echidna diggings		
	18/10/19	W	D2	NM	1305	1335	MSB	Nil	Good	25.7	16	Med lizard, Wallaby scat		
	21/10/19	E	D2	NM	1035	1105	Nil	Nil	Good	21.8	62	Bandicoot diggings, Wallaby scat, Lampropholis spp		
3	16/10/19	W	D1	NM	1145	1215	Nil	Nil	Good	25.4	67	Wallaby scat, bandicoot diggings		
	16/10/19	E	D1	NP	1145	1215	Nil	Nil	Good	25.4	67	Lampropholis spp., Bandicoot scat, water dragon scat, echidna diggings, Wallaby scat		
	18/10/19	W	D2	NP/NM	1000	1015	Nil	Nil	Good	22.3	31	Wallaby scat, bandicoot diggings		
	18/10/19	E	D2	NP/NM	1015	1030	Nil	Nil	Good	22.3	31	Lampropholis spp., Bandicoot scat, water dragon scat, echidna diggings, Wallaby scat		
2	16/10/19	W	D1	LA	14:30	1500	Nil	Nil	Good	25.4	67	Echidna & bandicoot diggings, Wallaby scat, Lampropholis spp		
	15/10/19	E	D1	LA				nil		25.4	67			
	21/10/19	W	D2	NM	1110	1140	Nil	Nil	Good	25.5	22	Lampropholis spp, Wallaby scat		
	21/10/19	E	D2	NM	1145	1215	Nil	Nil	Good	25.5	22	Wallaby scat, lace Monitor scat, Lampropholis spp		
1	16/10/19	W	D1	LA	1055	1125	RL	Nil	Good	25	65	EW dragon x2, Lampropholis spp x 1		
	16/10/19	E	D1	LA	1130	1200	RL	Nil	Good	25	65	EW dragon x3, Lampropholis spp x2, Fox scat		
	21/10/19	W	D2	NM	1307	1337	Nil	Nil	Good	28	17	EW dragon x 2, wallaby scat, Fox scat, bandicoot diggings		
	21/10/19	E	D2	NM	1235	1305	Nil	Nil	Good	26.6	16	Lampropholis spp		

Table C 6: Fauna captured during adjacent habitat trapping surveys during spring/summer and winter of year two operational monitoring WC2NH, 2020.

Site	Season	Date	Trap type	Species	Sex	Weight	Comments
11&12 west	Winter	16/06/20	Large Elliot	sugar glider	M	125	
11&12 west	Winter	16/06/20	Large Elliot	sugar glider	F	105	
11&12 west	Winter	16/06/20	Pitfall	3X Redbank toadlet			
9/10 east	Winter	16/06/20	Ground Elliot	Brown antechinus	M	40	
9/10West	Winter	16/06/20	Ground Elliot	FF Melomys	F	80	
11&12 East	Winter	17/06/2020	Ground Elliot	FF Melomys	M	76	
11&12 East	Winter	17/06/2020	Ground Elliot	FF Melomys	F	62	
11&12 west	Winter	17/06/2020	Cage trap	Black rat	N/A	N/A	Escaped
9/10 east	Winter	17/06/2020	Ground Elliot	Brown antechinus	M	47	
9/10West	Winter	17/06/2020	Ground Elliot	FF Melomys	F	46	Grey in colour, distinct mosaic tail pattern
9/10West	Winter	17/06/2020	Ground Elliot	FF Melomys	F	63	
11&12 west	Winter	18/06/2020	Large Elliot	sugar glider	M	127	
11&12 west	Winter	18/06/2020	Large Elliot	sugar glider	F	110	
8 west	Winter	18/06/2020	Pitfall	2x FF Melomys	M	NR	Deceased
2 west	Winter	19/06/2020	Ground Elliot	Black rat	M	139	Euthanised
2 west	Winter	19/06/2020	Ground Elliot	Black rat	F	155g	Euthanised
2 west	Winter	19/06/2020	Ground Elliot	Brown Antechinus	F	290g	
2 west	Winter	19/06/2020	Cage trap	Black rat			Escaped
2 east	Winter	19/06/2020	Ground Elliot	FF Melomys	F	73g	
2 east	Winter	19/06/2020	Ground Elliot	FF Melomys	F	54g	
2 East	Winter	19/06/2020	Pitfall	Limnodynastes peronii			
1 West	Winter	19/06/2020	Ground Elliot	Black rat	F	130g	
1 west	Winter	19/06/2020	Cage trap	Black rat	M		Escaped
3 east	Winter	20/06/2020	Ground Elliot	House mouse	M	17 grams	
3east	Winter	20/06/2020	Ground Elliot	Black rat	M	103 grams	
2 East	Winter	20/06/2020	Ground Elliot	FF Melomys	M	79g	
1 West	Winter	20/06/2020	Cage trap	SeBtP	F	-	Carrying young in pouch
1 west	Winter	20/06/2020	Ground Elliot	Black rat	F	136g	
2 East	Winter	21/06/2020	Pitfall	Limnodynastes peronii			
2 East	Winter	21/06/2020	Large Elliot	FF Melomys	F	63g	
1 east	Winter	21/06/2020	Cage trap	SeBtP	F	-	
1 east	Winter	21/06/2020	Ground Elliot	Black rat	-	-	
3 East	Winter	21/06/2020	Ground Elliot	Brown Antechinus	M	42g	
5/6 east	Winter	16/6/20	Ground Elliot	FF Melomys	F	52g	
5/6 west	Winter	16/6/20	Ground Elliot	Bush rat	F	94g	
5/6 west	Winter	16/6/20	Ground Elliot	Bush rat	F	90g	
7 west	Winter	16/6/20	Ground Elliot	FF Melomys	F	72g	
7 west	Winter	16/6/20	Ground Elliot	Brown Antechinus	M	54g	
5/6 west	Winter	17/6/20	Ground Elliot	Bush rat	F	60g	
7 east	Winter	17/6/20	Ground Elliot	Brown Antechinus	F	32g	
7 west	Winter	17/6/20	Ground Elliot	FF Melomys	F	90g	
7 west	Winter	17/6/20	Cage trap	SeBtP	NR	NR	
8 west	Winter	17/6/20	Ground Elliot	Brown Antechinus	M	36g	
8 west	Winter	17/6/20	Ground Elliot	FF Melomys	F	58g	
5/6 west	Winter	18/6/20	Ground Elliot	Brown Antechinus	M	NR	
5/6 west	Winter	18/6/20	Ground Elliot	Bush rat	M	NR	
5/6 west	Winter	18/6/20	Ground Elliot	Black rat	F	NR	euthanised
5/6 west	Winter	18/6/20	Ground Elliot	Brown Antechinus	M	NR	
7 west	Winter	18/6/20	Ground Elliot	FF Melomys	F	NR	
7 east	Winter	18/6/20	Arboreal Elliot	FF Melomys	F	NR	
7 east	Winter	18/6/20	Ground Elliot	Brown Antechinus	M	NR	
8 west	Winter	18/6/20	Ground Elliot	Brown Antechinus	M	NR	
8 west	Winter	18/6/20	Ground Elliot	Brown Antechinus	M	43g	
3 west	Winter	19/6/20	Ground Elliot	FF Melomys	F	54g	
3 west	Winter	19/6/20	Ground Elliot	House mouse	F	15g	Euthanised
3 west	Winter	19/6/20	Ground Elliot	Black rat	F	120g	Euthanised
4 west	Winter	19/6/20	Ground Elliot	FF Melomys	F	54g	
4 west	Winter	19/6/20	Ground Elliot	Bush rat	F	138g	
4 west	Winter	19/6/20	Arboreal Elliot	Brown Antechinus	F	17g	
4 west	Winter	19/6/20	Ground Elliot	Bush rat	M	146g	

2 west	Winter	20/2/20	Ground Elliot	Black rat	M	118g	Euthanised
2 west	Winter	20/2/20	Ground Elliot	Black rat	F	148g	Euthanised
4 west	Winter	20/2/20	Ground Elliot	FF Melomys	F	76g	
4 west	Winter	20/2/20	Ground Elliot	FF Melomys	F	56g	
4 west	Winter	20/2/20	Ground Elliot	Bush rat	F	136g	
4 west	Winter	20/2/20	Ground Elliot	Bush rat	M	128g	
4 west	Winter	20/2/20	Ground Elliot	Brown Antechinus	M	42g	
1 west	Winter	20/6/20	Cage trap	Black rat	NR	NR	
1 west	Winter	20/6/20	Pitfall	Striped marsh frog	N/A	N/A	
3 west	Winter	21/6/20	Ground Elliot	House mouse	M	8g	Euthanised
3 west	Winter	21/6/20	Ground Elliot	House mouse	M	7g	Euthanised
3 west	Winter	21/6/20	Pitfall	House mouse	M	7g	Euthanised
2 west	Winter	21/6/20	Ground Elliot	Brown Antechinus	M	28g	
2 west	Winter	21/6/20	Arboreal Elliot	Black rat	F	87g	Euthanised
2 west	Winter	21/6/20	Ground Elliot	Black rat	F	156g	Euthanised
2 west	Winter	21/6/20	Cage trap	Black rat	NR	NR	
2 west	Winter	21/6/20	Cage trap	Black rat	NR	NR	
1 west	Winter	21/6/20	Cage trap	Black rat	NR	NR	
1 west	Winter	21/6/20	Ground Elliot	House mouse	F	13g	Euthanised
1 west	Winter	21/6/20	Ground Elliot	Black rat	F	92g	Euthanised
4 west	Winter	21/6/20	Arboreal Elliot	Brown Antechinus	F	38g	
4 west	Winter	21/6/20	Ground Elliot	Black rat	F	138g	Euthanised
4 west	Winter	21/6/20	Ground Elliot	Bush rat	F	122g	
4 west	Winter	21/6/20	Ground Elliot	FF Melomys	F	46g	
4 west	Winter	21/6/20	Ground Elliot	Bush rat	M	138g	
5/6 west	Spring/summer	15/10/19	Pit	Calyptotis ruficauda	UK	NA	
5/6 west	Spring/summer	15/10/19	Small Elliot	Bush Rat	UK	UK	Escaped before processing
5/6 west	Spring/summer	15/10/19	Small Elliot	Brown Antechinus	F	26g	Parous, 6 pouch young.
5/6 east	Spring/summer	15/10/19	Pit	Calyptotis ruficauda	UK	NA	
5/6 east	Spring/summer	15/10/19	Small Elliot	FF Melomys	M	56g?	Weight may not be accurate
5/6 east	Spring/summer	15/10/19	Small Elliot	Brown Antechinus	F	27g	Parous, 5 pouch young.
8 east	Spring/summer	15/10/19	Small Elliot	FF Melomys	M	74g	
9/10 west	Spring/summer	15/10/19	Small Elliot	FF Melomys	M	54g	
9/10 west	Spring/summer	15/10/19	Small Elliot	FF Melomys	M	77g	
9/10 west	Spring/summer	15/10/19	Cage	SEBtP	F	NA	Young adult
11/12 east	Spring/summer	15/10/19	Small Elliot	FF melomys	M	80	
11/12 west	Spring/summer	15/10/19	Large Elliot	Sugar Glider	F	100	
11/12 west	Spring/summer	15/10/19	Pitfall	Lampropholis delicata x 4	UK	UK	
5/6 west	Spring/summer	16/10/19	Pit	Blackish blind snake	NA	Na	
5/6 west	Spring/summer	16/10/19	Pit	S Dwarf Crowned Snake	NA	NA	
5/6 west	Spring/summer	16/10/19	Pit	Brown Antechinus	F		Parous
5/6 east	Spring/summer	16/10/19	Small Elliot	FF Melomys		70g	
8 west	Spring/summer	16/10/19	Small Elliot	FF Melomys	M	96g	
9/10 east	Spring/summer	16/10/19	Cage	SEBtP	M	NA	
9/10 west	Spring/summer	16/10/19	Small Elliot	Black Rat	F	90g	
11/12 east	Spring/summer	16/10/19	Pitfall	P. Coriacea	UK	UK	
5/6 west	Spring/summer	17/10/19	Small Elliot	Brown Antechinus	F	26g	Parous, 7 pouch young
5/6 east	Spring/summer	17/10/19	Small Elliot	Black Rat	M	NA	Euthanised
5/6 east	Spring/summer	17/10/19	Small Elliot	FF Melomys	M	77g	
8 east	Spring/summer	17/10/19	Small Elliot	FF Melomys	M	82g	
8 east	Spring/summer	17/10/19	Large Elliot	FF Melomys	M	64g	
8 west	Spring/summer	17/10/19	Small Elliot	Brown Antechinus	F	33	Parous
8 west	Spring/summer	17/10/19	Small Elliot	FF Melomys	F	64g	
1 west	Spring/summer	18/10/19	Large Elliot	Black Rat	M	NA	Euthanised
2 west	Spring/summer	18/10/19	Pit	Swamp snake	NA	NA	
2 east	Spring/summer	18/10/19	Small Elliot	FF Melomys			
2 east	Spring/summer	18/10/19	Small Elliot	FF Melomys			
2 east	Spring/summer	18/10/19	Small Elliot	Brown Antechinus	F		
2 west	Spring/summer	18/10/19	Pit	L delicata x 5			
3 west	Spring/summer	18/10/19	Pit	P. coriacea	NA	NA	
7 west	Spring/summer	18/10/19	Small Elliot	Sugar Glider	M	120	
7 west	Spring/summer	18/10/19	Pitfall	House mouse	F	30	
7West	Spring/summer	18/10/19	Small Elliot	Brown Antechinus	F	30	With 7 young
7West	Spring/summer	18/10/19	Small Elliot	FF melomys	M	80	
4 west	Spring/summer	18/10/19	Small Elliot	FF melomys	F	65	
4 west	Spring/summer	18/10/19	Large Elliot	FF melomys	M	85	

4 east	Spring/summer	18/10/19	Small Elliot	FF melomys	M	65	
2 east	Spring/summer	18/10/19	Small Elliot	Brown Antechinus			
3 east	Spring/summer	18/10/19	Pit	Swamp snake			
1 west	Spring/summer	19/10/19	Small Elliot	Yellow-throated scrubwren			
2 west	Spring/summer	19/10/19	Small Elliot	Bush Rat	M	149	
2 east	Spring/summer	19/10/19	Small Elliot	Brown Antechinus	F	20	Parous with 2 young
2 east	Spring/summer	19/10/19	Small Elliot	FF Melomys	M	49	
3 east	Spring/summer	19/10/19	Pit	Red-backed toadlet			
7 west	Spring/summer	19/10/19	Small Elliot	FF melomys	M	85	
4West	Spring/summer	19/10/19	Small Elliot	Black Rat	F	95	
4 west	Spring/summer	19/10/19	Small Elliot	Black Rat			Escaped
4East	Spring/summer	19/10/19	Cage	Northern brown bandicoot	Na	Na	Minor injuries
3West	Spring/summer	19/10/19	Pitfall	Lampropholis delicata			
3West	Spring/summer	19/10/19	Cage	Northern brown bandicoot			Escaped
1 east	Spring/summer	20/10/19	Small Elliot	Brown Antechinus	F	31g	Parous with 8 pouch young
1 west	Spring/summer	20/10/19	Cage	SEBtP x 2	F		Mother and back young
2 east	Spring/summer	20/10/19	Small Elliot	Brown Antechinus	F		Parous with 7 young
2 east	Spring/summer	20/10/19	Small Elliot	Bush Rat		146g	
2 east	Spring/summer	20/10/19	Cage	Northern brown bandicoot			
2 east	Spring/summer	20/10/19	Pit	C. ruficauda			Check ID
7 west	Spring/summer	21/10/19	Cage	SEBtPoss	M		
7 west	Spring/summer	21/10/19	Small Elliot	Brown Antechinus	F		With young
7 west	Spring/summer	21/10/19	Small Elliot	FF melomys	NA	85	
4 west	Spring/summer	21/10/19	Large Elliot	FF melomys	NA		
4 east	Spring/summer	21/10/19	Small Elliot	FF melomys	NA		

Table C 7: Results from adjacent habitat hair-funnel analysis (14 days) during spring/summer and winter during year two of operational phase monitoring WC2NH, 2020.

Site	Side and bait (O=oats S=Sardines)	Winter 2020		
		Install Date	Collect date	Fauna
1	E-O	15/06/2020	22/06/2020	*Trichosurus sp.*
	E-S	15/06/2020	22/06/2020	
	W-O	15/06/2020	22/06/2020	*Trichosurus vulpecula, Mus musculous*

Site	Side and bait (O=oats S=Sardines)	Winter 2020		
		Install Date	Collect date	Fauna
	W-S	15/06/2020	22/06/2020	
2	E-O	15/06/2020	22/06/2020	*Antechinus spp, Vulpes vulpes*
	E-S	15/06/2020	22/06/2020	
	W-O	15/06/2020	22/06/2020	Rattus sp.
	W-S	15/06/2020	22/06/2020	*Rattus sp.*
3	E-O	15/06/2020	22/06/2020	
	E-S	15/06/2020	22/06/2020	
	W-O	15/06/2020	22/06/2020	Mus musculus
	W-S	15/06/2020	22/06/2020	
4	E-O	15/06/2020	22/06/2020	*Rattus sp.*
	E-S	15/06/2020	22/06/2020	
	W-O	15/06/2020	22/06/2020	*Rattus fuscipes(probable)*
	W-S	15/06/2020	22/06/2020	*Rattus sp.*
6	E-O	15/06/2020	22/06/2020	
	E-S	15/06/2020	22/06/2020	
	W-O	15/06/2020	22/06/2020	
	W-S	15/06/2020	22/06/2020	
7	E-O	15/06/2020	22/06/2020	*Antechinus spp*
	E-S	15/06/2020	22/06/2020	
	W-O	15/06/2020	22/06/2020	Antechinus sp., Rattus sp.
	W-S	15/06/2020	22/06/2020	
8	E-O	15/06/2020	22/06/2020	Trichosurus vulpecula, Rattus sp.
	E-S	15/06/2020	22/06/2020	
	W-O	15/06/2020	22/06/2020	Mus musculus
	W-S	15/06/2020	22/06/2020	
9/10	E-O	15/06/2020	22/06/2020	Trichosurus vulpecula, Antechinus sp.
	E-S	15/06/2020	22/06/2020	*Trichosurus sp.*
	W-O	15/06/2020	22/06/2020	*Rattus sp.*
	W-S	15/06/2020	22/06/2020	
11/12	E-O	15/06/2020	22/06/2020	*Mus musculus*
	E-S	15/06/2020	22/06/2020	
	W-O	15/06/2020	22/06/2020	*Mus musculus*
	W-S	15/06/2020	22/06/2020	
1	E-1	14/11/2019	28/11/2019	*Trichosurus sp.* (Brush-tail Possum)
	E-2	14/11/2019	28/11/2019	
	W-1	14/11/2019	28/11/2019	*Trichosurus sp.* (Brush-tail Possum)
	W-2	14/11/2019	28/11/2019	
2	E-1	14/11/2019	28/11/2019	*Antechinus* sp. Melomys cervinipes (Fawn-footed Melomys)
	E-2	14/11/2019	28/11/2019	
	W-1	14/11/2019	28/11/2019	
	W-2	14/11/2019	28/11/2019	*Rattus fuscipes* (Southern Bush-rat)
3	E-1	14/11/2019	28/11/2019	*Wallabia bicolor* (Swamp Wallaby)
	E-2	14/11/2019	28/11/2019	
	W-1	14/11/2019	28/11/2019	
	W-2	14/11/2019	28/11/2019	*Perameles nasuta* (Long-nosed Bandicoot)
4	E-1	14/11/2019	28/11/2019	*Isoodon macrourus* (Northern Brown Bandicoot)
	E-2	14/11/2019	28/11/2019	
	W-1	14/11/2019	28/11/2019	*Rattus fuscipes* (Southern Bush-rat) Isoodon obesulus (Southern Brown Bandicoot)
	W-2	14/11/2019	28/11/2019	*Rattus fuscipes* (Southern Bush-rat)
6	E-1	14/11/2019	28/11/2019	*Melomys cervinipes* (Fawn-footed Melomys)
	E-2	14/11/2019	28/11/2019	
	W-1	14/11/2019	28/11/2019	*Rattus fuscipes* (Southern Bush-rat)
	W-2	14/11/2019	28/11/2019	*Rattus fuscipes* (Southern Bush-rat)
7	E-1	14/11/2019	28/11/2019	*Melomys cervinipes* (Fawn-footed Melomys)
	E-2	14/11/2019	28/11/2019	
	W-1	14/11/2019	28/11/2019	

Site	Side and bait (O=oats S=Sardines)	Winter 2020		
		Install Date	Collect date	Fauna
	W-2	14/11/2019	28/11/2019	*Perameles nasuta* (Long-nosed Bandicoot)
8	E-1	14/11/2019	28/11/2019	
	E-2	14/11/2019	28/11/2019	*Trichosurus sp.* (Brush-tail Possum)
	W-1	14/11/2019	28/11/2019	
	W-2	14/11/2019	28/11/2019	*Trichosurus sp.* (Brush-tail Possum)
9/10	E-1	14/11/2019	28/11/2019	
	E-2	14/11/2019	28/11/2019	*Trichosurus sp.* (Brush-tail Possum)
	W-1	14/11/2019	28/11/2019	*Rattus* sp.
	W-2	14/11/2019	28/11/2019	*Trichosurus sp.* (Brush-tail Possum) Rattus rattus (Black Rat)
11/12	E-1	14/11/2019	28/11/2019	*Melomys cervinipes* (Fawn-footed Melomys)
	E-2	14/11/2019	28/11/2019	
	W-1	14/11/2019	28/11/2019	*Rattus rattus* (Black Rat)
	W-2	14/11/2019	28/11/2019	

Table C 8: Exclusion fence inspection data collected during winter 2020.

Date	Issue number	Observer	Side	Issue identified	Easting	Northing	Priority	Comments
17/06/2020	1	OT	W	Flap not lining up/minor gaps	494429	6604870	Low	
17/06/2020	2	OT	W	Flap not lining up/minor gaps	494478	6605344	Low	
17/06/2020	3	OT	W	Flap not lining up/minor gaps	494478	6605963	Low	
17/06/2020	4	OT	W	Flap not lining up/minor gaps	494740	6605963	Low	
17/06/2020	5	OT	W	Tree overhanging	494828	6606124	Medium	

17/06/2020	6	OT	W	Flap	495539	6607023	Low	
17/06/2020	7	OT	W	Tree overhanging	495330	6607430	Medium	
17/06/2020	8	OT	W	Vine growing over fence	496079	6608187	Medium	
17/06/2020	9	OT	W	Tree leaning over	496150	6608288	Medium	
17/06/2020	10	OT	W	Gap at drop down	496152	6608299	Medium	
17/06/2020	11	OT	W	Gap at gate	496450	6680788	Medium	
17/06/2020	12	OT	W	Branch on fence	496463	6608842	Medium	
17/06/2020	13	OT	W	Fence base not secure	496517	6609031	Low	
17/06/2020	14	OT	W	gate gap	496517	6609225	Medium	
17/06/2020	15	OT	W	Gaps around drain/dropdown	496562	6609436	Low	
17/06/2020	16	OT	W	Gap around drain	496574	6609461	Low	
17/06/2020	17	OT	W	Unlocked gate under bridge	492218	6598858	High	Gate closed
17/06/2020	18	SR	E	small gap under drain flap	494568	6605414	Low	
17/06/2020	19	SR	E	small tree over fence	494798	6605926	Low	
17/06/2020	20	SR	E	gap around drain flap	494798	6605926	Low	
17/06/2020	21	SR	E	small holes in fence either site of pipe	495236	6606743	Low	
17/06/2020	22	SR	E	tree overhanging fence	495585	6607311	Medium	
17/06/2020	23	SR	E	small gap next to drain flap	495598	6607408	Low	
17/06/2020	24	SR	E	small gap under gate	495651	6607507	Low	
17/06/2020	25	SR	E	Frog fence not in contact with ground	495859	6607825	High	
17/06/2020	26	SR	E	Substantial regrowth from point going 100m north	496069	6608159	High	
17/06/2020	27	SR	E	Gap between gates	496194	6608159	Low	
17/06/2020	28	SR	E	Fence above C7 damaged due to car crash	496501	66087211	High	
17/06/2020	29	SR	E	Hole dug under fence	493338	6601774	High	
17/06/2020	30	SR	E	small tree over fence	492482	6599196	Medium	

Warrell Creek to Nambucca Heads

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Document Review

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Project team:

Luke Andrews (Field survey, reporting)
Nirvarna Makings (Field survey)
Dr D. Rohweder (Project management, review, field survey)
Dr B. Taylor (Field survey)
Sam Rohweder (Field assistant)

Report prepared for:

Transport for New South Wales (TfNSW)

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
M 0401 195 480 | E david@sandpipereco.com.au

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1. Introduction

In 2015, Transport for NSW (TfNSW), in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages:

- Stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and
- Stage 2b - 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened on 29 June 2018.

The Ministerial Conditions of Approval (MCoA) for the WC2NH upgrade included a requirement (MCoA B10) to prepare an Ecological Monitoring Program (EMP). The EMP was developed and approved in 2014 and later amended in 2018 (RMS 2018). Species and mitigation measures targeted in the EMP include koala, spotted-tailed quoll, grey-headed flying-red fox, yellow-bellied glider, giant barred frog, green-thighed frog ponds, vegetated median, road-kill, exclusion fencing, threatened flora and fauna underpasses.

As part of the projects approval (MCoA B1, B2, B3) fauna underpasses have been installed at WC2NH "to maintain the viability of local terrestrial fauna populations by facilitating wildlife movement between proximate areas of habitat either side of the upgrade corridor and to accommodate use by several threatened fauna species including the spotted-tailed quoll, koala and giant barred frog" (RMS 2018). To assess the effectiveness of the of the fauna underpasses the EMP specifies operational monitoring to take place bi-annually (i.e spring/summer and autumn/winter for 5 years) in order to align with the breeding and dispersal periods of targeted threatened species (koala, spotted-tailed quoll and giant barred frog).

The following interim report presents methods and results of the year three spring/summer operational phase underpass and adjacent habitat monitoring. The objective of fauna underpass monitoring is "to assess use of underpasses by threatened and common fauna and to assess the effect of exclusion fencing on movement of small mammals, reptiles and frogs" (RMS 2018). Effectiveness of exclusion fence is also assessed in the annual road-kill report (see Sandpiper Ecological 2020b). The results are discussed in relation to the potential indicators of success detailed in the WC2NH EMP (RMS 2018) and recommendations regarding future monitoring are provided. The potential indicators of success used to assess the performance of the WC2NH underpasses include:

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. No change to densities, distribution, habitat use, and movement patterns compared to baseline population data of target species;
4. Evidence of use by dispersing individuals and different age cohorts;
5. Use by cover-dependent species and species with low mobility;
6. No breaches in fauna exclusion fencing;
7. Low incidences of fauna road strike mortality.

A list of species names for fauna referred to in text and Tables is provided in Appendix A.

2. Methods

2.1 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest. The WC2NH upgrade features 23 fauna underpasses, including 13 box culverts, three pipe culverts and seven bridges. Underpasses targeted for monitoring were specified in the WC2NH EMP and include eleven box culverts and one bridge (RMS 2018; Table 1). Eleven underpasses are situated north of the Nambucca River and one (Site 1) is situated at Upper Warrell Creek near the southern extent of the project (Figure 1). Sites four to twelve adjoin Nambucca State Forest and sites two and three adjoin remnant vegetation on private land (Figure 1). Site five includes a dual cell box culvert with one cell designated as a wet passage (for aquatic fauna) and the other as dry passage (Plate 1). The dry cell includes a concrete ledge that provides dry passage for terrestrial fauna. Sites 9/10, and 11/12 consist of corresponding culverts on either side of a vegetated median (Plate 1). Fauna underpasses were designed to target spotted-tailed quoll (*Dasyurus maculatus*), koala (*Phascolarctos cinereus*) and giant barred frog (*Mixophyes iteratus*). Giant barred frog is known to occur at site 1 (Upper Warrell Creek) only, whilst quoll and koala could occur at sites 2-12.

Table 1: Underpasses sampled during operational phase monitoring of the WC2NH upgrade. SQ = spotted-tailed quoll; K = koala; GBF = giant barred frog; * sites consist of dual cells 3x3m box culverts with one cell providing wet passage for aquatic fauna; P/A = presence/absence.

Site	Chainage	Type	Structure	Dimensions	Fauna Furniture (P/A)	Substrate	SQ	K	GBF
1	42500	Combined	Bridge		A	Soil			x
2	55120	Dedicated	Box Culvert	1 x 3000 x 3000	P	Concrete	x	x	
3	56410	Combined	Box Culvert	1 x 2400 x 2400	P	Concrete	x	x	
4	57770	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
5 *	58510	Combined	Box Culvert	2 x 3000 x 3000	A	Concrete	x	x	
6	58560	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
7	59090	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
8	59550	Dedicated	Box Culvert	1 x 3000 x 3000	P	Mulch	x	x	
9	59750 NB	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	
10	59760 SB	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	
11	60600 NB	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	
12	60610 SB	Dedicated	Box Culvert	1 x 2400 x 2400	P	Mulch	x	x	

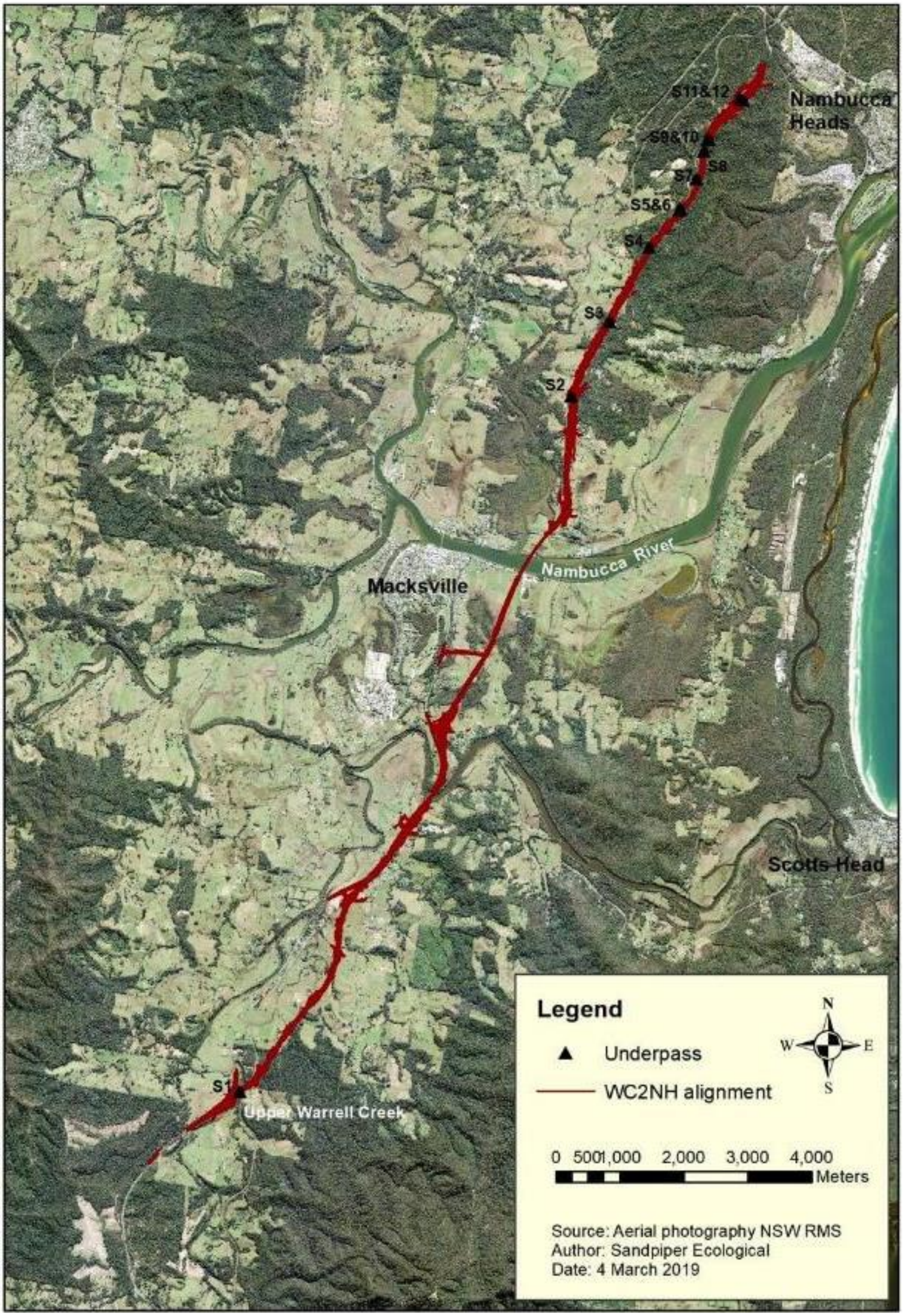

Figure 1: Underpass locations along the WC2NH alignment.

Plate 1. Dual box culverts with designated wet passage at site 5 (top left). Split median box culverts at site 9 and 10 (top right). Fauna furniture entering (bottom left) and exiting site 8 (bottom right).

2.2 Timing and weather conditions

Year 3 operational phase underpass and adjacent habitat surveys were conducted between 12 October 2020 and 04 January 2021 (spring/summer). Dry warm conditions occurred from October 2020 through to November 2020 with a total of 115 mm of rainfall being recorded at the Bureau of Meteorology Bellwood weather station (059150) (Appendix B, Table B1). Warm and wet conditions occurred during December 2020 and early January 2021 with the Bellwood station receiving 704.6mm (Table 2, Appendix B, Table B1). Conditions in December and January were conducive for the movement of amphibians through underpasses.

Table 2: Summary of weather conditions recorded at Coffs Harbour Airport (station 059151) and Bellwood weather station (rainfall only, 059150) during year three spring/summer operational phase monitoring.

Monitoring period	Total rainfall (mm)	No. rain days	Relative humidity (%)	Max temp range (^{0}C)	Min temp range (^{0}C)
Spring/Summer	665	37	>60% on 90% of days	21.7-32.1	6.7-25

2.3 Underpass monitoring

2.2.1 Sand pads

Sand pads were installed on 28 October 2020 (spring/summer sample). A 50:50 mix of brickies sand and washed beach sand was used for all sand pads. Two sand pads were installed at each site. In culverts, pads were installed 3-5m from each end, whilst at the bridge (site 1) two pads were installed on the northern side of Warrell Creek. Each pad was approximately 50mm deep by 1m wide and extended for the entire culvert width, or for 3-4m at site 1. At sites with a concrete ledge the pad covered both the floor and ledge (Plate 1). The exception was site 5 where the pad covered the ledge only due to standing water over the culvert floor on the eastern end.

Sand pads were inspected on eight consecutive days across all sites. Rain on 28 October 2020 led to complete or partial wash out of sand pads at sites 3, 2,and 12, with pads reinstalled on 29 October. Inspections were conducted by an ecologist and included a systematic scan of each pad searching for fauna tracks. A small torch was used to illuminate the pad, if required. Information recorded included species or fauna group, number of traverses, direction of traverse and pad condition (good, moderate, poor). Tracks were identified with reference to Triggs (2004) and advice from senior ecologists. Tracks that could not be identified insitu were photographed and referred to a senior ecologist for identification.

Plate 2. Sand pad being installed in a fauna underpass (Site 3) on the WC2NH upgrade.

2.2.2 Scat and track searches

Each underpass was searched by a senior ecologist and/or ecologist for scats and tracks on two occasions during the spring/summer and winter sample periods. The search involved a slow systematic traverse of each culvert using a hand-held spotlight (Led Lenser P14). Fauna furniture, the culvert floor, and joints were targeted. Areas of accumulated fine sediment were targeted for tracks. Tracks and scats were identified in-situ, with reference to Triggs (2004) and the ecologists experience or photographed and sent to colleagues for identification.

2.2.3 Tile checks

In autumn 2020 two roof tiles (300x200) were installed at both ends of underpasses 5m in from the entrance to target small mammals, reptiles and frogs. These were checked on two occasions during the spring/summer sample period.

2.2.4 Cameras

Two motion-activated infra-red cameras (Swift 3C, Swift Enduro or Reconyx HC500) were installed centrally in each culvert, with the exception of site five where one camera was mounted centrally in each cell. At site 1, Reconyx HC500 cameras were initially attached to steel posts, and following theft, were housed in security boxes attached to concrete posts. A single camera was installed at approximately 200mm above ground near the water's edge on each side of Upper Warrell Creek (site 1). In total, 24 cameras were installed. In underpasses, both cameras were installed centrally, one on the fauna furniture, and one approximately 300mm above the culvert floor. Cameras were oriented to the east except for site 1 where cameras were oriented perpendicular to the creek on the north and south banks. Cameras at site 10 were re-oriented to the west following a high incidence of false triggers cause by traffic on the southbound carriageway. Swift cameras were set to take 10 seconds of video with no delay between activation. Reconyx cameras were set on time-lapse mode to take a picture at 1-minute intervals between 8 pm and 6 am each day throughout the spring/summer sample period. Time-lapse mode is better suited to targeting frogs and was used successfully to monitor frog pipes on the Sapphire to Woolgoolga Pacific Highway Upgrade (Sandpiper Ecological 2017a, 2018a). Cameras at site 1 were inundated by floodwater on several occasions in December 2020.

During the spring/summer sample period, cameras at sites 1-12 were installed on 30-31 October 2020 and were inspected during the middle of each session to change batteries and SD cards. Cameras at sites 2-12 were retrieved on 4 January 2021 following a total sample period of 95 days (Table 3). Cameras at site 1 were retrieved on 23 December 2021 February following a sample period of 77 days (Table 3). Three of the 24 cameras were active for less than the 60-day minimum sample period with two a result of camera malfunction/battery failure and one due to flooding at site 1 south (Table 3). Overall, cameras were active for a period of 2024 days with all underpasses having at least one camera active for >60 days (Table 3). The total number of camera monitoring days achieved in spring/summer year 3 (i.e. 2024) exceeds the effort required by the EMP of 1440 days.

Table 3: Camera survey effort during year three operational phase monitoring**.** * = malfunction/battery failure ^ camera flooded.

Site	Cam location	Days active		
		Spr/Sum	Winter	Total
1	North	77		
	South	53^		
2	Furniture	74		
	Floor	95		
3	Furniture	95		
	Floor	95		
4	Furniture	95		
	Floor	48*		
5	North	95		
	South	30*		

Site	Cam location	Days active		
		Spr/Sum	Winter	Total
6	Furniture	95		
	Floor	95		
7	Furniture	95		
	Floor	95		
8	Furniture	61		
	Floor	95		
9	Furniture	95		
	Floor	95		
10	Furniture	95		
	Floor	95		
11	Furniture	95		
	Floor	95		
12	Furniture	95		
	Floor	66		
Totals		2024		

Image review

Images were uploaded to a computer and viewed using Windows Photo Viewer ©. A senior ecologist or ecologist reviewed all images, with reference to standard field guides (i.e. Menkhorst & Knight 2004; Pizzey & Knight 2007; Van Dyck *et al.* undated).

Fauna were scored making a complete or incomplete crossing:

- A complete crossing was scored when an animal showed directional movement when detected by the centrally mounted camera.
- An incomplete crossing was scored when an animal showed no directional movement (i.e. remained stationary in front of camera) or passed the camera but returned within 10 minutes.

Crossing definitions are consistent with those used at other Pacific Highway monitoring sites (e.g. Sandpiper Ecological 2017b, 2018b, 2019) and crossing structure research programs (e.g. Soanes *et al.* 2015). Further, it represents a conservative approach to identification of complete crossings. Data recorded for each active image included: site, date, time, species, accuracy (definite 90%+ certainty, probable 75-90% certainty, and possible 60-75% certainty), movement direction (east, west, no directional movement (animal stationary, returned), number of images and image numbers. A hierarchical approach was adopted to species identification that included: species, genus or group. Microbats were recorded as presence only due to their transient nature and none reliance on underpasses for thoroughfare.

Data analysis and interpretation

The adequately assess "use of underpasses" as per the EMP operation monitoring aim, complete crossings were used as the standard of measure as it encompasses the purpose of fauna underpasses (i.e. A structure that allows fauna to access habitat that has been fragmented by construction of a road or highway). To account for variations in survey effort between sites complete crossings/week and complete crossings/week/underpass were adopted. Birds and microbats were excluded from analysis as they do not require underpasses for thoroughfare.

As seen in dot point five in the potential indicators of success (see introduction), fauna with low mobility was not defined within the EMP. As such, fauna with low mobility has been assumed to include animals whose movement is generally limited by their size or behaviour. Hence, fauna that exhibit low mobility/cover dependence has been interpreted as frogs, small reptiles (excluding goanna and water dragon), rodents and bandicoots. Rodent spp were considered to be "undefined" in relation to whether they were introduced or native given the presence of black rats, bush rats and fauna-footed melomys.

2.3 Adjacent habitat survey

2.3.1 Survey design

A total of 18 sites were sampled at the 12 underpasses as part of adjacent habitat surveys. Sample sites were established on each side of an underpass or underpass pair in the case of sites 5/6, 9/10 and 11/12. Adjacent habitat at sites 5 and 6 was sampled as one site as the underpass entrances were located within 50m of each other. Survey effort was reduced at site 3 due to concern about disturbing neighbours. No spotlighting or arboreal Elliott trapping occurred on the west side at site 3 and the diurnal active search was restricted to a small (100m x 30m) triangular shaped remnant of vegetation in the road reserve.

2.3.2 Trapping

Trapping methods applied during the survey included: cage traps, ground Elliott traps (Type A), arboreal Elliott traps (Type B), pitfall traps, and hair funnels. Trapping occurred within a 1ha area immediately adjacent to each culvert entrance and was conducted over three nights at each site. All sites were sampled concurrently and trapping was conducted between 20 and 26 October 2020.

Traps were set in a "X" formation with five ground and five arboreal traps set at 20m intervals on one axis and two cage traps and two hair funnels set at 50m spacing on the other axis (Plate 2). A line of three pitfall traps with drift fence was set at the intersection of both lines (Plate 2). Pitfall traps typically followed the contour and were set near fallen logs and dense ground cover. Trap effort is summarised in Table 4.

Plate 3: Example of a pitfall trap line installed during adjacent habitat surveys (L). Setting up traps in adjacent habitat at site 1 (R).

Arboreal traps and ground Elliott traps were baited with a peanut butter, honey and oats mixture. Arboreal traps were installed 1.8m above ground and attached to a bracket. Honey water was sprayed on the trunk above each arboreal trap, and bait was replaced as required. A plastic bag was placed over the end of each trap to provide cover, and a small amount of leaf litter was placed inside the trap. In spring/summer, arboreal traps were set on the western side of trees to provide shelter from the morning sun. Cage traps were set in a sheltered location and alternately baited with either peanut butter, honey and oats, or sardines. A tuna oil and water mix was sprayed around the entrance to cage traps baited with sardines. All traps were checked within four hours of sunrise. In spring/summer cage and Elliott traps were closed following the morning inspection and re-opened in the late afternoon. Pitfall traps were checked in the morning and again in mid-afternoon.

Captured fauna were identified to species or genus, and, where possible, sexed and aged. Fauna were identified with reference to standard field guides (Van Dyck *et al.* 2013; Menkhorst & Knight 2004; Wilson & Swan 2010). Fauna were not marked as the aim of sampling was to determine the range of species present in adjacent habitat.

2.3.3 Diurnal active search

Diurnal active searches were conducted by one or two ecologists and involved a meandering traverse of habitat within 100m of the underpass entrance at each sample site. Surveys involved searching leaf litter, rolling logs, observing reptile habitat (i.e. log piles, rocks, dense leaf litter) and looking for fauna signs such as scats and tracks. Each site was sampled twice during each sample period for a minimum of 30 person minutes/sample. Spring/summer diurnal active searches were conducted between 13 and 16 October. A total of 1080 person minutes were spent conducting diurnal active searches during the spring/summer period (Table 4).

2.3.4 Nocturnal active search

Nocturnal surveys were conducted on each side of each underpass on two non-consecutive nights during the spring/summer sample period. One or two ecologists conducted spotlight surveys for 60 person minutes per underpass side/sample period (Table 4). Surveys were conducted using hand-held Led Lenser P14 spotlights and involved a meandering traverse of habitat within 200m of the culvert entrance. Fauna were detected by sight and call and identified to species or genus where possible. Spring/summer surveys were conducted between 13 and 29 October 2020. A total of 1080 person minutes were spent conducting nocturnal active searches (Table 4).

2.3.5 Opportunistic records

Opportunistic observations of fauna near culvert entrances made whilst doing other monitoring activities such as koala, giant barred frog and yellow-bellied glider monitoring were recorded. All fauna observed whilst setting up equipment, with exception of birds, were also recorded.

Table 4: Survey effort for sampling adjacent habitat on the WC2NH upgrade.

Component	Method / culvert side	No Samples	Total effort
Arboreal Elliott traps	5 x traps @ 20m spacing	3 nights/site	510 trap nights
Ground Elliott traps	5 x Type A Elliott traps @ 20m spacing	3 nights/site	540 trap nights
Cage traps	2 @ 50m spacing	3 nights/site	216 trap nights
Pitfall traps	1 x line of 3 pits with drift fence	3 nights/site	324 trap nights
Hair funnels	2 @ 50m spacing	14 nights/site	504 trap nights
Active diurnal search	30 person minute search at UP entrance	2 sample/site	1080 person minutes
Active nocturnal search	30 person minute search at UP entrance	2 samples/site	1080 person minutes

2.4 Exclusion fence

Inspection of the fauna exclusion fence is conducted in the winter sample period only.

3. Results

3.1 Underpasses

3.1.1 Camera monitoring

Species diversity and native fauna use

Eighteen species and six fauna groups were confirmed using (complete crossings) underpasses during camera monitoring (Table 5). The highest fauna diversity was recorded at site 4 and 7 with thirteen species/groups (combined ground and furniture), followed by sites 6 and 12 with eleven species/groups (Table 5). The lowest diversity was recorded at site 1 with only one species (swamp wallaby) being recorded (Table 5). Remaining sites recorded between 6 and 10 fauna species/groups (Table 5). Five introduced species were recorded including cat, dog, red fox, black rat and house mouse (Table 5).

The majority (91-94%) of fauna detections in underpasses were recorded as complete crossings (cc). Overall native species exhibited a higher rate of crossing completions in comparison to introduced species (Figure 2). Complete crossings by native species were recorded in all underpasses at an average rate of 2.12 ± 1.78cc/week/underpass (Figure 2, 3). Sites 4, 11 and 12 featured the highest use by native species with 5.09cc/week, 3.13cc/week and 2.68cc/week respectively (Figure 2). Sites 1 and 9 exhibited the lowest use by native species recording 0.1cc/week and 0.29cc/week (Figure 2).

Swamp wallaby was the most frequently recorded native species with a total of 6.22 cc/week across all sites (Plate 4, Table 5). This was followed by bandicoot spp. (5.49cc/week), lace monitor (3.14cc/week) and *Trichosurus* spp. (2.87cc/week) (Plate 4). Koala was the only threatened species recorded, with complete crossings using the culvert floor recorded at sites 4 and 8 (Table 5). Koala made six complete crossings (three east, three west) at site 4 and one complete crossing (west) at site 8 (see appendix C Table 1). Koala was also recorded making incomplete crossings at site 12 and 10 (Plate 4, Appendix C Table 1).

Use by cover dependent species with low mobility

Fauna with low mobility (see classification in methods) were recorded across all sites, except for site 1 (Table 5). In order of use, bandicoot spp (including long-nosed and northern brown bandicoots) recorded a total of 5.49 cc/week followed by black rat 3.94 cc/week and rodent spp. 2.32 cc/week (see total Table 5). Confirmed rodent species recorded were the introduced black rat (sites 2,4,5,7,8,9,10,12) and house mouse (site 3 and 12) with a probable record of native fawn-footed melomys (site 11) and water rat (site 5) (Table 5). *Antechinus* spp records were relatively scarce with complete crossings made on furniture at sites 2 (Plate 4), 7, 8, 10 and 11 (Table 5). *Egernia* spp. was the only cover dependent reptile recorded, with one complete crossing using furniture at site 9 (Plate 4, Table 5). No frogs were recorded using underpasses during camera monitoring.

Furniture vs Floor

Fauna was recorded using both the culvert floor and furniture during operation phase monitoring (Table 5). Use of the underpass floor was greater than use of furniture for natives, introduced rodents and feral predators (Table 5). Furniture use by feral predators was very low, with two complete crossings recorded by cat at sites 3 and 11 (Table 5, see Appendix C). *Trichosurus* spp and *Antechinus* spp, demonstrated preferential use of the fauna furniture, with *Trichosurus* spp accounting for the majority of crossings by native species on the furniture at sites 3 and 4 (Table 5). Use of furniture by black rats was recorded at sites 2,7,8 and 12 (Table 5). Koalas were recorded using the floor only (Table 5).

Plate 4: *Egernia* spp recorded on furniture at site 9 (Top left). Long-nosed bandicoot heading east at site 6 (Top right). Swamp wallaby travelling west at site 2 (Middle left). Koala recorded making an incomplete crossing at site 10 (Middle right). *Antechinus* spp recorded on fauna furniture at site 2 (Bottom left). Lace monitor recorded on fauna furniture at site 6 (Bottom right).

Table 5: Complete crossings/week made by each species/group at each of the 12 underpasses monitored on the WC2NH upgrade during year 3 spring/summer operational monitoring. Sites 1 and 5 did not contain fauna furniture. Species in bold denote threatened species, * = introduced species, FF= fauna furniture and G = ground (culvert floor). See appendix C, Table C1 for all data.

Species/groups	Site and camera location																								Total
	1		2		3		4		5		6		7		8		9		10		11		12		
	S	N	FF	G	FF	G	FF	G	N	S	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	
Short-beaked echidna										0.06				0.11						0.04					0.20
Antechinus spp.			0.12										0.04		0.13				0.15		0.04				0.48
Northern brown bandicoot								0.10				0.07												0.13	0.30
Long-nosed bandicoot						0.15		0.05				0.04		0.04						0.07					0.34
Peramelidae spp (bandicoot)				0.41		0.18		1.47				0.18		0.07		0.09		0.07		0.22		0.88		1.26	4.85
Koala								0.34								0.04									0.39
Common brushtail possum																		0.07		0.04					0.11
Short-eared brushtail possum						0.04	1.22	0.10				0.15	0.04												1.54
Trichosurus spp					0.90	0.07		0.05		0.06		0.04	0.07	0.04											1.22
Eastern grey kangaroo						0.04																			0.04
Red-necked wallaby						0.15																			0.15
Swamp wallaby	0.11			0.75		1.14		0.93				0.04		0.33		0.04						1.40		1.48	6.22
Wallaby spp.												0.04						0.04							0.07
House mouse*						0.04																		0.04	0.08
Fawn-footed melomys																						0.04			0.04
Water rat									0.06	0.11															0.17
Rodent spp.							0.05	0.20	0.17	0.06			0.11	0.29						0.04	0.70			0.04	1.65
Black rat*			0.04					0.05	0.11	0.11			1.40	0.18	0.22			0.07		0.04			0.09		2.32
Dog*				0.54		0.29		0.49	0.06			0.11		0.29		0.13		0.59		0.59		0.41		0.43	3.94
Fox*				0.04				0.64	0.11			0.44		0.96		0.31		0.18		0.15		0.92		0.91	4.67
Cat*					0.04	2.43						0.11		0.04		0.22		0.26		0.18	0.04	0.11		0.17	3.60
Lace monitor							0.10	0.49	0.11	0.11	0.04	0.29		0.52		0.90		0.07				0.29		0.22	3.14
Eastern water dragon					0.04	0.11		0.24														0.04		0.04	0.47
Egernia spp																	0.04								0.04
Species/group richness	**1**	**0**	**2**	**4**	**3**	**12**	**3**	**13**	**6**	**6**	**1**	**11**	**5**	**11**	**2**	**7**	**1**	**8**	**1**	**9**	**3**	**8**	**1**	**10**	**24**

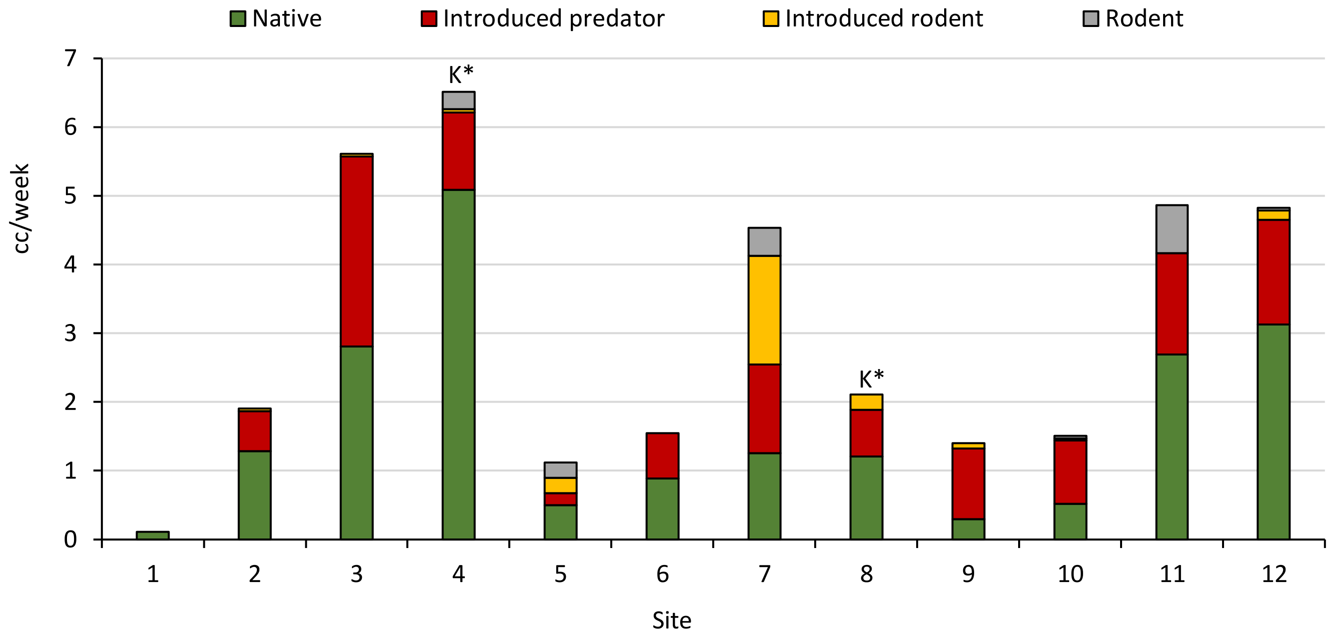

Figure 2: Complete crossings/week for native species, feral predators (combined cat, dog, red fox) introduced rodents (combined black rat and house mouse) and rodents at each underpass during year three spring/summer monitoring. *K = indicates complete crossing by koala.

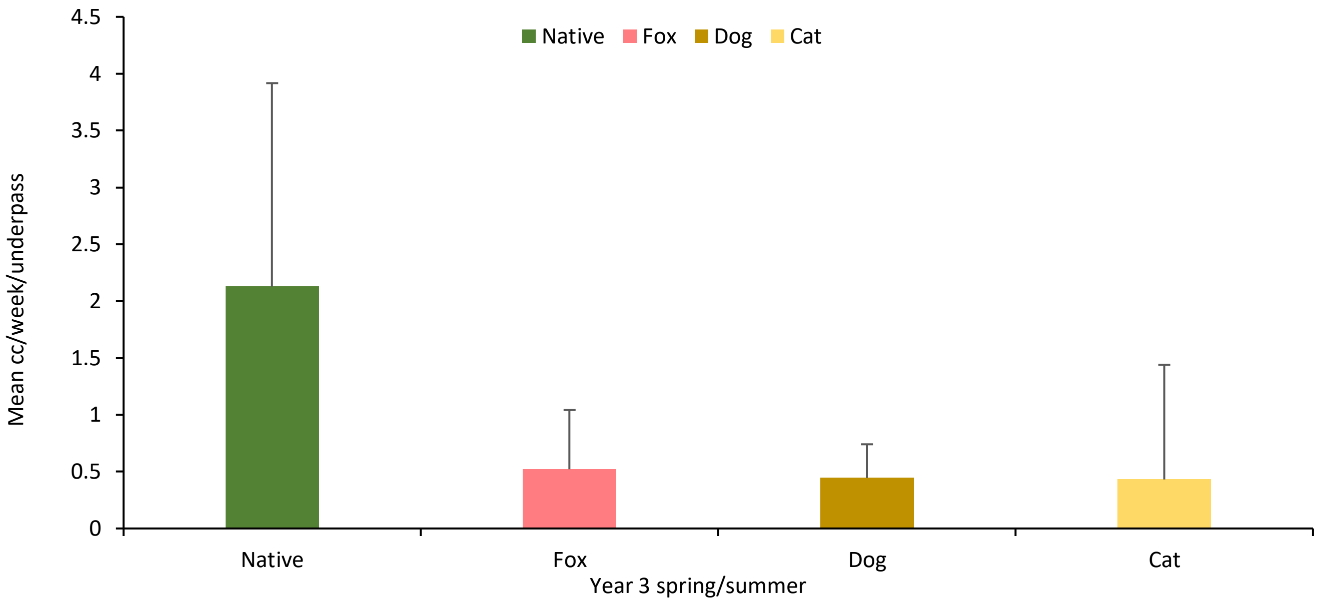

Figure 3: Mean number of complete crossing/week/underpass (+SD) for all native species and introduced predators (Fox, Dog, cat) during year 3 spring/summer operational monitoring.

Feral predator activity

Complete crossings by feral predators were recorded at all sites at an overall rate of 1.39 ± 0.67 cc/week/underpass (Figure 3). Feral predator activity was highest at sites 3, 11/12, 7 and lowest at sites 5, 2, 6 and 8 (Figure 4). Red fox was recorded at a rate of 0.52 ± 0.52 cc/week/underpass with detections in all underpasses aside from sites 1 and 3 (Figure 3 and 4). Dog (*Canis lupus* *familiaris*) exhibited 0.44 ± 0.29 cc/week/underpass and was detected at 11 of the 12 sites (Figures 3 and 4). Cat (*Felis catus*) recorded 0.43 ± 1 cc/week/underpass with detections at all sites except 4 and 5 (Figures 3 and 4). High use at site 3 can largely be attributed to frequent crossings (3.09 cc/week, Figure 4) by a distinctive resident individual (Plate 5). Red fox was frequently detected at sites 7 (1.03cc/week), 11/12 (0.91cc/week), and 4 (0.64cc/week) while dog detections were highest at sites 2 (0.54cc/week) and 4 (0.54cc/week) with one distinctive individual frequently detected at sites 4, 9, 10, 11 & 12 (Plate 5). No instances of predation were recorded in underpasses, although cats carrying prey (rodents) were recorded moving through site 3 on two occasions (see appendix C. Table C1).

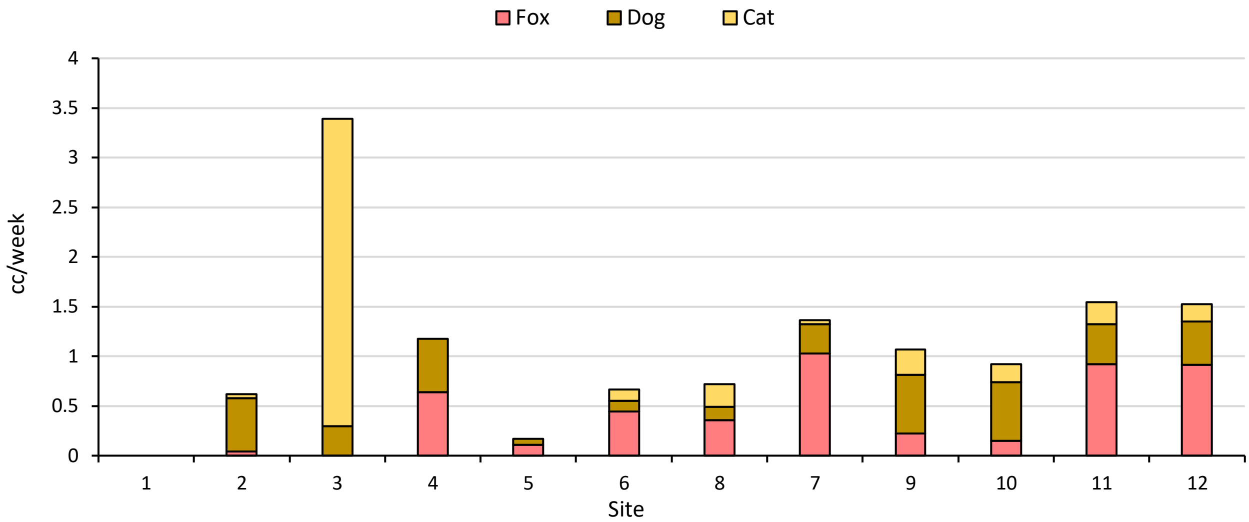

Figure 4: Complete crossings/week by feral predators (cat, red fox, dog) in underpasses during year 3 spring/summer operational monitoring at WC2NH.

Plate 5: Cat frequently recorded at site 3 (Left) and dog frequently recorded at sites 4, 9,10,11,12 (Right).

3.1.2 Sand pads

Fifteen species and fauna groups were recorded on sand pads during monitoring (Appendix C, Table C2). Species diversity was found to be highest at site 4 (six species/groups). Of the native species, bandicoot spp was the most commonly recorded fauna group with tracks identified at sites 2, 4, 6, 9, 11 and 12 (Plate 6, Appendix C, Table C2). *Trichosurus* spp were recorded using the culvert floor at site 4 (Plate 6). Of the smaller fauna groups (small mammals, reptiles and amphibians), probable *Antechinus* spp. was reported at sites 5, 10 and 11 (Appendix C, Table 2). Sand pad records of feral predators were similar to camera data with cat, dog and red fox confirmed using the underpasses at most sites.

Plate 6: Bandicoot tracks recorded alongside cat tracks at site 8 during spring/summer monitoring. *Trichosurus* spp heading east at site 4 (right)

3.1.2 Scat and track searches and tile checks

Five species, and six fauna groups were recorded during scat and track surveys during year three spring/summer monitoring (Appendix C. Table C3). As seen in camera data, sites 4 and 7 reported the highest diversity of fauna species with five and six fauna groups/species respectively. Native species/fauna groups were found to be using all culverts. Bandicoot spp was recorded at six sites with lace monitor at five sites during spring/summer. Records of small fauna included tracks and scats from *Antechinus* spp. at sites 6, 11 and 12. No fauna was recorded using tiles placed in underpasses.

3.2 Adjacent habitat

Thirty-one species and a further five fauna groups likely to use underpasses (species that don't rely on underpasses to cross the alignment such as birds, flying-foxes and gliders have been excluded) were recorded in habitat adjoining underpasses (Table 6. The majority of species/groups (20 in total) were detected by diurnal and nocturnal active searches (Table 6, appendix C. Table C4&5). During trapping surveys, a total of 12 species were recorded. Hair funnels recording five species (including one record of common ringtail possum) and two groups (Table 6). Several threatened species were recorded during spotlight surveys of adjacent habitat, including grey-headed flying fox, koala on the western side of site 7 and yellow-bellied glider on the west side at site 5/6 (Appendix C, Table C5). Koala scat was also recorded on the eastern side of 9/10 during diurnal surveys (Appendix C, Table 4).

During spring/summer trapping, fawn-footed melomys was the most frequently captured species, with 16 individuals, followed by bush rat (13 individuals); *Lampropholis delicata* (seven individuals), brown antechinus (six individuals; Plate 7) and black rat (4 individuals) (Appendix C, Table 6). Other species captured were red-tailed skink (*Calyptotis rudificauda)* dwarf-crowned snake, northern brown bandicoot, lace monitor, sugar glider, short-eared brushtail possum, and red-backed toadlet (*Pseudophryne coriacea)* (Plate 7).

Plate 7. Brown antechinus captured in a ground Elliot on the west side of site 8 (Left), and *Pseudophryne coriacea* found in a pitfall trap on the east side of site 2 (Right).

Table 6: Vertebrate species that require underpasses to cross the alignment recorded during surveys of adjacent habitat at WC2NH in spring/summer, 2020/2021. SS = Spring/Summer, W = Winter. * = Threatened species.; I = Introduced species.

Species	Active Search		Spotlight		Trapping		Hair funnel		Opportunistic records	
	SS	W	SS	W	SS	W	SS	W	SS	W
Mammals										
Short-beaked echidna	*									
Brown antechinus					*					
Antechinus spp							*			
Northern brown bandicoot					*		*			
Long-nosed bandicoot			*							
Peramelidae spp. (bandicoot)	*									
Koala*	*		*							
Common brushtail possum							*			
Short-eared brushtail possum			*		*					
Common ringtail possum							*			
Trichosurus spp.	*									
Swamp wallaby	*		*				*			
Wallaby spp.	*		*							
Fawn-footed melomys					*					
Bush rat					*		*			
House mouse [I]					*					
Black rat [I]					*					
Rattus spp.							*			
Red fox [I]	*									

Species	Active Search		Spotlight		Trapping		Hair funnel		Opportunistic records	
	SS	W	SS	W	SS	W	SS	W	SS	W
Dog	*									
Cat [1]	*									
Reptiles										
Common scaly-foot			*							
Lace monitor					*					
Blue-tongued skink									*	
Southern angle-headed dragon									*	
Calyptotis ruficauda	*				*					
Lampropholis delicata	*				*					
Lampropholis spp.	*									
Yellow-faced whipsnake									*	
Dwarf Crowned Snake					*					
Frogs										
Litoria gracilenta			*							
Litoria fallax			*							
Litoria peronii			*							
Litoria tyleri			*							
Adelotus brevis	*									
Pseudophryne coriacea					*					
Total N°. Species/groups	**13**		**10**		**12**		**7**		**3**	

3.2.1 Species recorded in underpasses and adjacent habitat

Due to duplication between species and fauna groups (e.g. wallaby spp. includes both red-necked and swamp wallaby) only confirmed species and unique genera have been included in the comparison between underpasses and adjacent habitat (Table 7. Species that do not rely on underpasses to cross the alignment such as birds, flying-foxes and gliders have also been excluded (Table 7). With the above exclusions 33 species and genera were confirmed using adjacent habitat and 21 species and genera were recorded using underpasses (Table 7). Red-necked wallaby, water rat, eastern-water dragon and *Egernia* spp were recorded in underpasses only and are assumed to reside in adjacent habitat (Table 7). With this assumption the proportion of species in adjacent habitat that utilised underpasses during spring/summer monitoring was 64% (Table 7). The proportion of mammals recorded in both adjacent habitat and underpasses was 94% with the common ringtail possum being the only species not recorded using underpasses. No species of frog were recorded using underpasses, while five frog species were reported in adjacent habitat (Table 7). Further, of the nine reptile species/families recorded during monitoring, only three (lace monitor, eastern water dragon & *Egernia* spp.) were confirmed using underpasses (Table 7).

Table 7: Species and genera recorded using underpasses and in adjacent habitat during year three monitoring. * denotes threatened species. + = species designation assumed based on frequent capture of only brown antechinus in adjacent habitat.

Species	Adjacent habitat	Underpass
Mammals		
Short-beaked echidna	*	*
Brown antechinus	*	+
Northern brown bandicoot	*	*
Long-nosed bandicoot	*	*
Koala*	*	*
Short-eared brushtail possum	*	*
Common brushtail possum	*	*
Common ringtail possum	*	
Swamp wallaby	*	*
Red-neck wallaby	+	*
Fawn-footed melomys	*	*

Species	Adjacent habitat	Underpass
Water rat	+	*
Bush rat	*	*
House mouse [I]	*	*
Black rat [I]	*	*
Dog [I]	*	*
Red fox [I]	*	*
Cat [I]	*	*
Sub-total mammals	**19**	**18**
Reptiles		
Lace monitor	*	*
Eastern water dragon	+	*
Blue-tongued skink	*	
Southern angle-headed dragon	*	
Calyptotis ruficauda	*	
Lampropholis delicata	*	
Egernia spp	+	*
Yellow-faced whipsnake	*	
Dwarf Crowned Snake	*	
Sub-total reptiles	**9**	**3**
Frogs		
Litoria gracilenta	*	
Litoria fallax	*	
Litoria peronii	*	
Adelotus brevis	*	
Pseudophryne coriacea	*	
Sub-total frogs	**5**	**0**
Total Nº. Species/genus	**33**	**21**

4. Discussion

4.1 Low rates of use of fauna underpasses and adjacent habitats by feral predators

Feral predators (combined cat, red fox and dog) recorded complete crossings in underpasses at an overall rate of 1.39 ± 0.67 cc/week/underpass. While what constitutes “low use” is not specified within the WC2NH EMP (RMS 2018), feral predators accounted for 40% of complete crossings (excluding unknown and introduced rodents) with lower rates than recorded for native species (2.12 ± 1.78cc/week/underpass). This suggests that feral predators are readily using underpasses to transverse the alignment at a rate that is similar to native fauna. No feral predators were recorded in adjacent habitat. Fox crossing the alignment was recorded at 10 sites (highest at 4, 6, and 11/12), Dog 11 sites (highest at 2,4, 9/10 and 11/12) and cat at eight sites (highest at 3).

As mentioned in response to the previous year 2 annual operational underpass monitoring report (Sandpiper, 2020c), Local Land Services in co-ordination with Transport for New South Wales have the option to place bait in culverts. Moving forward this may be a practical option given that the extent of dog activity has increased with records of complete crossings now at 11 of the 12 sites (previously recorded in 6 sites, Sandpiper, 2020c). Further, the rate of dog activity has increased from 0.1 ± 0.15 cc/week/underpass in year two (Sandpiper 2020c) to 0.44 ± 0.29 cc/week/underpass during the recent spring/summer monitoring period. Of particular concern is the level of use recorded at sites with known koala activity (i.e. sites 4, 8, 9/10 and 11/12). One individual dog has been identified frequently using underpasses 4-12 (Plate 4). The removal of this individual via targeted baiting in culverts (4, 8, 9/10 and 11/12), would decrease the predation risk to koala and other native fauna. Recently, the Forestry Corporation have implemented a wild dog and cat trapping program in the adjoining Nambucca State Forest with the deployment of 1080 baits and traps between 17 November 2020 to May 2021. A collaborative approach to feral predator control between Local Land Services, Transport for New South Wales and the Forestry Corporation would improve the success of future control programs.

The cat individual from site 3 (records in year 1, 2 and 3) continues to be frequently recorded crossing the alignment. Options for control include continued trapping, shooting and poisoning. Given that the cat is a domestic individual from a neighbouring property, shooting and poisoning have been deemed inappropriate, with trapping considered the best approach. During the winter surveys alternative baits and the 'free feeding' approach will be adopted as part of cage trapping. Free feeding involves leaving bait outside the trap for a number of days allowing the cat to become familiar with the trap before setting it up for capture.

4.2 High levels of fauna underpass use by a variety of native species

Native species frequented underpasses at a rate of 2.12 cc/week/underpass. A total of 15 native species/genera were recorded making complete crossings. Of the 27 native species/genera (includes species recorded in underpasses only) recorded in the adjacent habitat 59% (16 species/genera) were recorded using underpasses. This result is broadly consistent with findings at Sapphire to Woolgoolga (23% to 50%) and slightly higher than the 38% and 42% recorded at NH2U in 2018 and 2019 (Sandpiper Ecological 2018a; 2019d, 2020).

Fauna furniture was regularly used by native fauna to cross the alignment, with *Trichosurus* spp and *Antechinus* spp, demonstrating preferential use of the fauna furniture. In contrast, feral predators tended to use the culvert floor with only limited use of furniture by cat. Despite no evidence of predation occurring in the underpasses, the furniture is likely to act as a refuge for native fauna, alleviating predation risk and encouraging underpass crossings. Continued monitoring during the winter period (Year 3) will enable a comparison with previous years monitoring to assess its importance in providing refuge from feral predators. Use of underpasses by koalas was consistent with years one and two sampling (Sandpiper, 2019f and 2020c).

4.3 No change to densities, distribution, habitat use, and movement patterns compared to baseline population data of target species.

The target species for underpass monitoring, as outlined in the project brief, are spotted-tailed quoll, koala and giant barred frog. No spotted-tailed quolls have been detected to date, consistent with baseline monitoring (GeoLink 2014), and population monitoring of giant barred frogs at Upper Warrell creek is reported elsewhere.

In spring year 3, koalas were recorded using underpasses (complete crossings) at sites 4 and 8 with records of entering (incomplete crossings) at sites 10 and 12. Whilst there is no substantive baseline data to confirm if changes in habitat use and movement patterns have occurred monitoring suggests there is a temporal decline in the number of sites used by koala. Results also show that koalas continue to maintain territory on both sides of the alignment.

4.4 Evidence of use by dispersing individuals and different age cohorts

Accurately confirming age of individuals using underpasses is difficult using the survey methods outlined in the EMP. However, immature short-eared brushtail possums and juvenile swamp wallaby were regularly recorded making complete crossings at sites 2, 7, and 8. Other methods such as mark-release-recapture would likely be required to provide definitive proof of use by dispersing individuals and different age cohorts. Such a survey would be expensive and is not warranted.

4.5 Use by cover-dependent species with low mobility

Several cover-dependent species (typically small mammals, small reptiles and frogs) were recorded in adjacent habitat, including five frog species, three native mammals (brown antechinus, fawn-footed melomys and bush rat) and seven reptile species (excluding lace monitor). Of these, only two (*Antechinus* spp, fawn-footed melomys) were recorded using underpasses. Additional, cover dependent, species recorded in underpasses only were water rat and *Egernia spp*. Consistent with previous surveys there were limited records of reptiles and amphibians in underpasses. Low occurrence of frogs and reptiles is most likely due to the inability of cameras to detect these species as opposed to avoidance. This shortfall is assisted by the use of sand pads and scat and tracks searches to detect smaller fauna. Sand pads captured tracks of a probable *Antechinus* spp at sites 5, 11 and 12.

5. Contingency Measures and Recommendations

5.1 Contingency Measures

Contingency measures are summarised in Table 8.

Table 8: Potential problems outlined in the EMP and possible contingency measures. Mitigation measures applicable to the project are addressed in bold text in table below.

Problem	Contingency/Corrective Action	Proposed action
High rates of feral predator activity;	Control program	Implement a control programs targeting dogs at sites 4-12.
Low levels of native fauna movement and species diversity in underpasses;	Modify habitat structure near underpass entrances and/or modify underpass fauna furniture	Revegetation work has already occurred – no further action required.
No use of underpasses by cover-dependent species or species with low mobility or target threatened species	Modify or add potential groundcover resources	Continue with monitoring of tiles during winter survey with an increase in frequency of inspections.
High rates of fauna road mortality.	Modify exclusion fencing design, location or extent depending on the species and location of mortalities	Issues relating to road mortality are addressed in the quarterly and annual road-kill reports. At this stage no modifications to the location or extent of exclusion fence is proposed. No mortality of target species has been recorded during the monitoring program.

5.2 Recommendations

Recommendations are summarised in Table 9.

Table 9: Recommendations based on findings from year three spring/summer operational phase monitoring and response from TfNSW.

Number	Recommendation	Transport for NSW Response
1.	Contact Forestry Corporation to determine the extent of the trapping and baiting program being conducted in NSF. If the program does not cover sites 4, 8, 9/10 and 11/12 canid control should be implemented in autumn 2021.	TfNSW has contacted both Local Land Services (LLS) and Forestry Corporation to discuss options for canid control at the identified sites. Onsite inspections at relevant underpasses with LLS are planned for April 21 to determine if trapping is a viable option, and also to initiate risk assessments for potential baiting control later in 2021 / early 2022.
2.	Sandpiper Ecological to trial different trapping methods during the winter 2021 survey to capture the cat at site 3.	Agree and adopted
3.	Continue monitoring of tiles in underpasses during year 3 winter with an increase in effort (inspections to align with sand pad inspections = 8 inspections).	Agree and adopted

4.	At site 1 (Upper Warrell Creek), undertake an additional 6-8 weeks of camera monitoring in autumn (March/April), commencing in March 2021.	Agree and adopted
5.	Reduce sand pad sampling to one sand pad installed centrally within each culvert. This would minimise the risk of wash out and therefore improve the consistency of data collected.	Agree to be adopted.

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Appendix A – Species list

Table A1: Common and scientific names for all species recorded during year two and three operational monitoring at WC2NH. ^ = Threatened species.

Common Name	Scientific Name
Koala^	*Phascolarctos cinereus*
Swamp wallaby	*Wallabia bicolor*
Red-necked wallaby	*Macropus rufogriseus*
Wallaby spp.	
Short-beaked echidna	*Tachyglossus aculeatus*
Yellow-bellied glider^	*Petaurus australis*
Sugar glider	*Petaurus breviceps*
	Petaurus spp.
Short-eared brushtail possum	*Trichosurus caninus*
Common brushtail possum	*Trichosurus vulpecula*
Brushtail possum spp.	*Trichosurus spp.*
Common ringtail possum	*Pseudocheirus peregrinus*
Northern brown bandicoot	*Isoodon macrourus*
Long-nosed bandicoot	*Perameles nasuta*
Bandicoot species	*Peramelidae spp.*
Fawn-footed melomys	*Melomys cervinnipes*
	Melomys spp.
Water rat	*Hydromys chrysogaster*
Bush rat	*Rattus fuscipes*
Brown antechinus	*Antechinus stuartii*
	Antechinus spp.
Grey-headed flying red fox^	*Pteropus poliocephalus*
Flying red fox spp.	*Pteropus spp.*
Bent-wing spp.	*Miniopterus spp.*
Small mammal spp.	
	Dasyuridae spp.
Eastern crevice skink	*Egernia mcpheii*
Garden skink	*Lampropholis delicata*
Grass skink	*Lampropholis guichenoti*
	Lampropholis spp.
Red-tailed calyptotis	*Calyptotis ruficauda*
Eastern water-skink	*Eulamprus quoyii*
Three-toed skink	*Saiphos equalis*
Skink spp.	*Scincidae spp.*
Coastal carpet python	*Morelia spilota*
Red-bellied black snake	*Pseudechis porphyriacus*
Yellow-faced whipsnake	*Demansia psammophis*
Black-bellied swamp snake	*Hemiaspis signata*
Blackish blind snake	*Anilios nigrescens*
Bandy bandy	*Vermicella annulata*
Coastal carpet python	*Morelia spilota*
Burton's legless lizard	*Lialis burtonis*
Lace monitor	*Varanus varius*
Eastern water dragon	*Intellagama lesueurii*
	Agamid spp.
Freshwater turtle spp.	*Chelidae spp.*
Medium reptile spp.	
Small reptile spp.	

Eastern dwarf tree frog	*Litoria fallax*
Tyler's tree frog	*Litoria tyleri*
Red-eyed tree frog	*Litoria chloris*
Green tree frog	*Litoria cerulea*
Dusky toadlet	*Uperolia fusca*
Tusked frog	*Adelotus brevis*
Common eastern froglet	*Crinia signifera*
Giant barred frog^	*Mixophyes iteratus*
Striped marsh frog	*Limnodynastes peronii*
Red-backed toadlet	*Pseudophryne coriacea*
Medium frog spp.	
Cat	*Felis catus*
Red red fox	*Vulpes vulpes*
Black rat	*Rattus rattus*
European hare	*Lepus europaeus*
House mouse	*Mus musculus*

Appendix B – Weather and climatic conditions

Table B1: Weather during the year 3 spring/summer operational monitoring period. Rainfall taken from the BOM weather station at Bellwood (059150). Air temperature, wind and relative humidity collected from Coffs Harbour Airport (station 059151).

Date	Minimum temp (°C)	Maximum temp (°C)	Rainfall (mm)	Direction of maximum wind gust	9am relative humidity (%)
1/10/20	13.5	24.9	0	NE	57
2/10/20	9.9	23.2	0	S	63
3/10/20	11.1	24.4	0	NNE	60
4/10/20	15.5	26.6	0	NNE	57
5/10/20	17.6	27.2	0	NE	54
6/10/20	15.4	26	0	S	59
7/10/20	13.9	25.4	3	NE	64
8/10/20	18.1	28.5	1	NNE	60
9/10/20	16.3	25.9	0	S	61
10/10/20	11.3	23.4	0	ESE	50
11/10/20	9.4	24.1	11	NE	72
12/10/20	13.5	25.1	15	NNE	60
13/10/20	15.2	24.3	5	E	71
14/10/20	9.6	23.1	2	S	66
15/10/20	9.3	23.7	0	ENE	63
16/10/20	14.1	27.5	0	S	60
17/10/20	15.2	26	0	NNE	72
18/10/20	19.9	26.5	0	ENE	62
19/10/20	16.3	22.1	0	SSW	84
20/10/20	14.9	22.7	0	S	70
21/10/20	13.4	23	0	ENE	61
22/10/20	16.7	25.3	2	NE	70
23/10/20	16.5	25.4	2	NNE	68
24/10/20	19.5	25.1	0	N	83
25/10/20	19.2	28.3	0	S	68
26/10/20	16.4	23	0	SSW	86
27/10/20	14.5	23.6	0	S	75
28/10/20	15.9	22.8	0	E	82
29/10/20	13.6	22.2	0	SSW	84
30/10/20	11.9	24.7	0	NE	66
31/10/20	19.7	29.3	0	NE	67
1/11/20	12.9	24.5	0	SW	54
2/11/20	16.8	23.9	0	SSW	60
3/11/20	15	23.6	0	S	60
4/11/20	16.1	26.6	0	NE	59
5/11/20	16.3	30.7	0	SSW	52
6/11/20	13.7	24.2	0	SSW	52
7/11/20	11.2	22.7	0	S	63
8/11/20	15.1	22.2	0	SSW	71
9/11/20	15.8	21.7	0	SW	61
10/11/20	11.3	23.3	0	SE	63

Date	Minimum temp (°C)	Maximum temp (°C)	Rainfall (mm)	Direction of maximum wind gust	9am relative humidity (%)
11/11/20	15.1	25.2	0	NNE	56
12/11/20	17.7	27.3	0	NNE	59
13/11/20	20.3	25.1	1	NNE	64
14/11/20	16	27.5	0	N	69
15/11/20	16.1	27.1	0	SE	52
16/11/20	19	31.2	0	NNE	61
17/11/20	22.9	25.1	0	S	72
18/11/20	17.1	24.3	0	SW	65
19/11/20	15.1	25.8	5	NE	56
20/11/20	20.1	28.2	12	NE	61
21/11/20	17.4	27	0	N	62
22/11/20	19.9	27.6	0	NE	56
23/11/20	19.1	30	9	NE	59
24/11/20	20.3	25.4	5	SSW	67
25/11/20	16.9	25.3	5	SE	60
26/11/20	16.3	26.8	1	NE	59
27/11/20	16.4	27.5	0	NNE	64
28/11/20	20.3	29.5	0	NNE	57
29/11/20	18.6	31.2	35	SSW	64
30/11/20	21.2	26.3	22	S	66
1/12/20	19.3	27.2	0	NE	74
2/12/20	21.9	32.1	0	SW	76
3/12/20	19.6	27.6	6	WSW	88
4/12/20	21.1	29.4	8	NW	57
5/12/20	18.4	29.3	0	NE	71
6/12/20	22.7	27.1	3	NNW	82
7/12/20	21.9	27.2	0	SSW	76
8/12/20	19.3	25.2	0	S	68
9/12/20	14.7	25.4	0	SW	52
10/12/20	17.5	28.1	0	NNE	59
11/12/20	17.5	22.1	28	SSE	89
12/12/20	15.3	22.5	300	SE	96
13/12/20	18	24.8	12	SSE	62
14/12/20	18.2	23.1	19	E	89
15/12/20	20	23.7	66	ENE	93
16/12/20	21.3	24.9	138	NNE	92
17/12/20	22.4	27.3	0	NNE	87
18/12/20	21	29.6	↓	NE	71
19/12/20	21.2	27.8	6.02 days	SSW	75
20/12/20	21.4	30.7	5	S	81
21/12/20	22.3	26.7	7	NNE	91
22/12/20	22.3	31.7	9	N	71
23/12/20	21.3	26.4	0	S	49
24/12/20	18.8	25.1	0	SW	66
25/12/20	17.2	26.7	0	SSW	66

Date	Minimum temp (°C)	Maximum temp (°C)	Rainfall (mm)	Direction of maximum wind gust	9am relative humidity (%)
26/12/20	18.1	24.9	0	ENE	92
27/12/20	18	29.1	0	NNE	62
28/12/20	21.3	28.9	0	NE	70
29/12/20	20.2	27.7	0	SSW	75
30/12/20	19.9	25.2	25	SW	93
31/12/20	19	26.4	0.2	SSE	79
1/1/21	20.3	27.7	0	SE	77
2/1/21	20	25.8	68.6	SE	92
3/1/21	19.4	27.5	3.6	NE	82
4/1/21	22.9	27.4	0.4	N	77

Appendix C – Field data

Table C 1: Underpass camera data recorded during spring/summer and winter of year two operational monitoring WC2NH, 2020.

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
12	Furniture	24/10/2020	2339	Black rat	c	w	d	17	
12	Furniture	22/12/2020	2337	Black rat	c	e	d	42	
12	Ground	03/10/2020	0010	Fox	c	w	d	7	
12	Ground	3/10/2020	0427	Fox	c	e	d	8	
12	Ground	5/10/2020	0206	Swamp Wallaby	c	e	d	9	
12	Ground	5/10/2020	1845	Swamp Wallaby	c	e	d	11	
12	Ground	06/10/2020	0425	Fox	c	e	d	12	x2
12	Ground	08/10/2020	0100	Swamp Wallaby	c	w	d	13	
12	Ground	08/10/2020	0208	Swamp Wallaby	c	e	d	14	
12	Ground	08/10/2020	2247	Swamp Wallaby	c	w	d	16	
12	Ground	08/10/2020	2249	Northern Brown Bandicoot	c	e	d	17	
12	Ground	09/10/2020	0016	Northern Brown Bandicoot	c	w	d	18	
12	Ground	09/10/2020	0300	Northern Brown Bandicoot	c	e	d	19	
12	Ground	9/10/2020	0311	Fox	c	w	d	20	
12	Ground	9/10/2020	0407	Swamp Wallaby	c	e	d	21	
12	Ground	9/10/2020	0608	Dog	c	e	d	22	Black Dog
12	Ground	10/10/2020	0349	Swamp Wallaby	c	e	d	25	
12	Ground	10/10/2020	1326	Lace monitor	c	w	d	26	
12	Ground	10/10/2020	2208	Bandicoot spp	c	e	d	27	
12	Ground	11/10/2020	0156	Fox	c	w	d	28	
12	Ground	11/10/2020	2007	Bandicoot spp	c	w	d	30	
12	Ground	11/10/2020	2238	Bandicoot spp	c	e	d	31	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
12	Ground	12/10/2020	0143	Fox	c	e	d	32	
12	Ground	12/10/2020	0338	Swamp Wallaby	c	e	d	33	
12	Ground	13/10/2020	0311	Swamp Wallaby	c	e	d	45	
12	Ground	13/10/2020	1734	Dog	c	w	d	46	Black Dog
12	Ground	15/10/2020	0132	Cat	c	w	d	54	Tabby Cat
12	Ground	15/10/2020	0349	Swamp Wallaby	c	e	d	55	
12	Ground	16/10/2020	0007	Bandicoot spp	c	e	d	61	
12	Ground	16/10/2020	0019	Bandicoot spp	c	e	d	62	
12	Ground	16/10/2020	0453	Fox	c	e	d	63	
12	Ground	17/10/2020	0418	Fox	c	e	d	64	
12	Ground	17/10/2020	1834	Swamp Wallaby	c	w	d	65	
12	Ground	18/10/2020	0404	Swamp Wallaby	c	e	d	66	
12	Ground	19/10/2020	0138	Bandicoot spp	c	e	d	69	
12	Ground	19/10/2020	0330	Swamp Wallaby	c	e	d	70	
12	Ground	19/10/2020	2259	Swamp Wallaby	c	e	d	71	
12	Ground	20/10/2020	0046	Swamp Wallaby	c	e	d	72	
12	Ground	20/10/2020	0221	Swamp Wallaby	i	e	d	73-74	
12	Ground	20/10/2020	2359	Bandicoot spp	c	e	d	75	
12	Ground	22/10/2020	0407	Swamp Wallaby	c	e	d	78	
12	Ground	22/10/2020	2313	Bandicoot spp	c	e	d	80	
12	Ground	23/10/2020	0304	Swamp Wallaby	c	e	d	82	
12	Ground	23/10/2020	0200	Swamp Wallaby	c	e	d	83-87	
12	Ground	24/10/2020	0102	Fox	c	e	d	89	
12	Ground	24/10/2020	0421	Swamp Wallaby	c	e	d	90	
12	Ground	24/10/2020	2332	Rodent spp	c	e	d	92	
12	Ground	25/10/2020	0419	Swamp Wallaby	c	e	d	94	
12	Ground	25/10/2020	0954	Water Dragon	c	e	d	95	
12	Ground	28/10/2020	0537	Dog	c	e	d	120	Black Dog
12	Ground	29/10/2020	0304	Bandicoot spp	c	e	d	126	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
12	Ground	30/10/2020	2337	Cat	c	e	d	7	
12	Ground	31/10/2020	1917	Swamp Wallaby	c	w	d	10	
12	Ground	1/11/2020	0413	Swamp Wallaby	c	e	d	11	
12	Ground	1/11/2020	0537	Dog	c	e	d	12	Black Dog
12	Ground	2/11/2020	1939	Bandicoot spp	c	w	d	22	
12	Ground	2/11/2020	2123	Bandicoot spp	c	e	d	23	
12	Ground	03/11/2020	0142	Fox	c	w	d	24	
12	Ground	03/11/2020	0510	Dog	c	w	d	25	Black Dog
12	Ground	03/11/2020	1945	Swamp Wallaby	c	w	d	26-32	
12	Ground	04/11/2020	0129	Swamp Wallaby	c	e	d	33	
12	Ground	06/11/2020	0131	Bandicoot spp	c	e	d	37	
12	Ground	07/11/2020	1817	Dog	c	w	d	38	
12	Ground	07/11/2020	2303	Bandicoot spp	c	e	d	39	
12	Ground	08/11/2020	0258	Fox	c	e	d	40	
12	Ground	08/11/2020	2158	Bandicoot spp	c	w	d	41	
12	Ground	08/11/2020	2328	Bandicoot spp	c	e	d	42	
12	Ground	10/11/2020	0016	Fox	c	w	d	43	
12	Ground	11/11/2020	1918	House Mouse	c	e	d	44	
12	Ground	13/11/2020	2220	Bandicoot spp	c	e	d	50	
12	Ground	14/11/2020	0223	Fox	c	w	d	51	
12	Ground	14/11/2020	0340	Swamp Wallaby	c	e	d	52	
12	Ground	14/11/2020	0503	Dog	c	e	d	53	
12	Ground	14/11/2020	2037	Bandicoot spp	c	w	d	54	
12	Ground	15/11/2020	0104	Bandicoot spp	c	e	d	56	
12	Ground	15/11/2020	0930	Lace monitor	c	w	d	57	
12	Ground	15/11/2020	1937	Bandicoot spp	c	e	d	58	
12	Ground	15/11/2020	1947	Swamp Wallaby	c	w	d	59	
12	Ground	16/11/2020	0204	Fox	c	w	d	60	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
12	Ground	16/11/2020	0318	Swamp Wallaby	c	e	d	61	
12	Ground	16/11/2020	338	Fox	c	e	d	62-63	
12	Ground	16/11/2020	1443	Lace monitor	c	e	d	64-65	
12	Ground	16/11/2020	2015	Bandicoot spp	c	w	d	66	
12	Ground	17/11/2020	2300	Bandicoot spp	c	e	d	68	
12	Ground	18/11/2020	0027	Bandicoot spp	c	e	d	69	
12	Ground	18/11/2020	0551	Dog	c	e	d	70	
12	Ground	18/11/2020	2248	Bandicoot spp	c	e	d	72	
12	Ground	19/11/2020	0316	Fox	c	w	d	73-74	
12	Ground	19/11/2020	0341	Fox	c	e	d	75	
12	Ground	19/11/2020	1442	Lace monitor	c	w	d	76	
12	Ground	19/11/2020	1919	Bandicoot spp	c	w	d	77	
12	Ground	19/11/2020	2057	Bandicoot spp	c	w	d	79	
12	Ground	19/11/2020	2222	Bandicoot spp	c	e	d	80	
12	Ground	19/11/2020	2327	Bandicoot spp	c	e	d	81	
12	Ground	20/11/2020	0040	Koala	i	e-w	d	82-83	
12	Ground	20/11/2020	0404	Swamp Wallaby	c	e	d	83	
12	Ground	20/11/2020	1025	Lace monitor	c	e	d	84	
12	Ground	20/11/2020	1901	Dog	c	w	d	86	Black Dog
12	Ground	20/11/2020	2238	Swamp Wallaby	c	w	d	87	
12	Ground	21/11/2020	0203	Fox	c	e	d	88	
12	Ground	21/11/2020	0323	Swamp Wallaby	c	e	d	89	
12	Ground	22/11/2020	0203	Bandicoot spp	c	e	d	92	
12	Ground	22/11/2020	0414	Cat	c	w	d	93	Tabby Cat
12	Ground	24/11/2020	2030	Bandicoot spp	c	e	d	95	
12	Ground	25/11/2020	0343	Fox	c	e	d	96	
12	Ground	25/11/2020	0401	Swamp Wallaby	c	e	d	97	
12	Ground	25/11/2020	0344	Fox	c	e	d	98	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
12	Ground	25/11/2020	0401	Swamp wallaby	c	e	d	99	
12	Ground	27/11/2020	1901	Swamp wallaby	c	w	d	100	
12	Ground	29/11/2020	2241	Swamp wallaby	c	e	d	101	
12	Ground	30/11/2020	1931	Dog	c	e	d	112	
12	Ground	1/12/2020	0328	Cat	c	w	d	113	
11	Furniture	21/10/2020	1904	Antechinus spp	c	e	d	33	
11	Furniture	16/12/2020	2335	Rodent spp	c	e	d	71	
11	Furniture	17/12/2020	0354	Rodent spp	c	w	d	72	
11	Furniture	18/12/2020	0128	Rodent spp	c	e	d	73	
11	Furniture	18/12/2020	0246	Rodent spp	c	w	d	74	
11	Furniture	19/12/2020	0209	Cat	c	e	d	75	Tabby Cat
11	Furniture	20/12/2020	2041	Rodent spp	c	e	d	76-77	
11	Furniture	20/12/2020	2257	Rodent spp	c	e	d	78-79	
11	Furniture	21/12/2020	2153	Rodent spp	c	e	d	81	
11	Furniture	24/12/2020	2352	Rodent spp	c	e	d	83	
11	Furniture	25/12/2020	0117	Rodent spp	c	e	d	85-86	
11	Furniture	26/12/2020	0017	Rodent spp	c	e	d	87-88	
11	Furniture	27/12/2020	2153	Rodent spp	c	w	d	91	
11	Furniture	28/12/2020	2025	Rodent spp	c	w	d	92	
11	Furniture	29/12/2020	0405	Rodent spp	c	e	d	93	
11	Furniture	29/12/2929	2343	Rodent spp	c	w	d	94	
11	Furniture	30/12/2020	0156	Rodent spp	c	e	d	95	
11	Furniture	30/12/2020	0348	Rodent spp	c	w	d	96	
11	Furniture	30/12/2020	2002	Rodent spp	c	w	d	97	
11	Furniture	31/12/2020	330	Rodent spp	c	e	d	98	
11	Furniture	4/01/2021	0418	Rodent spp	c	e	d	102	
11	Ground	2/10/2020	1630	Fox	c	e	d	7	Times are out
11	Ground	9/10/2020	1353	Swamp wallaby	c	w	d	9	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
11	Ground	5/10/2020	651	Swamp wallaby	c	e	d	15	
11	Ground	5/10/2020	1626	Fox	c	e	d	16	x2
11	Ground	6/10/2020	1409	Swamp wallaby	c	e	d	18	
11	Ground	7/10/2020	1435	Swamp wallaby	c	e	d	19	
11	Ground	8/10/2020	1611	Swamp wallaby	c	e	d	23	
11	Ground	8/10/2020	1808	Dog	c	e	d	24	
11	Ground	9/10/2020	1553	Swamp wallaby	c	e	d	26	
11	Ground	10/10/2020	1354	Fox	c	w	d	28	
11	Ground	11/10/2020	1344	Fox	c	e	d	32	
11	Ground	11/10/2020	1554	Swamp wallaby	c	e	d	33	
11	Ground	12/10/2020	0317	Swamp wallaby	c	e	d	40	
11	Ground	13/10/2020	0608	Swamp wallaby	c	w	d	42	
11	Ground	13/10/2020	0617	Swamp wallaby	c	w	d	45	
11	Ground	13/10/2020	0640	Swamp wallaby	c	e	d	47	
11	Ground	14/10/2020	1552	Swamp wallaby	c	e	d	48	
11	Ground	15/10/2020	1616	Swamp wallaby	c	e	d	67	
11	Ground	18/10/2020	1558	Swamp wallaby	c	e	d	69	
11	Ground	19/10/2020	1505	Swamp wallaby	c	e	d	72	
11	Ground	23/10/2020	1302	Fox	c	e	d	79	
11	Ground	23/10/2020	1626	Swamp wallaby	c	e	d	80	
11	Ground	24/10/2020	1411	Fox	c	w	d	82	
11	Ground	25/10/2020	1196	Swamp Wallaby	c	e	d	94	
11	Ground	25/10/2020	981	Water Dragon	c	e	d	95	
11	Ground	28/10/2020	766	Dog	c	e	d	111	Black Dog
11	Ground	29/10/2020	551	Bandicoot spp	c	e	d	113	
11	Ground	30/10/2020	2339	Cat	i	e	d	5-6	Tabby Cat
11	Ground	1/11/2020	0413	Swamp Wallaby	c	e	d	10	
11	Ground	1/11/2020	0536	Dog	c	e	d	11-12	Black Dog

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
11	Ground	02/11/2020	2123	Bandicoot spp	c	e	d	19	
11	Ground	03/11/2020	0138	Fox	c	w	d	20	
11	Ground	03/11/2020	0507	Dog	c	w	d	21	Black Dog
11	Ground	04/11/2020	0159	Swamp Wallaby	c	e	d	23	
11	Ground	05/11/2020	2221	Fox	c	w	d	26	
11	Ground	07/11/2020	1815	Dog	c	w	d	32	Black Dog
11	Ground	08/11/2020	0258	Fox	c	e	d	33	
11	Ground	08/11/2020	300	Fox	c	e	d	35	
11	Ground	08/11/2020	306	Fox	c	e	d	36-37	
11	Ground	08/11/2020	2337	Bandicoot spp	c	e	d	39	
11	Ground	10/11/2020	0013	Fox	c	w	d	40	
11	Ground	12/11/2020	0344	Swamp Wallaby	c	e	d	44	
11	Ground	13/11/2020	1135	Dog	c	e	d	48	
11	Ground	13/11/2020	2219	Bandicoot spp	c	e	d	51	
11	Ground	14/11/2020	0220	Fox	c	w	d	52	
11	Ground	14/11/2020	0349	Swamp Wallaby	c	e	d	53	
11	Ground	14/11/2020	0502	Dog	c	e	d	56	
11	Ground	15/11/2020	0103	Bandicoot spp	c	e	d	58	
11	Ground	15/11/2020	0924	Lace monitor	c	w	d	59	
11	Ground	15/11/2020	1540	Lace monitor	c	w	d	60	
11	Ground	15/11/2020	1936	Bandicoot spp	c	e	d	61	
11	Ground	15/11/2020	2111	Bandicoot spp	c	e	d	63	
11	Ground	15/11/2020	2328	FF Melomys	c	e	d	64	
11	Ground	16/11/2020	0334	Swamp Wallaby	c	e	d	65	
11	Ground	16/11/2020	0337	Fox	c	e	d	66-67	
11	Ground	16/11/2020	0951	Lace monitor	c	e	d	68	
11	Ground	17/11/2020	1416	Lace monitor	c	w	d	70	
11	Ground	18/11/2020	0026	Bandicoot spp	c	e	d	71	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
11	Ground	18/11/2020	0549	Dog	c	e	d	73	
11	Ground	18/11/2020	0901	Lace monitor	c	e	d	74	
11	Ground	18/11/2020	2248	Bandicoot spp	c	e	d	76	
11	Ground	19/11/2020	0312	Fox	c	w	d	77-78	
11	Ground	19/11/2020	0340	Fox	c	e	d	79	
11	Ground	19/11/2020	1416	Lace monitor	c	w	d	80	
11	Ground	19/11/2020	2221	Bandicoot spp	c	e	d	84	
11	Ground	19/11/2020	2327	Bandicoot spp	c	e	d	85	
11	Ground	20/11/2020	0408	Swamp Wallaby	c	e	d	86	
11	Ground	20/11/2020	1857	Dog	c	w	d	89	
11	Ground	21/11/2020	0202	Fox	c	e	d	91	
11	Ground	21/11/2020	0339	Swamp Wallaby	c	e	d	92	
11	Ground	21/11/2020	2029	Bandicoot spp	c	e	d	96	
11	Ground	22/11/2020	0408	Cat	c	w	d	98	Tabby Cat
11	Ground	24/11/2020	0724	Swamp Wallaby	c	e	d	105	
11	Ground	24/11/2020	0817	Swamp wallaby	c	e	d	106	
11	Ground	24/11/2020	2029	Bandicoot spp	c	e	d	108	
11	Ground	25/11/2020	0341	Fox	c	e	d	109	
11	Ground	25/11/2020	0404	Swamp wallaby	c	e	d	110	
11	Ground	27/11/2020	0402	Swamp wallaby	c	e	d	117	
11	Ground	27/11/2020	1902	Swamp wallaby	c	w	d	118	
11	Ground	29/11/2020	2247	Swamp wallaby	c	e	d	129	
11	Ground	30/11/2020	1931	Dog	c	e	d	130	Black Dog
11	Ground	1/12/2020	0328	Cat	c	w	d	132	Tabby Cat
11	Ground	2/12/2020	0422	Swamp wallaby	c	e	d	134	
11	Ground	3/12/2020	1939	Cat	i	w	d	136	Black Cat
11	Ground	3/12/2020	2344	Bandicoot spp	c	e	d	138	
11	Ground	4/12/2020	2134	Bandicoot spp	c	e	d	142	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
11	Ground	5/12/2020	0223	Fox	c	e	d	143	
11	Ground	6/12/2020	0034	Swamp wallaby	c	e	d	148	
11	Ground	6/12/2020	2202	Bandicoot spp	c	e	d	155	
11	Ground	7/12/2020	2228	Bandicoot spp	c	e	d	159	
11	Ground	8/12/2020	0811	Swamp wallaby	c	w	d	162	
11	Ground	8/12/2020	0845	Swamp wallaby	c	e	d	164	
11	Ground	8/12/2020	2054	Swamp wallaby	c	e	d	167	
11	Ground	9/12/2020	0259	Swamp wallaby	c	w	d	168-169	
11	Ground	10/12/2020	0102	Swamp wallaby	i	e	d	173	
11	Ground	10/12/2020	0200	Swamp wallaby	c	w	d	174	
11	Ground	10/12/2020	1051	Lace monitor	c	w	d	175	
11	Ground	10/12/2020	1442	Lace monitor	c	e	d	176	
11	Ground	10/12/2020	2252	Bandicoot spp	c	e	d	177	
11	Ground	12/12/2020	0717	Dog	c	e	d	179	Black Dog
11	Ground	14/12/2020	2338	Fox	c	e	d	182	
11	Ground	15/12/2020	2132	Bandicoot spp	c	e	d	183	
11	Ground	19/12/2020	0058	Fox	c	w	d	191	
11	Ground	20/12/2020	0349	Fox	c	e	d	192	
11	Ground	20/12/2020	2332	Bandicoot spp	c	e	d	193	
11	Ground	26/12/2020	2155	Swamp wallaby	c	e	d	207	
11	Ground	26/12/2020	2135	Bandicoot spp	c	e	d	209	
11	Ground	27/12/2020	2352	Fox	c	w	d	210	
11	Ground	28/12/2020	0128	Fox	c	e	d	211	
11	Ground	29/12/2020	139	Swamp wallaby	i	e	d	212	
11	Ground	30/12/2020	216	Bandicoot spp	c	e	d	216	
11	Ground	01/01/2021	218	Cat	c	e	d	218	Black Cat
11	Ground	02/01/2021	2118	Bandicoot spp	c	e	d	220	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
11	Ground	03/01/2021	2030	Bandicoot spp	c	e	d	221	
10	Furniture			Nil recorded for spring/summer					
10	Furniture	25/12/2020	2004	Antechinus spp	c	w	d	43	
10	Furniture	29/12/2020	2158	Antechinus spp	c	e	d	47	
10	Furniture	29/12/2020	2201	Antechinus spp	c	w	d	48	
10	Furniture	31/12/2020	0119	Antechinus spp	c	e	d	51	
10	Ground	6/10/2020	0840	Dog	c	e	d	10	Black Dog
10	Ground	6/10/2020	0933	Dog	c	w	d	11	Black Dog
10	Ground	6/10/2020	1622	Dog	c	e	d	13-14	Black Dog
10	Ground	6/10/2020	1749	Dog	c	w	d	15	Black Dog
10	Ground	6/10/2020	2130	Cat	c	e	d	16	Tabby Cat
10	Ground	7/10/2020	0314	Fox	c	w	d	17	
10	Ground	15/10/2020	2311	Cat	c	w	d	53	Tabby Cat
10	Ground	20/10/2020	0047	Long Nose Bandicoot	c	w	d	55	
10	Ground	20/10/2020	0515	Dog	c	e	d	56	Black Dog
10	Ground	23/10/2020	0009	Black rat	c	w	d	60	
10	Ground	24/10/2020	0017	Fox	c	e	d	61-62	
10	Ground	26/10/2020	0200	Rodent spp	c	w	d	64	
10	Ground	30/10/2020	0013	Dog	c	w	d	109	Black Dog
10	Ground	30/10/2020	0207	Fox	c	w	d	110	
10	Ground	30/10/2020	0958	Dog	c	e	d	5	Black dog white chest
10	Ground	31/10/2020	0653	Dog	c	w	d	6	Black dog white chest
10	Ground	1/11/2020	0654	Dog	c	e	d	7	Black dog white chest
10	Ground	2/11/2020	0655	Dog	c	e	d	8	Black dog white chest

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
10	Ground	6/11/2020	0059	Fox	c	w	d	15	
10	Ground	6/11/2020	1803	Cat	c	e	d	16	
10	Ground	7/11/2020	2125	Cat	c	w	d	17	tabby
10	Ground	9/11/2020	1924	Dog	c	w	d	19	Black dog white chest
10	Ground	12/11/2020	2317	Echidna	c	e	d	21	
10	Ground	14/11/2020	0406	Dog	c	w	d	23	
10	Ground	14/11/2020	0925	**Koala**	I	e	d	25	Sits in front of camera
10	Ground	15/11/2020	2220	Common brushtail possum	c	e	d	26	juvenile x2
10	Ground	19/11/2020	1844	Dog	c	e	d	29	
10	Ground	20/11/2020	0131	Bandicoot spp	c	w	d	30	
10	Ground	23/11/2020	0643	Dog	c	e	d	31	
10	Ground	30/11/2020	0445	Dog	c	w	d	46	
10	Ground	2/12/2020	1756	Dog	c	w	d	49	
10	Ground	3/12/2020	2006	Bandicoot spp	c	w	d	51	
10	Ground	10/12/2020	1936	cat	c	w	d	53	
10	Ground	17/12/2020	2208	Bandicoot spp	c	w	d	59	
10	Ground	18/12/2020	2216	Long-nosed bandicoot	c	w	d	60	
10	Ground	20/12/2020	2146	Bandicoot spp	c	w	d	62	
10	Ground	21/12/2020	2311	Bandicoot spp	c	w	d	64	
10	Ground	2/01/2020	2014	Bandicoot spp	c	w	d	72	
9	Furniture			Nil recorded for spring/summer					Nil
9	Furniture	14/11/2020	1026	Egernia spp	c	e	d	13	Black Dog
9	Ground	6/10/2020	0838	Dog	c	e	d	5	Black Dog
9	Ground	6/10/2020	0930	Dog	c	w	d	6	Black Dog

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
9	Ground	6/10/2020	1620	Dog	c	e	d	7	Black Dog
9	Ground	6/10/2020	1745	Dog	c	w	d	8	Tabby Cat
9	Ground	6/10/2020	2134	Cat	c	e	d	9	
9	Ground	7/10/2020	0310	Fox	c	w	d	10	
9	Ground	8/10/2020	1039	Lace monitor	c	e	d	11-12	
9	Ground	9/10/2020	0952	Lace monitor	c	w	d	15	Tabby Cat
9	Ground	15/10/2020	2305	Cat	c	w	d	39	
9	Ground	17/10/2020	0247	Fox	c	e	d	40	
9	Ground	19/10/2020	0059	Black rat	c	e	d	41	Black Dog
9	Ground	20/10/2020	0512	Dog	c	e	d	42	
9	Ground	25/10/2020	0250	Fox	c	e	d	46	Black Dog
9	Ground	30/10/2020	0009	Dog	c	w	d	84	
9	Ground	30/10/2020	0202	Fox	c	w	d	85	
9	Ground	31/10/2020	0649	Dog	c	w	d	4	
9	Ground	2/11/2020	008	Dog	c	w	d	8	
9	Ground	2/11/2020	2110	Dog	c	e	d	13	
9	Ground	6/11/2020	0057	fox	c	w	d	19	
9	Ground	6/11/2020	1807	Cat	c	e	d	20	
9	Ground	7/11/2020	2044	Cat	c	w	d	21	
9	Ground	9/11/2020	0450	Dog	c	e	d	22	
9	Ground	9/11/2020	1922	Dog	c	w	d	24	
9	Ground	14/11/2020	0404	Dog	c	w	d	29	
9	Ground	15/11/2020	2220	Common brushtail possum	c	e	d	31	x2
9	Ground	18/11/2020	004	Bandicoot spp	c	e	d	33	
9	Ground	19/11/2020	1844	Dog	c	e	d	34	
9	Ground	23/11/2020	0642	Dog	c	e	d	37	
9	Ground	30/11/2020	1949	Dog	c	w	d	52	
9	Ground	2/12/2020	1754	Dog	c	w	d	56	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
9	Ground	3/12/2020	0303	Fox	I	w	d	58-59	
9	Ground	9/12/2020	0106	Cat	c	e	d	63	
9	Ground	10/12/2020	0241	Wallaby spp	c	e	d	71	
9	Ground	10/12/2020	1917	Cat	c	w	d	72	
9	Ground	20/12/2020	0105	Bandicoot spp	c	e	d	79	
9	Ground	24/12/2020	3037	Black rat	I	w	d	93	
9	Ground	31/12/2020	0235	Cat	c	e	d	96	
9	Ground	2/01/2020	2116	Black rat	c	e	d	97	
8	Furniture	3/10/2020	1913	Antechinus spp	c	e	d	3	Eating a spider
8	Furniture	5/10/2020	1914	Antechinus spp	c	w	d	5	
8	Furniture	5/10/2020	1925	Antechinus spp	c	w	d	6	
8	Furniture	2/11/2020	2017	Black rat	i	w	d	4	
8	Furniture	10/11/2020	2255	Black rat	c	w	d	14	
8	Furniture	10/11/2020	2310	Black rat	c	e	d	15	
8	Furniture	15/11/2020	0237	Black rat	c	w	d	19	
8	Furniture	15/11/2020	0247	Black rat	c	w	d	21	
8	Furniture	17/11/2020	0250	Black rat	c	e	d	22	
8	Ground	3/10/2020	0104	Fox	c	w	d	3	
8	Ground	3/10/2020	0122	Fox	i	ndm	d	4	
8	Ground	3/10/2020	0231	Fox	c	w	d	5-6	
8	Ground	4/10/2020	0927	Lace monitor	c	w	d	8	
8	Ground	04/10/2020	1041	Lace monitor	c	e	d	9	
8	Ground	04/10/2020	1244	Lace monitor	c	e	d	10	
8	Ground	5/10/2020	0358	Fox	c	e	d	12	
8	Ground	5/10/2020	1627	Lace monitor	c	w	d	15	
8	Ground	9/10/2020	0428	Fox	c	e	d	17	Black Dog
8	Ground	9/10/2020	0644	Dog	c	e	d	19	
8	Ground	11/10/2020	0915	Lace monitor	c	w	d	21	
8	Ground	11/10/2020	1431	Lace monitor	c	e	d	22	Black Dog

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
8	Ground	14/10/2020	0501	Dog	c	e	d	29	
8	Ground	15/10/2020	0138	Fox	c	e	d	30	
8	Ground	15/10/2020	0902	Lace monitor	c	w	d	31	
8	Ground	16/10/2020	1216	Lace monitor	c	e	d	41	
8	Ground	17/10/2020	1010	Lace monitor	c	e	d	43	
8	Ground	18/10/2020	0528	**Koala**	c	w	d	44	Tabby Cat
8	Ground	20/10/2020	555	Cat	c	w	d	45	Tabby Cat
8	Ground	20/10/2020	1656	Cat	c	e	d	46	
8	Ground	25/10/2020	2329	Bandicoot spp	c	e	d	49	
8	Ground	30/10/2020	0328	Fox	c	e	d	73	
8	Ground	14/11/2020	0411	Fox	c	e	d	3	
8	Ground	14/11/2020	2334	Cat	c	e	d	4	
8	Ground	15/11/2020	0330	Swamp wallaby	c	w	d	5	
8	Ground	15/11/2020	1055	Lace monitor	c	w	d	6	
8	Ground	16/11/2020	0829	Lace monitor	c	e	d	7	
8	Ground	20/11/2020	2039	Cat	c	e	d	34	
8	Ground	22/11/2020	1259	Lace monitor	c	e	d	37	
8	Ground	23/11/2020	0138	Bandicoot spp	c	e	d	38	
8	Ground	26/11/2020	1033	Lace monitor	c	w	d	48	
8	Ground	26/11/2020	1145	Lace monitor	c	e	d	49	
8	Ground	27/11/2020	1938	Dog	c	w	d	52	
8	Ground	31/10/2020	0905	Lace monitor	c	w	d	2	
8	Ground	31/10/2020	1347	Lace monitor	c	e	d	3	
8	Ground	31/10/2020	1928	Cat	c	e	d	e	
8	Ground	6/11/2020	0929	Lace monitor	c	w	d	14	
8	Ground	6/11/2020	1312	Lace monitor	c	e	d	15	
8	Ground	8/11/2020	1241	Lace monitor	c	e	d	22	
8	Ground	11/11/2020	1046	Lace monitor	c	w	d	24	dates goes until 2/12/2020
7	ground	1/10/2020	1838	Rodent spp	c	w	d	12	
7	ground	2/10/2020	1225	Lace monitor	c	e	d	13	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
7	ground	3/10/2020	0052	Fox	c	e	d	14	
7	ground	3/10/2020	1224	Lace monitor	c	w	d	15	
7	ground	3/10/2020	2022	Rodent spp	c	w	d	16	
7	ground	4/10/2020	1657	Fox	c	e	d	18	
7	ground	5/10/2020	2121	Dog	c	e	d	19	
7	ground	6/10/2020	1052	Lace monitor	c	e	d	21	
7	ground	8/10/2020	0211	Fox	c	e	d	22	
7	ground	8/10/2020	1044	Lace monitor	c	e	d	23	
7	ground	10/10/2020	0420	Fox	c	e	d	24	
7	ground	11/10/2020	0103	Fox	c	e	d	25	
7	ground	12/10/2020	1311	Lace monitor	c	w	d	27	
7	ground	13/10/2020	1135	Lace monitor	c	e	d	33	
7	ground	13/10/2020	1516	Fox	c	e	d	34	
7	ground	14/10/2020	0258	Fox	c	e	d	38	
7	ground	15/10/2020	1252	Lace monitor	c	w	d	39	
7	ground	16/10/2020	0944	Lace monitor	c	e	d	44	
7	ground	16/10/2020	1950	Bandicoot spp	c	e	d	45	
7	ground	16/10/2020	2349	Fox	c	e	d	46	
7	ground	17/20/2020	0217	Dog	c	w	d	47	
7	ground	20/10/2020	0352	Fox	c	e	d	49	
7	ground	20/10/2020	1604	Fox	c	e	d	51	
7	ground	20/10/2020	2330	Fox	c	e	d	52	
7	ground	21/20/2020	821	Fox	c	e	d	54	
7	ground	21/10/2020	0827	Dog	c	w	d	55	
7	ground	21/10/2020	2228	Fox	c	e	d	57	
7	ground	22/10/2020	0314	Fox	c	w	d	59	
7	ground	22/10/2020	1358	Fox	c	w	d	61	
7	ground	24/10/2020	0131	Rodent spp	c	w	d	62	
7	ground	24/10/2020	1002	Dog	c	w	d	63-131	x2
7	ground	25/10/2020	0011	Black rat	c	e	d	132	
7	ground	25/10/2020	2009	Fox	c	e	d	133	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
7	ground	26/10/2020	1442	Lace monitor	c	w	d	141	
7	ground	26/10/2020	2126	Fox	c	e	d	142	
7	ground	29/10/2020	1932	Fox	c	e	d	154	
7	ground	31/10/2020	2234	Rodent spp	c	e	d	7	
7	ground	1/11/2020	2013	Fox	c	w	d	9	
7	ground	3/11/2020	0019	Dog	c	w	d	13	
7	ground	6/11/2020	2107	Fox	I	e-w	d	19	
7	ground	6/11/2020	2240	Rodent spp	c	e	d	21	
7	ground	7/11/2020	2218	Brushtail possum spp	c	e-w-3	d	22-24	
7	ground	8/11/2020	2314	Long-nosed bandicoot	c	e	d	25	
7	ground	11/11/2020	0411	Swamp Wallaby	c	e	d	28	
7	ground	12/11/2020	2019	Swamp wallaby	c	w	d	30-31	
7	ground	14/11/2020	1826	Dog	c	w	d	34	
7	ground	15/11/2020	1753	Swamp Wallaby	c	e	d	36	
7	ground	16/11/2020	2117	Black rat	c	w	d	38	
7	ground	16/11/2020	2210	Bandicoot spp	c	e	d	40	
7	ground	17/11/2020	0106	Fox	c	e	d	41	
7	ground	17/11/2020	0127	Fox	c	w	d	42	
7	ground	17/11/2020	0351	Black rat	c	w	d	43	
7	ground	17/11/2020	2021	Swamp wallaby	c	w	d	45	
7	ground	18/11/2020	0327	Rodent spp	c	w	d	46	
7	ground	18/11/2020	0334	Swamp wallaby	c	e	d	47	
7	ground	19/11/2020	1057	Lace monitor	c	w	d	49	
7	ground	20/11/2020	2142	Swamp wallaby	c	w	d	51	
7	ground	21/11/2020	1555	Swamp wallaby	c	e	d	53	
7	ground	22/11/2020	0950	Lace monitor	c	w	d	54	
7	ground	22/11/2020	1239	Lace monitor	c	e	d	55	
7	ground	22/11/2020	2132	Rodent spp	c	e	d	56	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
7	ground	27/11/2020	2229	Swamp wallaby	c	e	d	59	
7	ground	28/11/2020	0902	Lace monitor	c	w	d	63	
7	ground	29/11/2020	1834	Cat	c	w	d	68	Spotted
7	ground	30/11/2020	0136	Echidna	c	w	d	69	
7	ground	4/12/2020	0115	Fox	c	e	d	76	
7	ground	4/12/2020	0957	Lace monitor	c	e	d	77	
7	ground	5/12/2020	0222	Fox	c	w	d	78	
7	ground	6/12/2020	2159	Fox	c	e	d	82	
7	ground	6/12/2020	2201	Fox	c	w	d	83	
7	ground	8/12/2020	2259	Fox	c	e	d	84	
7	ground	9/12/2020	2135	Swamp wallaby	c	w	d	92	
7	ground	10/12/2020	0210	Rodent spp	c	e	d	93-95	
7	ground	12/12/2020	1923	Dog	c	w	d	101	
7	ground	17/12/2020	0225	Black rat	c	e	d	110	
7	ground	17/12/2020	0313	Fox	i	e	d	111-112	
7	ground	23/12/2020	2128	Echidna	c	e	d	117	
7	ground	23/12/2020	2149	Echidna	c	e	d	118	
7	ground	31/12/2020	2239	Bandicoot spp	i	e-w	d	127	Ran fast back w
7	ground	1/01/2020	2118	Black rat	c	w	d	130	
7	Furniture	1/10/2020	1833	Black rat	c	w	d	10	
7	Furniture	1/10/2020		Black rat	c	e	d	12	
7	Furniture	3/10/2020	213	Rodent spp	c	e	d	13	
7	Furniture	4/10/2020	1927	Black rat	c	w	d	14	
7	Furniture	9/10/2020	2319	Black rat	c	w	d	15	
7	Furniture	10/10/2020	0142	Rodent spp	c	e	d	16	
7	Furniture	10/10/2020	2304	Rodent spp	I	e	d	17-18	
7	Furniture	12/10/2020	2057	Black rat	c	e	d	22	
7	Furniture	12/10/2020	2254	Black rat	c	e	d	24	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
7	Furniture	15/10/2020	2103	Brushtail possum spp.	c	e	d	28	
7	Furniture	18/10/2020	2108	Black rat	c	w	d	32	
7	Furniture	19/10/2020	1930	Black rat	c	e	d	33	
7	Furniture	22/10/2020	2046	Black rat	c	w	d	35	
7	Furniture	22/10/2020	2317	Black rat	c	e	d	36	
7	Furniture	24/10/2020	2239	Black rat	c	w	d	37-39	
7	Furniture	25/10/2020	0122	Black rat	c	e	d	41	
7	Furniture	25/10/2020	0146	Black rat	c	w	d	42	
7	Furniture	25/10/2020	2000	Black rat	c	w	d	43	
7	Furniture	25/10/2020	2026	Black rat	c	e	d	44	
7	Furniture	25/10/2020	2052	Black rat	c	w	d	45	
7	Furniture	26/10/2020	0314	Black rat	c	w	d	46	
7	Furniture	26/10/2020	2255	Black rat	c	e	d	49	
7	Furniture	27/10/2020	0317	Black rat	c	w	d	50	
7	Furniture	27/10/2020	2332	Black rat	c	w	d	57	
7	Furniture	28/10/2020	0304	Black rat	c	w	d	58	
7	Furniture	28/10/2020	2356	Black rat	c	w	d	62	
7	Furniture	29/10/2020	0303	Black rat	c	w	d	63	
7	Furniture	29/10/2020	0322	Black rat	c	w	d	64	
7	Furniture	29/10/2020	2139	Black rat	c	w	d	72	
7	Furniture	29/10/2020	2352	Black rat	c	e	d	74	
7	Furniture	2/11/2020	2202	Black rat	c	w	d	18	
7	Furniture	2/11/2020	2218	Black rat	c	e	d	19	
7	Furniture	2/11/2020	2218	Black rat	c	w	d	20	
7	Furniture	2/11/2020	2353	Black rat	c	w	d	21	
7	Furniture	4/11/2020	2141	Trichosurus spp	c	e	d	28	
7	Furniture	4/11/2020	2203	Short-eared brushtail possum	c	w	d	30	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
7	Furniture	7/11/2020	2125	Black rat	c	w	d	34	
7	Furniture	10/11/2020	0049	Black rat	c	w	d	41	
7	Furniture	16/11/2020	2108	Black rat	c	e	d	44	
7	Furniture	16/11/2020	2151	Black rat	c	e	d	45-49	
7	Furniture	18/11/2020	2017	Black rat	c	e	d	50	Feeding on insects
7	Furniture	19/11/2020	2153	Black rat	I	w	d	56-64	
7	Furniture	2/12/2020	0307	Black rat	c	e	d	77	
7	Furniture	4/12/2020	0052	Rodent spp	c	e	d	86	
7	Furniture	4/12/2020	2013	Black rat	c	e	d	87	
7	Furniture	14/12/2020	2327	Black rat	I	e-w	d	91-92	
7	Furniture	25/12/2020	2301	Black rat	I	e-w	d	99-102	
7	Furniture	30/12/2020	0020	Black rat	c	e	d	102-109	
7	Furniture	2/01/2020	2337	Antechinus spp	c	e	d	109	
6	Furniture	4/10/2020	1105	Lace monitor	c	w	d	1624	
6	Ground	2/10/2020	1246	Fox	c	w	d	4	
6	Ground	5/10/2020	0816	Lace monitor	c	w	d	10-13	
6	Ground	9/10/2020	0842	Dog	c	e	d	18	
6	Ground	21/10/2020	1120	Lace monitor	c	w	d	48	
6	Ground	24/10/2020	0238	Long-nosed bandicoot	c	e	d	50-51	
6	Ground	24/10/2020	1959	Short-eared brushtail possum	c	e	d	55	
6	Ground	2/11/2020	1956	Bandicoot spp	c	w	d	16	
6	Ground	3/11/2020	1701	Wallaby spp	c	e	d	21	
6	Ground	4/11/2020	0205	Fox	c	e	d	22	
6	Ground	4/11/2020	1330	Lace monitor	c	e	d	32	
6	Ground	4/11/2020	1754	Swamp wallaby	c	w	d	34	
6	Ground	5/11/2020	1818	Cat	c	w	d	37	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
6	Ground	5/11/2020	1748	Northern Brown Bandicoot	c	e	d	40	
6	Ground	5/11/2020	0921	Northern Brown Bandicoot	c	e	d	43	
6	Ground	5/11/2020	2319	Bandicoot spp	I	e	d	46-51	
6	Ground	6/11/2020	1145	Lace monitor	c	w	d	53	
6	Ground	9/11/2020	2102	Fox	c	e	d	61	
6	Ground	10/11/2020	0053	Short-eared brushtail possum	c	e	d	65-66	
6	Ground	10/11/2020	0134	Short-eared brushtail possum	c	W	d	67-68	
6	Ground	11/11/2020	2028	Short-eared brushtail possum	C	w	d	70	
6	Ground	14/11/2020	1816	Dog	c	e	d	82	
6	Ground	15/11/2002	1312	Lace monitor	c	e	d	85	
6	Ground	20/11/2020	2151	Cat	c	e	d	88	
6	Ground	21/11/2020	0217	Fox	c	e	d	91	
6	Ground	22/11/2020	0114	Trichsurus spp	c	e	d	94	
6	Ground	25/11/2020	1217	Lace monitor	c	w	d	99	
6	Ground	26/11/2020	0222	Dog	c	e	d	100	
6	Ground	1/12/2020	1053	Lace monitor	c	w	d	105	
6	Ground	2/12/2020	0914	Lace monitor	c	e	d	113	
6	Ground	3/12/2020	1121	Bandicoot spp	c	e	d	0123	
6	Ground	4/12/2020	1115	Bandicoot spp	c	e	d	124	
6	Ground	4/12/2020	2314	Bandicoot spp	c	e	d	125	
6	Ground	8/12/2020	1241	Fox	c	e	d	130	
6	Ground	17/12/2020	0250	Fox	c	e	d	133	
6	Ground	17/12/2020	2204	Fox	c	e	d	138	
6	Ground	19/12/2020	2347	Fox	c	e	d	139	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
6	Ground	24/12/2020	0152	Fox	c	e	d	148	
6	Ground	24/12/2020	0211	Bandicoot spp	c	e	d	152	
6	Ground	26/12/2020	2154	Fox	c	e	d	157	
6	Ground	28/12/2020	2113	Fox	c	e	d	160	
6	Ground	31/12/2020	1958	Cat	c	e	d	165	
6	Ground	1/01/2020	2132	Fox	c	w	d	166	
5	North	9/10/2020	0821	Dog	c	e	d	9	
5	North	11/10/2020	0646	Fox	c	e	d	10	Moves back and forth
5	North	21/10/2020	0903	Lace monitor	c	e	d	12-16	
5	North	27/10/2020	0855	Lace monitor	c	e	d	17	
5	North	15/11/2020	2039	Black rat	c	w	d	49	
5	North	17/11/2020	0134	Black rat	c	e	d	53	
5	North	23/11/2020	2045	Rodent spp	c	e	d	99	
5	North	23/11/2020	2257	Rodent spp	c	w	d	100	
5	North	6/12/2020	2013	Rodent spp	c	e	d	183	
5	North	17/12/2020	0140	Water rat	c	e	d	253	
5	North	22/12/2020	1733	Fox	c	e	d	254	
5	South	1/10/2020	1954	Short-eared brushtail possum	I	e	d	1-2	
5	South	1/10/2020	2047	Echidna	c	w	d	5	
5	South	11/10/2020	2233	Brushtail possum spp	c	e	d	8	
5	South	18/10/2020	0942	Lace monitor	c	e	d	12	
5	South	18/10/2020	1410	Lace monitor	c	w	d	13	
5	South	22/10/2020	0232	Rodent spp	c	e	d	22	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
5	South	22/10/20202	2323	Water rat	c	w	d	24	
5	South	23/10/2020	0345	Black rat	c	w	d	25	
5	South	23/10/2020	2222	Black rat	c	w	d	26	
5	South	30/10/2020	0231	Water rat	c	e	d	37	No images session 2
4	Furniture	5/10/2020	1039	Lace monitor	C	w	d	6	
4	Furniture	10/10/2020	2257	Short-eared brushtail possum	c	e	d	11-13	
4	Furniture	31/10/2020	2140	Short-eared brushtail possum	c	e	d	2	
4	Furniture	31/10/2020	2151	Short-eared brushtail possum	c	w	d	2	
4	Furniture	2/11/2020	2122	Short-eared brushtail possum	I	e-w	d	14	
4	Furniture	5/11/2020	2024	Short-eared brushtail possum	I	e-w	d	15-16	
4	Furniture	7/11/2020	2317	Short-eared brushtail possum	c	e	d	24	
4	Furniture	7/11/2020	2323	Short-eared brushtail possum	c	e	d	25	
4	Furniture	7/11/2020	2334	Short-eared brushtail possum	c	w	d	26-30	x2
4	Furniture	8/11/2020	0250	Short-eared brushtail possum	c	w	d	32	
4	Furniture	8/11/2020	0337	Short-eared brushtail possum	c	w	d	33	
4	Furniture	9/11/2020	2012	Short-eared brushtail possum	I	e-w	d	34-35	
4	Furniture	11/11/2020	2146	Short-eared brushtail possum	I	e-w	d	36-37	
4	Furniture	12/11/2020	0106	Short-eared brushtail possum	I	e-w	d	39-40	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
4	Furniture	12/11/2020	1308	Lace monitor	c	w	d	41	
4	Furniture	12/11/2020	2225	Short-eared brushtail possum	c	e	d	42	x2
4	Furniture	12/11/2020	2240	Short-eared brushtail possum	c	w	d	43	x2
4	Furniture	14/11/2020	2146	Short-eared brushtail possum	c	e	d	51	x2
4	Furniture	14/11/2020	2237	Short-eared brushtail possum	c	w	d	53	x2
4	Furniture	15/11/2020	2117	Short-eared brushtail possum	C	e	d	55	x2
4	Furniture	15/11/2020	2203	Short-eared brushtail possum	c	w	d	56	x2
4	Furniture	15/11/2020	2353	Rodent spp (Bush rat ??)	c	e	d	57	
4	Furniture	18/11/2020	002	Short-eared brushtail possum	c	e	d	59	x2
4	Furniture	18/11/2020	0012	Short-eared brushtail possum	c	e	d	60	x2
4	ground	4/10/2020	1731	Fox	c	W	D	5	
4	ground	5/10/2020	1732	Fox	c	W	D	6	
4	ground	8/10/2020	0211	Bandicoot spp	c	W	D	8	
4	ground	8/10/2020	0212	Eastern water dragon	c	W	D	9	
4	ground	9/10/2020	0244	Fox	c	W	D	10	
4	ground	9/10/2020	0805	Dog	c	W	D	11	
4	ground	9/10/2020	1216	Lace monitor	c	W	D	12	
4	ground	9/10/2020	1551	Dog	c	W	D	13	
4	ground	9/10/2020	2056	Bandicoot spp	c	w	D	14	
4	ground	9/10/2020	2351	Short-eared brushtail possum	c	w	d	15	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
4	ground	10/10/2020	2352	Short-eared brushtail possum	c	w	d	16	
4	ground	10/10/2020	1802	Swamp wallaby	c	w	d	17	
4	ground	11/10/2020	0021	Swamp wallaby	c	e	d	18	
4	ground	12/10/2020	2056	Bandicoot spp	c	w	D	19	
4	ground	13/10/2020	0032	Dog	c	w	d	21	
4	ground	13/10/2020	1551	Fox	c	w	d	24	
4	ground	15/10/2020	1026	Eastern water dragon	c	e	d	32	
4	ground	15/10/2020	2014	Bandicoot spp	c	e	d	34	
4	ground	17/10/2020	1022	Lace monitor	c	e	d	52	
4	ground	17/10/2002	1940	Bandicoot spp	c	e	d	53	
4	ground	19/10/2002	2036	Bandicoot spp	c	e	d	54	
4	ground	20/10/2020	1624	Fox	c	e	d	56	
4	ground	21/10/2020	1419	Fox	c	e	d	57	
4	ground	22/10/2020	1951	Bandicoot spp	c	e	d	59	
4	ground	24/10/2020	0246	Bandicoot spp	c	e	d	60	
4	ground	24/10/2020	2024	Bandicoot spp	c	e	d	61	
4	ground	26/10/2020	0233	Northern Brown Bandicoot	I	e-w	d	63	
4	ground	31/10/2020	1254	Eastern water dragon	C	e	w	3	
4	ground	31/10/2020	1257	Lace monitor	c	e	d	4	
4	ground	1/11/2020	0158	Fox	c	w	d	6	
4	ground	1/11/2020	2123	Bandicoot spp	c	e	d	12	
4	ground	2/11/2020	2349	Dog	c	e	d	20	Black dog
4	ground	3/11/2020	1518	Eastern water dragon	c	w	d	21	
4	ground	4/11/2020	0228	Fox	c	w	d	22	
4	ground	4/11/2020	1023	Eastern water dragon	c	e	d	28	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
4	ground	4/11/2020	2031	Bandicoot spp	c	e	d	32	
4	ground	5/11/2020	2024	Bandicoot spp	c	e	d	34	
4	ground	6/11/2020	2041	Bandicoot spp	c	e	d	35	
4	ground	7/11/2020	0001	Bandicoot spp	c	e	d	36	
4	ground	7/11/2020	1858	Bandicoot spp	c	e	d	38	
4	ground	7/11/2020	2006	Bandicoot spp	c	e	d	39	
4	ground	9/11/2020	2027	Bandicoot spp	c	e	d	41	
4	ground	9/11/2020	2121	Fox	c	e	d	42	
4	ground	10/11/2020	1005	Lace monitor	c	e	d	43	
4	ground	10/11/2020	1229	Lace monitor	c	e	d	44	
4	ground	10/11/2020	2232	Swamp wallaby	c	w	d	46	
4	ground	11/11/2020	0359	Swamp wallaby	c	e	d	47	
4	ground	12/11/2020	2248	Swamp wallaby	c	w	d	48	
4	ground	12/11/2020	2252	Swamp wallaby	c	e	d	49	
4	ground	13/11/2020	144	Bandicoot spp	c	w	d	52	
4	ground	13/11/2020	2119	Bandicoot spp	c	e	d	53	
4	ground	14/11/2020	1806	Dog	c	w	d	58	
4	ground	14/11/2020	2327	Koala	c	w	d	59	
4	ground	15/11/2020	100	Swamp wallaby	c	w	d	60	
4	ground	15/11/2020	0346	Swamp wallaby	c	e	d	61	
4	ground	16/11/2020	1359	Lace monitor	c	e	d	64	
4	ground	16/11/2020	1558	Dog	c	w	d	65	
4	ground	18/11/2002	1050	Lace monitor	c	e	d	70	
4	ground	18/11/2002	1823	Dog	I	w-e	d	71-72	White chest
4	ground	19/11/2020	2337	Northern Brown Bandicoot	c	e	d	73	
4	ground	21/11/2020	1908	Dog	c	w-e	d	75	
4	ground	22/11/2002	0055	Dog	c	78	d	78	
4	ground	22/11/2020	0154	Swamp wallaby	c	w	d	79	
4	ground	22/11/2020	0412	Swamp wallaby	c	e	d	80	
4	ground	23/11/2020	0253	Bandicoot spp	c	e	d	84	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
4	ground	26/11/2020	0314	Bandicoot spp	c	w	d	85	
4	ground	26/11/2020	0314	Long-nosed bandicoot	c	w	d	86	
4	ground	26/11/2020	2112	Bandicoot spp	c	e	d	89	
4	ground	26/11/2002	2238	Bandicoot spp	c	e	d	90	
4	ground	27/11/2020	00017	Dog	c	e	d	91	Black white chest
4	ground	29/11/2020	2338	Bandicoot spp	c	e	d	93	
4	ground	1/12/2020	1928	Bandicoot spp	c	e	d	94	
4	ground	1/12/2020	2049	Swamp wallaby	c	w	d	96	
4	ground	1/12/2002	2052	Swamp wallaby	c	e	d	97	
4	ground	1/12/2020	2134	Swamp wallaby	c	e	d	98	
4	ground	4/12/2020	0146	Fox	c	w	d	101	
4	ground	4/12/2020	2004	Bandicoot spp	c	e	d	102	
4	ground	4/12/2020	2101	Koala	c	e	d	103	
4	ground	5/12/2002	2305	Swamp wallaby	c	e	d	105	
4	ground	5/12/2020	2305	Swamp wallby	c	e	d	106	
4	ground	6/12/2020	2350	Bandicoot spp	c	e	d	108	
4	ground	7/12/2020	0251	Trichsurus spp	c	w	d	110	
4	ground	7/12/2020	2145	Black rat	c	e	d	112	
4	ground	8/12/2020	0102	Fox	c	e	d	113	
4	ground	8/12/2002	1930	Dog	c	e	d	116	
4	ground	8/12/2020	2048	Bandicoot spp	c	e	d	117	
4	ground	9/12/2020	2236	Koala	c	e	d	118	
4	ground	10/12/2002	2134	Swamp wallaby	c	w	d	119	
4	ground	10/12/2020	2146	Bandicoot spp	c	e	d	120	
4	ground	11/12/2020	0401	Swamp ballaby	c	e	d	121	
4	ground	13/12/2020	2356	Fox	c	e	d	125	
4	ground	14/12/2020	0335	Rodent spp	c	e	d	127	
4	ground	14/12/2020	2329	Fox	c	e	d	130	
4	ground	16/12/2020	0050	Northern Brown Bandicoot	c	e	d	132	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
4	ground	16/12/2020	0123	Koala	c	w	d	133	
4	ground	16/12/2020	2027	Koala	c	e	d	134	
4	ground	19/12/2020	0332	Bandicoot spp	c	e	d	137	
4	ground	22/12/2020	1812	Koala	c	w	d	141	
4	ground	27/12/2020	1225	Lace monitor	c	w	d	147	
4	ground	27/12/2020	1430	Lace monitor	c	e	d	148	
4	ground	29/12/2020	0303	Swamp wallaby	c	w	d	149	
4	ground	29/12/2020	0313	Swamp wallaby	c	e	d	150	
4	ground	30/12/2020	1506	Lace monitor	c	w	d	153	
4	ground	31/12/2020	0029	Rodent spp	c	w	d	154	
4	ground	2/01/2021	2226	Rodent spp	c	w	d	161	
4	ground	3/01/2021	2226	Rodent spp	c	e	d	163	
4	ground	4/01/2021	014	Koala	c	w	d	164	
3	Furniture	29/10/2020	2200	Cat	c	e	d	70	
3	Furniture	5/10/2020	0118	Brushtail possum spp	i	w	d	6-7	
3	Furniture	5/10/2020	2030	Brushtail possum spp	c	e	d	10	
3	Furniture	6/10/2020	1926	Brushtail possum spp	c	e	d	15	
3	Furniture	8/10/2020	0107	Brushtail possum spp	c	w	d	16	
3	Furniture	8/10/2020	0108	Brushtail possum spp	c	e	d	17	
3	Furniture	9/10/2020	1937	Brushtail possum spp	I	e	d	19-20	
3	Furniture	10/10/2020	2027	Brushtail possum spp	C	e	d	21	
3	Furniture	11/10/2020	2306	Brushtail possum spp	C	e	d	25	
3	Furniture	14/10/2020	2301	Brushtail possum	i	w-e	d	32	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
				spp					
3	Furniture	16/10/2020	2106	Brushtail possum spp	c	w	d	39	
3	Furniture	16/10/2020	2242	Brushtail possum spp	c	e	d	40	
3	Furniture	19/10/2020	2145	Brushtail possum spp	c	e	d	45	
3	Furniture	21/10/2020	0136	Brushtail possum spp	I	w-e	d	46	
3	Furniture	27/10/2020	0830	Eastern water dragon	c	e	d	58	
3	Furniture	28/10/2020	2208	Brushtail possum spp	I	w-e	d	63	
3	Furniture	31/10/2020	1000	Trichosurus spp	c	w	d	2	
3	Furniture	2/11/2020	2209	Trichosurus spp	c	e	d	3	
3	Furniture	4/11/2002	2206	Trichosurus spp	c	w	d	4	
3	Furniture	5/11/2002	0007	Trichosurus spp	c	e	d	6	
3	Furniture	5/11/2020	2107	Trichosurus spp	c	w	d	7	
3	Furniture	6/11/2020	0005	Trichosurus spp	c	e	d	8	
3	Furniture	12/11/2002	2020	Trichosurus spp	c	w	d	10	
3	Furniture	13/11/2002	222	Trichosurus spp	c	w	d	11	
3	Furniture	14/11/2020	1945	Trichosurus spp	c	w	d	12	
3	Furniture	17/11/2020	2015	Trichosurus spp	c	w	d	14	
3	Furniture	19/11/2020	0412	Trichosurus spp	c	e	d	16	
3	Furniture	21/11/2020	0024	Trichosurus spp	c	w	d	17	
3	Furniture	21/11/2020	0205	Trichosurus spp	c	e	d	18	
3	Furniture	11/12/2020	2021	Trichosurus spp	c	w	d	21	
3	Furniture	11/12/2020	2023	Trichosurus spp	c	e	d	23	Active
3	Ground	4/10/2020	0738	Swamp wallaby	c	e	d	7	
3	ground	4/10/2020	1816	Eastern grey	c	w	Pr	10	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
				kangaroo					
3	Ground	6/10/2020	1026	Swamp wallaby	I	w-e	d	12	
3	ground	6/10/2020	01923	Short-eared brushtail possum	I	e-w	d	15	
3	Ground	7/10/2020	0304	Cat	C	w	d	16	white socks
3	ground	7/10/2020	1951	Cat	C	e	d	16	white socks
3	Ground	8/10/2020	0836	Cat	C	w	d	20	white socks
3	ground	8/10/2020	1512	Bloke holding Machette	i	e-w	d	23	
3	Ground	10/10/2020	0029	cat	c	w	d	24	
3	ground	10/10/2020	2208	Bandicoot spp	c	e	d	26	
3	Ground	11/10/2020	0137	Swamp wallaby	c	e	d	27	
3	ground	11/10/2020	0545	Cat	c	e	d	29	White socks
3	Ground	12/10/2020	0526	Swamp wallaby x 2	c	e	d	31	
3	ground	13/10/2020	2112	Cat	c	w	d	41	Tabby
3	Ground	14/10/2020	0412	Cat	c	e	d	47	White socks
3	ground	15/10/2020	0224	Swamp wallaby	c	e	d	49	
3	Ground	15/10/2020	0613	Dog x2	c	e	d	50	Choc Kelpie
3	ground	15/10/2020	2204	Dog	c	w	d	56	
3	Ground	15/10/2002	2234	Bandicoot spp	c	e	d	57	
3	ground	15/10/2020	2246	Cat	c	e	d	58	
3	Ground	16/10/2002	0523	Swamp wallaby x 2	c	e	d	59	
3	ground	16/10/2020	0527	Cat	c	e	d	60	
3	Ground	17/10/2020	0224	Swamp wallaby	c	e	d	61	
3	ground	17/10/2020	0830	Swamp wallaby x 2	c	e	d	64	
3	Ground	18/10/2020	0154	Cat	c	w	d	65	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
3	ground	19/10/2020	0239	Cat	c	w	d	67	
3	Ground	19/10/2020	0404	Swamp wallaby	c	e	d	68	
3	ground	19/10/2020	0640	Swamp wallaby x 2	c	e	d	69	
3	Ground	19/10/2020	1900	Cat	c	e	d	70	white socks
3	ground	20/10/2020	0640	Swamp wallaby x 2	c	e	d	75	
3	Ground	20/10/2020	2007	Swamp wallaby	c	w	d	76	
3	ground	20/10/2020	2048	Cat	c	w	d	77	white socks
3	Ground	20/10/2020	2227	Cat	c	e	d	77	
3	ground	21/10/2020	0041	Swamp wallaby	c	e	d	79	
3	Ground	21/10/2020	1601	Eastern water dragon	c	e	d	80-81	
3	ground	21/10/2020	2117	Bandicoot spp	c	e	d	82	
3	Ground	21/10/2020	0252	Cat	c	w	d	83	
3	ground	22/10/2020	1901	Cat	c	e	d	83	
3	Ground	23/10/2020	0618	Cat	c	e	d	85	
3	ground	24/10/2002	2149	Short-eared brushtail possum	c	e	d	87	
3	Ground	25/10/2020	1429	Eastern water dragon x 2	c	e	d	88	
3	ground	25/10/2020	2336	Cat	c	e	d	91	
3	Ground	27/10/2020	0929	Eastern water dragon	I	e-w	d	103-104	
3	ground	27/10/2020	2006	Cat	c	w	d	105	prey in mouth
3	Ground	27/10/2020	2056	Cat	c	e	d	106	
3	ground	27/10/2020	2326	Swamp wallaby	c	e	d	107	
3	Ground	28/10/2020	0115	Cat	c	w	d	115	
3	ground	28/10/2020	1900	Cat	c	e	d	119	
3	Ground	29/10/2020	1913	Cat	c	w	d	125-	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
								127	
3	ground	29/10/2020	2032	Cat	c	w	d	128	
3	ground	2/11/2020	2120	Swamp Wallaby	c	e	d	4	
3	ground	2/11/2020	2336	Dog	c	w	d	6	Black with white chest
3	ground	3/11/2020	0208	Red necked Wallaby	c	e	d	8-9	
3	ground	3/11/2020	0624	Swamp Wallaby	c	e	d	10	
3	ground	3/11/2020	1804	Swamp Wallaby	i	w	d	12	
3	ground	3/11/2020	1910	Red necked Wallaby	c	w	d	14-15	
3	ground	3/11/2020	2223	Cat	c	w	d	16	Black Cat
3	ground	3/11/2020	2232	Swamp Wallaby	i	e	d	17	
3	ground	4/11/2020	0550	Cat	i	e	d	18	
3	ground	4/11/2020	1432	Swamp Wallaby	i	e	d	23	
3	ground	5/11/2020	2329	Cat	i	e	d	26	
3	ground	6/11/2020	2123	Bandicoot spp	c	e	d	28	
3	ground	7/11/2020	0218	Cat	c	w	d	29	Black Cat
3	ground	7/11/2020	0539	Cat	c	e	d	30	Black Cat
3	ground	8/11/2020	1638	Cat	i	e	d	33-34	Black Cat
3	ground	9/11/2020	0921	Cat	c	w	d	35	Black Cat
3	ground	9/11/2020	1219	Cat	c	w	d	36-37	Black Cat
3	ground	9/11/2020	1534	Cat	i	e	d	38	Black Cat
3	ground	10/11/2020	2146	Bandicoot spp	c	w	d	40-41	
3	ground	11/11/2020	2240	Cat	c	w	d	42	Black Cat
3	ground	12/11/2020	0045	Dog	c	w	d	43	Brown Dog
3	ground	12/11/2020	0526	Cat	i	w	d	46	Black Cat
3	ground	12/11/2020	0754	Cat	c	w	d	47	Black Cat
3	ground	12/11/2020	0811	Cat	i	e	d	48	Black Cat
3	ground	14/11/2020	0236	Cat	c	w	d	49	Black Cat

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
3	ground	14/11/2020	1556	Cat	i	e	d	50	Black Cat
3	ground	15/11/2020	0218	Cat	c	w	d	51	Black Cat
3	ground	15/11/2020	0257	Cat	c	e	d	52	Black Cat
3	ground	18/11/2020	0130	Brush tail possum spp	c	e	d	54	
3	ground	20/11/2020	0231	Dog	c	e	d	57	Brown Dog
3	ground	20/11/2020	0440	Red necked Wallaby x 2	c	e	d	58	
3	ground	20/11/2020	0710	Red necked Wallaby x 2	c	w	d	59-60	
3	ground	20/11/2020	2300	Cat	c	w	d	62	Black Cat
3	ground	21/11/2020	1906	Cat	c	e	d	63	Black Cat
3	ground	22/11/2020	0045	Cat	c	e	d	65	Black Cat
3	ground	23/11/2020	0209	Cat	c	e	d	66-67	Black Cat
3	ground	24/11/2020	0049	Cat	c	w	d	68	Black Cat
3	ground	24/11/2020	0635	Cat	i	e	d	70	Black Cat
3	ground	26/11/2020	0011	Cat	c	w	d	71	Black Cat
3	ground	26/11/2020	0349	Cat	c	e	d	72	Black Cat
3	ground	26/11/2020	2327	Cat	c	w	d	73	Black Cat
3	ground	27/11/2020	0028	Cat	c	e	d	74	Black Cat
3	ground	27/11/2020	2115	Brushtail possum spp	c	e	d	75	
3	ground	28/11/2020	0043	Cat	c	w	d	76	Black Cat
3	ground	28/11/2020	0500	Cat	i	e	d	77	Black Cat
3	ground	1/12/2020	0525	Dog	c	e	d	78	Black Dog
3	ground	3/12/2020	0143	House mouse	c	e	d	80	
3	ground	4/12/2020	2204	Cat	c	w	d	81	Black Cat
3	ground	5/12/2020	0043	Swamp Wallaby	c	e	d	82	
3	ground	5/12/2020	0107	Cat	c	e	d	83	Black Cat

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
3	ground	7/12/2020	0116	Cat	c	w	d	84	Black Cat
3	ground	7/12/2020	1758	Cat	i	e	d	88	Black Cat
3	ground	10/12/2020	0322	Swamp Wallaby	i	e	d	91	
3	ground	10/12/2020	0325	Cat	c	w	d	92	Black Cat
3	ground	10/12/2020	0351	Cat	c	e	d	93	Black Cat
3	ground	12/12/2020	2323	Cat	c	w	d	95	Black Cat
3	ground	13/12/2020	0439	Cat	c	e	d	96	Black Cat
3	ground	13/12/2020	1742	Swamp Wallaby	c	e	d	98-100	
3	ground	15/12/2020	0646	Swamp Wallaby	c	e	d	101	
3	ground	16/12/2020	0143	Cat	c	w	d	103	Black Cat
3	ground	16/12/2020	0337	Cat	i	e	d	104	Black Cat
3	ground	16/12/2020	0608	Swamp Wallaby	c	e	d	105	
3	ground	18/12/2020	0109	Dog	c	w	d	107	Brown Dog
3	ground	18/12/2020	0359	Swamp Wallaby	c	e	d	108	
3	ground	18/12/2020	1345	Water Dragon	i	e	d	109-110	
3	ground	20/12/2020	0603	Swamp Wallaby	c	e	d	138	
3	ground	21/12/2020	0103	Cat	c	w	d	140	Black Cat
3	ground	21/12/2020	0152	Swamp Wallaby	c	e	d	141	
3	ground	21/12/2020	0306	Cat	i	e	d	142	Black Cat
3	ground	22/12/2020	0308	Swamp Wallaby	c	e	d	144	
3	ground	23/12/2020	0528	Red necked Wallaby x 2	c	e	d	145	
3	ground	23/12/2020	1839	Cat	c	e	d	146-147	Black Cat
3	ground	23/12/2020	1856	Red necked Wallaby x 2	c	w	d	148	
3	ground	24/12/2020	0137	Cat	c	e	d	149	Black Cat
3	ground	25/12/2020	0222	Cat	c	w	d	150	Black Cat

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
3	ground	25/12/2020	0357	Cat	c	e	d	151	Black Cat
3	ground	26/12/2020	1410	Swamp Wallaby	c	e	d	152	
3	ground	27/12/2020	0207	Cat	c	w	d	153	Black Cat
3	ground	27/12/2020	0320	Cat	i	e	d	154	Black Cat
3	ground	27/12/2020	1708	Cat	c	w	d	155	Black Cat
3	ground	27/12/2020	1742	Cat	i	e	d	156	Black Cat
3	ground	28/12/2020	0128	Cat	c	w	d	157	Black Cat
3	ground	28/12/2020	1946	Cat	c	e	d	158	Black Cat
3	ground	29/12/2020	0243	Cat	c	w	d	159	Black Cat
3	ground	29/12/2020	0439	Cat	i	e	d	160	Black Cat
3	ground	29/12/2020	1322	Swamp Wallaby	c	w	d	161	
3	ground	30/12/2020	0219	Cat	i	r	d	162	Black Cat
3	ground	30/12/2020	2134	Swamp Wallaby	c	e	d	163	
3	ground	30/12/2020	2315	Kitten	c	w	d	164	Tabby Kitten
3	ground	30/12/2020	2352	Kitten	c	w	d	166-167	Tabby Kitten
3	ground	31/12/2020	0215	Kitten	c	e	d	168	
3	ground	2/01/2021	0538	Swamp Wallaby	i	e	d	170	
3	ground	2/01/2021	2203	Cat	i	w	d	171	Black Cat
3	ground	3/01/2021	0022	Cat	c	e	d	172	Black Cat
2	Furniture	17/10/2020	1018	Eastern water dragon	I	e-w	d	85-112	
2	Furniture	1/12/2020	0130	Black rat	c	e	d	87-93	
2	Furniture	29/12/2020	1126	Antechinus spp	c	e	d	111-123	
2	Furniture	30/12/2020	0302	Black rat	I	w-e	d	128-135	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
2	Furniture	31/12/2020	2121	Antechinus spp	C	w	d	148-149	
2	Furniture	31/12/2020	2139	Antechinus spp	I	e-w	d	148-149	
2	Furniture	1/01/2021	1939	Antechinus spp	c	e	d	168-172	
2	ground	2/10/2020	2343	Bandicoot spp	c	e	d	67	
2	ground	3/10/2020	0144	Swamp wallaby	c	e	d	68	
2	ground	3/10/2020	0531	Swamp wallaby	c	e	d	69	
2	ground	3/10/2020	0543	Dog	c	w	d	070	
2	ground	4/10/2020	0544	Dog	c	w	d	113	
2	ground	4/10/2020	1956	Swamp wallaby	c	w	d	175	
2	ground	5/10/2020	0019	Swamp wallaby	c	e	d	178	
2	ground	5/10/2020	0020	Dog	c	e	d	179	
2	ground	5/10/2020	0317	Swamp wallaby	c	e	d	180	
2	ground	5/10/2020	215	Bandicoot spp	c	e	d	227	
2	ground	6/10/2020	0305	dog	c	w	d	230	Sandy/cream
2	ground	6/10/2020	1945	Bandicoot spp	c	e	d	304	
2	ground	6/10/2020	2053	Dog	c	e	d	305	Sandy/cream
2	ground	8/10/2020	0345	Swamp wallaby	c	e	d	379	
2	ground	9/10/2020	1910	Dog	c	w	d	519	Sandy/cream
2	ground	10/10/2020	0518	Dog	c	w	d	520	Sandy/cream
2	ground	10/10/2020	0022	Swamp wallaby	c	w	d	572	
2	ground	13/10/2020	1912	Dog	c	e	d	725	Sandy/cream
2	ground	14/10/2020	0453	Dog	c	e	d	727	Sandy/cream
2	ground	14/10/2020	1756	cat	i	e	d	780	Tabby
2	ground	14/10/2020	1916	Bandicoot spp	c	e	d	782	
2	ground	14/10/2020	2252	dog	c	e	d	785	black mottled
2	ground	15/10/2020	0232	dog	c	w	d	786	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
2	ground	15/10/2020	0319	Bandicoot spp	c	w	d	788	
2	ground	15/10/2020	0408	Swamp wallaby	c	e	d	789	
2	ground	15/10/2020	0548	Dog	c	e	d	791	
2	ground	1/11/2020	0257	Swamp wallaby	c	e	d	62	
2	ground	2/11/2020	0417	Swamp wallaby	c	w	d	102-112	
2	ground	3/11/2020	006	Swamp wallaby	c	e	d	144	
2	ground	3/11/2020	0254	Swamp wallaby	c	e	d	145	
2	ground	4/11/2020	0126	Swamp wallaby	c	e	d	212	
2	ground	6/11/2020	2000	Bandicoot spp	c	c	d	364	
2	ground	7/11/2020	2156	Swamp wallaby	c	w	d	448	
2	ground	8/11/2020	0302	Fox	c	w	d	451	
2	ground	8/11/2020	0431	Swamp wallaby	c	e	d	453	
2	ground	9/11/2020	2206	Bandicoot spp	c	e	d	578	
2	ground	10/11/2020	2155	Bandicoot spp	c	e	d	633	
2	ground	11/11/2020	2105	Swamp wallaby	c	w	d	690	
2	ground	11/11/2020	213	Bandicoot spp	c	e	d	692	
2	ground	12/11/2020	0005	Dog	c	w	d	695	
2	ground	12/11/2020	0417	Swamp wallaby	c	e	d	697	
2	ground	12/01/2020	1940	Bandicoot spp	c	e	d	741	
2	ground	13/11/2020	0235	Swamp wallaby	c	e	d	743	final date 14/11/2020
1	North	Nil	Nil	Nil	Nil	Nil	Nil	Nil	1/10/2020-24/10/2020 recorded nil
1	North	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Regularly inundated
1	South	No images	No images	No images	No images	No images	No images	No images	
1	South	25/11/2020	0127	Swamp wallaby	c	w	d	399	

Site	Cam	Date	Time	Species	Complete or incomplete	Movement	Accuracy	Vid No.	Comments
1	South	25/11/2020	0131	Swamp wallaby	c	e	d	406	

Table C 2: Sand pad data recorded over 8 nights in spring/summer (ss) during year three of operational phase monitoring WC2NH, 2020/2021. + = probable records.

5pecies/Group	Site																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W
Short-beaked echidna			*																					
Antechinus spp.									+										+		+			
Peramelidae spp. (bandicoot)			*				*		*		*						*				*		*	
Trichosurus spp.							*																	
Swamp wallaby			*		*																*		*	
Wallaby spp.																								
Rodent spp.			*		*				*				*						*					
Dog							*						*		*		*		*		*		*	
Red fox I							*						*		*		*		*					
Cat I					*								*		*						*		*	
Lace monitor							*		*		*				*									
Eastern water dragon							*				*													
Medium reptile	*																							
Medium frog spp.	*																*							
Bird spp.	*																							
Total no. Species/groups	3		4		3		6		4		3		4		4		4		4		5		4	

Table C 3: Scat and track data recorded during camera monitoring (on two occasions 31 October 2020 and 4 January 2021) in spring/summer (ss) of year 3 operational phase monitoring WC2NH, 2020/2021. + = probable records.

Species/group	1		2		3		4		5		6		7		8		9		10		11		12	
	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W
Antechinus spp.											*										*		*	
Peramelidae spp. (bandicoot)			*				*				*		*				*		*					

Trichosurus spp.	*												*											
Swamp wallaby			*										*											
Wallaby spp.	*				*																*		*	
Rodent spp.							*		*				*											
Dog[I]							*						*				*		*		*		*	
Red fox [I]			*								*				*						*		*	
Cat [I]					*		*								*									
Lace monitor							*						*		*		*		*					
Large reptile					*																			
Total species/group	2		3		4		5		1		3		6		3		3		3		4		4	

Table C 4: Nocturnal (spotlighting) adjacent habitat surveys conducted during spring/summer year three of operational phase monitoring WC2NH, 2020.

Location	Side	Date	Obs. No.	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	Humidity	Comment
11&12	E	13/10/20	1	LA	1925	1955	Wallaby spp, Adelotus brevis	Nil	Nil	Good	15.4	75	
	W	13/10/20	1	NM	1925	1955	Nil	Nil	Nil	Good	15.4	75	
	E	15/10/20	2	LA	2235	2305	Nil	ML	Nil	Dark	18	75	
	W	15/10/20	2	NM	2235	2305	Sugar glider	ML	Nil	Dark	18	75	
9&10	E	13/10/20	1	LA	2006	2036	Nil	Nil	Nil	Good	15.4	75	
	W	13/10/20	1	NM	2006	2036	Nil	Nil	Nil	Good	15.4	75	
	E	15/10/20	2	LA	2200	2230	LN bandicoot	Nil	Nil	Good	18.7	69	
	W	15/10/20	2	NM	2200	2230	Swamp wallaby	Nil	Nil	Good	18.7	69	
8	E	13/10/20	1	LA	2045	2115	Wallaby spp,	Nil	Nil	Good	15.4	75	
	W	13/10/20	1	NM	2045	2115	Nil	Nil	Nil	Good	15.4	75	
	E	15/10/20	2	LA	2125	2155	LN bandicoot	Nil	Nil	Good	18.7	69	
	W	15/10/20	2	NM	2125	2155	Swamp wallaby	Nil	Nil	Good	18.7	69	
7	E	13/10/20	1	LA	2122	2152	Wallaby spp	Nil	Nil	Good	13.8	89	
	W	13/10/20	1	NM	2122	2152	GHFF	Nil	Nil	Good	13.8	89	
	E	15/10/20	2	BT	2243	2312	SeBtP (near entrance)	ML	Nil	Dark	18	75	Sitting on refuge pole near entrance
	W	15/10/20	2	BT	2210	2240	**Koala (**M?, twood, 37cm, 496416-6608715)	ML	Nil	Dark	18	75	Prob larger than M rescued near c10 east
5&6	E	13/10/20	1	LA	2200	2230	Litoria peronii, tyleri, flax. Koala Scat, wallaby, GHFF	Nil	Nil	Good	13.8	89	Koala scat under Tallowwood near entrance
	W	13/10/20	1	NM	2200	2230	**YBG,** aAelotus brevis,L. fallax	Nil	Nil	Good	13.8	89	
	E	15/10/20	2	BT	2103	2131	Lit fallax, Lit peroni, Lit tyleri	MSB	Nil	Dark	19	73	
	W	15/10/20	2	BT	2134	2202	Lit fallax, Lit peroni, Lit tyleri, Adelotis	MSB	Nil	Dark	19	73	

Location	Side	Date	Obs. No.	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	Humidity	Comment
							brevis						
4	E	13/10/20	1	LA	2234	2304	GHFF, wallaby, Adelotus brevis	Nil	Nil	Good	13.8	89	
	W	13/10/20	1	NM	2234	2304	Nil	Nil	Nil	Good	13.8	89	
	E	15/10/20	2	BT	1954	1923	GHFF, Wallaby sp.	MLB	Nil	Dark	20.1	70	
	W	15/10/20	2	BT	2025	2055	Wallaby sp. Lit peroni	MLB	Nil	Dark	20.1	70	
3 (E only)	E	13/10/20	1	LA/NM	2309	2339	Wallaby	Nil	Good	13.8	89	Nil	
	E	15/10/20	2	LA/NM	1930	2000	Nil	Nil	Nil	Good	18.7	69	
2	E	13/10/20	1	LA/NM	2342	0012	GHFF	Nil	Good	13.8	89	Nil	
	W	13/10/20	1	LA/NM	2342	0012	Nil	Nil	Good	13.8	89	Nil	
	E	15/10/20	2	LA	2030	2100	Nil	Nil	Nil	Good	18.7	69	
	W	15/10/20	2	NM	2030	2100	GHFF, Common scaly foot	Nil	Nil	Good	18.7	69	
1	E	15/10/20	1	LA	1930	2000	GHFF, Swamp wallaby Adelotus, Lit. fallax	Nil	Nil	Good	18.7	69	
	W	15/10/20	1	NM	1930	2000	Adelotus, Lit. fallax	Nil	Nil	Good	18.7	69	
	E	29/10/20	2	NM/BT	1945	2015	Fallax, SeBtp	Nil	Nil	Good	17.4	91	
	W	29/10/20	2	NM/BT	1945	2015	Swamp wallaby, Gracilenta	Nil	Nil	Good	17.4	91	

Table C 5: Diurnal adjacent habitat surveys conducted during spring/summer year three of operational phase monitoring WC2NH, 2020.

Location	Side	Date	Obs. No.	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	Humidity	Comment
11&12	E	12/10/20	1	LA	1331	1402	Wallaby spp scat, Calyptotis ruficauda, Fox scat.	MSB	Nil	Great	24.3	59	
	W	12/10/20	1	NM	1331	1402	3 x Lampropholis	MSB	Nil	Great	24.3	59	
	E	14/10/20	2	NM	1632	1702	Wallaby spp, bandicoot diggings, Lampropholis spp x 1	MSB	Nil	Great	21.8	58	
	W	14/10/20	2	NM	1600	1630	Lampropholis spp. X 1	MSB	Nil	Great	21.8	58	
9&10	E	12/10/20	1	LA	1412	1442	Wallaby spp and BtPoss scat	MSB	Nil	Great	24.3	59	
	W	12/10/20	1	NM	1412	1442	Swamp wallaby scat	MSB	Nil	Great	24.3	59	
	E	15/10/20	2	NM	1415	1445	Wallaby spp	MSB	Nil	Great	23	58	
	W	14/10/20	2	NM	1720	1750	Wallaby scat, bandicoot diggings, koala scat @ 496525,6609375	MSB	Nil	Great	21.2	54	
8	E	12/10/20	1	LA	1500	1530	Lace monitor, Swamp wallaby scat	MSB	Nil	Great	24.3	59	
	W	12/10/20	1	NM	1500	1530	Lampropholis delicata, swamp wallaby scat	MSB	Nil	Great	24.3	59	
	E	15/10/20	2	NM	1530	1600	Wallaby spp, Lampropholis spp x 1, bandicoot spp	MSB	Nil	Great	22.5	60	
	W	15/10/20	2	NM	1455	1525	Wallaby spp, bandicoot spp	MSB	Nil	Great	22.5	60	
7	E	12/10/20	1	LA	1542	1612	Lampropholis delicata, Bandicoot diggings. Swamy wallaby	MSB	Nil	Great	24.3	59	

Location	Side	Date	Obs. No.	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	Humidity	Comment
	W	12/10/20	1	NM	1542	1612	Lampropholis delicata, swamp wallaby scat, bandicoot diggings	MSB	Nil	Great	24.3	59	
	E	15/10/20	2	NM	1700	1730	Wallaby spp, Lampropholis spp x 1	MSB	Nil	Great	22.6	62	
	W	15/10/20	2	NM	1620	1650	Wallaby spp, bandicoot spp	MSB	Nil	Great	22.6	62	
5&6	E	13/10/20	1	LA	1431	1501	Lace monitor scat, wallaby scat, Lampropholis delicata	MSB	Nil	Great	23.7	58	
	W	13/10/20	1	NM	1431	1501	Lampropholis delicata, swamp wallaby scat, bandicoot diggings	MSB	Nil	Great	23.7	58	
	E	16/10/20	2	LA	1315	1345	No new records	Still	Nil	Good	27.7	37	
	W	15/10/20	2	NM	1735	1805	Swamp wallaby, Adelotus brevis	MSB	Nil	Great	22.6	62	
4	E	13/10/20	1	LA	1521	1551	Wallaby scat, Lampropholis spp	MSB	Nil	Great	23.7	58	
	W	13/10/20	1	NM	1521	1551	Koala scat, bandicoot diggings	MSB	Nil	Great	23.7	58	Photo available Luke’s phone
	E	16/10/20	2	LA	1206	1236	Dog tracks	Still	Nil	Good	27.7	37	Dog tracks in mud
	W	16/10/20	2	LA	1237	1307	Swamp wallaby	Still	Nil	Good	27.7	37	Guts found suggesting predation, small mammal
3 (E only)	E	13/10/20	1	LA	1558	1628	Wallaby scat, Lampropholis cat scat	MSB	Nil	Great	23.7	58	
	E	16/10/20	2	LA	1125	1155	Lampropholis spp x2, wallaby scat, bandicoot diggings	Still	Nil	Good	27.7	37	
2	E	13/10/20	1	LA	1634	1704	Wallaby scat, Lampropholis spp	MSB	Nil	Great	23.7	58	
	W	13/10/20	1	NM	1634	1704	Swamp wallaby scat, Lampropholis spp, lace Monitor	MSB	Nil	Great	23.7	58	

Location	Side	Date	Obs. No.	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	Humidity	Comment
	E	16/10/20	2	LA	1050	1120	Echidna diggings, Swamp wallaby	Still	Nil	Good	27.4	37	
	W	16/10/20	2	LA	1125	1155	Lampropholis spp x2	Still	Nil	Good	27.7	37	
1	E	13/10/20	1	LA	925	1005	BTP scat, medium lizard, Lampropholis spp	Still	Nil	Good	27.4	37	
	W	13/10/20	1	NM	925	1005	Lampropholis spp, wallaby scat	Still	Nil	Good	27.7	37	
	E	16/10/20	2	LA	1005	1035	Nil new	Still	Nil	Good	27.4	37	
	W	16/10/20	2	NM	1005	1035	Nil new	Still	Nil	Good	27.7	37	

Table C 6: Fauna captured during adjacent habitat trapping surveys during spring/summer of year three operational monitoring WC2NH, 2020.

Site	Side	Date	Trap type	Species	Sex	Weight	Comments
11/12	w	27/10/2020	Pitfalll	Lampropholis delicata			
11/12	w	27/10/2020	Large Elliot	SuG	M	128	
11/12	w	27/10/2020	Large Elliot	SuG	F	153	2X pouch young
11/12	e	27/10/2020	Cage	Lace monitor	Unk	Unk	
9/10	w	27/10/2020	Small Elliot	FF Melomys	Male	70	
9/10	w	27/10/2020	Cage trap	FF Melomys	Unk	Unk	
9/10	w	27/10/2020	Small Elliot	FF Melomys	M	78	
8	e	27/10/2020	Small Elliot	Black rat	M	174	
8 west	w	27/10/2020	Cage trap	Lace monitor			
7 east	e	27/10/2020	Small Elliot	FF Melomys	M	75	
7 east	e	27/10/2020	Small Elliot	FF Melomys	F		Escape
7 east	e	27/10/2020	Small Elliot	FF Melomys	M	65	
7 east	e	27/10/2020	Pitfall	Calyptotis ruficauda			
7 west	w	27/10/2020	Small Elliot	Brown Antechinus	F	27	
7 west	w	27/10/2020	Cage trap	Northern brown	Unk	Unk	
5/6 east	e	27/10/2020	Small Elliot	FF Melomys	F	63	
5/6	w	27/10/2020	Small Elliot	Bush rat	M	113	
5/6	w	27/10/2020	Small Elliot	Bush rat	M	95	
11/12	w	28/10/2020	Small Elliot	House mouse	F	14	
11/12	e	28/10/2020	Cage trap	Lace monitor	Unk	Unk	
9/10	w	28/10/2020	Small Elliot	Bush rat	M	92	
9/10	w	28/10/2020	Small Elliot	Bush rat	M	102	
9/11	w	28/10/2020	Pitfall	Lampropholis delicata			
9/11	E	28/10/2020	Cage trap	Short-eared brushtail possum	F	unk	
7	E	28/10/2020	Small Elliot	FF Melomys	F	68	
5/6	E	28/10/2020	Pitfall	Dwarf crowned snake			
5/6	E	28/10/2020	Small Elliot	FF Melomys	F	71	
5/6	W	28/10/2020	Small Elliot	Bush rat	M	113	
5/6	W	28/10/2020	Small Elliot	Bush rat	M	126	
5/6	W	28/10/2020	Cage trap	Bush rat	unk	unk	
11/12	E	29/10/2020	Small Elliot	FF Melomys	M	84	
11/12	W	29/10/2020	Small Elliot	Black rat	M	91	Euthanised
11/12	W	29/10/2020	Cage trap	Black rat	unk	unk	
11/12	W	29/10/2020	Large Elliot	Sugar glider	F	105	
11/12	W	29/10/2020	Pitfall	Lampropholis spp			
9/10	E	29/10/2020	Pitfall	Calyptotis ruficauda			
9/10	E	29/10/2020	Small elliot	FF Melomys	M	73	
7	W	29/10/2020	Small elliot	Brown Antechinus	F	unk	
7	W	29/10/2020	Small elliot	Brown Antechinus	F	unk	
7	E	29/10/2020	Small elliot	FF Melomys	F	73	
5/6	E	29/10/2020	Small elliot	FF Melomys	F	63	
3	W	27/10/2020	Pitfall	L. delicata x 2	Uk	Uk	
3	E	27/10/2020	Pitfall	L. delicata x 1	Uk	Uk	
3	E	27/10/2020	Pitfall	Pseudophryne coreacia x 2	Uk	Uk	
2	E	27/10/2020	Small elliott	Brown Antechinus	F	26gr	breeding
2	E	27/10/2020	Small elliott	Bush rat	F	123gr	
4	E	27/10/2020	Small elliott	FF Melomys	F	68gr	
4	W	27/10/2020	Small elliott	Bush rat	M	148gr	
4	W	28/10/2020	Cage trap	Bush rat	NR	NR	
4	W	28/10/2020	Pitfall	Pseudophryne coreacia x 2	Uk	Uk	
4	W	28/10/2020	Small elliott	Bush rat	M	148gr	
4	W	28/10/2020	Small elliott	Bush rat	M	149gr	
4	E	28/10/2020	Small elliott	FF Melomys	F	84gr	
3	W	28/10/2020	Pitfall	L. delicata	Uk	Uk	

Site	Side	Date	Trap type	Species	Sex	Weight	Comments
3	E	28/10/2020	Pitfall	Calyptotis ruficauda	Uk	Uk	
2	W	28/10/2020	Pitfall	L. delicata	Uk	Uk	
2	E	28/10/2020	Small elliott	Bush rat	F	132gr	
2	E	28/10/2020	Small elliott	Brown Antechinus	F	29gr	Breeding
1	W	28/10/2020	Pitfall	Dwarf-crowned snake	Uk	Uk	
1	W	28/10/2020	Cage trap	Short-eared brushtail possum	NR	NR	
1	W	28/10/2020	Small elliott	Black rat	F	111gr	Euthanised
2	E	29/10/2020	Small elliott	Brown Antechinus	F	NR	breeding
2	E	29/10/2020	Cage trap	Northern brown bandicoot	NR	NR	
4	E	29/10/2020	Pitfall	House mouse	F	NR	Euthanised
4	E	29/10/2020	Large Elliot	FF Melomys	F	NR	

Table C 7: Results from adjacent habitat hair-funnel analysis (9 days) during spring/summer year three of operational phase monitoring WC2NH, 2020.

Site	Side and bait (1=oats) 2=Sardines)	Spring/Summer 2020		
		Install Date	Collect date	Fauna
1	E-1	26/10/2020	4/11/2020	Trichosurus vulpecula
	E-2	26/10/2020	4/11/2020	
	W-1	26/10/2020	4/11/2020	Trichosurus vulpecula
	W-2	26/10/2020	4/11/2020	
2	E-1	26/10/2020	4/11/2020	
	E-2	26/10/2020	4/11/2020	Rattus fuscipes, Isoodon macrourus
	W-1	26/10/2020	4/11/2020	
	W-2	26/10/2020	4/11/2020	
3	E-1	26/10/2020	4/11/2020	
	E-2	26/10/2020	4/11/2020	
	W-1	26/10/2020	4/11/2020	
	W-2	26/10/2020	4/11/2020	
4	E-1	26/10/2020	4/11/2020	Rattus sp.
	E-2	26/10/2020	4/11/2020	
	W-1	26/10/2020	4/11/2020	Rattus fuscipes
	W-2	26/10/2020	4/11/2020	Rattus fuscipes
5/6	E-1	26/10/2020	4/11/2020	*Trichosurus vulpecula*
	E-2	26/10/2020	4/11/2020	
	W-1	26/10/2020	4/11/2020	Rattus fuscipes
	W-2	26/10/2020	4/11/2020	Rattus sp.
7	E-1	26/10/2020	4/11/2020	
	E-2	26/10/2020	4/11/2020	
	W-1	26/10/2020	4/11/2020	Antechinus sp.

Site	**Side and bait (1=oats) 2=Sardines)**	**Spring/Summer 2020**		
		Install Date	**Collect date**	**Fauna**
	W-2	26/10/2020	4/11/2020	
8	E-1	26/10/2020	4/11/2020	Trichosurus vulpecula
	E-2	26/10/2020	4/11/2020	
	W-1	26/10/2020	4/11/2020	Pseudocheirus peregrinus(probable)
	W-2	26/10/2020	4/11/2020	
9/10	E-1	26/10/2020	4/11/2020	
	E-2	26/10/2020	4/11/2020	
	W-1	26/10/2020	4/11/2020	*Rattus fuscipes*
	W-2	26/10/2020	4/11/2020	
11/12	E-1	26/10/2020	4/11/2020	
	E-2	26/10/2020	4/11/2020	
	W-1	26/10/2020	4/11/2020	
	W-2	26/10/2020	4/11/2020	Wallabia bicolor

Appendix B Giant Barred Frog

Transport
Roads & Maritime
Services

Warrell Creek to Nambucca Heads

Interim Giant Barred Frog Monitoring Report – spring year three operational phase

Transport for New South Wales | December 2020

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Document Review

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Project team:

Dr D. Rohweder (project management, survey, report writing)
Mr L. Andrews (field survey)
Dr B. Taylor (field survey, review)
Ms N. Makings (field survey)

Report prepared for:

Roads and Maritime Services NSW

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 0401 195 480 | E **david@sandpipereco.com.au**

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1. Introduction

In 2015, Roads and Maritime Services (RMS) NSW, in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages:

- Stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and
- Stage 2b - 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala, yellow-bellied glider, giant barred frog, green-thighed frog ponds, fauna underpasses, vegetated median, road-kill, exclusion fence, and threatened flora. Sandpiper Ecological Surveys (SES) has been contracted by RMS to deliver the WC2NH operational ecological and water quality monitoring program in accordance with the Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief (the Brief).

The following report details the methods and results of the spring year three operational phase giant barred frog (*Mixophyes iteratus*) population monitoring. The objective of giant barred frog monitoring, as outlined in the Giant Barred Frog Management Strategy (GBFMS), is "to demonstrate through the life of the Project that mitigation has maintained or improved population sizes and habitat of the giant barred frog. The use of preconstruction, during construction and post construction monitoring to measure frog distribution, abundance and habitat quality with defined thresholds will be used to measure the overall performance of the mitigation" (Lewis 2014).

1.1 Background

The giant barred frog is listed as 'Endangered' under both the NSW *Biodiversity Conservation Act 2016* (BC Act) and Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The impact of the upgrade on giant barred frog was assessed in the Project Environmental Assessment (Sinclair Knight Merz [SKM] 2010). Following identification of potential giant barred frog habitat during the Project environmental assessment, Lewis Ecological conducted targeted surveys (in November 2011 and January/February 2013) (Lewis 2014). A population of giant barred frog was subsequently confirmed at Upper Warrell Creek and a management strategy prepared (see Lewis 2014).

Measures proposed to manage impacts on giant barred frogs included: population monitoring, pre-clearing surveys, temporary frog fencing during construction, clearing supervision, dewatering procedures (tadpole surveys) and permanent frog exclusion fence. Population monitoring was recommended to occur within a 1km transect in spring, summer and autumn of Year 1 and 3 of the construction phase using the methods applied during pre-construction baseline surveys.

Pre-construction baseline surveys for giant barred frog were conducted between 20 September 2013 and 2 April 2014. The baseline surveys recorded 47 individuals, including 22 adults (11 females & 11 males), 8 sub-adults, and 8 juveniles. Based on these results the population of giant barred frog at the Upper Warrell Creek site was calculated as 45 adults (with a 1:1 sex ratio), 19 sub-adults, and 16 juveniles (Lewis Ecological 2014b). Geolink (2018) recalculated population size for baseline, year 1 and year 3 construction phase samples and obtained population estimates of 41 (2013/14), 7 (2015/16), and 8 (2017/18) respectively. The results suggest a substantial decline in population between 2013/14 and 2015/16.

During early construction work *Mixophyes* spp. tadpoles were recorded at Butchers Creek (Geolink 2015). There was some conjecture about the identification of tadpoles and targeted surveys for adult frogs and further consultation with frog specialists was undertaken in an attempt to confirm the identification. The final consensus was that the tadpoles were great barred frog (*Mixophyes fasciolatus*) and the giant barred frog was unlikely to occur at Butchers Creek (see Geolink 2015; Lewis 2015). Nonetheless, a precautionary approach was adopted and the Butchers Creek site was included in population monitoring (Geolink 2016). No giant barred frogs were recorded at Butchers Creek during the construction phase (Geolink 2018).

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest.

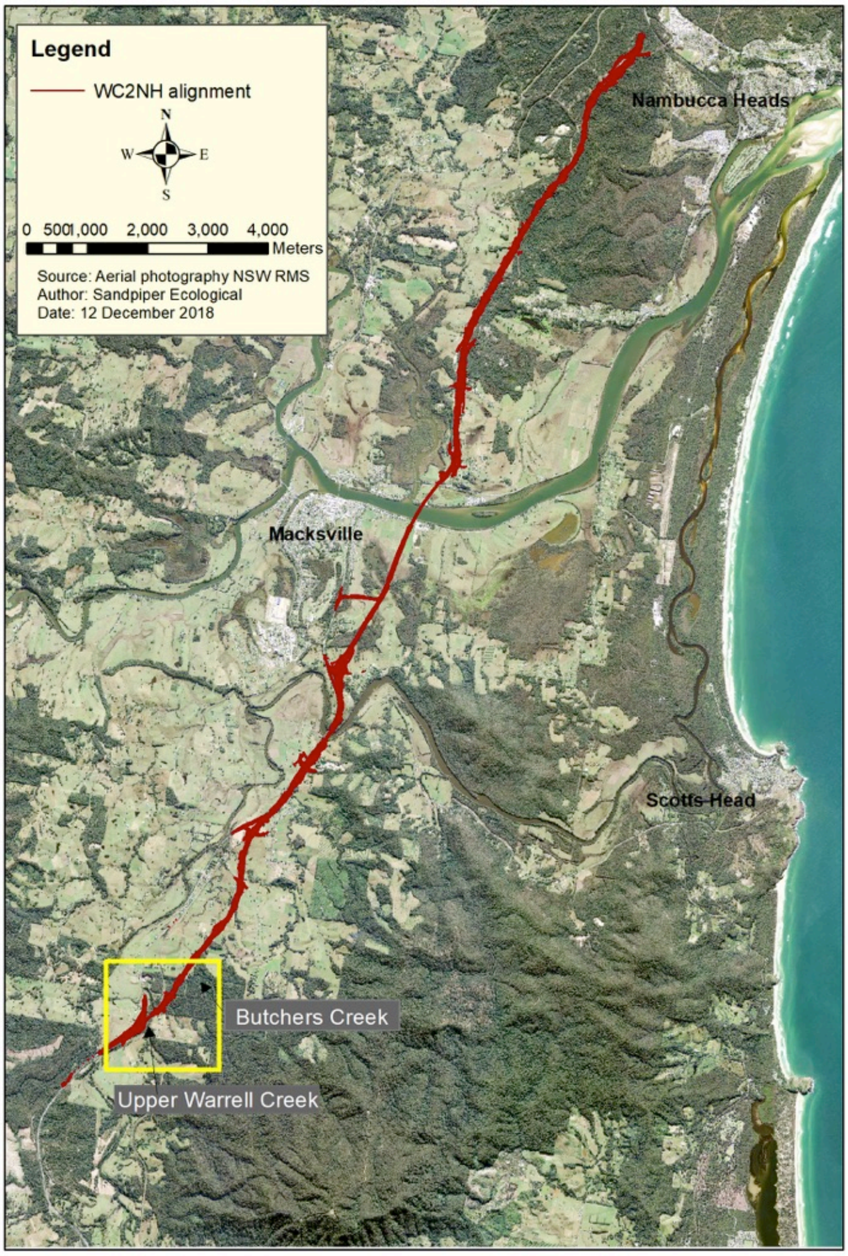

Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment.

2. Methodology

2.1 Frog survey

Frog surveys followed the method specified in the Brief and baseline population survey (Lewis 2014). The method involved:

1. Two ecologists conducted a nocturnal meandering foot-based traverse of each 50m survey zone on each side of the watercourse i.e. 40 zones at Upper Warrell Creek (20/side; Figure 2); and 16 zones at Butchers Creek (8/side; Figure 2).
2. Each ecologist was equipped with a 200-lumen spotlight and slowly traversed the riparian zone searching for frogs and listening for calls. Giant barred frog calls were broadcast through a 5-watt megaphone for five minutes within each zone. Both ecologists listened for call responses during and immediately after call broadcast.
3. All captured giant barred frogs were scanned with a Trovan Nanotransponder to determine if that frog had been previously pit-tagged. If the captured individual had not been pit-tagged and was deemed an adult (i.e. >60mm snout-vent length) a tag was inserted beneath the skin on the right side and the insertion hole sealed with vetbond. The insertion point was swabbed with disinfectant prior to the tag being inserted.
4. Data collected on each captured frog included:
    a. Survey zone (20x50m).
    b. Distance from the stream edge measured to the nearest 0.1m.
    c. Position within the microhabitat (i.e. under litter, above litter, exposed, on rock/log).
    d. Sex (male, female, unknown).
    e. Age class (adult=>60mm; sub-adult=40-60mm; juvenile=<40mm).
    f. Snout-vent length (mm).
    g. Weight (grams).
    h. Breeding condition:
        i. males assessed on the colouration of their nuptial pads (i.e. no colour, light, moderate, dark) in accordance with the classification developed by Lewis (2014b);
        ii. females assessed on whether they are gravid (i.e. egg bearing, with the typically adult weighing > 100 grams) or not gravid.
        iii. frogs with a snout vent length of <60 mm were classified as immature.

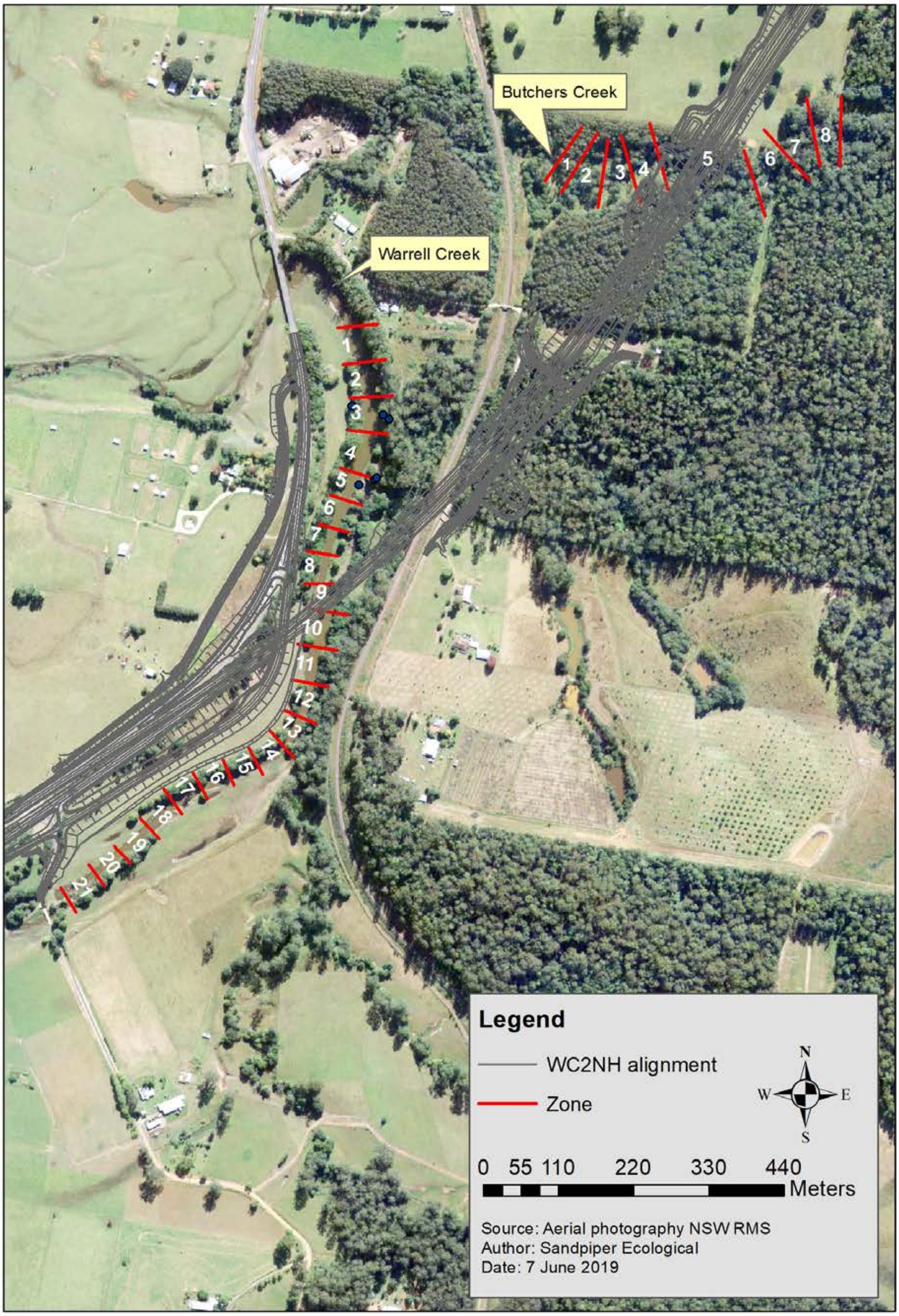

Figure 2: Survey zones within the Upper Warrell creek and Butchers Creek sample site.

2.2 Tadpole survey

Tadpole surveys were undertaken using the following procedure:

1. Dip-netting was undertaken by two ecologists within each survey zone. Dip-netting targeted areas of undercut bank and detritus.
2. One bait trap (~300 mm x 200 mm), baited with bread, was installed within each zone for 2½ -3 hours. This equated to 20 bait traps in Upper Warrell Creek and eight bait traps in Butchers Creek.
3. The following information was collected for each giant barred frog tadpole:
    a. Species
    b. Survey zone (20x50m).
    c. Sex (male, female, unknown).
    d. Weight (grams).

Tadpoles were identified with reference to Anstis (2001, 2017).

2.3 Habitat assessment

Key habitat components in each survey zone are required to be sampled annually (i.e. once/year). Habitat sampling was conducted during the summer sample period. A senior ecologist conducted a meandering traverse of each zone at each site, including both banks. Habitat data recorded in each zone at each site included:

1. Land use: Description of existing land uses e.g. grazing, dairy, horticulture, conservation, private native forestry.
2. Broad vegetation type within the immediate riparian zone (primary stream bank): Riparian Rainforest, Dry Sclerophyll, Wet Sclerophyll, Sedgeland, Grassland or Cleared Land.
3. In stream physical characteristics including stream width and depth(metres), presence of pools and/or riffles, bed composition (sand, clay, rock, organic or other to be specified), and type of emergent vegetation, if present.
4. Stream bank characteristics including bank profile expressed as steep, benched or a gradual incline from the water's edge.
5. Foliage projective cover of overstorey, midstorey and ground layer vegetation on the stream bank.
6. Groundcover expressed as a percentage of vegetation, leaf litter, soil, and exposed rock.
7. Litter depth - Deep (>10 mm); Moderate (20-100 mm); Shallow (>0-20 mm); or Absent (0 mm).

2.4 Water quality

Water samples and field measurements were taken at approximate locations E: 489301 N: 6594447 at Upper Warrell Creek and E: 489642 N: 6594927 at Butchers Creek. Three samples were collected at each site and placed immediately into an esky. One sample was sealed immediately after collection for dissolved oxygen analysis and the other samples were used for hydrocarbons, and general physicochemical parameters (see below). Samples were analysed by the Environmental Analysis Laboratory (EAL), a NATA accredited laboratory, at Southern Cross University. Water quality parameters measured included:

1. Heavy Metals including arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.
2. Nutrients including Nitrogen (as N), Suspended Solids and Total Phosphorus.
3. Turbidity and dissolved oxygen.

4. Hydrocarbons from the following groups:
    a. Naphthalene group including TRH>C10-C16, TRH>C10-C16 less Naphthalene (F2), TRH>C16-C34, TRH>34-C40, TRH C6-C10 and TRH C6-C10 LESS BTEX (F1).
    b. BTEX group including Benzene, Ethylbenzene, m&p-Xylenes, o-Xylene, Toluene and Xylenes – total.

Field physicochemical measurements including Conductivity, pH, and Temperature, were measured using a Horiba Laqua PC110 portable water quality meter.

3. Results and discussion

3.1 Survey timing, weather conditions and effort

The spring 2020 giant barred frog survey was conducted on 27 and 28 October 2020. Weather conditions were suitable for giant barred frog surveys. Air temperature was between 21 and 23^{0}C with high relative humidity (85-88%) and nil to light wind (Table 1). Rain occurred during the survey on 28/10/20 with up to 57mm recorded in the seven days preceding the surveys. Brief periods of heavy rain on 28/10/20 hampered sampling and may have affected frog activity. A total of 17 person hours were spent conducting nocturnal frog surveys, 12 hours at Upper Warrell Creek and 5 hours at Butchers Creek.

Table 1: Weather conditions and survey effort recorded during the spring 2020 giant barred frog survey. PH = person hours; Wind categories = 0 - no wind, 1 - rustles leaves, 2 - branches moving, 3 - canopy moving

Site	Date	Start/Finish	Observers	PH	Rainfall (present)	Rainfall (prev 24hr)	Rainfall (prev 7 days)	Rainfall (prev 30 days)	RH	Temp	Dew point	Wind
Butchers Creek	27/10/20	2000/2230	BT/NM	5hr	Nil	0	22	28	85	22.9	21.1	0
	28/10/20	2145-2200	DR/LA/NM/BT	1hr	Present	35	57	63	88	21.7	20.9	2
Warrell Creek	27/10/20	2000-2230	DR/LA	5hr	Nil	0	22	28	85	22.9	21.1	0
	28/10/20	1940-2130	DR/LA/NM/BT	7.33	Present	35	57	63	88	21.7	20.9	2

3.2 Frog survey

No giant barred frogs were recorded at Butchers Creek. Three adult giant barred frogs, two male and one female, were recorded at Upper Warrell Creek (Table 2). All individuals were recaptures. Frog 1 was recaptured on 27/10/20 in Zone 6 where it initially responded to playback (Plate 1). The individual was recorded calling from dense leaf litter close to the waters edge on a well vegetated lateral bar. Frog 1 was originally captured and micro-chipped on 6 November 2017 and has been recaptured on three occasions, including spring 2020. All captures of Frog 1 have occurred in Zone 5, with the first capture on the south bank and subsequent captures on the north bank (Figure 3).

Frog 2, an adult female, was recaptured on 27/10/20 in Zone 5. This individual was originally captured and micro-chipped on 5 February 2018 and has been recaptured on three occasions, including spring 2020. All captures have occurred in Zone 5, or on the boundary between 4 and 5 (Figure 3). Both Frogs 1 and 2 are associated with a vegetated lateral deposit that includes a sheltered back channel suitable for breeding.

Table 2: Giant barred frogs captured during the spring 2020 survey at Upper Warrell Creek.

Variable	Frog 1	Frog 2	Frog 3
Capture date	27/10/20	27/10/20	28/10/20
Zone	6	6	20
Creek side	Mid (on island)	North	North
GPS location	489323.6594415	489352.6594444	490654,6597518
Distance from stream edge (nearest 0.1m)	1.2	4	5
Position in micro-habitat*	Beneath ferns, dense leaf litter	On leaf litter - exposed	On leaf litter - exposed
Sex**	M	F	M
Age***	Adult	Adult	Adult
S/V length	83.7	98.7	75.3
Weight	85	141	58
Breeding condition#	Moderate	Gravid	Moderate
Microchip ID (new or re-capture)	Re-capture- 00077E8FEF	Re-capture- 00078Abbf2	Re-capture - 991001000620121
Original capture & recapture details	1. 6/11/17; 69gr; 72mm SV 2. 26/2/19; 85gr; 83.8mm SV 3. 20/3/19; 85gr; 81.8mm SV	1. 5/2/18; 152gr; 100mm SV 2. 26/2/19; 141gr; 101.5mm SV 3. 20/3/19; 165gr; 99.5mm SV	1. 19/3/19; 53gr; 75.9mm SV
Capture locations	1. 489302; 6594439 2. 489322, 6594426 3. 489320, 6594428	1. 489327, 6594425 2. 489354, 6594451 3. 489342, 6594424	1. 489323, 6594584

*Microhabitat: under leaf litter, under veg, on leaf litter, exposed, on a log/rock etc.
**Sex: Frogs >78mm were deemed female unless heard calling.
***Age: >60mm = adult, 40-60mm = sub, <40mm = Juv.
#Breeding: Males: colour of nuptial pads; light/moderate/dark/no colour. Females: Gravid, typically weighing >100g. Immature: SV length <60mm.

Frog 3, an adult male, was recaptured in Zone 20 on 28/10/20. It was originally captured on 19 March 2019 on the south bank of Zone 3 and has moved 880m upstream and crossed to the north bank where it was recorded in a narrow, degraded area of riparian vegetation with sparse leaf litter. The area is grazed by cattle and lacks good refuge habitat (Figure 3). This represents the first confirmed movement of giant barred frog across the WC2NH alignment.

3.2.1 Frog population

The three frogs recorded in spring 2020 compares favourably with spring 2018 when two individuals were recorded. However, all individuals were recaptures. Whilst it is too early in the year 3 monitoring program to draw conclusions on population size, the absence of new captures is concerning.

Figure 3: Location of frogs captured during the spring 2020 giant barred frog survey and all previous capture locations for these individuals at Upper Warrell Creek.

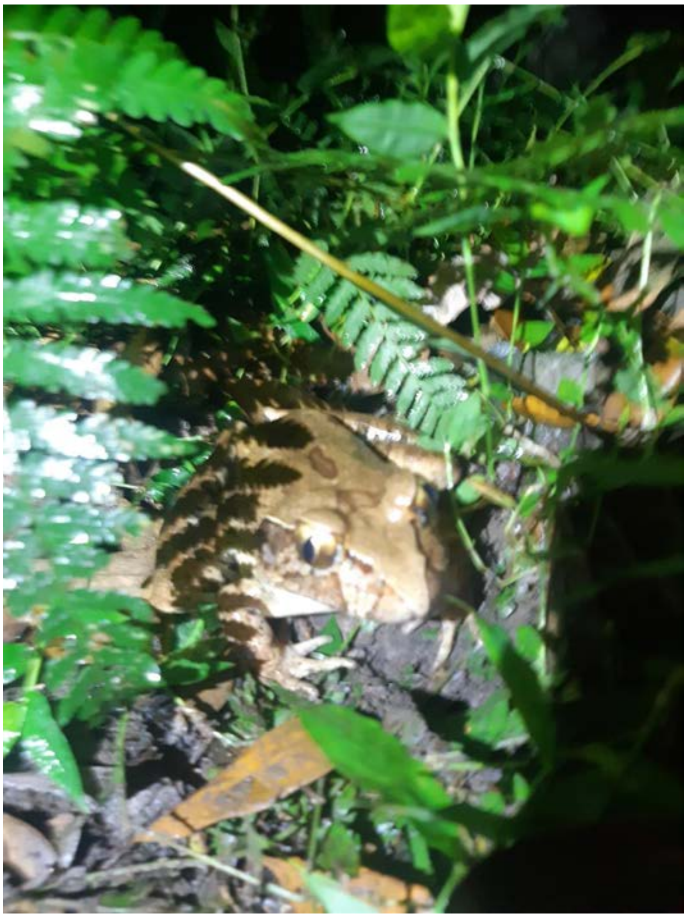

Plate 1: Male (PIT # 00077E8FEF**)** giant barred frog recorded at Upper Warrell Creek during the spring 2020 survey.

3.3 Tadpole survey

No giant barred frog tadpoles were recorded during the spring 2020 survey. At Butchers Creek, 32 great barred frog (*M. fasciolatus*) tadpoles were captured, 22 in bait traps, 17 in Zone 8, and five in Zone 7, and 10 in Zone 3 during dip netting (Plates 2&3). All tadpoles were between development stages 35 to 41 and would have hatched from eggs laid the previous autumn.

Plate 2: Great barred frog tadpoles recorded at Butchers Creek during the spring 2020 survey.

Plate 3: Remnant pool on edge of Zone 8 at Butchers Creek. This pool contained large numbers of well developed (stage 35-41) great barred frog tadpoles and was one of three water bodies within the Butchers Creek sample area during the spring 2020 survey.

3.4 Habitat

3.4.1 Upper Warrell creek

Habitat at Upper Warrell Creek ranged from grassland to moderate quality riparian and wet sclerophyll forest with a dense litter layer (Appendix A). Parts of the Upper Warrell Creek study area contained fragmented riparian forest that is grazed, whilst the remainder consists of a narrow riparian strip bordered by agricultural land. The width of riparian vegetation varied throughout the site but in virtually all zones was restricted to the bank and did not exceed 30m wide. Leaf litter cover ranged from high (>75%) in areas with an intact riparian zone to low (<40%) in cleared and grazed areas. Creek bank topography varies throughout the transect, with a steep bank on both sides downstream of the alignment (i.e. Zones 1-6), and on the north bank upstream of the alignment (zones 11-13), a flatter bank profile occurs on the north bank near the alignment (Zones 7-11), and upstream, Zones 14-18.

One notable aspect of concern was growth of pigeon grass (S*etaria sphacelata*) and broad-leaved paspalum (*Paspalum mandiocanum*) on the north bank in zones 5, 7 and 8. Pigeon grass also dominated the south bank of zones 10, 11, 19, 20 & 21. Whilst giant barred frogs have been recorded in broad-leaved paspalum (Sandpiper Ecological 2019a), dense grass represents a barrier to movement. Geolink (2015, 2018) recorded paspalum and/or pigeon grass in zones 7, 8 and 10, and images presented by Geolink

(2018) show pigeon grass in zones 8 and 10. Based on available information, it seems likely that pigeon grass was present at commencement of construction. It is likely that grazing by stock kept grass under control and the exclusion of stock, particularly on the south bank, has contributed to excess grass growth. Dense grass presently represents a barrier to movement and whilst TfNSW has implemented some work (i.e. slashing & some planting) to reduce grass density in Zones 7 and 8 more intensive work is required.

Review of old aerial photographs from 2010 and 2013 shows a narrow main channel and small back channel with lateral bar (south bank) within and adjoining the alignment (Figure 4). Enlargement of the section within the alignment suggests that the narrow section of creek was linked to the existing back channel situated on the north bank. The extent of riparian habitat is difficult to determine, although the section within the alignment seems to contain fragmented riparian vegetation. Combined, these habitat features likely represented important breeding habitat within the 1km sample area. Further assessment of pre-construction creek morphology will be undertaken for the annual year 3 report.

3.4.2 Butchers Creek

Habitat at Butchers Creek varied substantially between zones. The west side of the alignment was characterised by a narrow degraded riparian zone that was predominantly cleared immediately prior to the spring 2018 survey. In spring 2020, previously cleared areas were dominated by pigeon grass with some regrowth lantana (*Lantana camara*) and small-leaved privet (*Ligustrum sinense*). East of the alignment habitat was characterised by wet sclerophyll forest that extended well beyond the riparian zone. The substrate consisted of rock and gravel with a steep bank and gravel bars. Leaf litter cover varied from 25 to 80% and ground vegetation cover from 10 to 60%. Water was restricted to three small pools.

Habitat at Butchers Creek does not contain the moist micro-climate that is typical of many giant barred frog habitats. The site lacks continuous overhanging riparian vegetation and the thick dense leaf litter and ground vegetation required to create moist ground conditions and in addition the creek is highly ephemeral. Based on surveys in 2018/19 and spring 2020 we conclude that Butchers Creek is unsuitable for giant barred frog. This conclusion is supported by the absence of confirmed records despite regular surveys since 2011 (Lewis 2014; Geolink 2015, 2018; Sandpiper Ecological 2019b). Lewis (2014) surveyed Butchers Creek on two occasions in summer 2011 and on three occasions in spring 2013. No giant barred frogs were recorded during these surveys and Butchers Creek was not included in the WC2NH Giant Barred Frog Management Strategy (Lewis 2014).

During construction, *Mixophyes* tadpoles were captured in Butchers Creek and identified as giant barred frog (Geolink 2015). Subsequently, Lewis (2015) conducted additional nocturnal frog and diurnal tadpole surveys. No giant barred frogs were recorded during these surveys, however, adult and juvenile tadpoles of the great barred frog (*M. fasciolatus*) were recorded. Two tadpoles were retained and grown-out and these were identified as great barred frog. Despite evidence to the contrary, TfNSW adopted a precautionary approach and included Butchers Creek in the Giant barred frog monitoring program. Subsequent population monitoring surveys in 2016, 2017, 2018, 2019 and 2020 (Geolink 2016, 2018; Sandpiper Ecological 2019, this study) have not detected giant barred frog. The overwhelming evidence suggests that Butchers Creek does not support giant barred frog.

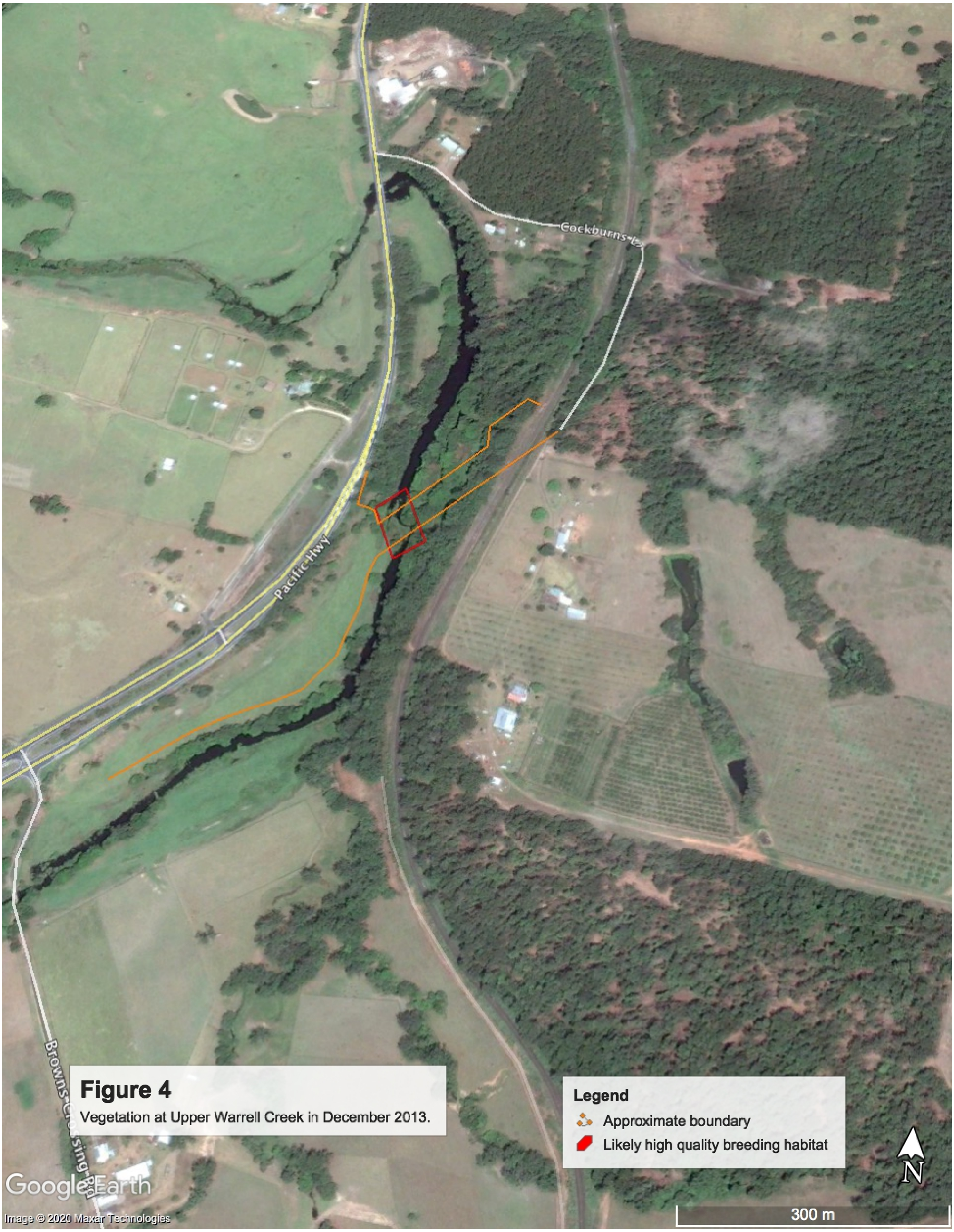

Figure 4: Aerial photograph of the Warrell Creek site from 1 December 2013 with approximate highway boundary and area of important giant barred frog habitat.

3.5 Water quality

Most water quality parameters were within the ANZECC trigger values for freshwater ecosystems in south eastern Australia (Table 2). Exceptions were Total phosphorus and Total nitrogen, which exceeded the ANZECC thresholds for freshwater ecosystems at both sites, and dissolved oxygen, which was substantially lower than the ANZECC trigger value at both sites. Results at Butchers Creek are likely skewed by the absence of stream flow and need to sample in one small stagnant pool. Findings are broadly consistent with the spring 2018 and spring/summer/autumn 2017/18 results (Geolink 2018; Sandpiper Ecological 2018). Elevated nutrients recorded in spring 2020 are attributed to recent run-off from adjoining farmland at Warrell Creek and absence of stream flow at Butchers Creek. The nature of water quality sampling, that is, one-off samples months or years apart, is unlikely to provide data representative of water quality at either site.

Table 3: Results of water sample analysis for Upper Warrell creek and Butchers Creek. ID = insufficient data to derive a reliable trigger value (ANZECC 2000); NS – parameter not sampled.

Parameter	Warrell Creek	Butchers Creek	ANZECC/ARMCANZ Trigger value for freshwater (95% species level of protection)
Temperature (^{0}C)	24.6	19.7	
pH	7.07	6.2	6.5-8.0
Conductivity (us/cm)	0.396	0.212	125-2200
Dissolved oxygen (mg/L O_2)	NS	0.54	9-10.5
Total Suspended Solids (mg/L)	4	4	
Turbidity (NTU)	0.258	0.138	6-50
Total Phosphorus (mg/L P)	0.03	0.03	0.025
Total Nitrogen (mg/L N)	0.37	0.43	0.35
<u>BTEX</u>			
Benzene (µg/L or ppb)	<0.5	<0.5	950
Toluene (µg/L or ppb)	<0.5	<0.5	ID
Ethylbenzene (µg/L or ppb)	<0.5	<0.5	ID
m+p-Xylene (µg/L or ppb)	<1	<1	200
o-Xylene (µg/L or ppb)	<0.5	<0.5	350
Naphthalene (µg/L or ppb)	<0.5	<0.5	16
<u>Total Recoverable Hydrocarbons (TRH)</u>			
C6-C9 Fraction (µg/L or ppb)	NS	NS	ID
C10-C14 Fraction (µg/L or ppb)	<50	<50	ID
C15-C28 Fraction (µg/L or ppb)	<100	<100	ID
C29-C36 Fraction (µg/L or ppb)	<50	<50	ID
C10-C16 Fraction (µg/L or ppb)	<60	<60	ID
C10-C16 less Naphthalene Fraction (µg/L or ppb)	NS	NS	ID
C16-C34 Fraction (µg/L or ppb)	<200	<200	ID
C34-C40 Fraction (µg/L or ppb)	<100	<100	ID
Sum C10-C36 Fraction (µg/L or ppb)	<100	<100	ID
<u>Heavy Metals</u>			
Silver (mg/L)	<0.001	<0.001	0.05
Aluminium (mg/L)	0.099	0.012	55
Arsenic (mg/L)	0.001	<0.001	24
Cadmium (mg/L)	<0.001	<0.001	0.2
Chromium (mg/L)	<0.001	<0.001	1.0
Copper (mg/L)	<0.001	<0.001	1.4

Parameter	Warrell Creek	Butchers Creek	ANZECC/ARMCANZ Trigger value for freshwater (95% species level of protection)
Iron (mg/L)	0.802	0.030	ID
Manganese (mg/L)	0.190	0.009	1900
Nickel (mg/L)	0.001	<0.001	11
Lead (mg/L)	<0.001	<0.001	3.4
Selenium (mg/L)	<0.002	<0.002	11
Zinc (mg/L)	0.003	0.010	8
Mercury (mg/L)	<0.0005	<0.0005	0.6

4. Recommendations

Recommendations are presented in Table 4.

Table 4: Recommendations based on findings of the spring year 3 operational phase giant barred frog monitoring program.

Number	Recommendation	Transport for NSW Response
1.	Continue river bank restoration on the north bank of Zones 7, 8 & 9 at Upper Warrell Creek. Additional planting and maintenance of *Waterhousia floribunda* and understorey shrubs, and control of grass is required to improve connectivity.	The following works are to be undertaken by the WC2NH contractor in zones 7, 8 and 9 - - Works to reduce Pigeon Grass *(Setaria species)* extent and density - Planting of 60 *Waterhousia floribunda* - Plant out wetland plant tubestock to bolster the now established wetland plantings in the area. This scope of works has been developed in consultation with and is endorsed by the EPA. The works are expected to commence in late 2020
2.	Due to the pattern of population decline at UWC detected in construction and operational surveys additional survey effort is recommended at that site for the remaining summer and autumn year 3 operational phase surveys. Further assessment, in accordance with Performance Criteria in the Giant Barred Frog Management Strategy, would be undertaken following population analysis conducted in the annual report, which is due in autumn 2021.	Agree and adopted

5. References

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Appendix A – Habitat data

Table A1: Habitat data collected in 21 zones at Upper Warrell Creek in spring 2020.

Zone	Bank	Landuse (E&W)	Broad veg community (E&W)	In-stream physical characteristics (logs, boulders etc)	Stream width	Stream depth	Presence of pools or riffles	Bed composition	Emergent veg
1	N	Agriculture	Riparian	Rare snags & logs, knotweed & matrush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & matrush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
2	N	Agriculture	Riparian	Rare snags & logs, knotweed & matrush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & matrush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
3	N	Agriculture	Riparian	Rare snags & logs, knotweed & matrush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & matrush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
4	N	Agriculture	Riparian	Tall (Tassal) sedge & knotweed dominate waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & matrush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
5	N	Agriculture	Riparian	Snags, matrush at waters edge, water lily, undercut bank	20	1-2m	No	Unknown	Water lily, occ
	S	Agriculture	Riparian	Snags, matrush at waters edge, water lily, undercut bank	20	1-2m	No	Unknown	Water lily, occ
6	N	Road reserve	Riparian	Logs, snags, water lily, matrush at waters edge	15	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Logs, snags, water lily, matrush at waters edge	15	1-2m	No	Unknown	Water lily
7	N	Road reserve	Riparian	Mostly knot weed & pigeon grass	15	1-2m	No	Unknown	Water lily, knot weed
	S	Agriculture	Riparian	Logs, snags, water lily, matrush at waters edge	15	1-2m	No	Unknown	Water lily
8	N	Road reserve	Grassland	Boulders, logs, waterlily, Juncus, Schoenoplectus (triangle)	8	1m	Yes	Silt& gravel	Water lily, water primrose
	S	Road reserve	Grassland/ riparian	Boulders, logs, waterlily, Juncus, Schoenoplectus (triangle)	8	1m	Yes	Silt& gravel	Water lily, water primrose
9	N	Road reserve	Riparian/cleared	Boulders, logs, waterlily, Juncus, Schoenoplectus (triangle)	8	1m	Yes	Silt& gravel	Water lily, water primrose
	S	Road reserve	Grassland/ riparian	Boulders, logs, waterlily, Juncus, Schoenoplectus (triangle)	8	1m	Yes	Silt& gravel	Water lily, water primrose
10	N	Agriculture	Riparian	Occ logs & snags	15	1-2m	Yes	Unknown	Water lily, water primrose
	S	Road reserve	Grassland	Occ logs & snags	15	1-2m	Yes	Unknown	Water lily, water primrose

11	N	Agriculture	Riparian	Snags, logs, aquatic veg	12	1-2m	No	Unknown	Water lily
	S	Road reserve	Grassland	Snags, logs, aquatic veg	12	1-2m	No	Unknown	Water lily
12	E	Agriculture	Riparian	Occ logs, water lily, snags	15	1-2m	No	Unknown	Water lily
	W	Road reserve	Riparian	Occ logs, water lily, snags	15	1-2m	No	Unknown	Water lily
13	E	Agriculture	Riparian	Occ logs, water lily, snags	13	1-2m	No	Unknown	Water lily
	W	Road reserve	Riparian	Occ logs, water lily, snags	13	1-2m	No	Unknown	Water lily
14	E	Agriculture	Grassland	Occ logs, water lily (cape sis & indica), elodea	13	1m	No	Unknown	Water lily
	W	Road reserve	Riparian	Occ logs, water lily (cape sis & indica), elodea	13	1m	No	Unknown	Water lily
15	E	Agriculture	Grassland	Occ logs, clumps of matrush, water lily, knot weed	11	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occ logs, clumps of matrush, water lily	11	Unknown	No	Unknown	Water lily
16	E	Agriculture	Grassland	Occ logs, clumps of matrush, water lily, knot weed	11	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occ logs, clumps of matrush, water lily	11	Unknown	No	Unknown	Water lily
17	E	Agriculture	Grassland	Occ logs, clumps of matrush, water lily	11	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occ logs, clumps of matrush, water lily	11	Unknown	No	Unknown	Water lily
18	E	Agriculture	Riparian	Occ logs; grass to water level	5	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occ logs; grass to water level	5	Unknown	No	Unknown	Water lily
19	E	Agriculture	Riparian	Occ logs; grass to water level	9	Unknown	No	Unknown	Water lily
	W	Road reserve	Grassland	Occ logs; grass to water level	9	Unknown	No	Unknown	Water lily
20	E	Agriculture	Riparian	Occ logs; grass to water level	9	Unknown	No	Unknown	Water lily
	W	Road reserve	Grassland	Occ logs; grass to water level	9	Unknown	No	Unknown	Water lily
21	E	Agriculture	Riparian	Occ logs; grass to water level	9	Unknown	No	Unknown	Water lily
	W	Road reserve	Grassland	Occ logs; grass to water level	9	Unknown	No	Unknown	Water lily

Table A2: Habitat data collected in 21 zones at Upper Warrell creek in spring 2020.

Zone	Bank	Stream bank characteristics	Bank profile	Bank vegetation cover	Groundcover composition	Depth of leaf litter	Tadpoles (trap) weight, sex, location.	Tadpoles (dip net) weight, sex, location.
1	N	Intact riparian zone 25m, waterhousia, flooded gum, matrush at waters edge, lantana,	Steep 20m	65.0%	Matrush, lantana, shrubs	40-50mm	0	0
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, matrush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80%	Matrush, fishbone fern, vines	75-100mm	0	0
2	N	Intact riparian zone 25m, waterhousia, flooded gum, matrush at waters edge, lantana,	Steep 20m	65.0%	Matrush, lantana, shrubs	40-50mm	0	0
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, matrush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80%	Matrush, fishbone fern, vines	75-100mm	0	0
3	N	Intact riparian zone 25m, waterhousia, flooded gum, matrush at waters edge, lantana,	Steep 20m	65.0%	Matrush, Carex , BL paspalum	40-50mm	0	0
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, matrush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80%	Matrush, fishbone fern, vines	75-100mm	0	0
4	N	Immediate bank cleared - BL paspalum, pigeon grass, knot weed, tall (Tassal) sedge within 15m of bank, riparian on slope, waterhousia, flooded gum 40m, dense ground cover on immediate bank	Flat for 20m, Steve 40m	25%%	BL paspalum, pigeon grass, occ matrush	50mm	0	0
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, matrush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80%	Matrush, fishbone fern, vines	75-100mm	0	0
5	N	Riparian 40m incl side channel, waterhousia, matrush, BL paspalum, SL privet, dense shrub & ground layer	Vertical 2m, moderate 20m	60.0%	Matrush, BL paspalum, lantana	40mm	0	0
	S	Intact riparian zone 15m wide from water to top of bank, waterhousia, some lantana, matrush at waters edge	Vertical 0.5m, steep 13m	55	Matrush, shrubs, lantana,	100mm	0	0
6	N	Riparian 40m incl side channel, waterhousia, matrush, BL paspalum, SL privet, dense shrub & ground layer, contains back channel	Vertical 2m, moderate 20m	60.0%	Matrush, BL paspalum, lantana	40mm	0	0
	S	Established riparian zone 13m, waterhousia, good litter cover	Vertical 0.75m, steep 12m	70.0%	Leaf litter, matrush at waters edge, occ vines & low shrubs	30mm	0	0
7	N	80% pigeon grass & knot weed, 20% Established riparian zone 13m, waterhousia, good litter cover, contains back channel	Vertical 0.75m, steep 12m	80.0%	Leaf litter, matrush at waters edge, occ vines & low shrubs; dense pigeon grass & knot weed in cleared area	30mm	0	0
	S	Established riparian zone 13m, waterhousia, moderate litter cover	Vertical 0.75m, steep 12m	70.0%	Leaf litter, matrush at waters edge, occ vines & low shrubs	30mm	0	0
8	N	20% of bank Scour protection, immediate bank is flat, occ boulders, gravel, sedges, to waters edge, partial revegetation	Flat 20m	50.0%	Knotweed, Schoenoplectus, Juncus, Cyperus spp, Carex, matrush	<10mm	0	0
	S	20% Scour protection - now covered in knot weed, immediate bank is flat, occ boulders, gravel, sedges, to waters edge	Flat 20m	100%%	Knotweed, Schoenoplectus, Juncus, Cyperus spp, Carex	10mm	0	0
9	N	Scour protection, flat bank profile under bridge, 20m riparian zone, waterhousia, matrush at waters edge,	Flat beneath bridge, moderate 20m	55%	Matrush, low shrubs	50mm	0	0
	S	Scour protection, immediate bank is flat, occ boulders, gravel, sedges, to waters edge	Flat 20m	35.0%	Knotweed, Schoenoplectus, Juncus, Cyperus spp, Carex	<10mm	0	0
10	N	Established riparian zone 25m, waterhousia, flooded gum,	Vertical 1m, moderate	80.0%	Matrush, BL paspalum, shrubs	40mm	0	0

		matrush at waters edge, established mid storey	15m, steep 10m					
	S	Scour protection (under bridge), knot weed, pigeon grass, occ waterhousia	Vertical 1.5m, mod slope 3m	90.0%	Knot weed, pigeon grass, BL paspalum	20mm	0	0
11	N	Established riparian zone 25m, waterhousia, flooded gum, matrush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80.0%	Matrush, BL paspalum, shrubs	40mm	0	0
	S	Cleared grassland, pigeon grass, knotweed to waters edge, sparse mucronatus.	Flat 3m, vertical 1m	95.0%	Pigeon grass, knot weed	20mm	0	0
12	E	Established riparian zone 25m, waterhousia, flooded gum, matrush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80.0%	Matrush, BL paspalum, shrubs	50mm	0	0
	W	Fragmented riparian/grassland, waterhousia, pigeon grass, knotweed & matrush at waters edge	Vertical 1m, steep 2.5m	50%	Pigeon grass, matrush, knotweed to waters edge	50mm	0	0
13	E	Established riparian zone 35m, waterhousia, flooded gum, matrush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80.0%	Matrush, BL paspalum, shrubs	50	0	0
	W	Riparian 7m wide, waterhousia, wattles, matrush & knot weed on bank, fallen logs, woody debris	Vertical 1m, steep 2m	75%	Knotweed, matrush, basket grass, BL paspalum	75mm	0	0
14	E	Cleared grassland, knotweed to water level	Steep 0.5m	60.0%	Knotweed	Nil	0	0
	W	Riparian 7m wide, waterhousia, wattles, matrush & knot weed on bank, fallen logs, woody debris	Vertical 1m, steep 2m	75%	Knotweed, matrush, basket grass, BL paspalum	75mm	0	0
15	E	Cleared grassland, knotweed to water level	Vertical 1m	55.0%	Pasture grass, knot weed	Nil	0	0
	W	Riparian, waterhousia, camphor, matrush at water level (clumps)	Vertical 1m, moderate 2.5m	70.0%	Matrush, BL paspalum	75mm	0	0
16	E	Cleared grassland, knotweed to water level	Vertical 1m	55.0%	Pasture grass, knot weed	Nil	0	0
	W	Riparian, waterhousia, matrush at water level	Steep 4m	75.0%	Matrush, BL paspalum, lantana	50	0	0
17	E	Cleared, grassland	Vertical 1m	60.0%	Pasture grass, knot weed	Nil	0	0
	W	8m riparian zone, waterhousia	Steep 4m	65.0%	Matrush, low shrubs	50mm	0	0
18	E	Fragmented, grazed, half cleared, waterhousia, camphor	Moderate slope 2m	40.0%	Knot weed, pigeon grass	10mm	0	0
	W	Fragmented riparian, waterhousia, camphor, pigeon grass & knot weed on immediate bank	Steep, with back channel	90%	Knot weed, pigeon grass	20mm	0	0
19	E	Fragmented riparian veg, waterhousia, flooded gum, grazed, cleared u/S	Sloping, moderate	70%	Sparse matrush, BL paspalum	10mm	0	0
	W	Cleared grassland, dense pigeon grass	Steep, with back channel	90.0%	Pigeon grass	10mm	0	0
20	E	Fragmented riparian veg, waterhousia, flooded gum, grazed, cleared u/S	Sloping, moderate	70%	Sparse matrush, BL paspalum	10mm	0	0
	W	Cleared grassland, dense pigeon grass	Steep, back channel	90.0%	Pigeon grass	10mm	0	0
21	E	Fragmented riparian veg, waterhousia, grazed, cleared u/S	Sloping, moderate	70%	Sparse matrush, BL paspalum	10mm	0	0
	W	Cleared grassland, dense pigeon grass	Steep, back channel	90.0%	Pigeon grass	10mm	0	0

Table A3: Habitat data collected within 8 zones at Butchers Creek in spring 2020.

Zone	Bank	Landuse (E&W)	Broad veg community (E&W)	In-stream physical characteristics (logs, boulders etc)	Stream width	Stream depth	Presence of pools or riffles	Bed composition	Emergent veg
1	N	Agriculture	Camphor forest	Pool/riffle with rocks	3	Nil	Nil	Rock 50%; litter 25%; veg 25%	Mat rush
	S	Agriculture	Shrubs and	Pool/riffle with rocks	3	Nil	Nil	Rock 50%; litter 25%; veg 25%	Mat rush
2	N	Agriculture	Grassland	Pool rifle with rocks, pigeon grass & privet in channel	3.5	Nil	Nil	Rock 20%; litter 30%; grass 50%	Grass
	S	Agriculture	Wet sclerophyll	Pool rifle with rocks	3.5	Nil	Nil	Rock 25%; litter 40%; grass 40%	Grass
3	N	Agriculture	Wet sclerophyll	Pool/riffle with rocks	3	0.5m	Nil	Rock 30%; litter 60%; silt 20%	Mat rush
	S	Agriculture	Disturbed grassland	Pool/riffle with rocks	3	0.5m	Nil	Rock 30%; litter 60%; silt 20%	Mat rush
4	N	Agriculture	Wet sclerophyll	Pool/riffle with rocks	4.5	Nil	Nil	Rock 70%; gravel 10%; silt 10%; organic 10%	Nil
	S	Agriculture	Disturbed grassland	Pool/riffle with rocks	4.5	Nil	Nil	Rock 70%; gravel 10%; silt 10%; organic 10%	Nil
5	N	Agriculture	Wet sclerophyll	Pool/ riffle with rocks	6	Nil	Nil	Rock 60%; litter 40%	Nil
	S	Agriculture	Wet sclerophyll	Pool/ riffle with rocks	6	Nil	Nil	Rock 60%; litter 40%	Nil
6	N	Conservation	Wet sclerophyll	Pool/ riffle with rocks	6	Nil	Nil	Rock 60%; litter 40%	Nil
	S	Conservation	Wet sclerophyll	Pool/ riffle with rocks	6	Nil	Nil	Rock 60%; litter 40%	Nil
7	N	Conservation	Wet sclerophyll	Pool/ riffle with rocks	5	0.7m	Nil	Rock 60%; litter 40%	Nil
	S	Conservation	Wet sclerophyll	Pool/ riffle with rocks	5	0.7m	Nil	Rock 60%; litter 40%	Nil
8	N	Agriculture	Wet sclerophyll	Pool/ riffle with rocks	6-7	0.3m	Nil	Rock 60%; litter 40%	Nil
	S	Conservation	Wet sclerophyll	Pool/ riffle with rocks	6-7	0.3m	Nil	Rock 60%; litter 40%	Nil

Table A4: Habitat data collected within 8 zones at Butchers Creek in spring 2020.

Zone	Bank	Stream bank characteristics	Bank profile	Bank vegetation cover	Groundcover composition	Depth of leaf litter	Tadpoles (trap) weight, sex, location.	Tadpoles (dip net) weight, sex, location.
1	N	Camphor, mat rush, lantana, privet, degraded	Vertical 1.25m	60.0%	Mat rush, Carex, lantana, pigeon grass	25mm		
	S	Mat rush, Lilly pilly, privet, Brown kurrajong degraded	Steep slope 2m	60.0%	Mat rush, BL paspalum, regrowth shrubs, pigeon grass	<10mm		
2	N	No o/S, grass & lantana	Vertical 1m	90%%	Pigeon grass, lantana	20mm		
	S	2m wide, camphor, flooded gum, red ash, degraded	Vertical 2m	60.0%	Mat rush, lantana, BL paspalum, pigeon grass	20mm		
3	N	3m wide, camphor, lantana, privet, highly degraded	Vertical 1.5m	60.0%	Gahnia, mat rush, ferns, BL paspalum, pigeon grass	50mm	Nil	10 M fasciolatus
	S	2m wide riparian zone, catacomb, lantana, degraded	Vertical 1.5m	60%	Matrush, gahnia, lantana, ferns, pigeon grass	25mm		
4	N	5m wide riparian zone, clumps of lomandra & gahnia, degraded	Vertical 2m	75%	Gahnia, mat rush, ferns, BL paspalum	50mm		
	S	2m wide riparian zone, Callicoma, lantana, degraded	Vertical 2m	10.0%	BL paspalum, pigeon grass	25mm		
5	N	Rocky substrate, dense cover of lantana, matrush, BL paspalum	Sloping - steep	75.0%	Matrush, lantana, BL paspalum	30-50mm	Evidence of clearing since initial survey	
	S	Intact riparian zone, water vine, lantana, flooded gum, camphor laurel	Steep	80.0%	Matrush, lantana, BL paspalum	50-100mm		
6	N	5-10m riparian, flooded gum, camphor laurel, dense midstorey	Steep	75	Occasional matrush & ferns	30-50mm		
	S	20m + riparian, various midstorey rainforest species	Moderate slope	80	Occasional matrush & ferns	30-50mm		
7	N	5-10m riparian, flooded gum, camphor laurel, dense midstorey	Steep slope	80.0%	Very sparse, low shrubs	50-75mm		
	S	20m + riparian, various midstorey rainforest species	Steep slope	80%	Very sparse, low shrubs, matrush	50-75	5 M fasciolatus	No dip netting
8	N	5-10m riparian, flooded gum, blackbutt, camphor laurel, dense midstorey	Vertical- 7m	70%	Very sparse, low shrubs	<20mm		
	S	20m + riparian, various midstorey rainforest species laurel	Variable	80%	Matrush, lantana, BL paspalum, saw-sedge	30-50mm	17 M. fasciolatus	No dip netting

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Customer feedback
Roads and Maritime
Locked Bag 928,
North Sydney NSW 2059

December 2020

Warrell Creek to Nambucca Heads: interim giant barred frog monitoring report - summer year three operational phase

Transport for New South Wales | March 2021 | Final report

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Mr L. Andrews (field survey)
Dr B. Taylor (review)

Report prepared for:

Roads and Maritime Services NSW

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 0401 195 480 | E **david@sandpipereco.com.au**

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1. Introduction

In 2015, Transport for New South Wales, in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages:

- Stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and
- Stage 2b - 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala, yellow-bellied glider, giant barred frog, green-thighed frog ponds, fauna underpasses, vegetated median, road-kill, exclusion fence, and threatened flora. Sandpiper Ecological Surveys (SES) has been contracted by Transport for NSW to deliver the WC2NH operational ecological and water quality monitoring program in accordance with the Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief (the Brief).

The following report details the methods and results of the summer year three operational phase giant barred frog (*Mixophyes iteratus*) population monitoring. The objective of giant barred frog monitoring, as outlined in the Giant Barred Frog Management Strategy (GBFMS), is "to demonstrate through the life of the Project that mitigation has maintained or improved population sizes and habitat of the giant barred frog. The use of preconstruction, during construction and post construction monitoring to measure frog distribution, abundance and habitat quality with defined thresholds will be used to measure the overall performance of the mitigation" (Lewis 2014).

1.1 Background

The giant barred frog is listed as 'Endangered' under both the NSW *Biodiversity Conservation Act 2016* (BC Act) and Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The impact of the upgrade on giant barred frog was assessed in the Project Environmental Assessment (Sinclair Knight Merz [SKM] 2010). Following identification of potential giant barred frog habitat during the Project environmental assessment, Lewis Ecological conducted targeted surveys (in November 2011 and January/February 2013) (Lewis 2014). A population of giant barred frog was subsequently confirmed at Upper Warrell Creek and a management strategy prepared (see Lewis 2014).

Measures proposed to manage impacts on giant barred frogs included: population monitoring, pre-clearing surveys, temporary frog fencing during construction, clearing supervision, dewatering procedures (tadpole surveys) and permanent frog exclusion fence. Population monitoring was recommended to occur within a 1km transect in spring, summer and autumn of Year 1 and 3 of the construction phase using the methods applied during pre-construction baseline surveys.

Pre-construction baseline surveys for giant barred frog were conducted between 20 September 2013 and 2 April 2014. The baseline surveys recorded 47 individuals, including 22 adults (11 females & 11 males), 8 sub-adults, and 8 juveniles. Based on these results the population of giant barred frog at the Upper Warrell Creek site was calculated as 45 adults (with a 1:1 sex ratio), 19 sub-adults, and 16 juveniles (Lewis Ecological 2014b). Geolink (2018) recalculated population size for baseline, year 1 and year 3 construction phase samples and obtained population estimates of 41 (2013/14), 7 (2015/16), and 8 (2017/18) respectively. The results suggest a substantial decline in population between 2013/14 and 2015/16.

During early construction work *Mixophyes* spp. tadpoles were recorded at Butchers Creek (Geolink 2015). There was some conjecture about the identification of tadpoles and targeted surveys for adult frogs and further consultation with frog specialists was undertaken in an attempt to confirm the identification. The final consensus was that the tadpoles were great barred frog (*Mixophyes fasciolatus*) and the giant barred frog was unlikely to occur at Butchers Creek (see Geolink 2015; Lewis 2015). Nonetheless, a precautionary approach was adopted and the Butchers Creek site was included in population monitoring (Geolink 2016). No giant barred frogs were recorded at Butchers Creek during the construction phase, or in year one of the operational phase (Geolink 2018; Sandpiper Ecological 2019).

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest.

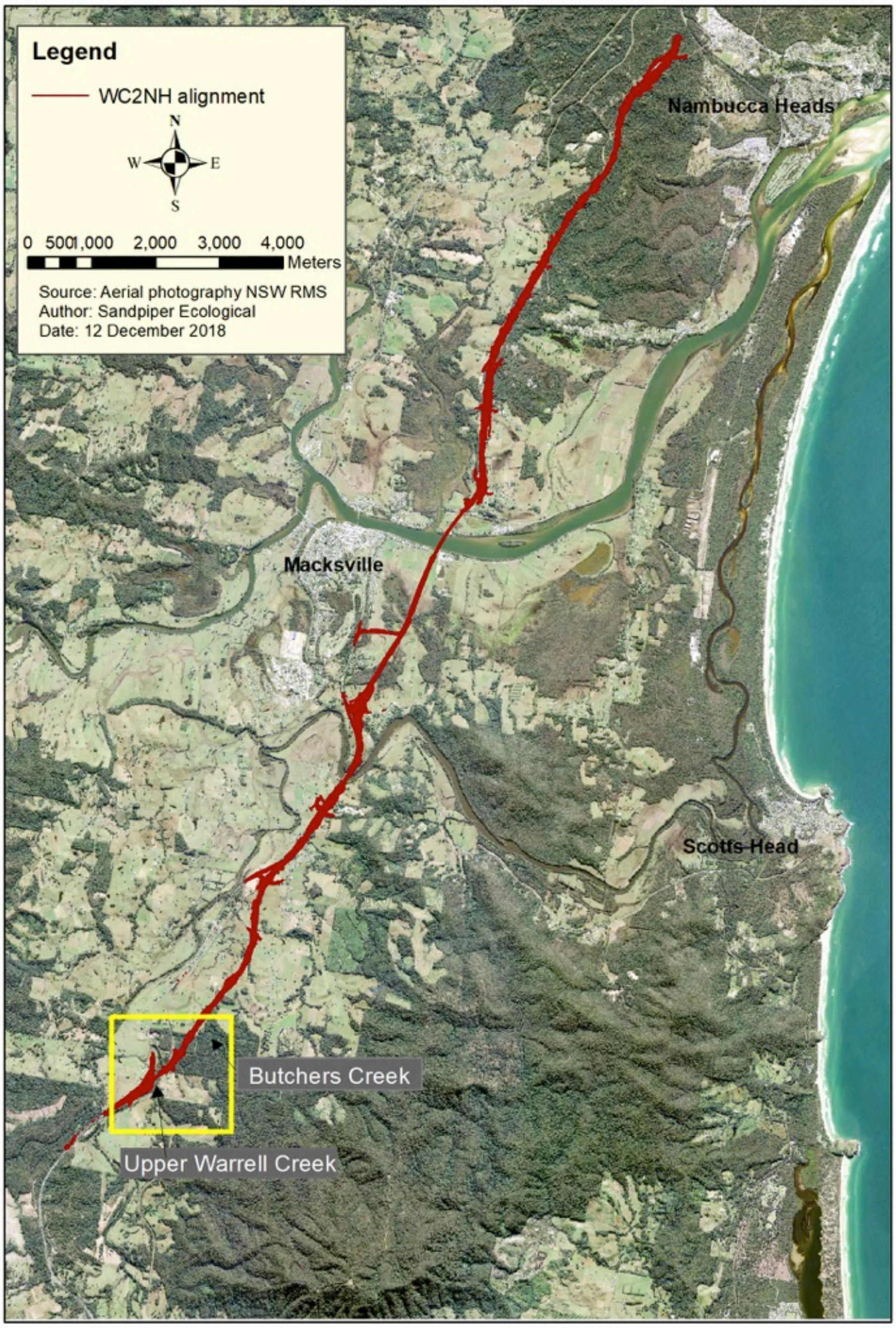

Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment.

2. Methodology

2.1 Frog survey

Frog surveys followed the method specified in the Brief and baseline population survey (Lewis 2014), with the inclusion of additional survey effort at Upper Warrell Creek as recommended by Sandpiper Ecological (2020). The method involved:

1. Two ecologists conducted a nocturnal meandering foot-based traverse of each 50m survey zone on each side of the watercourse i.e. 42 zones at Upper Warrell Creek (20/side; Figure 2); and 16 zones at Butchers Creek (8/side; Figure 2).
2. Each ecologist was equipped with a 200-lumen spotlight and slowly traversed the riparian zone searching for frogs and listening for calls. Giant barred frog calls were broadcast through a 5-watt megaphone for 2-3 minutes within each zone. Both ecologists listened for call responses during and immediately after call broadcast.
3. All captured giant barred frogs were scanned with a Trovan Nanotransponder to determine if that frog had been previously pit-tagged. If the captured individual had not been pit-tagged and was deemed an adult (i.e. >60mm snout-vent length) a tag was inserted beneath the skin on the right side and the insertion hole sealed with vetbond. The insertion point was swabbed with disinfectant prior to the tag being inserted.
4. Data collected on each captured frog included:
    a. Survey zone (20x50m).
    b. Distance from the stream edge measured to the nearest 0.1m.
    c. Position within the microhabitat (i.e. under litter, above litter, exposed, on rock/log).
    d. Sex (male, female, unknown).
    e. Age class (adult=>60mm; sub-adult=40-60mm; juvenile=<40mm).
    f. Snout-vent length (mm).
    g. Weight (grams).
    h. Breeding condition:
        i. males assessed on the colouration of their nuptial pads (i.e. no colour, light, moderate, dark) in accordance with the classification developed by Lewis (2014b);
        ii. females assessed on whether they are gravid (i.e. egg bearing, with the typically adult weighing > 100 grams) or not gravid.
        iii. frogs with a snout vent length of <60 mm were classified as immature.

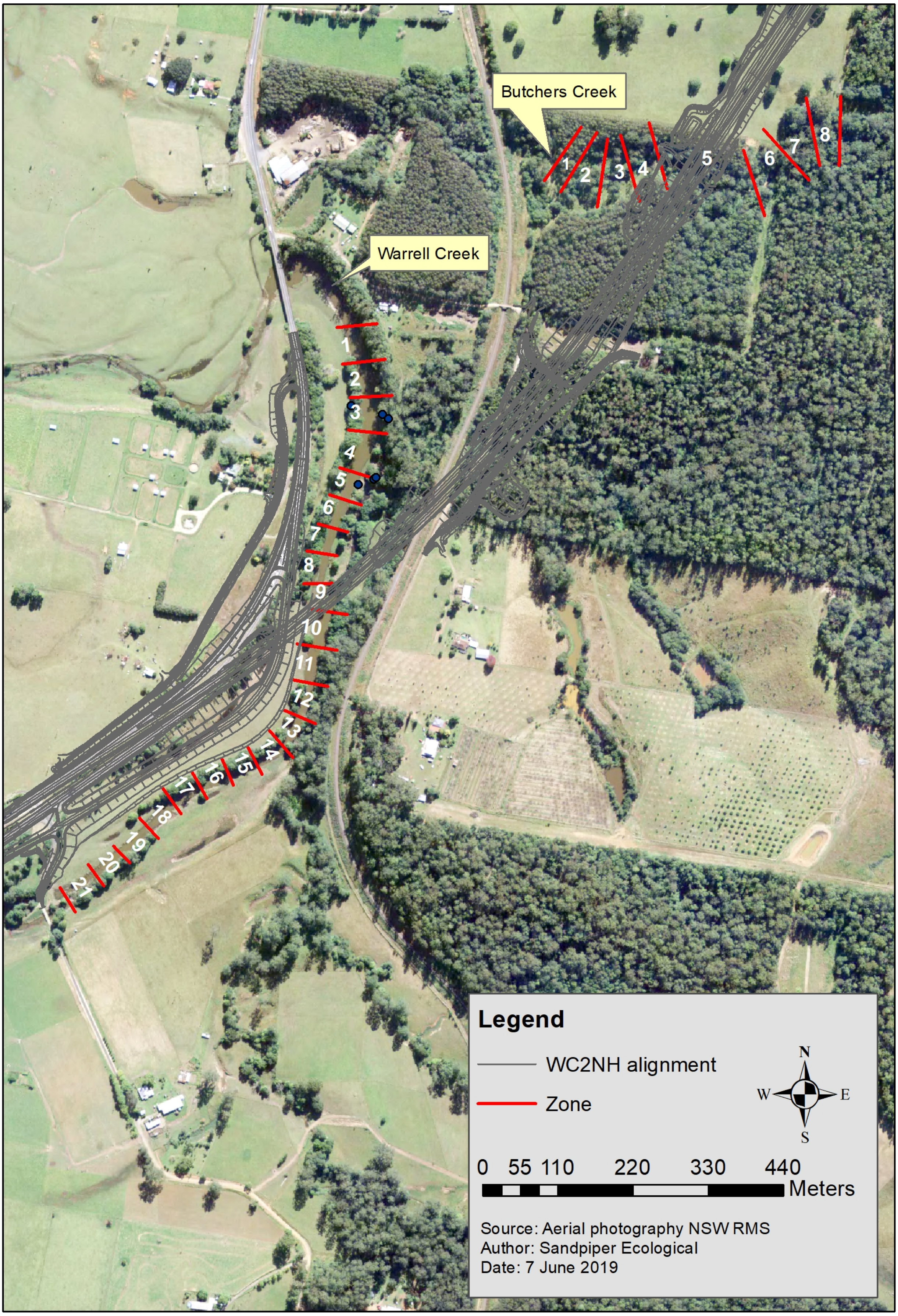

Figure 2: Survey zones within the Upper Warrell Creek and Butchers Creek sample sites.

2.2 Water quality

Water samples and field measurements were taken at approximate locations E: 489301 N: 6594447 at Upper Warrell Creek and E: 489642 N: 6594927 at Butchers Creek. One sample were collected at each site and placed immediately into an esky. Samples were analysed by the Environmental Analysis Laboratory (EAL), a NATA accredited laboratory, at Southern Cross University. Water quality parameters measured included:

1. Heavy Metals including arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.
2. Nutrients including Nitrogen (as N), Suspended Solids and Total Phosphorus.
3. Turbidity and dissolved oxygen.
4. Hydrocarbons from the following groups:
    a. Naphthalene group including TRH>C10-C16, TRH>C10-C16 less Naphthalene (F2), TRH>C16-C34, TRH>34-C40, TRH C6-C10 and TRH C6-C10 LESS BTEX (F1).
    b. BTEX group including Benzene, Ethylbenzene, m&p-Xylenes, o-Xylene, Toluene and Xylenes – total.

Field physicochemical measurements including Conductivity, pH, and Temperature, were measured using a Horiba portable water quality meter.

3. Results and discussion

3.1 Survey timing, weather conditions and effort

The summer 2021 giant barred frog survey was conducted on 16 and 17 February 2021. Weather conditions were suitable for giant barred frog surveys. Air temperature was between 20.4 and 23.1^{0}C with high relative humidity (84-100%) and nil to light wind (Table 1). Showers occurred throughout the survey with up to 94mm recorded in the seven days preceding the surveys. A total of 17.5 person hours were spent conducting nocturnal frog surveys, 16 hours at Upper Warrell Creek and 1.5 hours at Butchers Creek.

Table 1: Weather conditions and survey effort recorded during the summer 2021 giant barred frog survey. PH = person hours; Wind categories = 0 - no wind, 1 - rustles leaves, 2 - branches moving, 3 - canopy moving

Site	Date	Start/Finish	Observers	PH	Rainfall (present)	Rainfall (prev 24hr)	Rainfall (prev 7 days)	Rainfall (prev 30 days)	RH	Temp	Dew point	Wind
Butchers Creek	17/2/21	2000-2045	DR & LA	1.5	Showers	17mm	60mm	94mm	95	20.4	20.4	1
Warrell Creek	16/2/21	2000-0015	DR & LA	8.5	Showers	16mm	44mm	77mm	84	23.1	20.5	1
	17/2/21	2100-0045	DR & LA	7.5	Showers	17mm	60mm	94mm	100	21.3	20.4	0

3.2 Frog survey

No giant barred frogs were recorded at Butchers Creek. One adult male, three sub-adult (40-60mm S-V length) and two juvenile (<40mm S-V length) giant barred frogs were recorded at Upper Warrell Creek (Table 2). The adult male was recorded calling sporadically from a sheltered location on the south bank in zone 6 (Figure 3). The individual was unable to be captured during the survey. Sub-adult frogs were recorded in zones 8, 16 and 17 on the south bank only, with juvenile frogs recorded in zones 6 and 17 also on the south bank (Figure 3). Snout-Vent length of juvenile and sub-adult frogs ranged from 36.1 to 51.4mm and none were PIT tagged. Weights ranged from five to 15 grams and distance from the stream edge from 0.2 to 5m (Table 2).

Table 2: Giant barred frogs captured during the spring 2020 survey at Upper Warrell Creek. HC – heard calling; NC – not captured

Variable	Year 3 frog number					
	Frog 4	Frog 5	Frog 6	Frog 7	Frog 8	Frog 9
Capture date	17/2/21	17/2/21	17/2/21	17/2/21	17/2/21	17/2/21
Zone	8	6	6	16	17	17
Creek side	South	South	South	South	South	South
GPS location	489261,6594336	489285,6594410	489283,6594403	489108,6594022	489050,653989	489050,6593989
Distance from stream edge (nearest 0.1m)	0.2	0.5-1m	4	3.5	4.5	5
Position in micro-habitat*	On exposed leaf litter	On bank	On leaf litter exposed	On bare ground/sparse leaf litter	On bare ground/sparse leaf litter	On bare ground/sparse leaf litter
Sex**	Immature	Male - HC	Immature	Immature	Immature	Immature
Age***	Sub-adult		Juvenile	Sub-adult	Sub-adult	Juvenile
S/V length	51.4	NC	36.1	42.6	44.2	39.4
Weight (gr)	15		<5	10	10	6
Breeding condition#	N/A	N/A	N/A	N/A	N/A	N/A
Microchip ID (new or re-capture)	N/A	N/A	N/A	N/A	N/A	N/A
Original capture & recapture details	N/A	N/A	N/A	N/A	N/A	N/A

*Microhabitat: under leaf litter, under veg, on leaf litter, exposed, on a log/rock etc.
**Sex: Frogs >78mm were deemed female unless heard calling.
***Age: >60mm = adult, 40-60mm = sub, <40mm = Juv.
#Breeding: Males: colour of nuptial pads; light/moderate/dark/no colour. Females: Gravid, typically weighing >100g. Immature: SV length <60mm.

3.2.1 Frog abundance

The number of immature frogs (i.e. frogs with a S-V length <60mm) recorded in summer 2021 exceeded that recorded during year one of the operational phase (1 individual), and years one and three of the construction phase (2 individuals). However, the result is less than during the baseline surveys when 16 immature frogs were recorded (Lewis 2014). The size range of immature frogs recorded in summer 2021 suggests that they would have hatched in summer/autumn 2020. Due to the influence of environmental conditions on growth it is difficult to determine when the subject individuals metamorphed. However, the smaller individuals may have metamorphed in spring 2020. The higher number of immature frogs recorded in summer 2021 is likely to be a direct response to good breeding conditions in 2020. The result highlights the influence that environmental conditions have on frog abundance. The presence of immature frogs shows that breeding is occurring in the locality and is encouraging for the Upper Warrell Creek frog population particularly given the good breeding conditions recorded in 2020/2021.

Whilst reviewing capture records of immature frogs from previous surveys an error with operational phase monitoring methods was identified. During the operational phase the threshold for pit-tagging was set at 60mm S-V length, which is the immature/adult transition point. This contrasts to the baseline and construction phase surveys where the threshold for pit-tagging was set at 40mm S-V length, which is the juvenile/sub-adult transition point. This error has not affected population calculations as immature frogs are not included in the Peterson-Lincoln index, and the effect on detecting movements is limited as only a small number of individuals between 40 and 60mm have been captured during the operational phase. During all future sampling the threshold for pit-tagging will be set at 40mm S-V length.

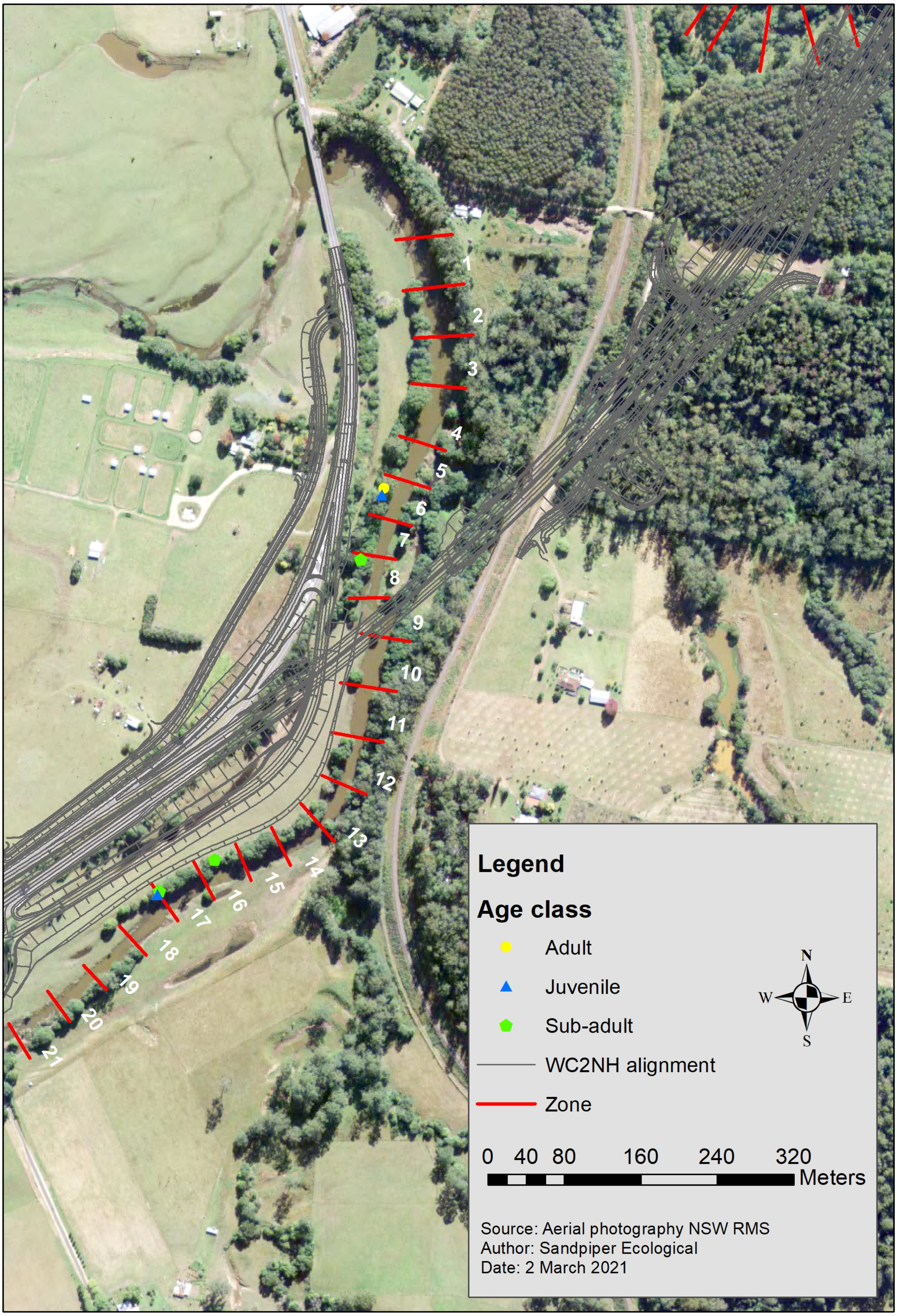

Figure 3: Location of frogs captured during the summer 2021 giant barred frog survey at Upper Warrell Creek.

3.2.2 Distribution

The distribution of immature frogs provides some insight into potential breeding habitat, and/or suitable tadpole habitat. Zones 16 and 17 contain low quality breeding habitat and no adult frogs have been recorded in those zones during the construction or operation phases. It seems likely that the immature frogs recorded in those zones metamorphed from tadpoles that hatched upstream. Both zones are situated near a small lateral bar that would provide sheltered habitat for tadpoles washed downstream during floods. Similarly, zones 6-8 occur near areas that contain sheltered aquatic habitat. Both the immature frogs recorded during the construction phase were found in zone 6, and six immature frogs were recorded in zones 6 and 8 during the baseline survey.

3.3 Water quality

Most water quality parameters were within the ANZECC trigger values for freshwater ecosystems in south eastern Australia (Table 3). Exceptions were Total phosphorus, which exceeded the ANZECC thresholds for freshwater ecosystems at both sites, dissolved oxygen, which was lower than the ANZECC trigger value at both sites, and turbidity, which exceed the threshold at Butchers Creek. Findings are broadly consistent with spring 2020 and most likely reflect the elevated water level and high rainfall prior to the survey (Sandpiper Ecological 2020). Importantly, all BTEX and Total Recoverable Hydrocarbon levels were below ANZECC trigger levels. Heavy metals were not analysed in summer 2021. The nature of water quality sampling, that is, one-off samples months or years apart, is unlikely to provide data representative of water quality at either site.

Table 3: Results of water sample analysis for Upper Warrell creek and Butchers Creek. ID = insufficient data to derive a reliable trigger value (ANZECC 2000); NS – parameter not sampled.

Parameter	Warrell Creek	Butchers Creek	ANZECC/ARMCANZ Trigger value for freshwater (95% species level of protection)
Temperature (^{0}C)	22.3	21.1	
pH	6.31	6.19	6.5-8.0
Conductivity (us/cm)	0.171	0.108	125-2200
Dissolved oxygen (mg/L O_2)	6.23	6.51	9-10.5
Total Suspended Solids (mg/L)	<1	4	
Turbidity (NTU)	4.7	11.6	6-50
Total Phosphorus (mg/L P)	0.05	0.04	0.025
Total Nitrogen (mg/L N)	0.24	0.10	0.35
BTEX			
Benzene (µg/L or ppb)	<0.5	<0.5	950
Toluene (µg/L or ppb)	<0.5	<0.5	ID
Ethylbenzene (µg/L or ppb)	<0.5	<0.5	ID
m+p-Xylene (µg/L or ppb)	<1	<1	200
o-Xylene (µg/L or ppb)	<0.5	<0.5	350
Naphthalene (µg/L or ppb)	<0.5	<0.5	16
Total Recoverable Hydrocarbons (TRH)			
C6-C9 Fraction (µg/L or ppb)	<40	<40	ID
C10-C14 Fraction (µg/L or ppb)	<50	<50	ID
C15-C28 Fraction (µg/L or ppb)	<100	<100	ID
C29-C36 Fraction (µg/L or ppb)	<50	<50	ID
C10-C16 Fraction (µg/L or ppb)	<60	<60	ID
C10-C16 less Naphthalene Fraction (µg/L or ppb)	NS	NS	ID

Parameter	Warrell Creek	Butchers Creek	ANZECC/ARMCANZ Trigger value for freshwater (95% species level of protection)
C16-C34 Fraction (µg/L or ppb)	<200	<200	ID
C34-C40 Fraction (µg/L or ppb)	<100	<100	ID
Sum C10-C36 Fraction (µg/L or ppb)	<100	<100	ID
Heavy Metals			
Silver (mg/L)	NS	NS	0.05
Aluminium (mg/L)	NS	NS	55
Arsenic (mg/L)	NS	NS	24
Cadmium (mg/L)	NS	NS	0.2
Chromium (mg/L)	NS	NS	1.0
Copper (mg/L)	NS	NS	1.4
Iron (mg/L)	NS	NS	ID
Manganese (mg/L)	NS	NS	1900
Nickel (mg/L)	NS	NS	11
Lead (mg/L)	NS	NS	3.4
Selenium (mg/L)	NS	NS	11
Zinc (mg/L)	NS	NS	8
Mercury (mg/L)	NS	NS	0.6

4. Recommendations

Recommendations are presented in Table 4.

Table 4: Recommendations based on findings of the summer year 3 operational phase giant barred frog monitoring program.

Number	Recommendation	Transport for NSW Response
1.	Continue river bank restoration on the north bank of Zones 7, 8 & 9 at Upper Warrell Creek. Additional planting and maintenance of *Waterhousia floribunda* and understorey shrubs, and control of grass is required to improve connectivity.	The following works are to be undertaken by the WC2NH contractor in zones 7, 8 and 9 - - Works to reduce Pigeon Grass *(Setaria species)* extent and density - Planting of 60 *Waterhousia floribunda* - Plant out wetland plant tubestock to bolster the now established wetland plantings in the area. This scope of works has been developed in consultation with and is endorsed by the EPA. The works were expected to commence in late 2020, however due to numerous high rain events and localised flooding, these works are now expected to commence before July 2021.
2.	Due to the pattern of population decline at UWC additional survey effort is recommended at that site for the remaining autumn year 3 operational phase survey. Further assessment, in accordance with Performance Criteria in the Giant Barred Frog Management Strategy, would be undertaken following population analysis conducted in the year 3 operational phase annual report, which is due in autumn 2021.	Agree and adopted

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Customer feedback
Roads and Maritime
Locked Bag 928,
North Sydney NSW 2059

March 2021

Appendix C Yellow-bellied glider

Pacific Highway Upgrade – Warrell Creek to Nambucca Heads

Yellow-bellied Glider (*Petaurus australis*) Population Monitoring

Year 2 Operation Phase

Sandpiper Ecological

1/94 Main Street
Alstonville

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Version 2

1 April 2020

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Project team: Dr B. Taylor (reporting, field survey)
Dr D. Rohweder (project management, review)
Mr N. Priest (field survey)
Ms N. Makings (field survey)
Mr G. McDonald (field survey)

Report prepared for: Transport for NSW

ABN: 82 084 096 828
PO Box 401
ALSTONVILLE NSW 2477
P 0401 195 480 | E enquire@sandpipereco.com.au

Cover Photo: Adult female yellow-bellied glider (*Petaurus australis*) (Photo: B. Taylor)

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1. Introduction

1.1 Background

Transport for NSW (TfNSW), in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH) in 2015. The upgrade was subsequently completed and the final stage of the project open to traffic in June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala *Phascolarctos cinereus*, yellow-bellied glider *Petaurus australis*, giant barred frog *Mixophyes iteratus*, constructed ponds for green-thighed frog *Litoria brevipalmata*, fauna underpasses, vegetated median, road-kill, exclusion fence, and threatened flora. Sandpiper Ecological Surveys (Sandpiper Ecological) was contracted by TfNSW to deliver the WC2NH operational ecological and water quality monitoring program in accordance with the WC2NH Operational Ecological and Water Quality Monitoring Brief (the Brief) as informed by the WC2NH Ecological Monitoring Program (EMP) (RMS 2018).

The EMP sets out a yellow-bellied glider monitoring program that extends to year 10 of the operational phase and refers to details provided in the WC2NH Ecological Monitoring Program for the Yellow-bellied Glider (YBGEMP) (Goldingay 2014). The program was largely based on pre-construction phase (baseline) surveys completed in 2014 (Goldingay 2015) and aims to assess both individual level and population level responses to the highway upgrade.

An individual level response will be measured by comparing forest use adjacent the highway upgrade before and after construction whereas a population level response will be measured by comparing the proportion of survey sites occupied by yellow-bellied gliders in Nambucca State Forest with that measured at reference locations before and after construction (RMS 2018). Assessment of the individual level response to the highway upgrade will be conducted using spotlighting and song meters to detect and record calls of the yellow-bellied glider near the highway upgrade (RMS 2018). Assessment of population response will be measured using spotlight transects located in Nambucca State Forest (SF) and at reference sites located in Yarriabini National Park (NP) and Ngambaa Nature Reserve (NR).

The EMP also required completion of construction phase yellow-bellied glider population surveys which were conducted in 2016/17 (Sandpiper Ecological 2018). Operation phase monitoring is required to occur in years 1, 2, 4, 7 and 10. Year one operation phase was completed in 2018/19 (Sandpiper Ecological 2019a). The following report refers to year two (2019/20) monitoring activities.

1.2 Species ecology

The yellow-bellied glider is Australia's largest Petaurid glider, weighing between 450 - 700 g (Russell 1995). It feeds on a range of food including plant and insect exudates (sap, manna gum, honeydew, nectar and pollen) as well as insects and spiders (Goldingay and Jackson 2004). Population abundance is strongly related to the degree of forest maturity and the diversity of floristic resources (Kavanagh 1987). Yellow-bellied gliders den within tree hollows in small family groups of 2 - 6 individuals, including an adult male and one to two females and their offspring (Goldingay and Kavanagh 1991). Breeding females give birth to one offspring in most years but may not breed when environmental conditions are poor (Craig 1985; Goldingay 1992).

Yellow-bellied gliders are highly mobile and family groups feature home ranges in the order of 25 - 84 ha (Goldingay and Jackson 2004). The species are also highly vocal and may be heard well over 200 m away. Individuals call up to 15 times/hour for several hours after dark (Goldingay 1994). Calls are given at frequencies of 700-6400 Hz (main energy band 1000 - 3000 Hz) and range in duration from less than one second for a gliding moan, and up to four seconds for a full call (Goldingay 1992). The loudness and frequency of yellow-bellied glider calling make them relatively detectable during population surveys. This is enhanced by use of call playback which is known to elicit higher calling rates (Goldingay 1994).

1.3 Scope of works

The current reporting year (i.e. 2019/20) represents year two of the operational phase. The scope of works included:

1. Spotlight surveys of all 92 transects across Nambucca SF (40 sites), Yarriabini National Park (20 sites) and Ngambaa Nature Reserve (32 sites) on three occasions during late winter/spring;
2. Installation of six song meters within each of the three Nambucca SF blocks (18 units in total), including six units near the alignment and six units away from the alignment in the north-west and south blocks, for a period of six months;
3. Analysis of song meter recordings for presence and frequency of yellow-bellied glider calls using Kaleidoscope Pro software.

The following report details and discusses the current years' monitoring activities. The report also considers the two Performance Indicators for yellow-bellied glider population monitoring stated in the EMP:

1. No reduction in proportion of sites occupied by yellow-bellied gliders in Nambucca SF post-construction.
2. No reduction in forest use adjacent to the highway in Nambucca SF post-construction.

2. Study Area

Surveys were conducted within Nambucca SF, Yarriabini NP and Ngambaa NR. The reserves are all located on the mid-north coast of NSW (Figure 1). Transects (200m long) were established during the pre-construction surveys in 2014 and were located on management tracks within the respective reserves. Transects were located a minimum of 500m apart to increase the likelihood of independence. Forty transects were positioned in Nambucca SF (Figure 2), 20 in Yarriabini NP (Figure 3) and 32 in Ngambaa NR (Figure 4). The three study areas featured similar dry open forest habitat with moist gullies.

Nambucca SF featured three blocks: north-east, north-west and south with the latter two blocks separated by the highway corridor (Figure 2). The north-east block has been heavily logged whereas the north-west and south blocks of Nambucca SF, Yarriabini NP, and Ngambaa NR have experienced less intensive, selective logging.

Figure 1: Location of three study areas surveyed for yellow-bellied glider.

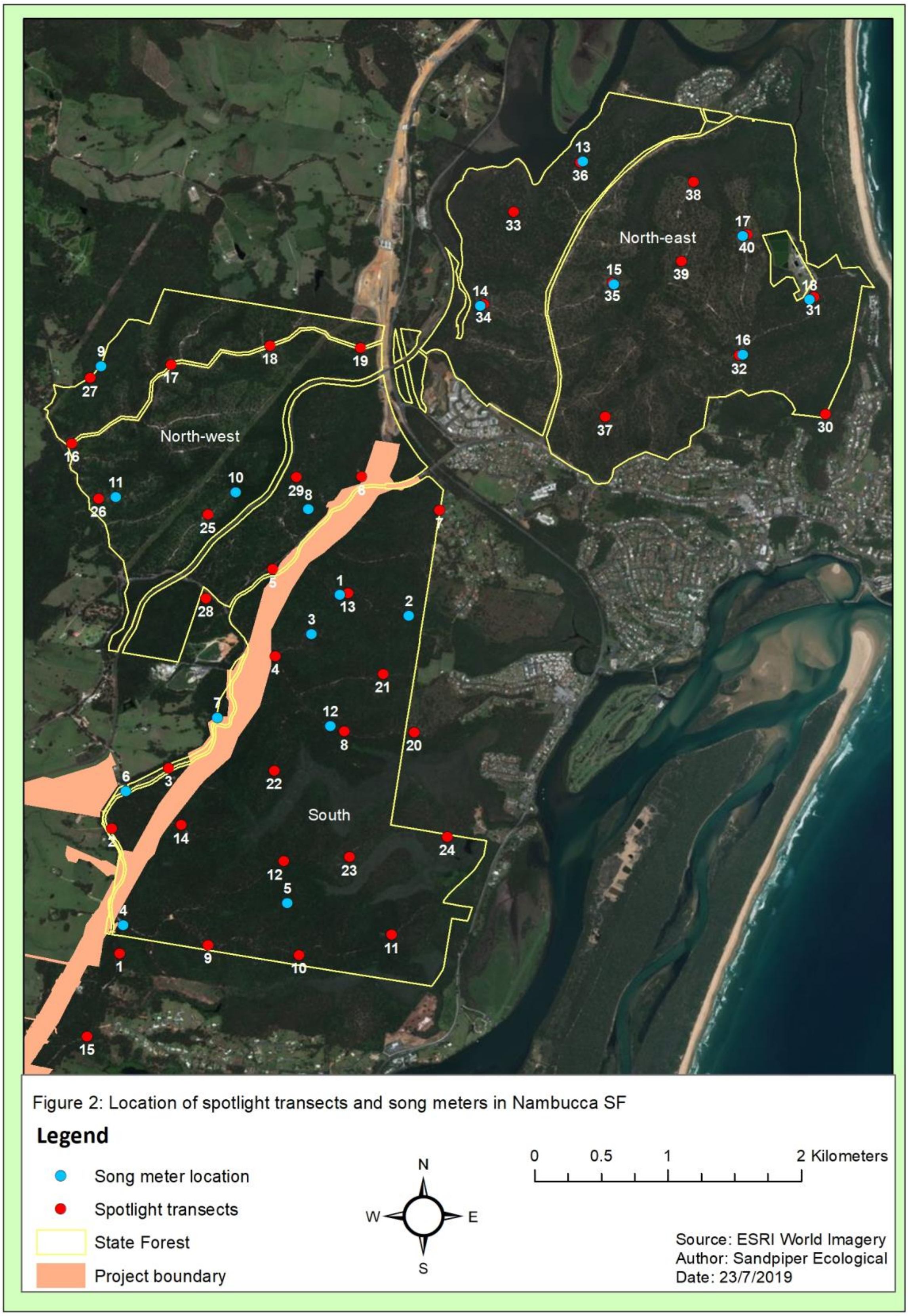

Figure 2: Location of 40 spotlight transects and 18 song meters within Nambucca SF.

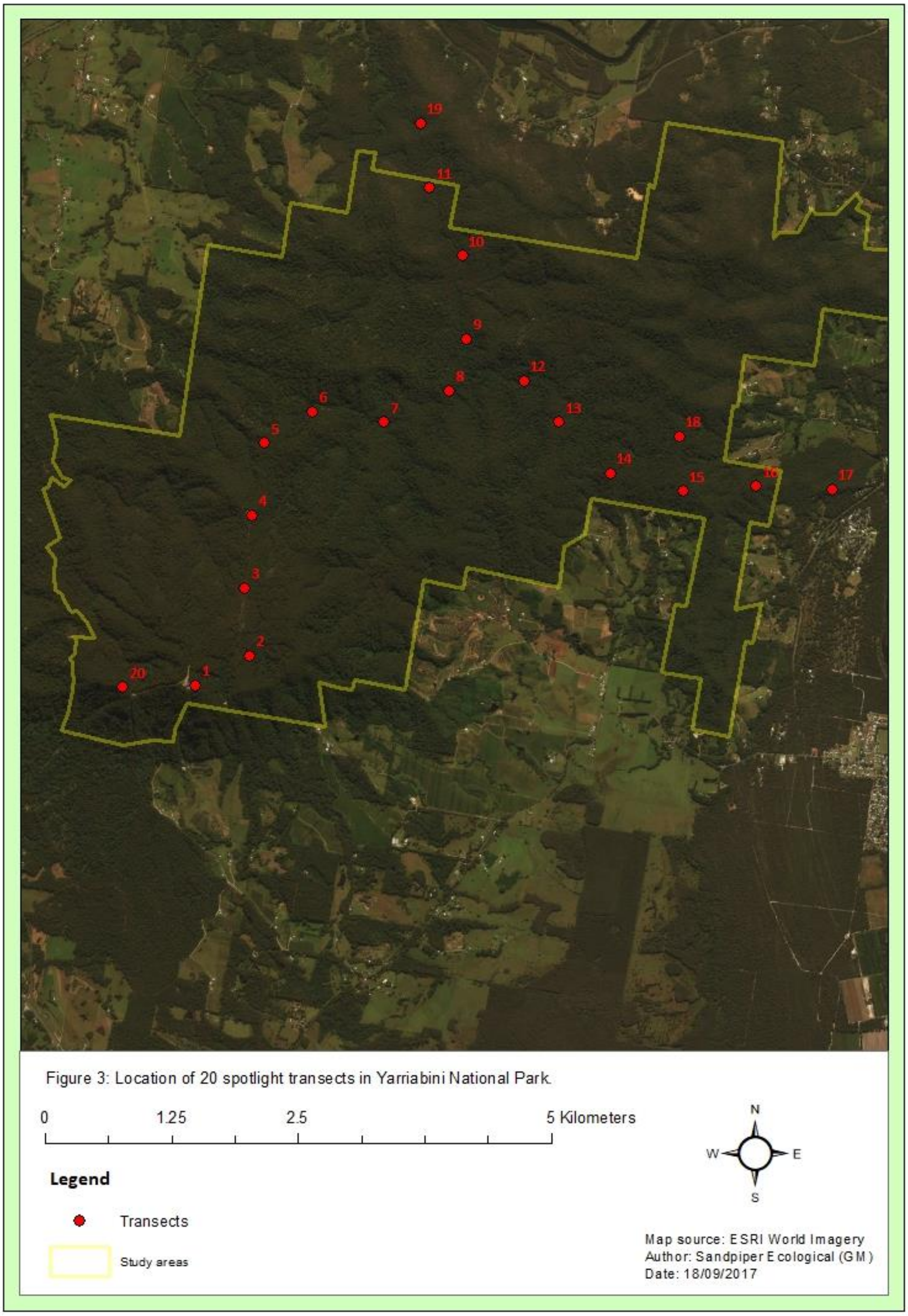

Figure 3: Location of 20 spotlight transects in Yarriabini NP.

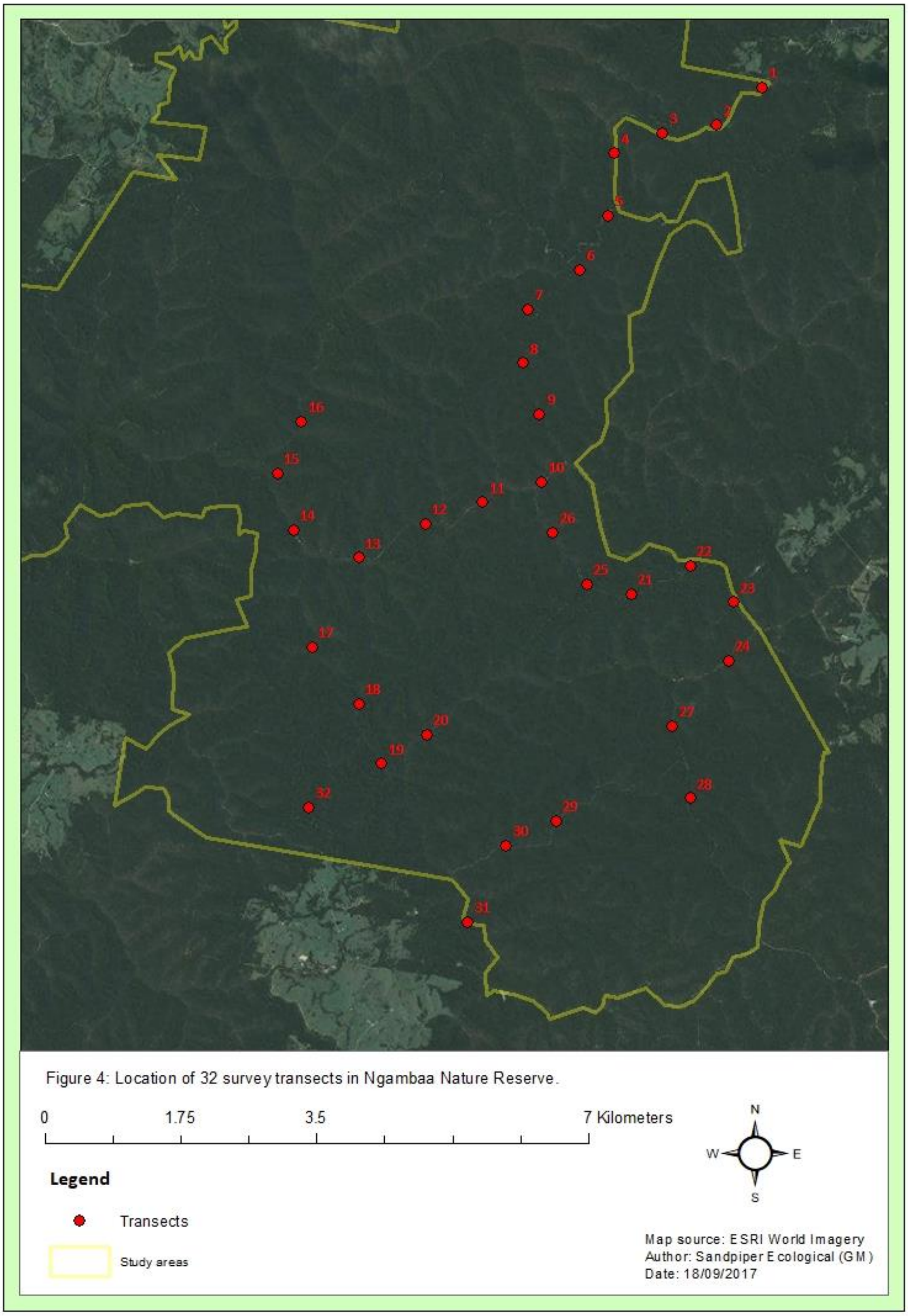

Figure 4: Location of 32 transects in Ngambaa NR.

3. Methods

3.1 Spotlight/Call Playback Surveys

Three spotlight/call playback survey sessions targeting yellow-bellied gliders were conducted during late winter/spring 2019. Surveys followed the method described for pre-construction surveys and utilised the same transect locations (Goldingay 2015). At the beginning of the survey period, transects were located and their start and end points marked with a combination of flagging tape and reflective tape. Surveys occurred on 12-15 August (session 1), 2-5 September (session 2) and 30 September – 3 October (session 3). Surveys were completed by a team of three to four ecologists operating concurrently on proximal transects. Surveys commenced when dark, approximately 40 minutes after sunset (i.e. after civil twilight), and most surveys were completed within 4 hours of sunset.

Transects were spotlighted on one occasion during each session. Each transect was spotlighted for a minimum of 20 minutes by one operator using a 250-lumen spotlight (Led Lenser P14 or equivalent) and binoculars, as required. At the 10-minute mark, four recorded calls of the yellow-bellied glider and four recorded calls of the powerful owl were broadcast from a 10watt megaphone. Call broadcast volume was calibrated to be audible to the human ear to approximately 200m and therefore easily audible to yellow-bellied glider within this range.

Information recorded for each yellow-bellied glider detection included: time, distance along transect, approximate distance and compass bearing from operator and mode of detection (i.e. heard call, saw individual, heard movement, saw eye-shine). The time and direction of yellow-bellied glider detections were compared at completion of surveys to ensure double counting did not occur for neighbouring transects.

Surveys were mostly conducted around the dark phase of the moon between third quarter and first quarter. Weather conditions were fine and dry during surveys with occasions of moderate to strong winds in the early evening. A bushfire burnt approximately 40 ha of forest within the central section of the south block of Nambucca SF on 8 September 2019, between the time of the second and third spotlight survey. The understory to the level of mid-canopy was burnt out in parts of transects 4, 8, 13 and 20.

Full details of weather conditions and survey effort are provided in Appendix A.

3.2 Song Meter Surveys

3.2.1 Song meter recording

Eighteen song meters (SM4 manufactured by Wildlife Acoustics, USA) were installed across Nambucca SF on 13-15 August 2019 (Figure 2). The spatial configuration of the array was as per 2018/19 surveys and was as follows:

- North-east block: six units evenly spread across block.
- North-west block: 3 units <300m from highway (i.e. near), 3 units >700m from highway (i.e. away).
- South block: 3 units <300m from highway, 3 units >700m from highway.

Song meters were strapped to trees with a python lock at approximately 6m above ground level using a ladder. Each unit was powered by four 1.5v D-size batteries and received either two 32 gigabyte or one 64 gigabyte memory card. Units were programmed to record three hours of audio nightly beginning approximately one hour after sunset. Song meters were inspected on 2 October 2019 to replace batteries and SD cards. The bushfire in the south block of Nambucca SF on 8 September 2019 burnt the song meter at site 12 although the memory card was unaffected. The unit was replaced 26 days later. Further, planned logging operations reduced the duration of the song meter deployment by three weeks. All units were collected on the 13 January 2020.

3.2.2 Song meter analysis

Analysis of 2016/17 and 2018/19 audio recordings was performed using Song Scope (Version 4.0; Wildlife Acoustics) sound recognition software. This software has been largely superseded by Kaleidoscope Pro (version 5.1.9g, Wildlife Acoustics), a more advanced sound recognition software package. Kaleidoscope Pro enables users to undertake cluster analysis of sound recordings and to develop an advanced classifier to detect a vocalization of interest – in this case, the yellow-bellied glider.

An advanced classifier (i.e. YbG-AC) was built using annotated calls of the yellow-bellied glider derived from sound recordings from Nambucca SF in 2016/17 and 2018/19. The building process involves ‘training’ the advanced classifier to detect or match vocalisations of the yellow-bellied glider from sound recordings. Numerous sensitivity analysis tests are also performed to determine optimal signal parameters. In this way, the building process is highly iterative and proceeds through numerous ‘tuning’ phases whereby batches of sound files are progressively analysed and incorrectly labelled vocalisations (i.e. false positives) are removed and the classifier algorithm updated or refined. The outcome of this process was final candidate model YbG-AC (Settings: Range = 250-10000 Hz; Length = 1.0 – 7.5 sec; Max inter-syllable gap = 0.35 sec; FFT window = 5.33 ms; Max distance from cluster center = 1.4; Max states = 12; Max distance to cluster center for building clusters = 0.5; Max clusters = 500).

To determine the relative performance capabilities of the final candidate advanced classifier (YbG-AC), we analysed seven sound recording files previously analysed by the Song Scope Recogniser (i.e. YbG-Rec) and known to contain calls of yellow-bellied gliders. The YbG-AC detected equal or greater the number of calls than the YbG-Rec on four of the seven sound files (i.e. 57%). This suggested that the YbG-AC was moderately more effective than the YbG-Rec in detecting yellow-bellied glider vocalisations and thereby appropriate for analysing 2019/20 sound recordings.

The YbG-AC was then used to analyse recordings from each of the 18 song meters using the Batch processing option. All audio recordings positively identified by the YbG-AC were subsequently checked and true-positive call detections logged. The number of true-positive call detections and number of nights when calls were detected were then tabulated for each song meter site.

4. Results

4.1 Spotlight Surveys

Yellow-bellied gliders were not detected on any of the forty transects in Nambucca SF during the three 2019 surveys (Figure 5; Table 1). At the Yarriabini NP reference site, yellow-bellied gliders were detected on two transects in survey one and on one transect each in survey two and three, including two on one transect in survey two. Overall, yellow-bellied gliders were detected on three of 20 transects (i.e. 15% of transects). Across the 32 transects in Ngambaa NR, yellow-bellied gliders were detected on one transect in each survey. Overall, detections were made on two transects (i.e. 6.3% of transects).

Across the three survey sites combined (i.e. 92 transects), yellow-bellied gliders were detected on seven occasions on five transects. All detections were of single individuals except two were observed on one occasion at Yarriabinni NP. All detections were initially made by call. Gliders were detected by call before call broadcast on 43% of occasions and after call broadcast on 57% of occasions, mostly within a few minutes.

Full details of yellow-bellied glider spotlight surveys are provided in Appendix A.

Table 1: Yellow-bellied glider detections at Nambucca SF and two reference sites (Yarriabini and Ngambaa). Data are pooled for three surveys.

Site	Nambucca	Yarriabini	Ngambaa
Number of transects	40	20	32
Number of transects YbG detected on	0	3	2
% of transects YbG detected on	0%	15%	6.3%

A comparison across the survey periods shows a relatively consistent downward trend in occupation rate in Nambucca SF and Ngambaa NR and a downward trend followed by a modest upturn at Yarriabinni NP (Figure 5). Despite the upturn at Yarriabinni NP, the operation phase occupation rate at all three sites has remained at levels well below that recorded during pre-construction. This includes a 100% decline at Nambucca SF and a 79.7% decline at Ngambaa NR between pre-construction and operation year 2. The decline at Yarriabinni NP for the same period was 57.1%.

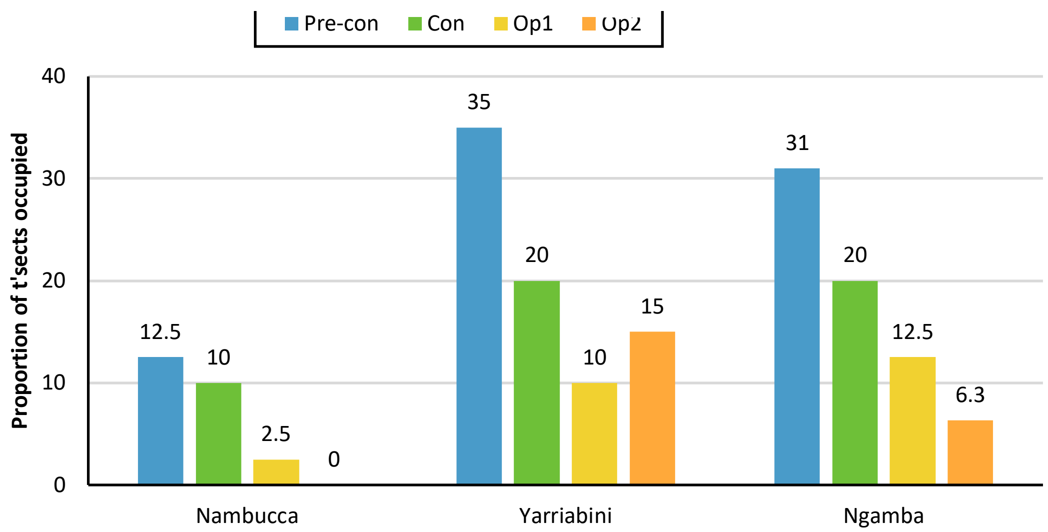

Figure 5: Proportion of survey site spotlight transects occupied by yellow-bellied gliders for each survey period. Pre-con = pre-construction; Con = construction; Op1 = operation phase year 1; Op2 = operation phase year 2.

4.2 Song Meter Surveys

The 18 song meters operated for a total of 2,626 nights and units were active for between 112 – 153 nights (mean 145.9 ± 11.6 nights) during the 22-week deployment. Calls of the yellow-bellied glider were detected at SM4 and SM7 near the highway but no calls were detected at units away from the highway (Figure 6 & 7). Calls were detected on two nights or 1.8% of nights at SM4 and 15 nights or 9.8% of nights at SM7 for an average of 1.0 and 1.2 calls/night, respectively. Overall, calls were detected on 17 nights or 0.6% of sampling nights. No calls were detected in the north-east block (i.e. SM13-18). Excluding song meter data for the north-east block, which did not receive song meters during pre-construction or construction phase, calls were detected on 1.0% of sampling nights.

Calls of the yellow-bellied glider were detected at one of the three near-highway song meter sites where they were previously recorded (Figure 6). Yellow-bellied glider calls were also detected at SM4 where they had not been previously detected. At site SM7, the percentage of nights with calls (i.e. 9.8%) was higher than that recorded during pre-construction (i.e. 3%) (Figure 6). The mean rate of nights with calls for the six near song meters declined from 1.67% (± 1.86 sd) to 0.77% (± 1.1 sd) between pre-construction and operation year 1 and increased during operation year 2 (1.93 ± 3.92% sd) although the mean value was highly inflated by the high call rate at SM7. Yellow-bellied glider call detections at away from the highway declined from three sites during operation year 1 to zero in the current year (Figure 6). Yellow-bellied glider calls were detected at one of two away sites during pre-construction.

Full details of song meter deployment are provided in Appendix B.

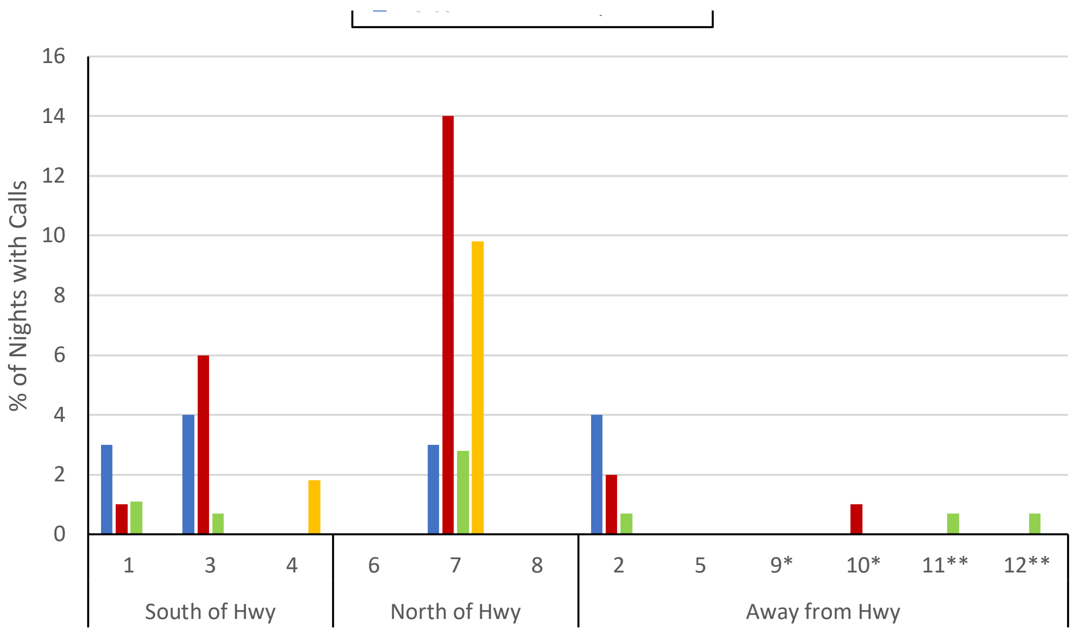

Figure 6: Percentage of nights in which yellow-bellied gliders were detected by song meters in the north-west and southern blocks (numbered 1-12) near the highway alignment (i.e. <300m) and away from the alignment (i.e. >700m) during pre-construction (Pre-con), construction (Con) and operation year 1 (Op1) and year 2 (Op2). * = song meters 9 & 10 deployed during construction and operation phases only; ** = song meters 11 & 12 deployed during operation phases only.

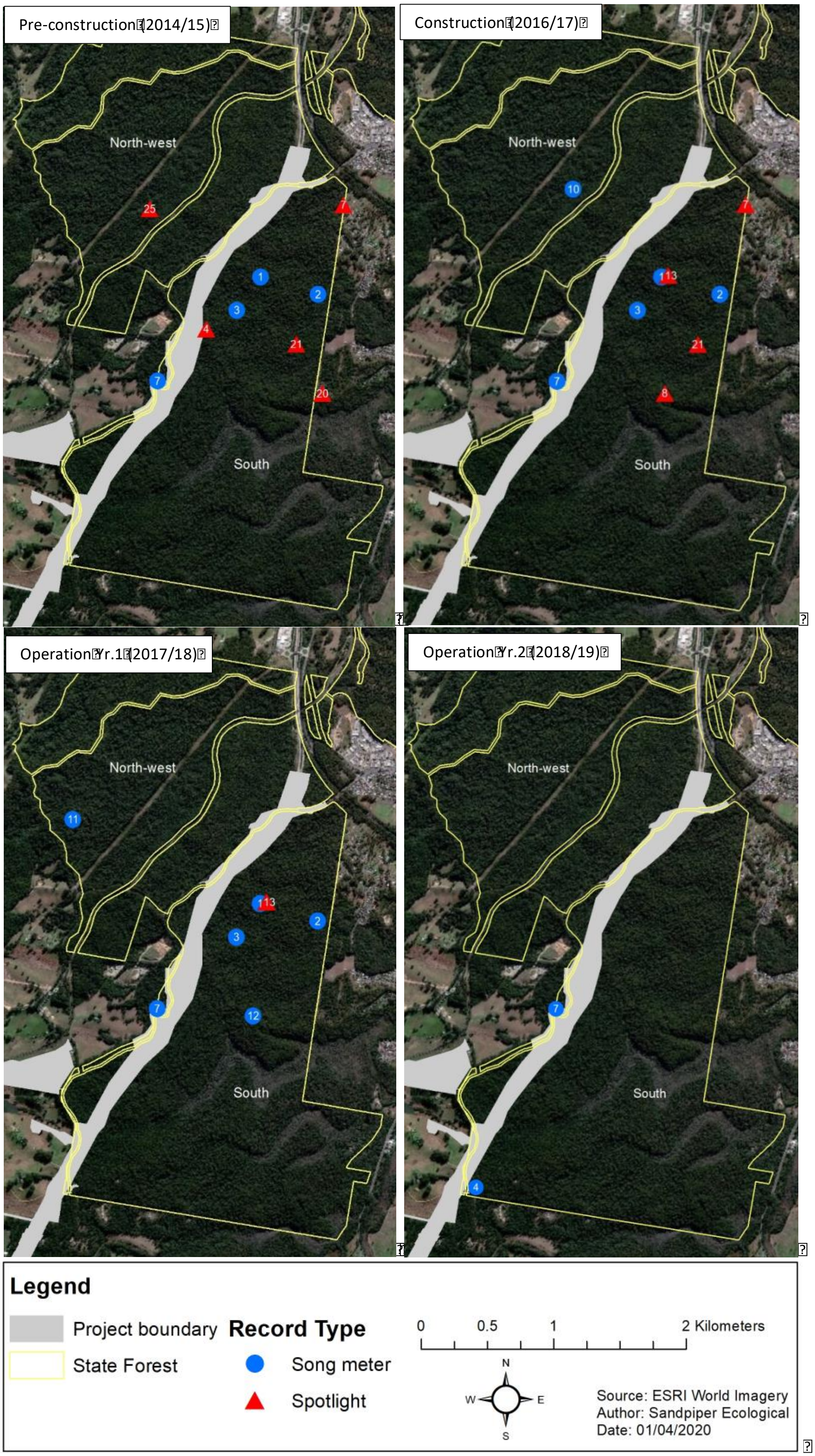

Figure 7: Song meter and spotlight transect locations where yellow-bellied glider calls were detected during the current and previous monitoring years.

4.3 Aggregation of spotlighting and song meter data

Both the spotlighting and song meter data from the current and previous periods demonstrate a marked decline in the number of yellow-bellied glider social groups residing in Nambucca SF. The six social groups identified during pre-construction and five identified during operation year one have contracted to two social groups in the southwest portion of the south block (Figure 7). Neither song meters nor spotlighting recorded evidence of the previously extant groups in the central regions of the south block and north-west block. Both methods also confirmed the continued absence of yellow-bellied gliders in the north-east block.

If we disregard song meter and spotlighting effort in the north-east block, song meters have consistently detected yellow-bellied glider calls between 0.9% and 2.3% of sampling nights, including 1.0% of sampling nights during the current reporting period (Figure 8). By contrast, spotlighting failed to detect yellow-bellied gliders during the current reporting period but recorded higher detection rates compared with song meters during previous survey periods (Figure 8).

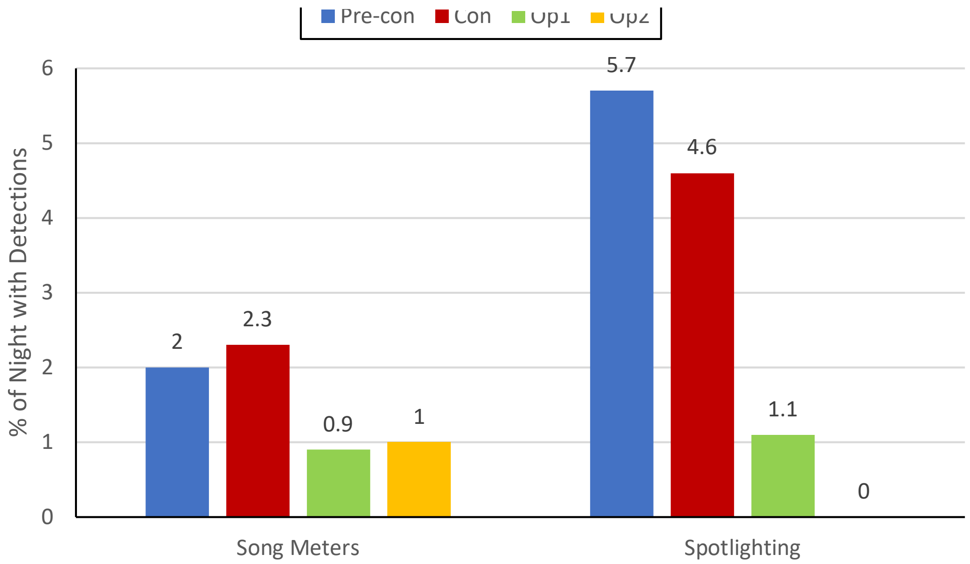

Figure 8: Percentage of survey nights in which yellow-bellied gliders were detected by song meters and spotlighting during pre-construction, construction, operation year 1 and year 2 within Nambucca SF. Data from north-east block not included. Song meter data are for eight units during pre-construction (SM1-8), 10 units during construction (SM1-10) and 12 units during operation phases (SM1-12). Spotlighting detections are from three surveys of 29 sites across the north-west and south blocks in each monitoring period. Pre-con = pre-construction; Con = construction; Op1 = operation phase year 1; Op2 = operation phase year 2.

5. Discussion

Results of the year two operation phase yellow-bellied glider population monitoring are discussed with reference to the performance indicators described in the EMP.

5.1 Population Level Response

5.1.1 No reduction in proportion of sites occupied by yellow-bellied gliders in Nambucca SF post-construction

The proportion of spotlight survey sites occupied by yellow-bellied gliders in Nambucca SF has declined markedly from pre-construction levels. The scale of the decline during the operation phase has been in the order of 80% and 100%, for years one and two respectively. Although not as pronounced, song meter data largely confirmed the scale of this decline and the likely loss of up to four social groups since 2014.

The frequency of call detections at SM7 (i.e. 9.8% of sampling nights) as well as several incidental records of calls approximately 400m to the north of this site (Sandpiper Ecological 2019b) suggest that a social group is continuing to persist in this section of Nambucca SF. Conversely, the low frequency of call detections at SM4 (i.e. 1.8% of sampling nights) suggests that forest around this site is used infrequently and perhaps only more recently. Moreover, the absence of any prior records at this site or at nearby song meter or spotlight sites suggests that this record may represent dispersal or range movement away from the central area of the south block where yellow-bellied gliders appear to have receded from. It is also feasible that the few detections at site SM4 represent a social group persisting to the south although the lack of contiguous forest in this area suggests this is highly unlikely.

The decline in abundance of yellow-bellied gliders at Nambucca SF largely reflects the population trend evident at Yarriabinni NP and Ngambaa NR reference sites. Occupation rates at these two sites have declined from pre-construction levels by 71% and 57% (Yarriabinni NP) and 59% and 80% (Ngambaa NR) for year 1 and year 2 operation phase, respectively. Indeed, the modest rise between year 1 and year 2 operation phase at Yarriabinni NP belies the fact that year 2 rates are still well below pre-construction levels.

5.1.2 Explaining population declines

The apparent decline in population numbers across all three locations suggests the primary cause is not the highway upgrade although it may be an ancillary or contributing factor. If the highway upgrade were the primary cause then we would expect to see evidence of this at the Nambucca site only. The reference sites are far enough away from the highway upgrade not to be directly affected. The most plausible explanation for the decline is climatic conditions during the period since the pre-construction surveys.

Yellow-bellied glider abundance is sensitive to changes in climatic conditions driven by rainfall which trigger variations in food availability (Goldingay 1992). Rainfall data for Bowraville (the closest long-term Bureau of Meteorology weather station to the three sites) shows that the area has received below average rainfall for the last four years, including only 42% of the long-term mean during 2019. By comparison, the five years leading up to pre-construction surveys were all years of above average rainfall (Bureau of Meteorology).

In the pre-construction survey report, Goldingay (2015) suggested that yellow-bellied glider populations in the region were likely at or above their long-term average because of the preceding years of favourable conditions. Indeed, he conceded that any decline in rainfall over the next several years after pre-construction surveys were likely to be associated with lower population indices (Goldingay 2015). It is likely this scenario is playing out amongst focal populations in the study area and echoed in yellow-bellied glider population trends at the Woolgoolga to Ballina (W2B) upgrade site (Sandpiper Ecological 2020). This may be further compounded by recent bushfires that occurred across the north coast region in late 2019. The fire in the Nambucca SF, which covered approximately 40 ha of the central part of the south block, mostly affected the understory/mid-canopy and did not penetrate the canopy so its impact on yellow-bellied gliders may not have been significant.

Both the YBGEMP (Goldingay 2014) and the pre-construction survey report (Goldingay 2015) note that some disruption to the local population is expected during the first two years post-construction. Such disruption is likely compounded by a decline in the local population (due to climatic factors) and further compounded by the low fecundity of yellow-bellied gliders which effectively prolongs population recovery (Goldingay and Kavanagh 1993). Timber harvest activities planned for the southern block in early 2020 will likely cause further disruption. Timber harvest activities and fire are both listed as triggers in the EMP for an additional round of spotlighting and song meter surveys. Harvest activities are due for completion in June 2020 which would enable supplementary spotlighting/song meter surveys to commence in late winter/early spring 2020

5.1.3 Spotlighting versus song meters for detecting population responses

As directed by the YBGEMP (Goldingay 2014), the effectiveness of spotlight surveys versus song meter surveys for detecting yellow-bellied gliders in Nambucca SF should be compared at completion of year four monitoring. If song meters prove more effective, consideration should be given to phasing out spotlight surveys. Evidence gathered to date suggests that song meters are more effective at detecting the presence of yellow-bellied gliders particularly when they occur at low abundance.

5.2 Individual Level (Habitat Use) Response

5.2.1 No reduction in forest use adjacent to the highway in Nambucca SF post-construction

The EMP states that an individual level response will be measured by comparing forest use adjacent to the highway upgrade (i.e. ‘near’ song meter sites) before and after construction (RMS 2018). This should enable an assessment of whether gliders near the highway are affected by highway construction. As noted in the pre-construction survey report (Goldingay 2015), the process of habitat clearing and construction will cause some disruption to yellow-bellied gliders previously utilising this habitat.

Calls of the yellow-bellied glider were detected at two (i.e. SM4 and SM7) of the six ‘near highway’ sites during the current year (Figure 6). This compares with detections at three near highway sites during each of the preceding three monitoring periods (i.e. pre-construction, construction, & operation year 1). As discussed above, the location of near highway detections suggests that two social groups are living in forest near the highway – one group east of the highway (SM4) and a second group west of the highway (SM7). The social group detected at site SM7 has persisted since pre-construction surveys whereas the social group represented by site SM4 may represent more recent use of this area of forest and indicate dispersal or range movement away from the central area of the south block where yellow-bellied gliders appear to have receded from.

In summary, although there has been a modest reduction in forest use near or adjacent the highway (i.e. decline from three to two near highway song meter sites), this decline has occurred on a much lesser scale than for ‘away’ sites within the forest interior. Indeed, near highway sites were the only locations where yellow-bellied gliders were detected during the current reporting period.

6. Recommendations

1. Conduct an extra round of spotlighting (i.e. three repeat surveys) and song meter surveys (i.e. six-month deployment) in late winter/spring 2020 in response to the bushfire that occurred in Nambucca SF during September 2019 and planned timber harvest activities for early 2020.

2. Compare effectiveness of spotlighting versus song meter surveys for detecting yellow-bellied gliders in Nambucca SF at completion of year four operation phase surveys. If song meters prove more effective, consider phasing out spotlight surveys in Nambucca SF.

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Appendix A – Yellow-bellied glider spotlight surveys field data

Table A1: Yellow-bellied glider detections and weather conditions during three spotlight/call playback surveys conducted in late winter/spring 2019 in Nambucca State Forest. hc = heard call.

Transect	Date	Observer	Start	Finish	OBS type (< or > PB), Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
N1	14/8/19	NP	2224	2244							
	2/9/19	NP	2120	2140		New	16.2	67	Nil	Nil	RL
	30/9/19	NP	2125	2145		1/4	17.5	77	Nil	4/8	Msb
N2	14/8/19	LA	1800	1820							
	2/9	LA	1810	1830		1/4	18.7	69	Nil	Nil	MSB
	30/9/19	LA	1830	1850		New	17.2	81	Nil	9/9	Nil
N3	14/8/19	NM	1800	1820							
	2/9	Nm	18:13	1833		1/4	18.7	69	Nil	Nil	RL
	30/9/19	NM	1830	1850		New	17.2	81	Nil	9/9	Nil
N4	14/8/19	BT	1833	1854		Full	15.9	75	Nil	4/8	Still
	2/9/19	BT	1908	1929		New	18.7	64	Nil	0/8	MLB
	30/9/19	BT	2021	2043		New	17.5	82	Nil	8/8	MSB
N5	14/8/18	LA/NM	2215	2234							
	2/9/19	NM/La	2225	2245			15.1	75			RL
	30/9/19	Nm/LA	21.45	22.05			17.6	74	Nil	9/9	RL
N6	14/8/19	BT	2135	2156		Full	13.9	75	Nil	4/8	ML
	2/9/19	BT	2134	2155		New	16.2	67	Nil	0/8	MSB
	30/9/19	BT	2147	2208		New	17.5	82	Nil	8/8	MLB
N7	14/8/19	BT	2104	2125		Full	14.5	90	Nil	4/8	ML
	2/9/19	BT	1810	1831		New	18.9	70	Nil	0/8	MLB
	30/9/19	BT	2121	2143		New	17.5	82	Nil	8/8	MSB
N8	14/8/19	BT	1927	1948		Full	13.9	75	Nil	4/8	Still
	2/9/19	BT	2004	2025		New	17.1	70	Nil	0/8	MSB
	30/9/19	BT	1923	1944		New	17.5	82	Nil	8/8	MSB
N9	14/8/19	BT	2142	2203		Full	13.8	91	Nil	4/8	ML

Transect	Date	Observer	Start	Finish	OBS type (< or > PB), Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
	2/9/19	NP	1815	1835		New	18.7	69	Nil	Nil	MC
	30/9/19	NP	2102	2122		1/4	17.5	77	Nil	4/8	Msb
N10	14/8/19	NP	2155	2218							
	2/9/19	NP	1901	1921		New	18.7	69	Nil	Nil	MC
	30/9/19	NP	2038	2058		1/4	17.3	77	Nil	4/8	Msb
N11	14/8/19	NP	2130	2150							
	2/9/19	NP	1924	1944		New	18.6	62	Nil	Nil	MLB
	30/9/19	NP	2016	2036		1/4	17.3	77	Nil	4/8	Msb
N12	14/8/19	BT	2210	2230		Full	13.8	91	Nil	4/8	ML
	2/9/19	NP	1837	1857		New	18.7	69	Nil	Nil	MC
	30/9/19	NP	1950	2010		1/4	17.3	77	Nil	4/8	Msb
N13	14/8/19	BT	1803	1824		Full	15.9	75	Nil	4/8	Still
	2/9/19	BT	1838	1900		New	18.9	70	Nil	0/8	MLB
	30/9/19	BT	2049	2112		New	17.5	82	Nil	8/8	MSB
N14	14/8/19	NP	2100	2120							
	2/9/19	NP	2047	2107		New	18.6	62	Nil	Nil	MLB
	30/9/19	NP	1922	1942		1/4	17.2	80	Nil	4/8	Msb
N15	14/8/19	NM/LA	2215	2235							
	2/9/19	NP	2145	2205		New	16.2	67	Nil	Nil	RL
	30/9/19	NP	2147	2207		1/4	17.5	77	Nil	4/8	Msb
N16	14/8/19	NM	2005	2025							
	2/9/19	La/nm	2030	2050		1/4	16.6	66	Nil	Nil	RL
	30/9/19	LA	2015	2035		New	17.2	76	Nil	9/9	RL
N17	14/8/19	LA	2005	2025							
	2/9	La/nm	2005	2025		1/4	16.6	66	Nil	Nil	RL
	30/9/19	NM	2015	2035		New	17.2	76	Nil	9/9	RL
N18	14/8/19	LA	1940	2000							
	2/9/19	LA	1930	1950		1/4	18.7	69	Nil	Nil	MSB
	30/9/19	LA	1940	2000		New	17.2	76	Nil	9/9	RL
N19	14/8/19	NM	1940	2000							
	2/9/19	NM	1930	1950		1/4	18.7	69	Nil	Nil	MSB
	30/9/19	NM	1940	2000		New	17.2	76	Nil	9/9	RL
N20	14/8/19	BT	1953	2015		Full	13.9	75	Nil	4/8	MSB

Transect	Date	Observer	Start	Finish	OBS type (< or > PB), Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
	2/9/19	BT	2028	2050		New	17.1	70	Nil	0/8	ML
	30/9/19	BT	1855	1916		New			Nil	8/8	MLB
N21	14/8/19	BT	2023	2045		Full	13.9	75	Nil	4/8	ML
	2/9/19	BT	2055	2117		New	17.1	70	Nil	0/8	MSB
	30/9/19	BT	1830	1852		New			Nil	8/8	MSB
N22	14/8/19	BT	1900	1922		Full	15.9	75	Nil	4/8	Still
	2/9/19	BT	1936	1957		New	18.7	64	Nil	0/8	MLB
	30/9/19	BT	1955	2016		New	17.5	82	Nil	8/8	MSB
N23	14/8/19	NP	2030	2050							
	2/9/19	NP	1953	2013		New	18.6	62	Nil	Nil	MLB
	30/9/19	NP	1856	1916		1/4	17.2	80	Nil	4/8	Msb
N24	14/8/19	NP	2004	2024							
	2/9/19	NP	2017	2037		New	18.6	62	Nil	Nil	MLB
	30/9/19	NP	1830	1850		1/4	17.2	80	Nil	4/8	Msb
N25	14/8/19	LA	2032	2052							
	2/9	LA	2120	21:40							
	30/9/19	LA	2105	2125		New	17.5	77	Nil	9/9	Nil
N26	14/8/19	LA/NM	1912	1932							
	2/9	LA NM	20:55	21:15							
	30/9/19	LA/NM	2040	2100		New	17.5	77	Nil	9/9	RL
N27	14/8/19	LA/NM	1845	1905							
	2/9/19	NM	18:50	19:10							SB
	30/9/19	La/nm	19.05	19.25		New	17.2	81	Nil	9/9	Nil
N28	14/8/19	NM	2032	2052							
	2/9/19	NM	2120	2140		1/4	16.6	66	Nil	Nil	RL
	30/9/19	NM	2105	2125		New	17.5	77	Nil	9/9	Nil
N29	14/8/19	NM/LA	2105	2125							
	2/9	NM/LA	2200	2220							
	30/9/19	Nm/LA	21.45	22.05			17.6	74	Nil	9/9	RL
N30	15/8/19	NP	2022	2042							
	5/9/19	BT	1815	1836		1/4	17.1	83	Nil	0/8	ML
	3/10/19	BT	1829	1850		New	18.5	75	Nil	0/8	MLB
N31	15/8/19	BT	1950	2012		Full	16.3	73	Nil	0/8	MSB

Transect	Date	Observer	Start	Finish	OBS type (< or > PB), Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
	5/9/19	BT	2036	2057		1/4	14.3	93	Nil	0/8	ML
	3/10/19	BT	2033	2054		New	18.4	73	Nil	0/8	ML
N32	15/8/19	BT	1853	1914		Full	16.7	72	Nil	0/8	MSB
	5/9/19	BT	1848	1909		1/4	17.1	83	Nil	0/8	ML
	3/10/19	BT	1856	1916		New	18.5	75	Nil	0/8	MLB
N33	15/8/19	NP	1824	1845							
	5/9/19	NP	2125	2145		New	12.6	93	Nil	Nil	Nil
	3/10/19	NM	1855	1915		Blackbutt	17.6	78	Nil		RL
N34	15/8/19	NP	1922	1942							
	5/9/19	NP	2028	2048		New	14	92	Nil	Nil	Nil
	3/10/19	NM	1830	1850			17.6	78	Nil		RL
N35	15/8/19	NP	1852	1912							
	5/9/19	NP	2102	2122		New	14	92	Nil	Nil	Nil
	3/10/19	NM	1945	2005		Blackbutt	18.4	74	Nil		Msb
N36	15/8/19	NP	1800	1829							
	5/9/19	BT	2108	2128		1/4	14.3	93	Nil	0/8	ML
	3/10/19	NM	1920	1940		Blackbutt	18.5	74	Nil		Nil
N37	15/8/19	NP	1952	2012							
	5/9/19	NP	2002	2022		New	14	92	Nil	Nil	Nil
	3/10/19	NM	2008	2028		Blackbutt	18.4	72	Nil		Nil
N38	15/8/19	BT	1801	1822		Full	16.7	72	Nil	0/8	ML
	5/9/19	BT	1938	2000		1/4	15.6	89	Nil	0/8	ML
	3/10/19	BT	1944	2005		New	18.5	75	Nil	0/8	ML
N39	15/8/19	BT	1827	1848		Full	16.7	72	Nil	0/8	MSB
	5/9/19	BT	1912	1932		1/4	15.6	89	Nil	0/8	ML
	3/10/19	BT	1920	1941		New	18.5	75	Nil	0/8	MSB
N40	15/8/19	BT	1920	1942		Full	16.3	73	Nil	0/8	MSB
	5/9/19	BT	2007	2028		1/4	15.6	89	Nil	0/8	ML
	3/10/19	BT	2009	2030		New	18.4	73	Nil	0/8	ML

Table A2: Yellow-bellied glider detections and weather conditions during three spotlight/call playback surveys conducted in late winter/spring 2019 in Yarriabinni National Park. hc = heard call.

Transect	Date	Observer	Start	Finish	OBS type (< or > PB), Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
Y1	12/8/19	NP	18:00	1820							MLB
	14/9/19	NP	2019	2039		New	13.6	97	Nil	Nil	RL
	2/10/19	NP	1852	1912		1/4	17.3	65	Nil	Nil	MC
Y2	12/8/19	NP	1855	1915							Nil
	4/9/19	NP	1955	2015		New	13.6	97	Nil	Nil	RL
	2/10/19	NP	1830	1850		1/4	17.3	65	Nil	Nil	MC
Y3	12/8/19	NP	1918	1938							MLB
	4/9/19	NP	1927	1947	2; HC <pb 1934 60degNE 120m, 118degSE.100m	New	13.6	97	Nil	Nil	RL
	2/10/19	NP	1942	2002		1/4	12.8	83	Nil	Nil	Msb
Y4	12/8/19	NP	1942	2002							MC
	4/9/18	NP	1904	1924		New	17.1	84	Nil	Nil	Nil
	2/10/19	NP	2005	2025		1/4	12.8	83	Nil	Nil	Msb
Y5	12/8/19	NP	2005	2025							
	4/9/19	NP	1842	1902		New	17.1	84	Nil	Nil	Nil
	2/10/19	NP	2027	2047		1/4	12.8	83	Nil	Nil	Msb
Y6	12/8/19	NP	2030	2050							
	4/9/19	NP	1815	1835		New	17.1	84	Nil	Nil	Nil
	2/10/19	NP	2052	2112		1/4	12.8	83	Nil	Nil	Msb
Y7	12/8/19	NM	19:45	20:05							
	4/9/19	NM	2020	2040		1/3	11.3	91	Nil	Nil	Nil
	2/10/19	NM	1828	1848		1/4	17.3	65	Nil	Nil	Nil
Y8	12/8/19	LA	19:45	20:05							
	4/9/19	NM	1953	2013		1/3	14	92	Nil	Nil	RL
	2/10/19	NM	1853	1913		1/4	17.3	65	Nil	Nil	MSB
Y9	12/8/19	NM	1905	1925							
	4/9/19	NM	1928	1948		1/3	14	92	Nil	Nil	Nil
	2/10/19	NM	1915	1935		1/4	12.8	83	Nil	Nil	Nil

Transect	Date	Observer	Start	Finish	OBS type (< or > PB), Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
Y10	12/8/19	LA	19:05	19:25							
	4/9/19	NM	1903	1923		1/3	18.5	74	Nil	Nil	Nil
	2/10/19	NM	1940	2000		1/4	12.8	83	Nil	Nil	Nil
Y11	12/8/19	NM/LA	1830	1852							
	4/9/19	NM	1840	1900		1/3	18.5	74	Nil	Nil	Nil
	2/10/19	NM	2006	2026		1/4	12.1	88	Nil	Nil	Nil
Y12	12/8/19	BT	2036	2057	1; Hc@2045<&>pb @100w80n@330deg	Full	7.6	84	Nil	0/8	MSB
	4/9/19	NM	2053	2114		New	13.4	99	Nil	0/8	ML
	2/10/19	BT	2059	2120		New	12.8	83	Nil	0/8	ML
Y13	12/8/19	BT	2012	2032		Full	7.6	84	Nil	0/8	MLB
	4/9/19	BT	2026	2047		New	13.4	99	Nil	0/8	ML
	2/10/19	BT	2035	2055		New	12.8	83	Nil	0/8	MSB
Y14	12/8/19	BT	1947	2008		Full	8.9	81	Nil	0/8	MLB
	4/9/19	BT	2000	2022		New	13.5	93	Nil	0/8	ML
	2/10/19	BT	2011	2032		New	12.8	83	Nil	0/8	MSB
Y15	12/8/19	BT	1857	1919		Full	13.2	61	Nil	1/8	MLB
	4/9/19	BT	1906	1928		New	13.5	93	Nil	0/8	ML
	2/10/19	BT	1920	1942		New	13.8	76	Nil	0/8	MLB
Y16	12/8/19	BT	1836	1848	1; HCx5@1838<PB @30w70n@310deg	Full	13.2	61	Nil	1/8	MSB
	4/9/19	BT	1840	1900		New	18.3	77	Nil	0/8	MSB
	2/10/19	BT	1854	1915	1; HCx4 @1906>PB @100e80s@175deg	New	17.3	65	Nil	0/8	MLB
Y17	12/8/19	BT	1807	1828		Full	13.2	61	Nil	1/8	MSB
	4/9/19	BT	1815	1836		New	18.3	77	Nil	0/8	MSB
	2/10/19	BT	1831	1851		New	17.3	65	Nil	0/8	MLB
Y18	12/8/19	BT	1922	1943		Full	8.9	81	Nil	0/8	MLB
	4/9/19	BT	1933	1953		New	13.5	93	Nil	0/8	MSB
	2/10/19	BT	1946	2007		New	13.8	76	Nil	0/8	MSB
Y19	12/8/19	Nm/LA	1800	1820							
	4/9/19	NM	1810	1830		1/3	18.5	74	Nil	Nil	Nil
	2/10/19	NM	2030	2050		1/4	12.1	88	Nil	Nil	Nil

Transect	Date	Observer	Start	Finish	OBS type (< or > PB), Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
Y20	12/8/19	NP	1826	1846							MC
	4/9/19	NP	2042	2102		New	11.3	91	Nil	Nil	Msb
	2/10/19	NP	1915	1935		1/4	17.3	65	Nil	Nil	MC

Table A3: Yellow-bellied glider detections and weather conditions during three spotlight/call playback surveys conducted in late winter/spring 2019 in Ngambaa Nature Reserve. hc = heard call.

Transect	Date	Observer	Start	Finish	No. YbG ind's; observ type; Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
U1	13/8/19	NP	2148	2208							
	3/9/19	NM	2145	2205		1/4	8.4	97	Nil	Nil	Nil
	1/10/19	NM	2150	2210		New	11.6	98	Nil	Nil	Nil
U2	13/8/19	NM/LA	2155	2215							Nil
	3/9/19	LA	2145	2205		1/4	8.4	97	Nil	Nil	Nil
	1/10/19	LA	2150	2210		New	11.6	98	Nil	Nil	Nil
U3	13/8/19	NM	2155	2215							Nil
	3/9/19	NM	2115	2135		1/4	8.4	97	Nil	Nil	Nil
	1/10/19	NM	2125	2145		New	11.6	98	Nil	Nil	Nil
U4	13/8/19	LA	2120	2140							Nil
	3/9/19	LA	2115	2135		1/4	8.4	97	Nil	Nil	Nil
	1/10/19	LA	2125	2145		New	11.6	98	Nil	Nil	Nil
U5	13/8/19	NM	2045	2105							Nil
	3/9/19	Nm	2035	2055		1/4	11.6	85	Nil	Nil	Nil
	1/10/19	NM	2055	2115		New	12.4	98	Nil	Nil	Nil
U6	13/8/19	LA	2045	2105							Nil
	3/9/19	LA	20:35	20:55		1/4	11.6	85	Nil	Nil	Nil
	1/10/19	LA	2055	2115		New	12.4	98	Nil	Nil	Nil
U7	13/8/19	NP	2118	2138							
	3/9/19	NP	2125	2145		New	9.4	87	Nil	Nil	RL
	1/10/19	NP	1825	1845		1/4	17.3	74	Nil	Nil	Nil
U8	13/8/19	NP	2053	2113							
	3/9/19	NP	2102	2122		New	9.4	87	Nil	Nil	RL

Transect	Date	Observer	Start	Finish	No. YbG ind's; observ type; Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
	1/10/19	NP	1847	1907		1/4	17.3	74	Nil	Nil	Nil
U9	13/8/19	NP	2032	2052							
	3/9/19	NP	2038	2058		New	9.4	87	Nil	Nil	RL
	1/10/19	NP	1910	1930		1/4	17.3	74	Nil	Nil	Nil
U10	13/8/19	NP	2003	2025							
	3/9/19	NP	2012	2032		New	12	85	Nil	Nil	RL
	1/10/19	NP	1935	1955		1/4	13.3	86	Nil	Nil	Nil
U11	13/8/19	NP	1940	2000							
	3/9/19	NP	1950	2010		New	12	85	Nil	Nil	RL
	1/10/19	NP	2000	2020		1/4	13.3	86	Nil	Nil	Nil
U12	13/8/19	NP	1817	1937							
	3/9/19	NP	1925	1945		New	12	85	Nil	Nil	RL
	1/10/19	NP	2023	2043		1/4	13.3	86	Nil	Nil	Nil
U13	13/8/19	BT	1805	1825		Full	12	64	Nil	1/8	Still
	3/9/19	BT	2140	2202		New	9.2	92	Nil	0/8	Still
	1/10/19	NP	2201	2222		New	12.1	99	Nil	0/8	Still
U14	13/8/19	NP	1852	1912							
	3/9/19	NP	1858	1918		New	17.1	61	Nil	Nil	Nil
	1/10/19		2048	2108		1/4	12.5	98	Nil	Nil	Nil
U15	13/8/19	NP	1828	1848							
	3/9/19	NP	1834	1854		New	17.1	61	Nil	Nil	Nil
	1/10/19	NP	2110	2130		1/4	12.5	98	Nil	Nil	Nil
U16	13/8/19	NP	1805	1825							
	3/9/19	NP	1810	1839		New	17.1	61	Nil	Nil	Nil
	1/101/9	NP	2132	2152		1/4	12.5	98	Nil	Nil	Nil
U17	13/8/19	BT	1831	1852		Full	12	64	Nil	1/8	Still
	3/9/19	BT	2115	2136		New	9.2	92	Nil	0/8	Still
	1/10/19	BT	2141	2202		New	12.1	99	Nil	0/8	Still
U18	13/8/19	BT	1856	1916		Full	12	64	Nil	2/8	Still
	3/9/19	BT	2050	2111		New	10.6	86	Nil	0/8	Still
	1/10/19	BT	2116	2137		New	12.1	99	Nil	0/8	Still
U19	13/8/19	BT	1950	2012	1; Hc@2011>pb @50s100w@245deg	Full	8.9	79	Nil	4/8	Still

Transect	Date	Observer	Start	Finish	No. YbG ind's; observ type; Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
	3/9/19	BT	1953	2014		New	13.2	74	Nil	0/8	MSB
	1/10/19	BT	2020	2041		New	12.1	95	Nil	0/8	ML
U20	13/8/19	BT	2021	2042		Full	8.9	79	Nil	4/8	Still
	3/9/19	BT	1927	1947		New	13.2	74	Nil	0/8	MSB
	1/10/19	BT	1955	2015		New	13.3	86	Nil	0/8	ML
U21	13/8/19	NM	1930	1950							Nil
	3/9/19	NM	1920	1940	1; hc @150deg, 100W, 45S >PB 1935	1/4	11.6	85	Nil	Nil	Nil
	1/19/19	Nm	1940	8:00	1; Hc@30deg, 80m, 0malong, < and > pb	New	12.4	98	Nil	Nil	Nil
U22	13/8/19	LA	1930	1950					Nil	Nil	Nil
	3/9/19	LA	1920	1940		1/4	11.6	85	Nil	Nil	Nil
	1/10/19	La	19.35	19.55		New	12.4	98	Nil	Nil	Nil
U23	13/8/19	LA	1900	1920							Nil
	3/9/19	NM	1850	1910		1/4	16.9	63	Nil	Nil	Nil
	1/10/19	NM	1900	1920		Full	16.3	80	Nil	Nil	Nil
U24	13/8/19	NM	1900	1920							Nil
	3/9/19	LA	1850	1910		1/4	16.9	63	Nil	Nil	Nil
	1/10/19	LA	1900	1920		Full	16.3	80	Nil	Nil	Nil
U25	13/8/19	LA	2000	2020							Nil
	3/9/19	LA	19:55	20:15	Nil	1/4	11.6	85	Nil	Nil	Nil
	1/10/19	LA	2015	2035		New	12.4	98	Nil	Nil	Nil
U26	13/8/19	NM	2000	2020							Nil
	3/9/19	Nm	1955	2015		1/4	16.9	63	Nil	Nil	Nil
	1/10/19	NM	2015	2035		New	12.4	98	Nil	Nil	Nil
U27	13/8/19	NM	1830	1850							Nil
	3/9/19	LA	1810	1830		1/4	16.9	63	Nil	Nil	Nil
	1/10/19	LA	1830	1850		Full	16.3	80	Nil	Nil	Nil
U28	13/8/19	LA	1830	1850							Nil
	3/9/19	NM	1810	1830		1/4	16.9	63	Nil	Nil	Nil
	1/10/19	NM	1830	1850		Full	16.3	80	Nil	Nil	Nil
U29	13/8/19	BT	2054	2115		Full	7.2	88	Nil	7/8	Still
	3/9/19	BT	1809	1830		New	16.9	63	Nil	0/8	Still
	1/10/19	BT	1831	1852		New	15.1	83	Nil	0/8	ML

Transect	Date	Observer	Start	Finish	No. YbG ind's; observ type; Time; Bearing; Distance	Moon	Temp	Humidity	Rain	Cloud	Wind
U30	13/8/19	BT	2121	2142		Full	7.2	88	Nil	7/8	Still
	3/9/19	BT	1834	1855		New	16.9	63	Nil	0/8	Still
	1/10/19	BT	1856	1917		New	15.1	83	Nil	0/8	Nil
U31	13/8/19	BT	2148	2209		Full	7.2	88	Nil	7/8	Still
	3/9/19	BT	1859	1920		New	13.2	74	Nil	0/8	ML
	1/10/19	BT	1926	1946		New	13.3	86	Nil	0/8	ML
U32	13/8/19	BT	1924	1944		Full	8.9	79	Nil	4/8	Still
	3/9/19	BT	2022	2043		New	10.6	86	Nil	0/8	ML
	1/10/19	BT	2047	2108		New	12.1	95	Nil	0/8	ML

Appendix B – Song meter deployment data

Table B1: Song meter deployment data for 2018/19 monitoring period.

Site No.	Forest Block	Easting	Northing	Deploy Date	Check Date	Status	Battery (volts)	SD	Time/ date	Collect Date	Status	Total Days Active	Notes
SM1	S	497127	6609463	15/8/19	3/10/19	Active	4.1	26/64	OK	13/1/20	active	151	
SM2	S	497643	6609308	15/8/19	3/10/19	Active	4.1	26/64	OK	13/1/20	active	151	
SM3	S	496914	6609169	15/8/19	3/10/19	Active	4.1	26/64	OK	13/1/20	inactive	130	Ants
SM4	S	495500	6606980	14/8/19	2/10/19	Active	3.9	25/64	OK	13/1/20	full sd	112	
SM5	S	496730	6607147	14/8/19	2/10/19	Active	4.1	25/64	OK	13/1/20	active	152	
SM6	NW	495517	6607987	14/8/19	2/10/19	Active	4	25/64	OK	13/1/20	active	151	
SM7	NW	496204	6608540	14/8/19	2/10/19	Active	4.1	25/64	OK	15/1/20	active	153	
SM8	NW	496890	6610107	14/8/19	3/10/19	Active	4	26/64	OK	13/1/20	active	151	
SM9	NW	495333	6611184	14/8/19	2/10/19	Active	3.8	Dirty	OK	13/1/20	full sd	143	
SM10	NW	496345	6610236	14/8/19	3/10/19	Active	4.1	26/64	OK	13/1/20	active	152	
SM11	NW	495445	6610199	14/8/19	2/10/19	Active	4.3	25/64	OK	13/1/20	active	152	
SM12	S	497064	6608479	14/8/19	3/10/19	Active	burnt	ok	OK	13/1/20	active	126	New unit (19 replaced 4); Moved after fire; SD card ok; unit out for 26 days
SM13	NE	498950	6612723	13/8/19	1/10/19	Active	4.4	26/64	OK	13/1/20	active	152	
SM14	NE	498181	6611637	13/8/19	1/10/19	Active	4.1	25/31,0/31	OK	13/1/20	inactive	142	
SM15	NE	499184	6611800	13/8/19	1/10/19	Active	4.4	25/64	OK	13/1/20	active	152	
SM16	NE	500154	6611271	13/8/19	1/10/19	Active	4.3	25/32	OK	13/1/20	active	152	
SM17	NE	500154	6612164	13/8/19	1/10/19	Active	4.1	24/32	OK	13/1/20	active	152	
SM18	**NE**	500653	6611684	13/8/19	1/10/19	Active	4.1	20/31	OK	13/1/20	active	152	

Appendix D Microbat roost

Warrell Creek to Nambucca Heads

Microchiropteran Bat Monitoring Annual Report, Year Two - Operational Phase

Transport for New South Wales | August 2020

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Document Review

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Project team:

Ms. N. Makings (reporting, field survey)
Dr. D. Rohweder (project management, review)
Mr. L. Andrews (field survey)

Report prepared for:

Transport for NSW

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 02 6628 3559 | E david@sandpipereco.com.au

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1. Introduction

In 2015, Transport for NSW (TfNSW) (previously Roads and Maritime Services), in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced upgrading the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages:

- Stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and
- Stage 2b - 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala, yellow-bellied glider, giant barred frog, green-thighed frog ponds, microchiropteran bats (microbats), underpasses, vegetated median, roadkill, exclusion fence, and threatened flora. Sandpiper Ecological Surveys (Sandpiper) has been contracted by TfNSW to deliver the WC2NH operational ecological and water quality monitoring program.

1.1 Background

During pre-construction microbat surveys, three species of microbat were detected roosting in existing bridge and culvert structures associated with the WC2NH project, including two threatened species listed under the NSW *Biodiversity Conservation Act 2016* (BC Act) (Lewis 2014). These were southern myotis (*Myotis macropus*) and little bent-wing bat (*Miniopterus australis*), both listed as *vulnerable*. No species listed by the federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) were identified during pre-construction surveys.

The Minister's Condition of Approval B31(b)(iv) in the project Ecological Monitoring Program (EMP) states; "*A microbat management strategy must be developed in the case that microbats or evidence of roosting are identified during pre-construction surveys. The strategy shall detail measures to avoid, minimise and mitigate impacts to these species and identified roost sites, including short and long-term management measures*". Pursuant to pre-construction survey results, a microbat management strategy (MMS) was developed in October 2014 (Lewis 2014).

Section 3.0 of the MMS outlined management strategies to be adopted as part of the upgrade. Part A of section 3.0 required the installation of microbat boxes as supplementary roost sites across the project and part G1 outlined the monitoring requirements associated with the installation of microbat boxes. Monitoring of bat boxes was to commence 6 months after their installation, followed by quarterly inspections for 2 years before addressing corrective actions. Monitoring of the boxes would continue until Year 6 (i.e. 4 surveys per year for 5 years) with the boxes inspected to determine species presence/absence, an estimate or count of numbers of micro bats and breeding activity. The following report details the methods and results of year two operational phase microbat box monitoring.

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Upper Warrell Creek in the south to Nambucca Heads in the north (Figures 1-3). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest.

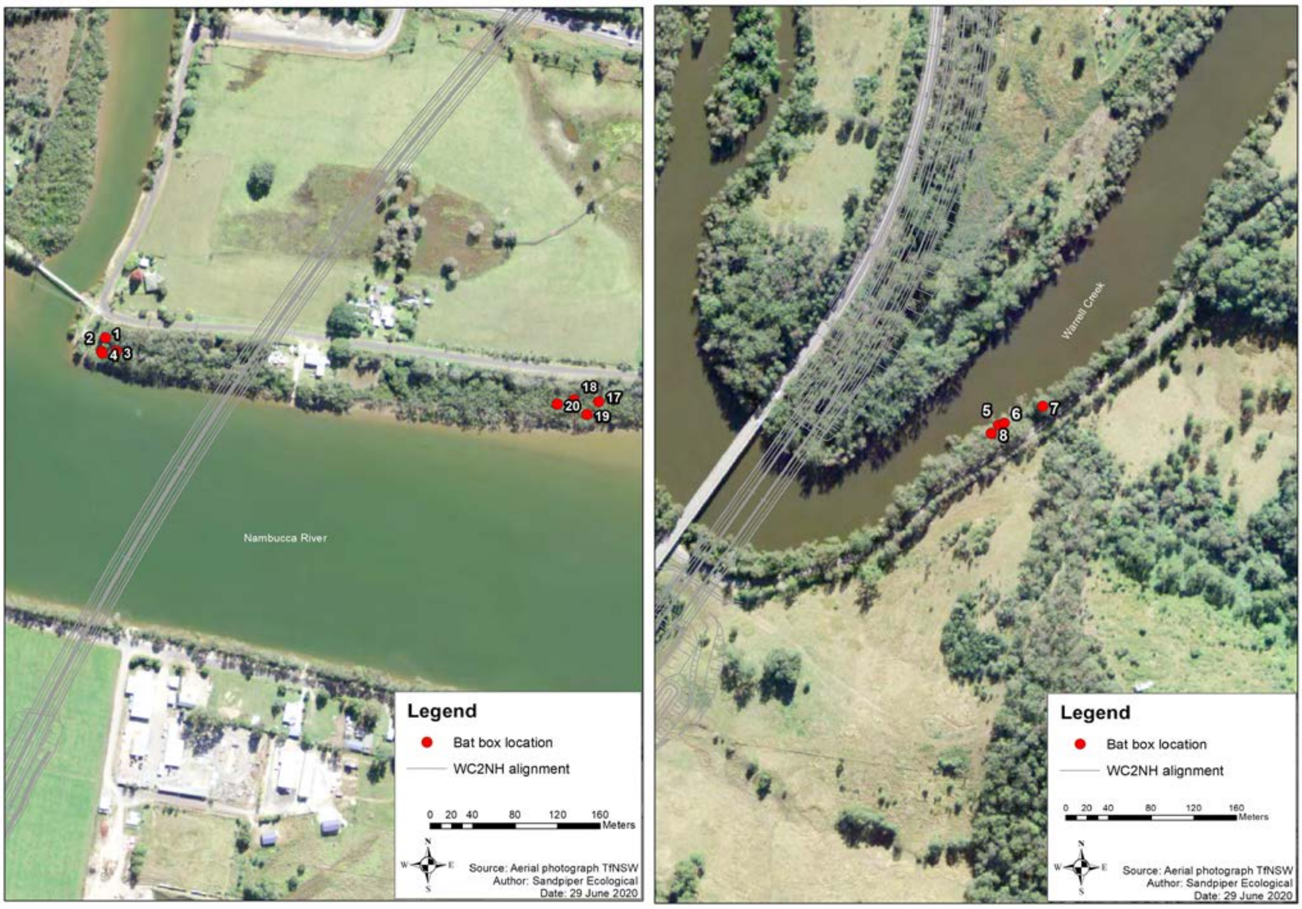

Figure 1: Location of microbat boxes installed on the WC2NH alignment.

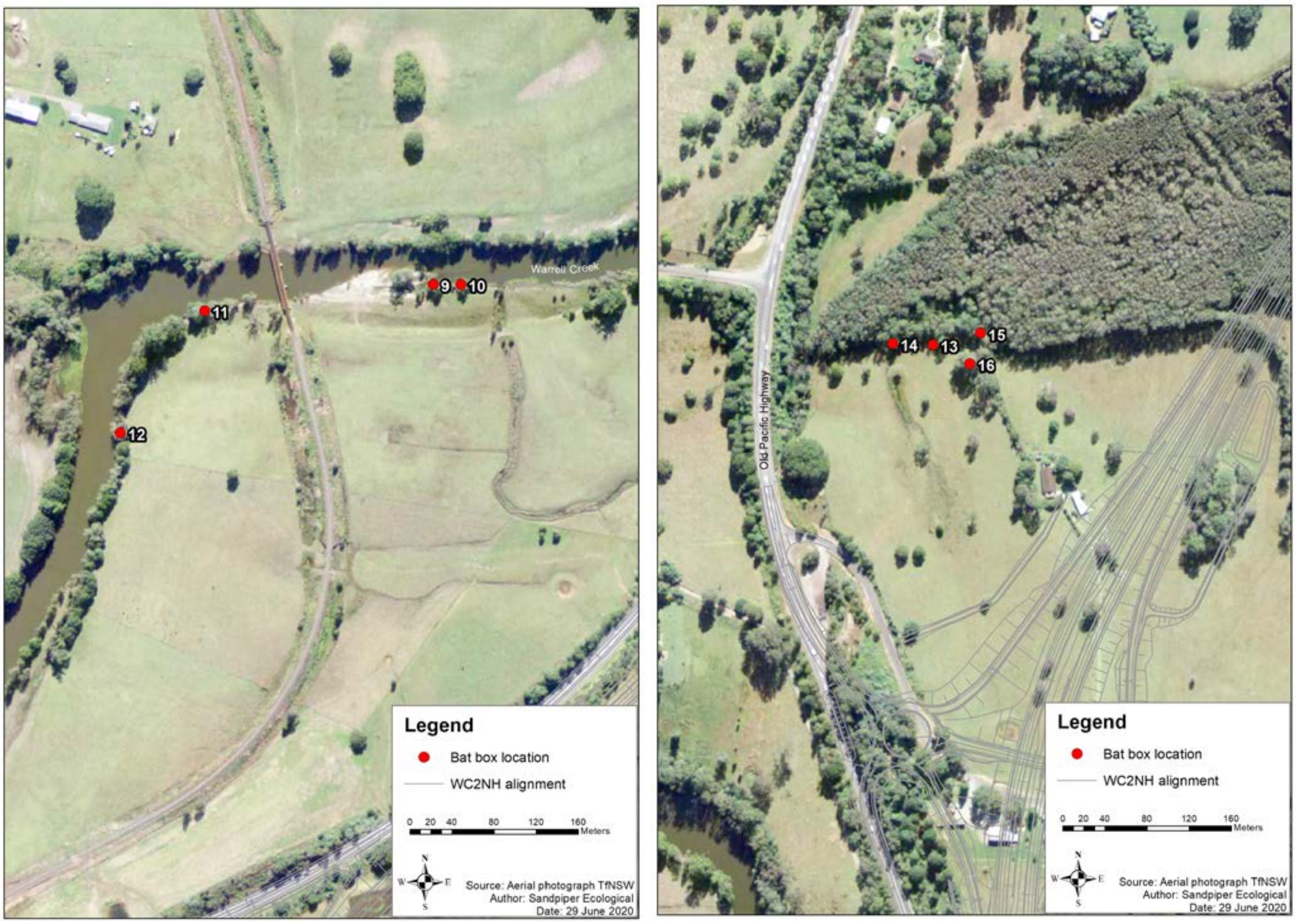

Figure 2: Location of microbat boxes installed on the WC2NH alignment.

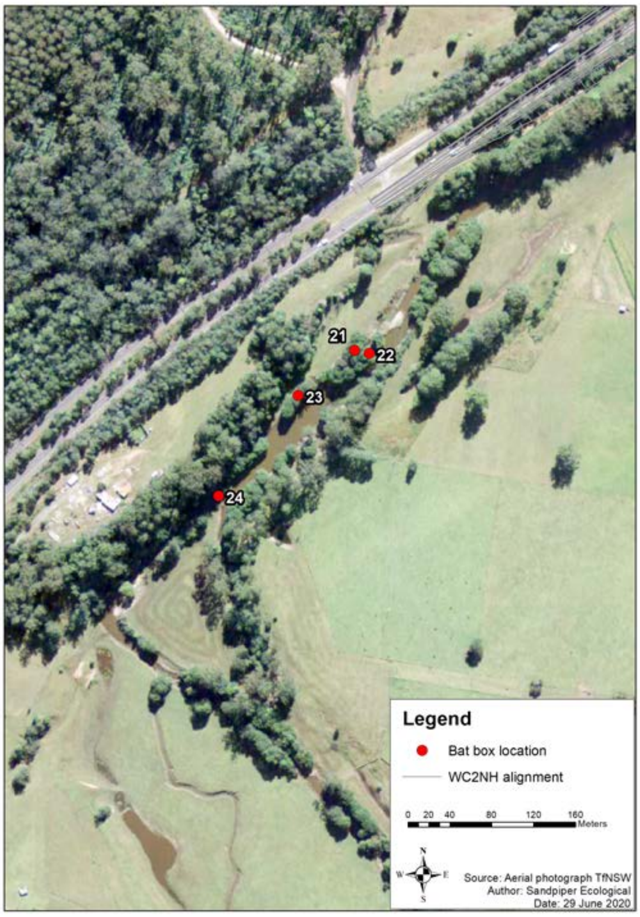

Figure 3: Location of microbat boxes installed on the WC2NH alignment.

2. Methodology

2.1 Timing and weather conditions

Year two operational phase seasonal surveys were conducted on 21 October 2019 (spring), 25 February 2020 (summer), 5 June 2020 (autumn), and 19 July 2020 (winter). The autumn sample event was not conducted until early June due to a programming error. Rainfall data was collected from Bellwood (Nambucca Heads) weather station and maximum temperature, wind and cloud cover were collected from South West Rocks (Smoky Cape lighthouse). All surveys were conducted during day light hours.

2.2 Microbat box survey

Surveys were conducted by two ecologists using a combination of a hand-held 200-lumen spotlight, binoculars, a ladder, climbing equipment, and where necessary, a GoPro camera attached to a 10m extendable pole. Microbats were identified to species level where possible. To avoid disturbing the roost, microbats were not removed from boxes for identification. Data were recorded on a standardised proforma including date, box number, location, species present, evidence of use, such as scats or wear, evidence of breeding and box condition. Scat deposits in masonry boxes were removed during each sample allowing determination of microbat use at the next sample. Counts are considered minimums due to the roosting habit of microbats, which makes precise counts difficult.

2.3 Temporal comparison

Results from year two operational phase microbat monitoring were compared to year one operational phase and construction phase survey results. Year one operational phase surveys were carried out in spring, summer, autumn and winter 2018/2019, and construction phase surveys were carried out in summer, autumn and spring of 2015, all seasons in 2016 and 2017, and summer and autumn of 2018 (GeoLink 2018). These results are presented in section 3.2 of this report.

3. Results

3.1 Weather conditions

Weather variables for each of the seasonal survey samples are presented in Table 1 below. All surveys were conducted in warm temperatures with variable cloud cover.

Table 1: Daily weather conditions for each of the seasonal microbat box survey events. Rainfall data is from the Bellwood (Nambucca Heads) weather station and max temperature, wind and cloud cover are collected from South West Rocks (Smoky Cape lighthouse). Wind and cloud cover were recorded on the survey day at 9am.

Date	Survey	Max temperature (°C)	Rainfall (mm)	Wind (km/hr)	Cloud cover
21/10/2019	Spring	24.8	0	4	3/8
25/2/2020	Summer	29.0	20.0	11	7/8
05/06/2020	Autumn	20.1	0	11	3/8
19/7/2020	Winter	23.5	0	22	0/8

3.2 Microbat box survey results

The number of microbats detected varied between samples (Figure 4). Four individuals were recorded in spring, 20 in summer, 10 in autumn and there were no detections in winter (Figure 4). A total of 34 microbats were recorded roosting in microbat boxes over the four sample events. Species detected included the vulnerable southern myotis *Myotis macropus* (n= 7), long-eared bats (n= 26) (*Nyctophilus* spp.) and a probable chocolate wattled bat *Chalinolobus morio* (n= 1) (Figure 5).

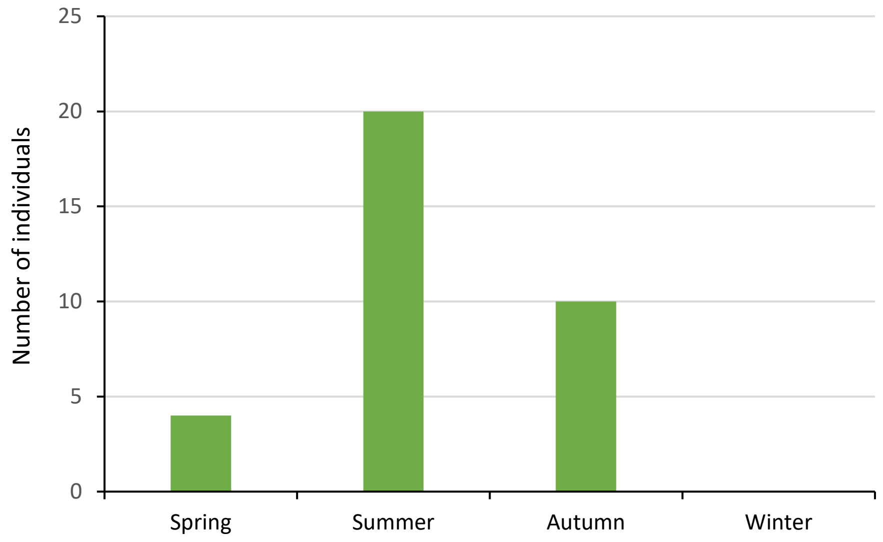

Figure 4: Number of microbats detected roosting in boxes over four sample periods during year two operational phase monitoring.

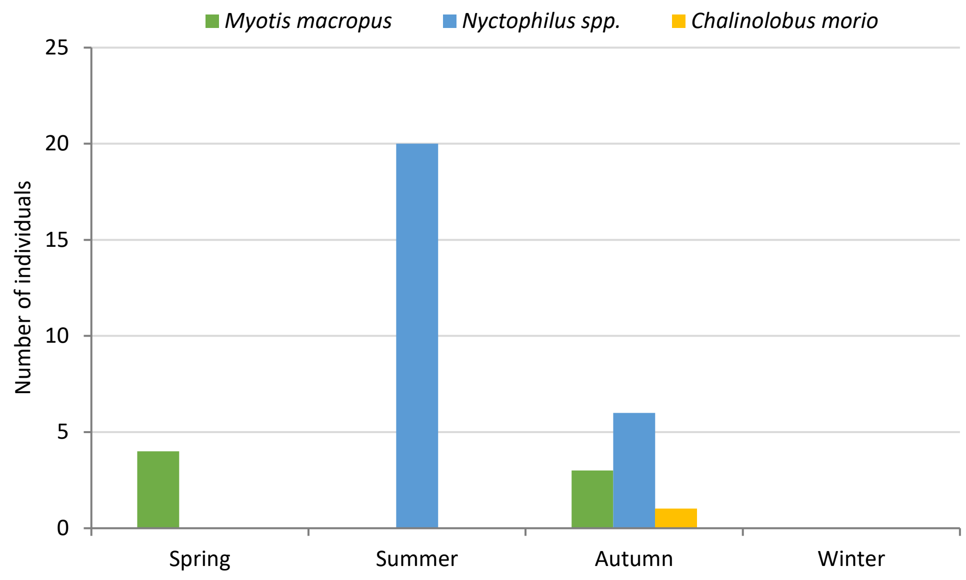

Figure 5: Number of individuals and species detected during each quarterly sample.

In total, 10 individual boxes were either occupied or showed evidence of use (Figure 6). No evidence of breeding was recorded during any of the samples. Box 19 installed on Nambucca River was occupied by southern myotis in autumn. It also had significant scat deposits in the other three surveys, suggesting regular use. Box 4 and 10 were occupied by *Nyctophilus* spp. on two occasions, and box 12 by southern myotis on two occasions. Box 7 was replaced during the winter survey, and the remaining boxes were in good condition and did not require maintenance or replacement.

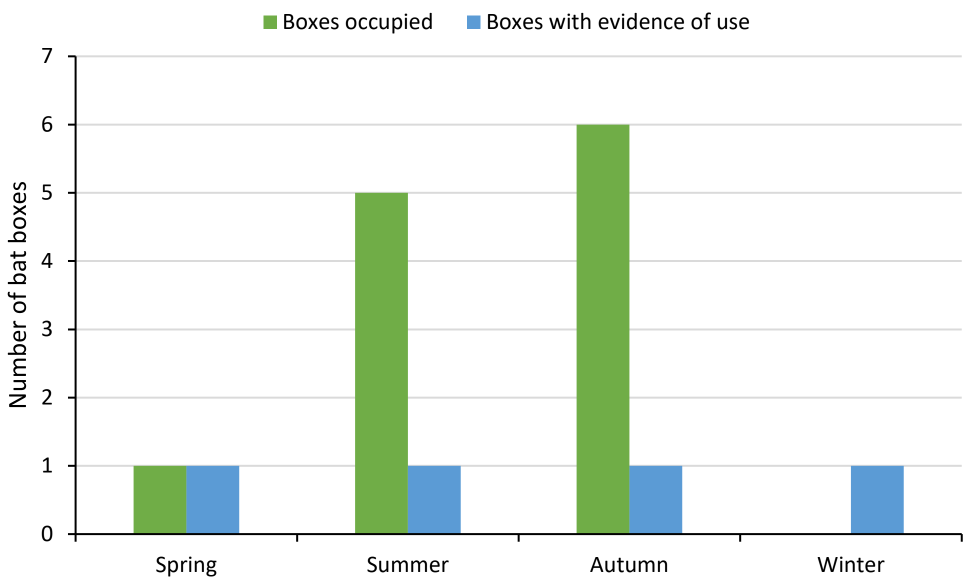

Figure 6: Number of boxes occupied and showing evidence of use over the four samples.

3.2 Temporal comparison

The only survey year with fewer individuals than 2019/20 (n = 34) was 2015, when two individuals were recorded from three surveys (Figure 7). All other construction phase surveys (2016-2018) and the 2018/19 operational phase survey resulted in a greater number of individuals (Figure 7). The total number of boxes occupied or showing evidence of use was greater during 2019/20 than 2015 (n = 7), the same as 2016 (n = 10), and less than 2017 (n = 22), 2018 (n = 13) and 2018/19 (n = 14) (Figure 7).

Species diversity ranged from one to four across all monitoring years, with the lowest diversity (1 species) recorded in 2015, and the highest (4 species) in 2017 (Figure 8).

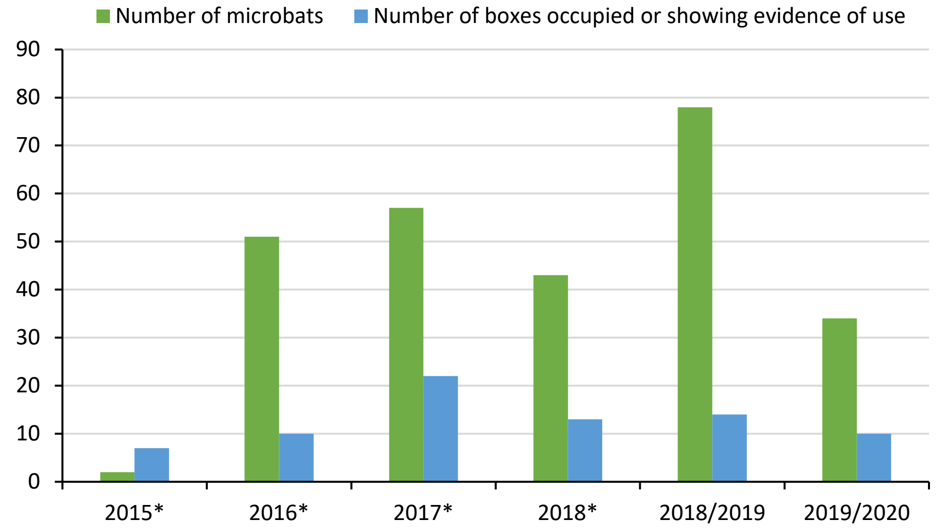

Figure 7: Total number of microbats detected during each monitoring year and total number of boxes occupied or showing evidence of use. *= construction phase monitoring.

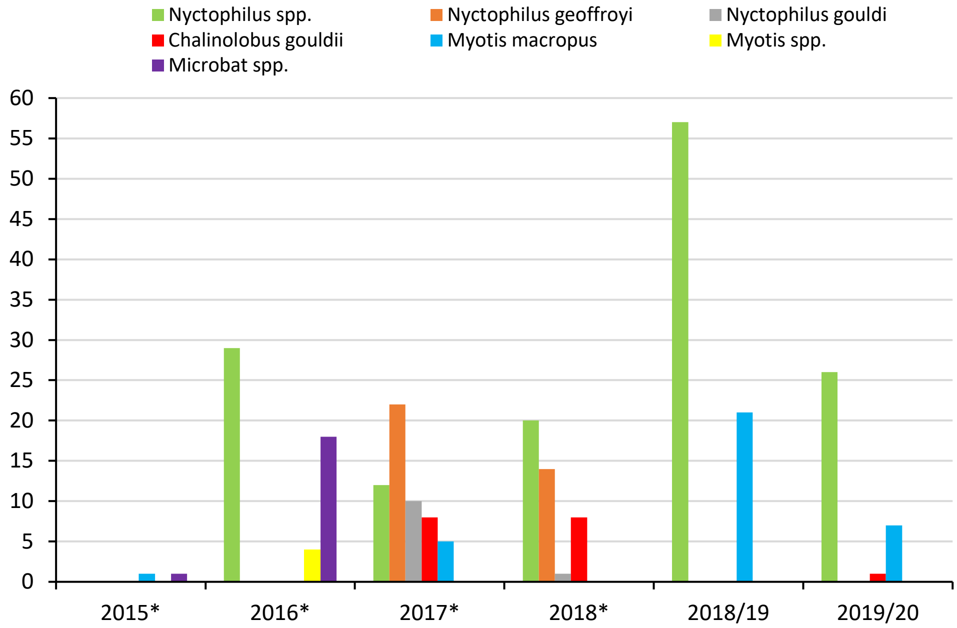

Figure 8: Number of individuals of each species/group across all monitoring periods. * = construction phase monitoring.

5. Discussion

Year two operational phase monitoring represents the sixth and final year of sampling. Results show that microbats are continuing to use the supplementary roost boxes, including the vulnerable southern myotis. Monitoring from 2015 to 2019 revealed an annual temporal increase in the number of bats. However, this trend did not continue in the 2019/2020 sample period when abundance declined. A common finding of bat box programs is that the longer the boxes are installed the more likely they are to be detected and used by microbats. Bender and Irvine (2001) found that bats usually need several years before they accept boxes. However, several other factors may influence usage including the success of the breeding year, bat influx from other areas/groups and natural variability in roost use.

Microchiropteran bat species exhibit a spectrum of roost-switching behaviour, from roost lability (daily changes), to high levels of fidelity (Rhodes 2007). Southern myotis for example has been found to show high fidelity where conditions are optimal (Campbell 2009), whereas *N. geoffroyi* shift roost sites regularly within a defined area (Churchill 2008). Temporal roost variation may be in response to maternity, over wintering and other seasonal factors or environmental cues (Lewis 2014). Specifically, for this monitoring period, the recent drought, followed by the wet summer and autumn may have influenced roost selection and overall abundance. One-off seasonal samples and use of a small number of boxes increase the likelihood that roost lability will have a negative effect on cumulative counts, as bats may simply be absent during the one day sample period. Evidence of this was obtained in June 2020 when bats were observed (opportunistically) in two boxes that were not occupied one month later in July 2020.

Species diversity varied slightly across all monitoring years. No bent-wing bats (*Miniopterus* spp.) were detected during construction or operational monitoring. Bent-wing bats are generally considered cave-dwelling bats (Churchill 2008) and, in the authors knowledge, have not been recorded roosting in nest boxes mounted in trees. *Miniopterus* spp. have been recorded using microbat boxes mounted in culverts and under bridges on sections one and two of the Woolgoolga to Ballina Pacific Highway Upgrade (Sandpiper 2018). This observation is more consistent with the cave roosting behaviour of the species. Given the known roosting preference of bent-wing bats the lack of uptake of tree-mounted boxes is not unexpected.

It is possible that additional species were roosting in boxes. Long-eared bats (*Nyctophilus* spp.) are difficult to identify to species level without examining an individual in-hand. However, removing individuals from boxes for identification typically causes other individuals to leave the roost and defeats the intent that boxes provide secure roosting habitat. There are three species of long-eared bat that occur on the mid-north coast: *N. gouldi*, *N. bifax* and *N. geoffroyi* (Churchill 2008). Of these, *N. gouldi* is the most common species in coastal northern NSW, and is readily recorded roosting in bat boxes and using boxes as maternity sites (Smith & Agnew 2002). Whilst most of the *Nyctophilus* spp. recorded would be *N. gouldii* occurrence of other *Nyctophilus* species can not be discounted.

5.1 Effectiveness of bat boxes as a mitigation measure

Consistent use of microbat boxes over the six year monitoring period, including regular use by southern myotis, provides further evidence on the efficacy of bat boxes. Success of the program was dependent on placing boxes on large waterways, which represent suitable habitat for southern myotis. This approach is superior to placing boxes on smaller drainage lines or placing boxes in forested areas where bentwing bats are the target species. Indeed, the use of tree-mounted bat boxes to provide alternate roost habitat for bent-wing bats is questionable.

Surveys of newly constructed structures (drains, bridges, culverts) on completed sections of the Pacific Highway have shown a robust uptake of roost sites by bent-wing bats (Sandpiper 2016, 2017, 2018, 2019). Indeed, bent-wing bats have been detected roosting in several culverts within the WC2NH and W2B upgrade sections (Sandpiper unpublished data). Southern myotis have also utilised boxes installed within culverts and beneath bridges in the Nambucca Heads to Urunga and Halfway Creek to Glenugie upgrade sections. Monitoring results from various upgrades supports installation of bat boxes beneath large bridges and in culverts in preference to adjacent forest. Even as a ‘temporary’ offset measure the value of installing boxes in adjacent forest is questionable, with the exception of boxes on large watercourses for large-footed myotis. Whilst mitigation of impacts on important bat roosts should be assessed on a case-by-case basis the general emphasis should be on culverts and bridges rather than adjacent forest.

6. Recommendations

Recommendation No.	Recommendation	TfNSW response
1	The microbat monitoring component of the WC2NH Ecological Monitoring Program has been completed and additional operational phase bat box monitoring is not warranted.	Noted and agree
2	Temporary installation of bat boxes to offset the loss of culvert or bridge roosts should be assessed on a case-by-case basis and consider the species effected, known use of bat boxes, roost fidelity, and proximity of alternate roosting habitat.	Noted for future projects
3	Installation of bat boxes in forested habitat should be avoided unless targeted at a specific species known to utilise such boxes e.g. myotis along suitable waterways.	Noted for future projects.

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Smith, G. C. and Agnew, G. (2002). *Ecological Management and Restoration.* Vol. 3, Issue 1. pp. 37-46. The value of 'bat boxes' for attracting hollow-dependent fauna to farm forestry plantations in southeast Queensland.

Appendix A – Survey data

Table A1: Survey data from year one operational phase microbat box monitoring at WC2NH, 2019/20. FtG = Feathertail glider.

Bat Box ID	Spring	Summer	Autumn	Winter
1				
2				
3				
4		*Nyctophilus* spp. x 13	*Nyctophilus* spp. x 1	
5		*Nyctophilus* spp. x 1		
6				
7			Microbat scat	
8				
9				
10		*Nyctophilus* spp. x 4	*Nyctophilus* spp. x 1 (prob gouldii)	
11				
12	*Myotis macropus* x 4		*Myotis macropus* (prob)	
13				
14				
15				
16			*Chalinolobus morio* (Chocolate wattle bat)	
17		*Nyctophilus* spp. x 1		
18				
19	Significant scat deposits	Significant scat deposits	*Myotis macropus* x2	Significant scat deposits
20		*Nyctophilus* spp. x 1		
21	Old FtG nest		*Nyctophilus* spp. x 4	
22				
23				
24				

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Customer feedback
Roads and Maritime
Locked Bag 928,
North Sydney NSW 2059

August 2020

Appendix E Threatened Flora

Warrell Creek to Nambucca Heads Upgrade

Operational Phase Monitoring of Threatened Flora Translocations, In-situ Threatened Plants and Slender Marsdenia and Woolls' Tylophora Habitat Condition

Annual report Year 3 (2020) Ver. 3

Transport for NSW February 2021

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Project team:

Dr A. Benwell (project management, survey reporting)

Mr J. Benwell (field survey, reporting)

Report prepared for:

Transport for NSW

ABN:35 111 003 019

PO Box 641
MULLUMBIMBY NSW 2482
P 0487050005 | andrewbenwell@bigpond.com

Warrell Creek to Nambucca Heads Upgrade

Operational Phase Monitoring of Threatened Flora Translocations, In-situ Threatened Plants and Slender Marsdenia and Woolls' Tylophora Habitat Condition – Year 3 (2020) Ver.3

Prepared for:

Sandpiper Ecological Surveys

PO Box 401, Alstonville 2477

Prepared by:

ECOS Environmental Pty Ltd

PO Box 641 Mullumbimby, NSW 2482

ph 0487050005; email: andrewbenwell@bigpond.com

Ver. 3

23/4/2021

Contents

Executive Summary

This report describes the results of monitoring (i) threatened flora translocations, (ii) in situ threatened flora and (iii) Slender Marsdenia and Woolls' Tylophora habitat condition, for the Warrell Creek to Nambucca Heads (WC2NH) upgrade of the Pacific Highway. Five threatened and one rare plants species impacted by the WC2NH project were included in the monitoring program: -

- Slender Marsdenia (*Marsdenia longiloba*) (listed as endangered under the *Biodiversity Conservation (BC) Act 2016* and vulnerable under the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*)
- Woolls' Tylophora (Tylophora woollsii) (listed as endangered under the BC Act and the EPBC Act)
- Rusty Plum (*Niemeyera whitei*) (listed as vulnerable under the BC Act)
- Spider Orchid (*Dendrobium melaleucaphilum*) (listed as endangered under the BC Act)
- Floyds Grass (*Alexfloydia repens*) (listed as endangered under the BC Act)
- Koala Bells (*Artanema fimbriatum*) (nationally rare and proposed for State listing).

Monitoring was implemented according to the project threatened flora management plan (RMS 2016 - updated).

To date, three years of construction phase monitoring and two years of operational phase monitoring have been carried out. The third year of operational phase monitoring was conducted by Ecos Environmental in November 2020, making a total of six years since salvage translocations were implemented prior to the start of construction.

Translocated threatened flora

Six years after salvage translocations were implemented, high survival rates were recorded for Slender Marsdenia (68%), Woolls' Tylophora (67%), Spider Orchid (100%), Rusty Plum (86%) and Floyds Grass (well in excess of the donor population). Koala Bells had died out, although this reflects the species' short life cycle and need for open, recently disturbed habitat.

The stem growth response of 164 transplanted Slender Marsdenia was highly variable and included a large percentage of plants that exhibited oscillating stem regrowth. A detailed analysis of stem growth patterns was carried out. Monitoring increased information on the autecology of this species.

In situ threatened flora

The survival rate of in-situ threatened species at the end of Year 6 (Nov 2020) was 100% for Spider Orchid, and Rusty Plum. After declining from 40% in 2018 to <1% in 2019, Maundia recovered to about 20% in 2020 and is likely to regain all its original area as regrowth continues following the end of the 2019 drought. Slender Marsdenia, survival rate was roughly stable although there was evidence that stems had died back and reshot, from the same point or close-by from tuberous roots.

Threatened flora habitat condition

The monitoring plot data found no evidence of declines in Woolls' Tylophora and Slender Marsdenia habitat condition along the edge of clearing next to the new highway.

1 Introduction

The Warrell Creek to Nambucca Heads (WC2NH) project is 19.6 km section of the Pacific Highway upgrade between Warrell Creek and Nambucca Heads on the NSW Mid North Coast (Figure 1). Construction of the WC2NH project began in February 2015 and the new section of highway was opened to traffic (i.e. operational) in July 2018.

A Threatened Flora Management Plan (TFMP) was prepared for threatened plant species impacted by the project (RMS 2016) which included a monitoring program aimed at recording and assessing three components of threatened flora management: (i) threatened flora translocation (ii) in-situ threatened flora populations and (iii) Slender Marsdenia and Woolls' Tylophora habitat condition, to be monitored during construction and operation of the project.

Previous translocation results were recorded for three years during the construction phase (Year 1 - Ecos Environmental 2016a, Year 2 - Ecos Environmental 2017, Year 3 - Ecos Environmental 2018a) and two years during operation (Ecos Environmental 2018b, Ecos Environmental 2019. In November 2020, Ecos Environmental carried out the third year of operational phase monitoring for the present report. Operational phase monitoring is being conducted for four years.

Results are described and analysed in the following sections of this report:

- Section 2: Threatened Flora Translocations
- Section 3: In-situ Threatened Flora Populations
- Section 4: Slender Marsdenia and Woolls' Tylophora Habitat Condition.

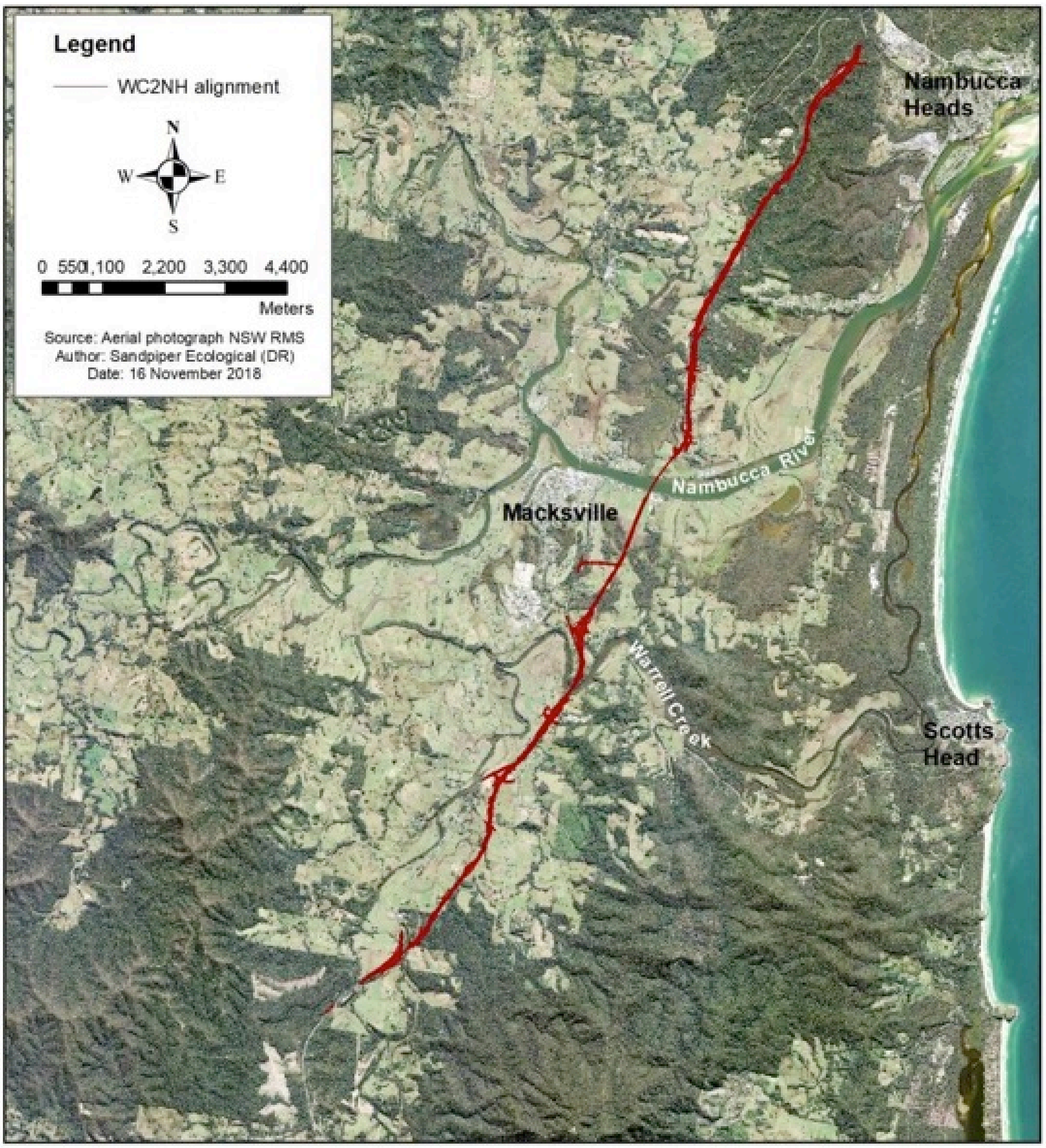

Figure 1: Location of the WC2NH alignment.

2 Threatened Flora Translocation

2.1 Aim and Species Translocated

The translocation component of the TFMP (RMS 2016) was based on guidelines for planning threatened flora translocations by the Australian Network for Plant Conservation (ANPC 2004).

The general aim of translocation was to salvage individuals of threatened species impacted by construction and re-establish them in suitable habitat adjacent to the highway corridor, near the impact sites. Some propagation was also carried out to provide replacements for potential losses during salvage transplanting. The purpose of translocating threatened flora is to maintain population size and avoid loss of numbers occurring in local threatened flora populations during construction. Translocation of each species involved three main actions:

- Salvage transplanting of impacted individuals and re-establishment at receival sites containing habitat closely approximating the impact/donor sites;
- Propagation and introduction of additional individuals as back-up in case of losses; and
- Follow-up maintenance to promote successful establishment and ensure good habitat condition.

Five threatened and one nationally rare plant species were translocated on the WC2NH project:

- Slender Marsdenia (*Marsdenia longiloba*) (listed as endangered under the *BC Act* and vulnerable under the *EPBC Act*)
- Woolls' Tylophora (*Tylophora woollsii*) (listed as endangered under the *BC Act* and the *EPBC Act*)
- Rusty Plum (*Niemeyera whitei*) (listed as vulnerable under the *BC Act*)
- Spider Orchid (*Dendrobium melaleucaphilum*) (listed as endangered under the *BC Act*)
- Floyds Grass (*Alexfloydia repens*) (listed as endangered under the *BC Act*)
- Koala Bells (*Artanema fimbriatum*) (nationally rare and has been proposed for State listing).

2.2 Methods

2.2.1 Receival Sites

Nine receival sites were selected for the species being translocated. All were located in the road reserve (i.e. on RMS property), seven where the highway corridor crosses Nambucca State Forest, one adjacent the new highway bridge at Warrell Creek, and one at the southern end of the upgrade (Table 1 and Figure 2). For further details on receival site selection and a description of each site, refer to any of the construction phase monitoring reports (Ecos Environmental 2016a, 2017 and 2018a).

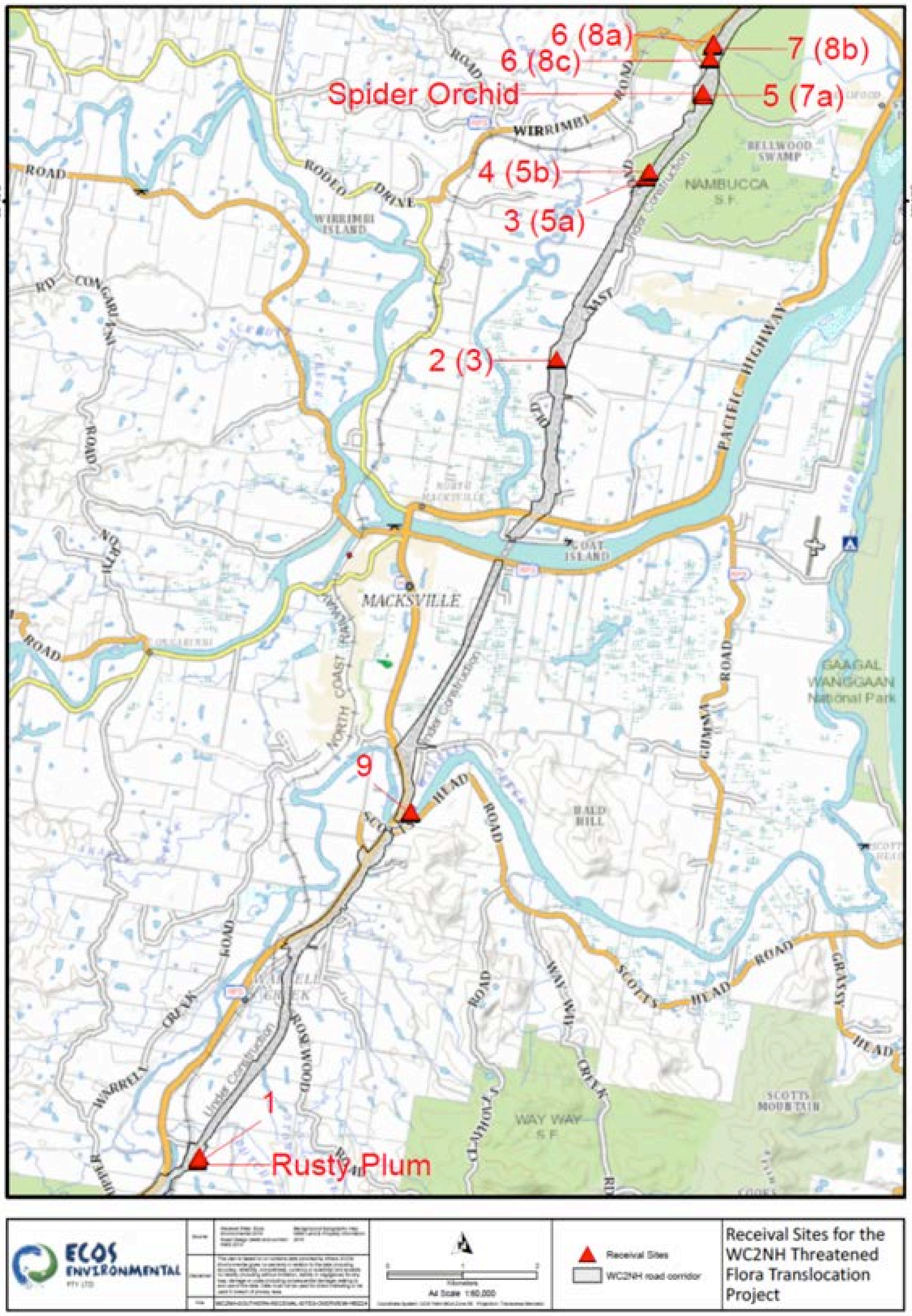

Figure 2: Location of threatened flora translocation receival sites for the WC2NH section of the Pacific Highway upgrade.

Table 1: Translocation receival sites and species translocated. The bracketed identifier is the original number used during selection of the receival sites. A question mark after Woolls' Tylophora indicates that identification is not confirmed (i.e. based on leaves, not flowers).

Receival Site	Species
1 (Cockburns Lane)	Slender Marsdenia, Rusty Plum
2 (3)	Slender Marsdenia
3 (5a)	Slender Marsdenia
4 (5b)	Slender Marsdenia (and Large-flowered Marsdenia)
5 (7a)	Slender Marsdenia, Spider Orchid, Rusty Plum direct seeding, Slender Marsdenia population enhancement.
6 (8a)	Slender Marsdenia, Woolls' Tylophora(?)
7 (8b)	Koala Bells
8 (8c)	Slender Marsdenia
9 (Warrell Creek)	Floyds Grass, Koala Bells population enhancement

2.2.2 Direct Transplanting

Threatened species were translocated from the construction footprint using the direct transplanting method. Direct transplanting involves plant excavation, transport to the receival site and replanting in a single operation, as expeditiously as possible. Trees and saplings are usually dug out with an excavator and small plants with hand tools. The general approach is to excavate each plant with a reduced but partly intact shoot system and root ball, so the plant continues to function physiologically and can regenerate new shoots, leaves and roots. The stem system is pruned back to adjust the root: shoot ratio and reduce evapotranspiration stress, which is the main cause of mortality during transplanting. Regular watering for the first month or so is essential.

Compared to other translocation techniques such as gradual transplanting or propagation from seed or cuttings, direct transplanting can have several advantages:

- Trees and shrubs begin flowering and seed production earlier.
- Less risk of transferring diseases (through handling or from a nursery environment).
- Mycorrhizae and soil microflora are maintained by moving plant and soil together.
- Suitable for large numbers of individuals, large or small.
- Suitable for implementation in rough, forested terrain
- Cost-effectiveness

In a developmental context, some workers prefer translocation by propagating the species from seed or cuttings in a nursery environment followed by introduction to the field. However, Primack (1996) has pointed out the advantages of salvage transplanting: "There are nonetheless ecological advantages to using transplanted plants rather than seeds in reintroduction (translocation) efforts. Plants, particularly adult plants have a higher likelihood of successful establishment than seeds (or seedlings) if they are planted into a suitable site and well-tended. These plants have overcome the most vulnerable stages in their life cycle (seed germination and seedling establishment) so that their chances of surviving in the new habitat are greatly increased. These individuals also have proven genotypes that are free of lethal mutations and adapted to the general environmental conditions. When reintroduction efforts involve reproductively mature adult plants, the new population has the potential to flower, produce and disperse seeds and create a second generation of plants within a year (or so) of transplantation".

Translocation methods applied to each species on the WC2NH project are described in more detail below.

2.2.3 Slender Marsdenia

2.2.3.1 Salvage Transplanting

Slender Marsdenia was transplanted in February 2015. Seven receival sites were used (Table 6), which were placed near the donor sites to maintain roughly the original population distribution. Stems were moved in blocks of soil about 30 cm wide and 20 cm deep dug out with a spade. This usually meant breaking the plants' tuberous rhizome which grows horizontally in the topsoil. Each salvage point in the TFMP, often included two or more stems (i.e. stem-individuals), sometimes attached to the same rhizome. Stem individuals were generally removed individually as they were not well separated. All stem-individuals were transplanted, including any previously unrecorded ones.

Plants and soil were kept damp during transport and watered as soon as they were planted. The 'stem-individuals' were planted at 5 m intervals along lines to minimise bias in selecting a planting point and to make monitoring easier. Additional plants were translocated in 2016 due to a modification in the road design. In total, 175 stem-individuals were translocated.

The transplants were watered once every two days for the first week then once a week for four weeks. Chicken wire cylinders were installed to prevent animal grazing, to act as a climbing frame and to facilitate monitoring. Flagging tape was attached to the base of each stem just above the ground to make it easier to check if stems that had died back were still alive. Flagging tape with the individual's monitoring number and source code as per the TFMP was attached to each cage. Multiple individuals from the same mapped point were indicated by additional numbers on the source plant code – e.g. ML 46-6, ML46-7.

2.2.3.2 No Fertiliser

Previous translocation work with Slender Marsdenia on the Bonville project found that addition of slow release fertiliser adversely effected the survival of transplanted Slender Marsdenia (although not when grown in pots). Therefore, no fertilisers or mulch were applied to this species during the WC2NH translocation. An experimental comparison of fertiliser and no fertiliser treatments on the NH2U project indicated that even a light application of slow release fertiliser resulted in decreased growth (Ecos Environmental 2016).

2.2.3.3 Propagation of Population Enhancement Plants

Propagation of Slender Marsdenia from rhizome pieces collected during transplanting had poor results. The strike rate of rhizome cuttings was <5% and shoot and root growth was very slow. This was unexpected as the species produces new stems by budding off its rhizome, although these are relatively sparse. A similar low strike rate by propagating from rhizome pieces was recorded on the NH2U project. The few plants propagated were grown-on for two years and planted out in November 2017 at Receival Site 7a.

Searches for Slender Marsdenia pods to propagate from seed were carried out in December 2016, focusing on known large plants on the WC2NH, NH2U and S2W sections of the Pacific highway, but no pods were found. A single pod was found on the WC2NH section in the summer of 2014/15 during other flora survey work. The pod contained about 100 seeds and nearly all germinated successfully. The seedlings were used on the NH2U project in experimental trials underway at that time (Ecos Environmental 2016).

2.2.4 Woolls' Tylophora

2.2.4.1 Species Identification

Woolls' Tylophora has not been positively identified on the WC2NH project, as no flowering plants have been found. A few plants were tentatively identified as Woolls' Tylophora during TFMP surveys, based on leaf features. Typically, Slender Marsdenia has a more elongated leaf, pinnate venation, cordate leaf base and is glabrous (without hairs). Woolls' Tylophora has a broader leaf with purplish tinges (not always), tends to be more 3-veined at the base and is sparsely hairy (hand lens needed). The two species flower at different times - Woolls' Tylophora from the Bonville project flowered in late August, whereas Slender Marsdenia from NH2U flowered in November and occasionally later (pers. obs.).

Several Slender Marsdenia plants were observed flowering on the WC2NH project, but no Woolls' Tylophora. If Woolls' Tylophora is present, it appears to be rarer than Slender Marsdenia.

2.2.4.2 Salvage Transplanting

Individuals tentatively identified as Woolls' Tylophora were transplanted using the same methods applied to Slender Marsdenia. Both species are vines with tuberous roots. Woolls' Tylophora was translocated to Receival Site 8a, which also received some Slender Marsdenia.

2.2.5 Rusty Plum

2.2.5.1 Salvage Transplanting

All Rusty Plums were salvaged from the Cockburn's Lane section at the southern end of the project and were transplanted into the adjacent road reserve (Receival Site 1). An excavator was used to trench around Rusty Plum trees up to 12 m high, forming a soil-root ball about 1-1.5 m wide and 0.7 m deep. The root ball was undercut, and the tree leaned to the side where the trunk, branches and roots were pruned.

The transplants were watered for the first month. Sugar cane mulch was spread around each plant and hessian barriers erected for shade, as the site was exposed to the afternoon sun. No fertilisers were used.

Several Rusty Plums remained in-situ outside the clearing/construction boundary.

2.2.5.1 Population Enhancement by Direct Seeding

To enhance the population of Rusty Plum on the WC2NH corridor, plants were introduced to one receival site by direct seeding. About 50 fruits were collected in Nambucca State Forest in November 2017. The single large seed were separated from the outer fleshy layer and direct seeded next to Receival Site 7a on the 7th December 2017. The site is in a minor gully supporting wet sclerophyll forest (Flooded Gum) with a rainforest understorey. As trials with direct seeding of Rusty Plum on NH2U had shown the seed is taken by animals and the seedlings grazed (Ecos Environmental 2015), seeds were placed inside metal mesh cylinders. Fourteen cylinders were set out and three or four seeds placed on the soil surface in each cylinder and covered lightly with leaf litter. The cylinders were tagged for monitoring and locations recorded with a GPS.

2.2.6 Spider Orchid

2.2.6.1 Salvage Transplanting

Two mature Spider Orchid plants were salvaged from Prickly Paperbark (*Melaleuca styphelioides*) trees on the WC2NH footprint. The section of branch supporting the orchid was removed so there was minimal disturbance of the orchid root system growing on the tree bark. The branch with orchid was attached to a small tree in a shaded gully at Receival Site 5 (7a). Apart from keeping plants damp during transport, no watering was carried out.

2.2.6.2 Population Enhancement

The TFMP planned to propagate Spider Orchid plants and introduce them to suitable habitat areas to enhance the local population of this species. Vegetative propagation by division of clumps was not an acceptable option due to the low number of wild plants. Propagation from seed was possible and searches were carried out to try and find seed pods of this species focusing on known locations, but they were unsuccessful.

One seed pod was produced in a translocated population of 55 Spider Orchids on the NH2U project in Spring 2016, but the pod opened between site visits in November 2016 and all the seed were dispersed before they could be collected.

The large Spider Orchid plant translocated on WC2NH flowered each year for six years from 2015 to 2020, but no seed pods were produced (monitoring was carried out in November after flowering in September so it is unlikely pods were missed). An in-situ plant was also monitored but no seed were produced.

2.2.7 Koala Bells

2.2.7.1 Salvage Transplanting

Koala Bells was transplanted in blocks of soil 40 cm wide by 20 cm deep. Plants were pruned and the soil block planted at Receival Site 8b, which was the only site found in the WC2NH road reserve with swamp forest similar to Koala Bells habitat. Wire cylinders were installed around the plants and follow-up watering carried out. No fertilisers were applied.

2.2.7.2 Population Enhancement

Cuttings of Koala Bells were propagated at Ecos Environmental’s nursery in summer 2015-2016. The cuttings struck successfully and flowered over summer and autumn, died back in winter then reshot in spring 2016, all while the plants were still in pots. Regrowth in spring 2016 was less vigorous and small adventitious shoots were produced around the edge of the pots. (Vegetative propagation was also observed in some transplants in the field on NH2U.) Twenty plants were introduced to Receival Site 9b, the Floyds Grass translocation site at Warrell Creek in January 2017. This site is on alluvial soil and had an open ground layer with little competition from other ground layer plants, conditions that seem to be preferred by Koala Bells.

2.2.8 Floyds Grass

2.2.8.1 Removal of BLP and topsoil seedbank

Floyds Grass was planted into two 20 m x 20 m areas located on the northern side of Warrell Creek close to the donor site on the edge of the creek. The two areas referred to as Receival Sites 9a & 9b are about 25 m apart. Topographically the site was ideal for Floyds Grass, being on alluvium and close to Warrell Creek but the vegetation was very weedy.

The site was densely covered in Broad-leaved Paspalum (BLP) and Lantana. To prepare the site for introduction of Floyds Grass, a stripping process was carried out, where weeds and the topsoil layer with its weed seedbank were scrapped off using an excavator. As the site was on relatively deep alluvium, there was sufficient depth of well-drained soil left for Floyds Grass to establish after the stripping operation. Killing the BLP and other weeds with herbicide would have left the soil seedbank to contend with and it would not have been impossible to spray weed seedlings without hitting Floyds Grass as it spreads by runners close to ground. Therefore, the strategy was to completely remove BLP and the soil seedbank, then plant Floyds Grass into the weed free site.

Preparation of the site was carried out as follows. First, ground layer vegetation consisting mainly of BLP and Lantana was scrapped off using an excavator bucket. After exposing the soil surface, the top 10 cm of soil was scrapped off and placed on the edge of the site. The soil beneath the uppermost 10 cm was found to have a moderately high clay content, but soil texture and drainage were still suitable for young plant growth. Sed fencing was installed around the site to prevent run-off of soil material to Warrell Creek and to act as a barrier to deter wallaby grazing.

2.2.8.2 Salvage Transplanting

Small clumps of Floyds Grass were dug out with a spade from the bridge site on the edge of Warrell Ck and planted into Receival Site 9a. The plants were watered, and sugar cane mulch (weed free) spread lightly over the soil surface to minimise raindrop compaction. Follow-up watering was carried out as conditions were dry. ‘Seasol’ (seaweed and fish emulsion) fertiliser was applied two weeks after introduction to stimulate growth. As the site was exposed to the afternoon sun, 1 m high shade-cloth fences were erected to provide additional shade (see Plate x).

Although the topsoil seedbank had been removed, some seed germinated from deeper in the soil, notably *Phytolacca octandra* (Ink Weed), a large herbaceous shrub. There was very little BLP germination.

2.2.8.3 Population Enhancement

To increase the size of the salvaged population, approximately 100 additional Floyds Grass were propagated at Ecos Environmental’s nursery and planted in Receival Site 9b in March 2016. Plants were propagated vegetatively from small pieces of runner that broke off during transplanting. As site 9b was more exposed than site 9a, the shade cloth fences had a roof to protect from the overhead sun. Follow-up hand weeding to remove exotic and native species was carried out.

2.2.9 Monitoring and Data Analysis

Monitoring during the construction phase (2015-2018) was conducted quarterly in the first 12 months, biannually in the second 12 months and then annually. Monitoring during the operational phase from 2018 to 2020 was carried out annually.

The following data were recorded to assess survival and growth:

- All species except Spider Orchid: Monitoring Number, Date, Line, Source Label (species translocation plant label), Species (Current ID), Overall Condition (see below), Height (cm), New Shoots (Y/N), Comments, Significant Growth (+) or Significant Dieback (-), Coordinates.

- Spider Orchid: Monitoring Number, Date, Source Label, Species, Number of Pseudobulbs with Leaves, Length of the Longest Pseudobulb, New growth, Overall Condition, Coordinates.

Plant condition was scored on a scale of 0 to 5, where zero = dead and 5 = fully mature, reproductive (Table 2-4). Slender Marsdenia individuals that had died back to the ground were scored as 1 rather than 0 (dead) as stems could reshoot from below ground. Some died back and reshot repeatedly, and some took two years to reshoot. Only plants with above ground stem growth were included in calculation of survival% (i.e. condition score of 2 or greater). Individuals with a condition score of 1 were not included as some of these could have been dead. The survival rate reported is therefore slightly lower than the actual survival rate. The condition-score scale was defined slightly differently for each species, as shown in Tables 2-4 below.

Percent Survival was defined as:
number of individuals in condition classes 2+3+4+5/total *100.

Species height at each monitoring event was averaged for all plants present at the start of monitoring in June 2015, and included plants with zero height that had died back to ground level (i.e. condition class 1 or 0 in the case of Slender Marsdenia).

Table 2: Condition scores applied to Slender Marsdenia and Woolls' Tylophora.

Score	Condition
0 – dead	Dead, no sign of reshooting 2 years after dying back
1 –poor	Stem died back to ground level, possibly dead, live stem stub may be present
2 – fair	Plant <75 cm tall, with leaves or leafless, new shoots or active growth present or absent
3 – good	Plant >75 cm tall, stem with leaves, new shoots or active growth present or absent, if stem leafless or leaves discoloured score as 2
4 – advanced	Plant >2.5m tall with >15 leaves
5 – mature	Mature, plant flowering or seeding

Table 3: Condition scores applied to Rusty Plum and Koala Bells.

Score	Condition
0	Dead
1	Leafless and no sign of re-shooting
2	Pruned foliage retained, or small amount of re-shooting after defoliating, or foliage sparse/discoloured (<40 cm tall for Koala Bells)
3	Vigorous re-shooting (>40 cm tall for Koala Bells)
4	Crown recovering, foliage healthy
5	Growing actively, flowering or seeding recorded

Table 4: Condition scores applied to Spider Orchid.

Score	Condition
0	Dead
1	Pseudobulbs discoloured or grazed or withering, no new growth
2	Pseudobulbs healthy in colour, not withering, no new growth
3	Plant small, few healthy pseudobulbs, new growth occurring
4	Several healthy pseudobulbs present, new growth occurring
5	Several good sized, healthy pseudobulbs, flowering or seeding recorded

<u>Pattern of Stem Growth in Slender Marsdenia</u>

Slender Marsdenia showed complex variation in tpattern of stem regrowth after transplanting. Nearly all plants reshot but some plants stayed small and changed little over six years, while others grew tall (>2 m) or maintained steady growth the whole time. Most noticeable were plants that fluctuated in height, reshooting then dying back then reshooting again, sometimes in repeated cycles over six years. After dying back, some plants took more than a year to reshoot, while others died back and reshot twice in one year. The dead stems of these plants were still visible on the wire cage. This variation was perplexing when the volume of soil containing plant and rhizome was initially about the same size (~30 cm x 10 cm x 10 cm), or not greatly different, although the thickness of rhizomes varied (not recorded, but mostly 4-6 mm diameter).

To examine the different pattens of stem growth amongst individuals after transplanting in more detail, 12 categories of stem height change were defined, as shown in Table 5. These were derived by combining stem height data for all individuals in a single spreadsheet for each receival site, then subjectively identifying characteristic syndromes of height change (Table 5). Number of individuals in each category were tallied and expressed as percentages of the total.

Table 5: Categorisation of syndromes of stem height change in Slender Marsdenia over a six-year period after salvage transplanting. Three primary syndromes were recognised – those that died or were probably dead (D), those with relatively little growth that remained small for six years (S), and those that showed relatively vigorous growth (T). Twelve sub-categories were recognised, as defined below.

Sub-categories with "(O)" showed pronounced oscillation in stem growth with cycles of stem dieback and regrowth.

Code	Regrowth response syndromes of transplanted individuals
D	**Dead or possibly dead; all ht = 0 at Nov/2020**
D1	Never reshot
D2	Small shoot then died back to ground, probably dead
D3 (O)	Reshot, reached small to medium height (<1.2 m) then died back to ground, some fluctuated (i.e. dieback-reshoot-dieback)
D4	Reshot, grew tall (~2 m+) then died back to ground, probably dead
S	**Small, growing very slowly, or declining**
S1	Stayed small, mostly less than 10 cm high (occasionally to 50 cm), little change in height in 6 years
S2 (O)	Died back to ground and reshot once or twice, continuously small (mostly <50 cm)
S3	Declining or bell shaped (increase-decrease), some to ~130cm at peak, continuously alive but stem mostly small (<50 cm)
S4 (O)	Fluctuating – e.g. 'small-medium/tall-small'; or 'grew medium/tall then died back to small
T	**Thriving, plant relatively tall, continuing to grow, or maintaining size, healthy**
T1	Tall (1.5 m+), substantial increase in height/number of leaves, or maintained tall height
T2	Moderately tall (0.75 – 1.5 m +), moderate increase in height (δ = 0.5 – 1 m or more), or height constant
T3 (O)	Died back to ground then reshot vigorously (>1 m)
T4	Small for several monitoring events then suddenly grew taller (>1 m)

2.3 Translocation Results

2.3.1 Survival Summary – All Species

Six years after salvage translocation and three years into operational phase monitoring, high survival rates were recorded for all six threatened plant species: Slender Marsdenia 68%, Woolls' Tylophora 67%, Spider Orchid 100%, Rusty Plum 86% and Floyds Grass (see Table 6).

No plants of the rare species Koala Bells were alive after six years. This species appears to be naturally short-lived and requires recently disturbed habitat to recruit new seedlings. Koala Bells can be found on the edge of forest tracks where it grows from seed. As ground layer vegetation become thicker it loses vigour and dies out, but probably persists in the soil seedbank. It grew well at the two receival sites (8b and 9b) for the first 1-2 years and produced seed. Similar results were recorded in other translocations of this species (e.g. NH2U).

Table 6: Survivorship (% alive) of species at six receival sites over 6 years (2015-2020), after salvage translocation.

Species/Receival Site	**No. plants transl.**	**Survival (%)**					
		Aug 2015 (~6 mth)	**Jan 2017 (~2 Yrs)**	**Nov 2017 (~3 Yrs)**	**Nov 2018 (~4 Yrs)**	**Nov 2019 (~5 Yrs)**	**Nov 2020 (~6 Yrs)**
Slender Marsdenia(*Marsdenia longiloba*)							
Receival Site 1 - Cockburns Lane	27	93	75	63	59	59	56
Receival Site 2 (3) – Old Coast Rd	17	91	93	88	88	88	88
Receival Site 3 (5a) – Old Coast Rd	22	81	91	73	77	68	68
*Receival Site 4 (5b) – Old Coast Rd	16	94	81	69	69	50	71
Receival Site 5 (7a) – Old Coast Rd	57	90	72	74	72	56	61
Receival Site 6 (8a) – Old Coast Rd	8	75	75	75	88	86	93
Receival Site 8 (8c) – Old Coast Rd	28	100	86	82	79	70	67
Total/All Sites	164 (175)	91	80	74	74	68	68
Rusty Plum(*Niemeyera whitei*)							
Receival Site 1 - Cockburns Lane	7	100	86	86	86	86	86
Wooll's Tylophora (*Tylophora woollsii* – unconfirmed)							

Species/Receival Site	No. plants transl.	Survival (%)					
		Aug 2015 (~6 mth)	Jan 2017 (~2 Yrs)	Nov 2017 (~3 Yrs)	Nov 2018 (~4 Yrs)	Nov 2019 (~5 Yrs)	Nov 2020 (~6 Yrs)
Receival Site 6 (8a) – Old Coast Rd	6	100	100	83	67	67	67
Spider Orchid (*Dendrobium melaleucaphilum*)							
Receival Site 5 (7a) – Old Coast Rd	2	100	100	100	100	100	100
Floyds Grass (*Alexfloydia repens*)							
Receival Site 9a – Warrell Creek	54 clumps	94	Substantial cover	Substantial cover	Substantial cover	Substantial cover	Fair cover
Receival Site 9b – Warrell Creek	61 clumps	Not planted yet	98	93	70	Reasonable cover	Fair cover
Koala Bells (*Artanema fimbriatum*)							
Receival Site 7 (8b) – Old Coast Rd	16	63	25	13	6	0	0
Receival Site 9 – Warrell Creek	14	Not planted yet	Not yet planted	57	86	75	0
Total	30	63	25	34	43	37	0

* Note – Site 5b included 9 *Marsdenia liisae* and 7 *M. longiloba*. These species had a survival rate of 78% and 71% respectively.

2.3.2 Slender Marsdenia (*Marsdenia longiloba*)

2.3.2.1 Summary

Combining data for all six receival sites, the survival rate of Slender Marsdenia after 6 years was 68%, the same as last year (Table 6). Survivorship per site ranged from 56% to 93%. Overall, two sites had very high survival rates (3, 8a) and four sites had moderately high survival rates (1, 5a. 7a, 8c).

High survival rates were maintained despite the severe drought conditions in 2019. Given the tendency of Slender Marsdenia to die back and reshoot again, some individuals recorded as dead (ie Ht = 0) may still reshoot, so the actual survival rate is probably slightly higher, around 75%.

When observed in November 2019 during drought there was no sign of moisture stress such as wilting and many plants had new shoots, a sign of active growth. This suggests that the tuberous rhizome of Slender Marsdenia stores water as well as photosynthate, which the plant draws on to initiate new growth in spring when conditions on average are dry.

2.3.2.2 Changes in mean height

Mean plant height is a measure of how well Slender Marsdenia regrew and recovered from transplanting at each site. Mean height was calculated by averaging across all individuals including those with zero height, which underestimates the mean height of live plants, but arguably gives a better estimate of overall performance by factoring in mortalities.

Mean stem height of Slender Marsdenia at receival sites after six years ranged from 35.0 cm to 97.6 cm (Table 7), similar to last year.

After the initial period of height increase in Year-1 there was relatively little change in mean height in Year 2 at the six receival sites (Figure x), then in Year 3 mean heights in the receival sites started to diverge more, staying relatively constant in sites 7a, 5a and 1, and increasing in sites 3, 8c and 8a. This difference appeared to reflect the higher mortality of plants in sites 7a, 5a and 1, or greater number of zeros in the data.

Oscillations in mean height at the different receival sites are evident in Figure 3. This is partly due to the tendency of Slender Marsdenia to die back then resprout again (see next section). There is little correspondence between the six sites in the pattern of rises and dips, which suggests that fluctuations are not related to the macro environment (e.g. rainfall pattern) but perhaps to differences in habitat and internal rhythms of plant growth.

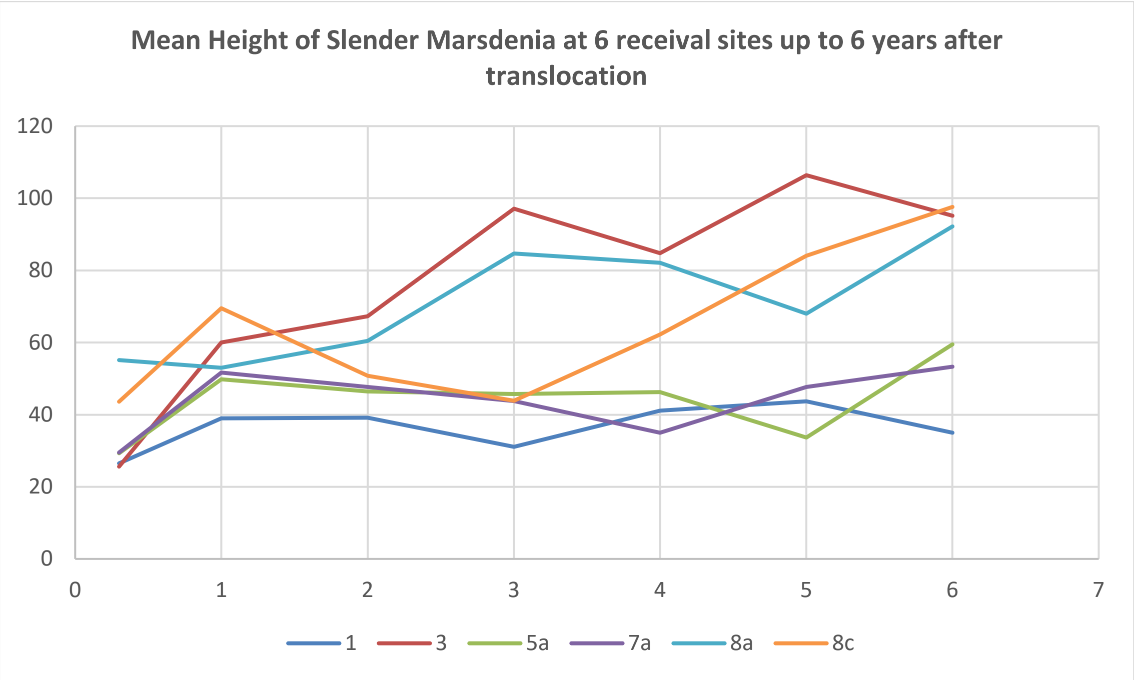

Figure 3: Changes in the mean height Slender Marsdenia at 6 receival sites after during years 1-6 after transplanting. Mean height diverges more from Year 3 onwards, staying relatively flat in sites 7a, 5a and 1, and increasing in sites 3, 8c and 8a. This is due to higher mortality in sites 7a, 5a and 1.

Table 7: Mean height (cm) ± standard error of Slender Marsdenia at 6 receival sites from June 2015 to November 2020 (six years after translocation). This data is plotted in Fig 3.

Receival site	n	June 2015 (6 mths)	Feb 2016 (~1 yr)	Jan 2017 (~2 yrs)	Nov 2017 (~3 yrs)	Nov 2018 (~4 yrs)	Nov 2019 (~5 yrs)	Nov 2020 (~6 yrs)
Receival Site 1	27	26.5±6.5	39.0±10.4	39.2±10.6	31.1±10.3	41.13±9.5	43.7±8.8	35.0±12.0
Receival Site 2 (3)	11	25.6±10.1	60.8±15.5	67.3±13.6	97.1±14.2	84.8±12.7	106.4±13.2	95.2±15.9
Receival Site 3 (5a)	22	29.3±7.5	49.8±11.2	46.4±9.5	45.7±9.3	46.3±10.8	33.7±9.5	59.5±15.0
Receival Site 5 (7a)	57	29.5±3.7	51.7±6.9	47.7±7.6	43.8±8.1	35.0±6.3	47.7±5.7	53.3±10.6
Receival Site 6 (8a)	8	55.1±22.2	53.0±17.9	60.5±17.5	84.7±18.3	82.1±19.1	68.0±17.7	92.2±25.9
Receival Site 8 (8c)	28	43.6±6.3	69.5±9.1	50.8±5.9	43.9±5.4	62.2±10.6	84.1±9.6	97.6±26.1

The averaged height data presented in Figure 3 are informative but do not show what is happening to individual plants. This is examined in the next section.

2.3.2.3 Pattern of stem growth response in transplanted Slender Marsdenia

The stem regrowth response of Slender Marsdenia after transplanting varied greatly both within and between receival sites. Of the three main categories of response taken over six years (D, S and T), D (dead) ranged from 7.1% to 44.4% between receival sites, S (small) ranged from 5.9% to 38.1%, and T (tall or thriving) ranged from 9.1% to 82.4%.

Table 8 shows the percentage of three primary categories and 12 sub-categories of stem regrowth response defined above in Section x which are shown graphically in Figs 3 and 4.

Table 8: Percentage of three primary categories and 12 sub-categories of stem regrowth response after transplanting. Sub-categories with "(O)" showed pronounced oscillation in stem growth with cycles of stem dieback and regrowth.

	Stem Height Growth Syndromes of transplanted individuals – see notes		**Receival sites**					
		1 (Cb)	**2 (3)**	**3 (5a)**	**5 (7a)**	**6 (8a)**	**8 (8c)**	**All**
D	**Dead or possibly dead; all ht = 0 at Nov/2020**							
D1	Never reshot	3.7	0	4.5	5.3	7.1	0	3.0
D2	Small shoot then died back to ground, probably dead	14.8	11.1	9.1	7.0	7.1	3.7	8.5
D3 (O)	Reshot, reached small to medium height (<1.2 m) then died back to ground, some fluctuated (i.e. dieback-reshoot-dieback)	25.9	0	18.2	26.3	0	25.9	20.0
D4	Reshot, grew tall (~2 m+) then died back to ground, probably dead	0	0	9.1	0	0	3.7	0.6
	Sub-total	44.4	11.7	38.1	38.6	7.1	33.3	32.1
S	**Small, growing very slowly, or declining**							
S1	Stayed small, mostly less than 10 cm high (some to 50 cm), little height change in 6 yrs	7.4	5.6	0	7.0	0	7.4	5.5
S2 (O)	Died back to ground and reshot once or twice, continuously small (mostly <50 cm)	11.1	0	4.5	7.0	0	0	5.5
S3	Declining or bell shaped (increase-decrease), some to ~130cm at peak, continuously alive but stem mostly small (<50 cm)	7.4	0	18.2	3.5	0	3.7	4.9
S4 (O)	Fluctuating – e.g. 'small-medium/tall-small'; or 'grew medium/tall then died back to small	11.1	0	9.1	14.0	28.6	7.4	11.5
	Sub-total	33.3	5.9	38.1	31.6	35.7	18.5	27.3
T	**Thriving, plant relatively tall, continuing to grow, or maintaining size, healthy**							
T1	Tall (1.5 m+), substantial increase in height/no. of leaves, or maintained height	3.7	5.6	9.1	5.3	7.0	18.5	7.9
T2	Moderately tall (0.75 – 1.5 m +), moderate increase in height (δ = 0.5 – 1 m or more), or height constant	7.4	66.7	13.6	22.8	50.0	25.9	26.7
T3 (O)	Died back to ground then reshot vigorously (>1 m)	11.1	0	4.5	1.8	0	0	3.0
T4	Small for several monitoring events then suddenly grew taller (>1 m)	0	11.1	0	0	0	3.7	3.0
	Sub-total	22.2	82.4	9.1	29.8	57.1	48.1	40.6
	% Survivorship 6 yrs	55.6	88.2	68.2	61.4	92.9	66.6	67.9
	Total individuals	27	17	22	57	14	27	164

In the D group (Dead or possibly dead, Ht = 0) – 32.1%

- Most of the D group reshot, grew small to medium in size then died back to the ground (Ht = 0), sometimes in two cycles.
- A low 3% out of 164 transplants failed to show any recovery after transplanting (i.e. D1).

In the S group (Small) – 27.3%

- 5.5% remained small (<10 cm high) for 6 years (i.e. S1)
- 5.5% died back and reshot one or more times, but stayed small (i.e. S2)
- 11.5% fluctuated from small to medium or large and then small again (i.e. S4)

In the T group (Tall or Thriving) – 40.6%

- 35% maintained relatively tall height after regrowth in Year 1 (T1 & T2)
- 6% fluctuated dying back then reshooting and growing tall again (T3 and T4)

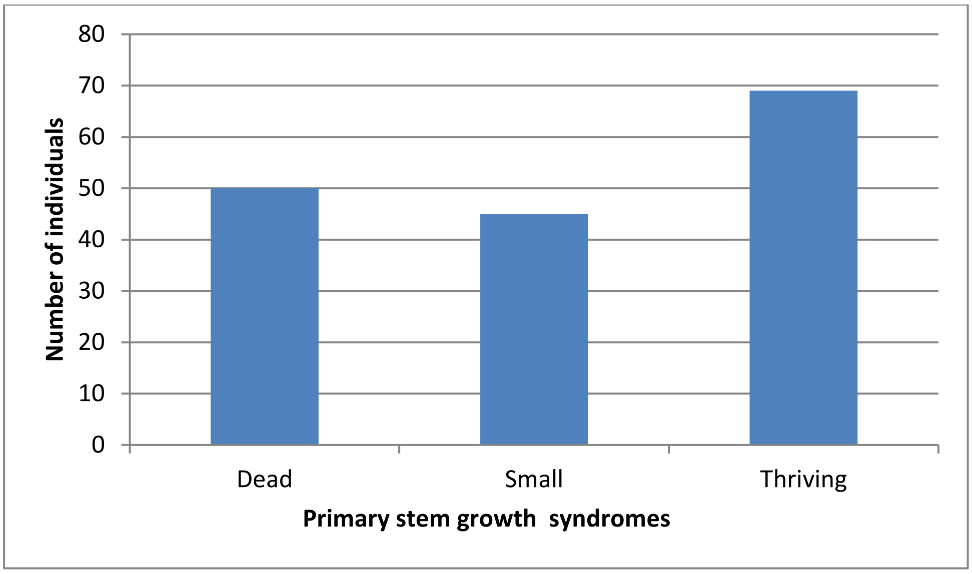

Figure 4: Frequency of the three main regrowth outcomes in transplanted Slender Marsdenia over six years. Data pooled for 6 receival sites.

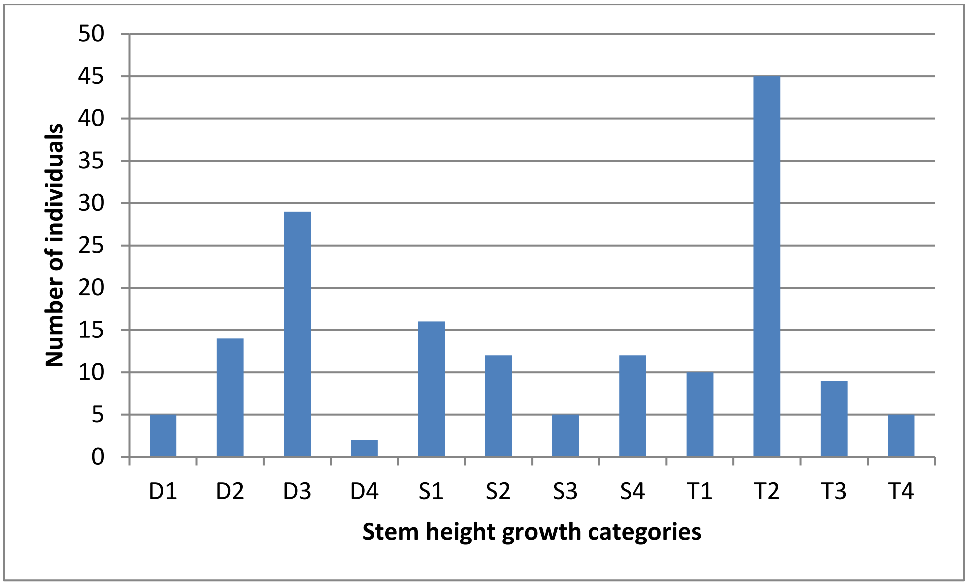

Figure 5: Stem growth pattern of 164 translocated Slender Marsdenia. Data from six receival sites combined. Primary categories: D = dead, S = surviving, T = thriving. See Table 5 for definition of stem height growth sub-categories.

2.3.2.4 Receival site and stem growth

Inspection of Table 8 shows that the 6 receival sites fall into 3 groups with respect to patterns of stem growth: -

> Receival sites 1 and 7a had high D and S and low T; these sites also had a lower incidence of plants with new shoots.
>
> Receival sites 3 and 8a had low D and S and high T; these sites also had a higher incidence of plants with new shoots.
>
> Receival sites 8a and 5 have intermediate values of D, S and T.

At least some individuals at all receival sites reached the T1 or T2 categories (i.e thriving).

There was no obvious factor underlying the variability in stem regrowth response. Two general factors could be involved: -

1. Differences in the quality or vigour of stem individuals transplanted from donor sites to the receival sites. The donor sites for receival sites 1 and 7a included many small, stem-individuals, while receival sites 3 and 8a received larger, more vigorous plants.
2. Habitat differences including soil moisture, soil nutrient availability, associated species and light levels may have affected stem growth. Receival sites 1, 7a and 5a with lower mean height and higher mortality, were in wet sclerophyll with a denser rainforest mid-stratum and lower light levels. Sites 3, 8a and 8 c with higher mean height and lower mortality were more open wet sclerophyll with higher light levels.

2.3.2.5 Incidence of stem height oscillation

Most new shoot growth in Slender Marsdenia is produced from early spring to early summer. Stems often grew ~10 cm to 1 m on the wire mesh cylinders then die back to ground, then produced another stem, sometimes in the same season, or 1 or even 2 years later. Such oscillating or transitory stem growth is common even though some plants maintain roughly constant height or continue to grow. New stems grow from the tuberous rhizomes of Slender Marsdenia, which they appear to produce selectively and in low number.

Several categories of stem height change in Table 5 over 6 years involve stems dying back then new stems being produced again from the same point (i.e. D3, D4, S2, S4, T3). Stem height fluctuation was more common in smaller plants but also recorded occasionally in large plants. Reshooting after dieback generally occurred within 12 months, but sometimes not for 18 months, and in a few cases longer.

Modifying the primary categories of stem height change in Table 8 to emphasise stem height fluctuation (i.e. D3+D4+S2+S4+T3), 39% of transplanted stems exhibited stem height oscillation over the six year monitoring period.

Possible functions underlying stem height fluctuation in Slender Marsdenia include:-

(i) *Seasonal growth response.*To replenish food storage in tuberous roots (the reshooting phase), while minimising consumption of stored food if conditions for photosynthesis decline (the die back phase).

(ii) *Gauging the environment.* Fluctuating small shoots may represent the plant testing microsites for growth potential before committing to expenditure of stored resources by producing stem and leaf growth.

(iii) *Budgeting strategy.* Stem height fluctuation may represent a strategy for budgeting the consumption of limited resources during changing conditions of supply (ie. photosynthate, or raw materials for photosynthesis) and demand (i.e. consumption of photosynthate or raw materials).

(iv) *Exploratory module.* Slender Marsdenia may produce different kinds of exploratory stem with different functions in informing or coordinating the whole plant before attempting growth tall, flowering stem.

The oscillation in stem height recorded during monitoring reflects Slender Marsdenia’s habit of producing transitory stems that appear to ‘test’ the environment, or ‘prepare’ the plant, before initiation of tall stem growth and possible flowering. Slender Marsdenia has a rhizome network that enables the plant to move the position of stems around its immediate habitat, by extending rhizomes and sending up new exploratory stems that may provide directions to the rhizome on which direction to grow, to reach a favourable light gap and soil niche for example.

2.3.2.6 Comparison of stem height pattern in in-situ plants

Monitoring of in-situ plants of Slender Marsdenia on the WC2NH and NH2U projects indicates that stem height fluctuation is present to much the same extent in naturally occurring in situ populations, and size class distribution is also much the same and not an artefact of translocation. For example, most plants observed in in situ populations were small stem shoots and these were often short-lived. Large plants (>2.5 m) with foliage in the forest mid-stratum were rare.

2.3.2.7 Reproduction

Flowering

Only one out of 164 transplants flowered in six years, and this plant flowered twice - last year and this year (2019, 2020). In Nov 2020, the plant (Receival Site 3, no. 5) was 2.8 m high and had ~40 leaves, the same measurements being recorded last year. This plant appears to to have reached a size where it can reproduce without growing any larger.

The same very low incidence of flowering was recorded in translocated Slender Marsdenia on the NH2U project (one individual flowered). No flowering was recorded in-situ plants, and flowering is rarely observed in other naturally occurring plants although this could be because the inconspicuous flowers (and pods) are produced higher up in mid-stratum trees where hard to see.

Vegetative reproduction

Some plants appeared to be producing new stem individuals by shooting from rhizomes below ground. It was difficult to distinguish vegetative reproduction from plant regrowth after dying back.

2.3.3 Rusty Plum (*Niemeyera whitei*)

Survival rate of transplanted Rusty Plums at Receival Site 1 remained at 86% after six years. All six had increased in height and were in good condition. It may be another 10 years before the largest individuals reach reproductive maturity.

For the population enhancement component, direct seeded Rusty Plum germinated in 8 out of 14 chicken-wire cylinders in 2017. At least half the seed sown (3 per cylinder) rotted and failed to germinate. This was due to the poor quality of the seed (undersized) produced in drought years.

In November 2020, seedlings were still present in 7 cylinders, the tallest being 25 cm. This represents zero growth since last year, again possibly due to effects of previous drought years. No fertiliser has been added to the plots/cylinders.

2.3.4 Wooll’s Tylophora (*Tylophora woollsii* – unconfirmed)

At Receival Site 6 (8a), six transplanted individuals that could be Woolls’ Tylophora (identification unconfirmed) were mainly in good condition, showing new shoot growth and maintaining or increasing stem height.

2.3.5 Large-flowered Milk Vine (*Marsdenia*)

Some of the Marsdenia vines salvaged to Receival Site 4 (5b) are *Marsdenia liisae*, not *Marsdenia longiloba* as first thought. Its leaves are larger, thicker and often darker green.

Marsdenia liisae ranges between the Hastings River (Pt Macquarie) and the Nightcap Range in NSW and is considered rare, but not listed as threatened.

The survival rate of 9 *Marsdenia liisae* after six years was 78%, about the same as *Marsdenia longiloba*.

2.3.6 Spider Orchid (*Dendrobium melaleucaphilum*)

The two translocated Spider Orchid plants were in good condition after six years. Both plants continued to flower in spring (August - September) but set no seed (no pods formed), possibly due to absence of pollinators. Flowering was evident in November from persistent raceme axes projecting between the leaves. Some pseudobulbs (stem units) died and new ones were produced demonstrating active growth.

2.3.7 Floyds Grass (*Alexfloydia repens*)

Floyds Grass has persisted in the two areas where it was translocated to in Receival Site 9. Merging of patches and loss of tags due to floods has made monitoring of tagged individuals impractical and has been replaced by an overall assessment of the extent of Floyds Grass and habitat condition in the two sub-areas (9a and 9b).

<u>Area 9a</u>

About half the fenced area comprising Area 9a contained Floyds Grass in Nov/2020, six years after translocation. This is about the same area of coverage as recorded last year, which has been stable for about 3 years. Plants are found in the half of the fenced area closest to Warrell Creek, about 10 m away. The other half has a high percentage of Broad-leaved Paspalum, but it doesn’t appear to be spreading any further in the section where Floyds Grass if found. A high density of native Ottochloa grass is present, which Floyds Grass appears to be able to co-exist with. Where there are small shrubs and saplings, Floyds Grass has climbed up above Ottochloa using the shrubs for support and is more visible.

<u>Area 9b</u>

Floyds Grass is still present in reasonable number in this section of the translocation area, although close inspection is required to see it below the Broad-leaved Paspalum that covers most of area 9b. Planted Swamp Oaks are still alive in wire cages but have not been maintained and are heavily grazed, most likely by swamp wallabies.

This area was included in additional maintenance carried out last year. A selective herbicide was applied to this area in an attempt to eradicate Broad-leaved Paspalum while leaving Floyds Grass unharmed. Some yellowing of BLP was observed but it was not killed and this year is as dense as before. Floyds Grass was unharmed by the herbicide.

Habitat Restoration

Considering that (i) BLP poses a medium to long-term threat to the viability of the translocated population; (ii) substantial investment has been made into translocating Floyds Grass to this site; and (iii) this is the southern-most occurrence of the species (which is listed as Endangered – State and Federally), it is recommended that maintenance work using methods originally proposed by Ecos Environmmental be undertaken in 2021, consisting of hand weeding of BLP within the two translocation areas, herbicide spraying in a wide perimeter band around the two areas) and additional planting of Swamp Oak tubestock.

2.3.8 Koala Bells (*Artanema fimbriatum*)

Koala Bells transplanted to Receival Site 7 (8b) has died out, Flowering and seeding occurred for two years so dormant seed may be present in the soil seedbank, allowing for regeneration in future if suitable conditions appear (e.g. after bushfire or track maintenance). Koala Bells appears to be short-lived, so this is a normal pattern of growth in this species.

Propagated Koala Bells was introduced to Receival Site 9b in autumn 2017. The plants were mature and flowering and seeding occurred straight away so that recruitment from seed was recorded a few months later in spring 2017. These plants persisted in spring 2019 but had died out this year (spring 2020). There was no further recruitment. The site has grown over with Broad-leaved Paspalum which inhibits plant growth and seed germination. Koala Bells is short-lived perennial and prefers disturbed areas where there is high light and minimal competition from other plant species. These conditions were created at Receival Site 9b by stripping away the BLP dominated ground layer vegetation.

2.4 Performance Criteria

Table 9: Performance Criteria for Assessing Threatened Translocation Areas

Performance criteria	Yes/No
1. All recorded directly impacted individuals were translocated.	Yes
2. At least 60% of transplant and enhancement individuals are surviving after the first year, 50% after five years and 40% after eight years.	Yes
3. At the end of the monitoring program at least 50% of surviving individuals have a Condition Class of 3.	Not applicable yet
4. Habitat at receival sites in good condition conducive to medium term survival (i.e. 10 years)	Yes for all sites except Receival Site 9 (Floyds Grass) where habitat condition has deteriorated in Area 9b and remains only fair in Area 9a due to dense Broad-leaved Paspalum directly adjoining the site

2.5 Work Schedule for Year 4 (Dec 2020 – May 2022)

Table 10: Work Schedule for Year 4 of operational phase threatened flora management (Dec/2020 – May/2022).

Task	**Time**
Monitoring	
Fourth annual operational phase monitoring	Nov/2021 (to coincide with flowering of Slender Marsdenia and Rusty Plum)
Reporting	
Fourth annual operational phase monitoring report	Dec/2021-Jan/2022
Maintenance of Floyds Grass TA	
Proposed maintenance of Receival Site 9 a & b (Floyds Grass) to remove exotic species, particularly Broad-leaved Paspalum; spray out surrounding exotics, repair/remove shade cloth shelters, maintain planted Swamp Oak, plant more Swamp Oak etc, Steps to be implemented as listed below:-	May/2021- May/2022
1.Weed control/habitat restoration	
Hand weed Broad-leaved Paspalum; set up wick wip test in sub-sample area; spray out 10 m habitat restoration zone	May-June/2021

around Area 1 and 2; remove flood debris etc.	
2.Follow-up tubestock planting and weed removal	
Plant tubestock in habitat restoration zone Swamp Oak, Flooded Gum, Forest Red Gum and install 1.2 m high chicken wire tree guards to prevent wallaby grazing	Aug-Sept/2021
3.Follow-up weed control	3-6 monthly
4.Monitor results of maintenance works (include in WC2NH annual translocation monitoring)	Nov-Dec/2021 (6 months after first treatment)

3 In-Situ Threatened Flora Populations

3.1 Methods

The In-situ Threatened Flora Populations component of the TFMP comprises the following threatened plant species:

- Maundia (*Maundia triglochinoides*)
- Rusty Plum (*Niemeyera whitei*)
- Slender Marsdenia (*Marsdenia longiloba*)
- Spider Orchid (*Dendrobium melaleucaphilum*)
- Woolls' Tylophora (*Tylophora woollsii*).

Individuals of these threatened species were located and tagged before clearing and construction of the WC2NH section of the Pacific Highway began. All individuals occurred within the project boundary but outside the clearing limit (Figures 5-9) and have remained in-situ during the pre-construction, construction and operation phases of the upgrade.

GeoLINK conducted pre-construction and construction monitoring of the in-situ threatened species between January 2015 and October 2017. The following identification and condition data were recorded for each in-situ plant:

- Genus and species
- Plant identification number
- Overall plant condition scored on scale between 0 and 5 (see Tables 2-4)
- Presence of flowers and/or fruit
- Any new growth
- Any recruitment
- Any weed infestations or other impacts.

See *Warrell Creek to Nambucca Heads Monitoring of In-situ Threatened Flora (Annual Report – Spring 2017)* (GeoLINK 2017) for more information.

Ecos Environmental conducted the first yearly operation phase monitoring of the in-situ threatened species in November 2018. All tagged plants were located and the same condition data as recorded by GeoLINK were collected. Additionally, Ecos Environmental recorded the height of each individual to assess plant growth and performance throughout the monitoring program. In November 2020, Ecos Environmental conducted the third yearly operational phase monitoring, which is described in this report.

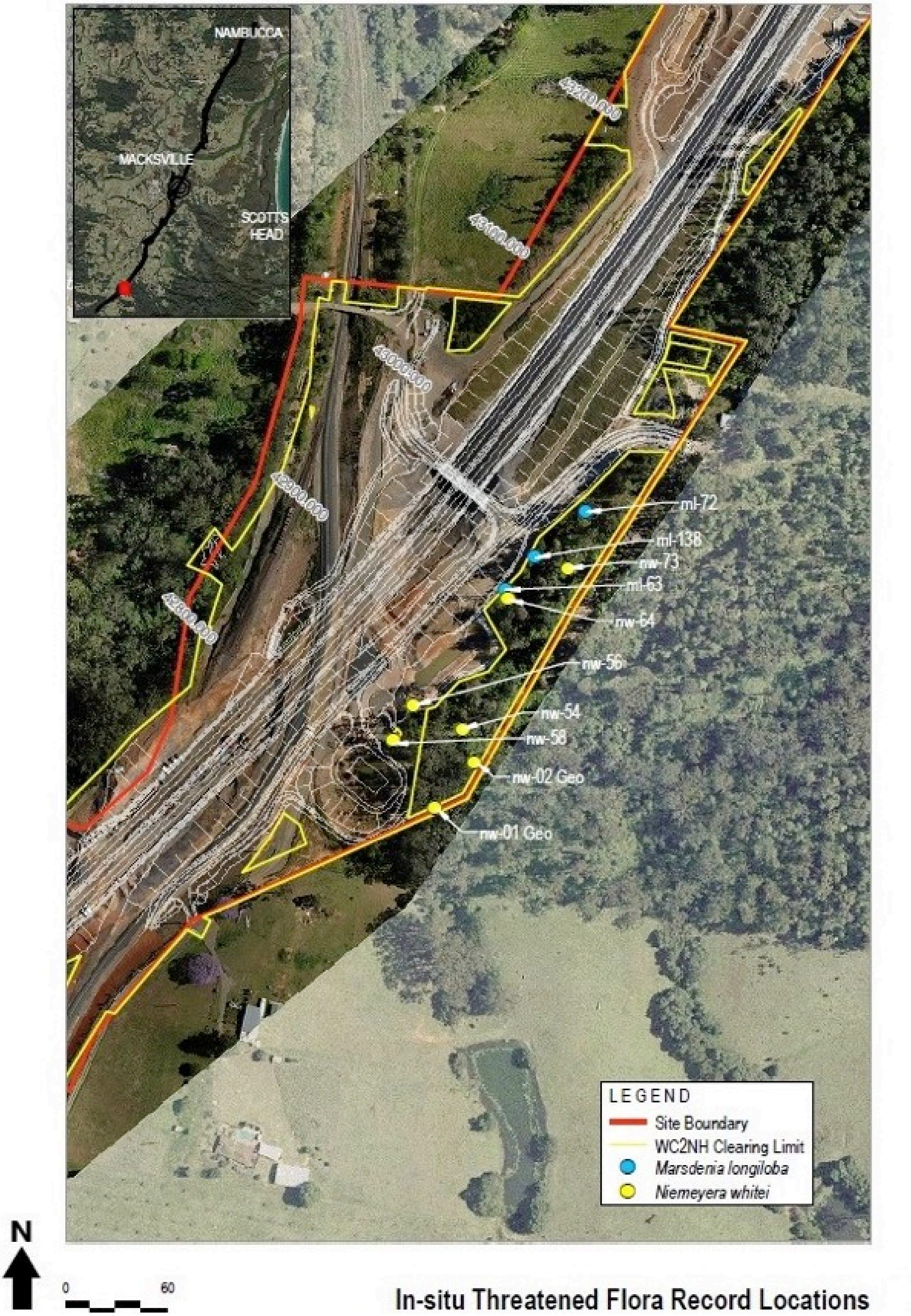

Figure 5: In-situ Slender Marsdenia and Rusty Plum at Cockburns Lane, WC2NH. Map sourced from GeoLINK (2017).

Figure 6: Maundia population at Nambucca Floodplain, WC2NH. Map sourced from GeoLINK (2017).

Figure 7: In-situ Slender Marsdenia, WC2NH. Map sourced from GeoLINK (2017).

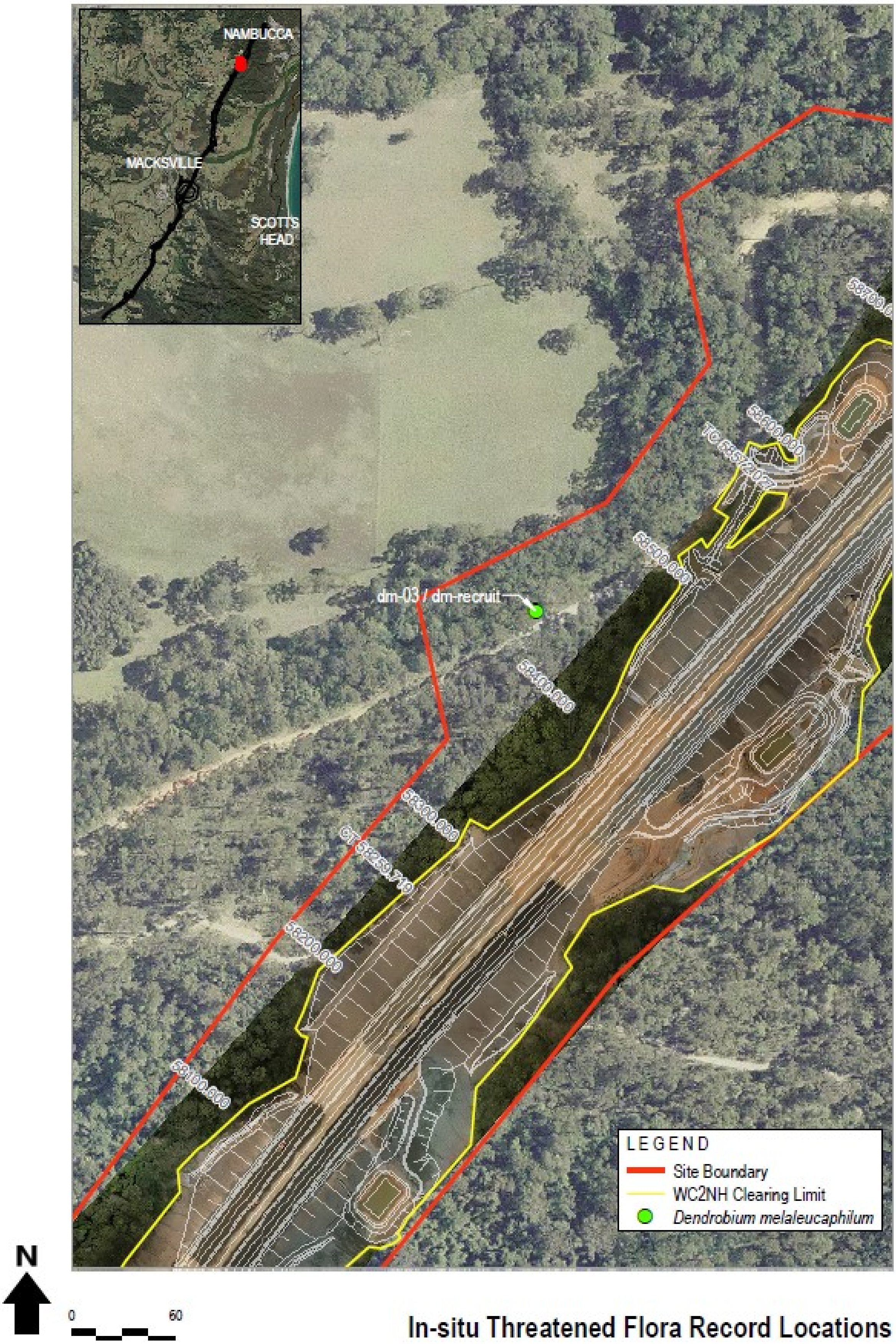

Figure 8: In-situ Spider Orchid, WC2NH. Map sourced from GeoLINK (2017).

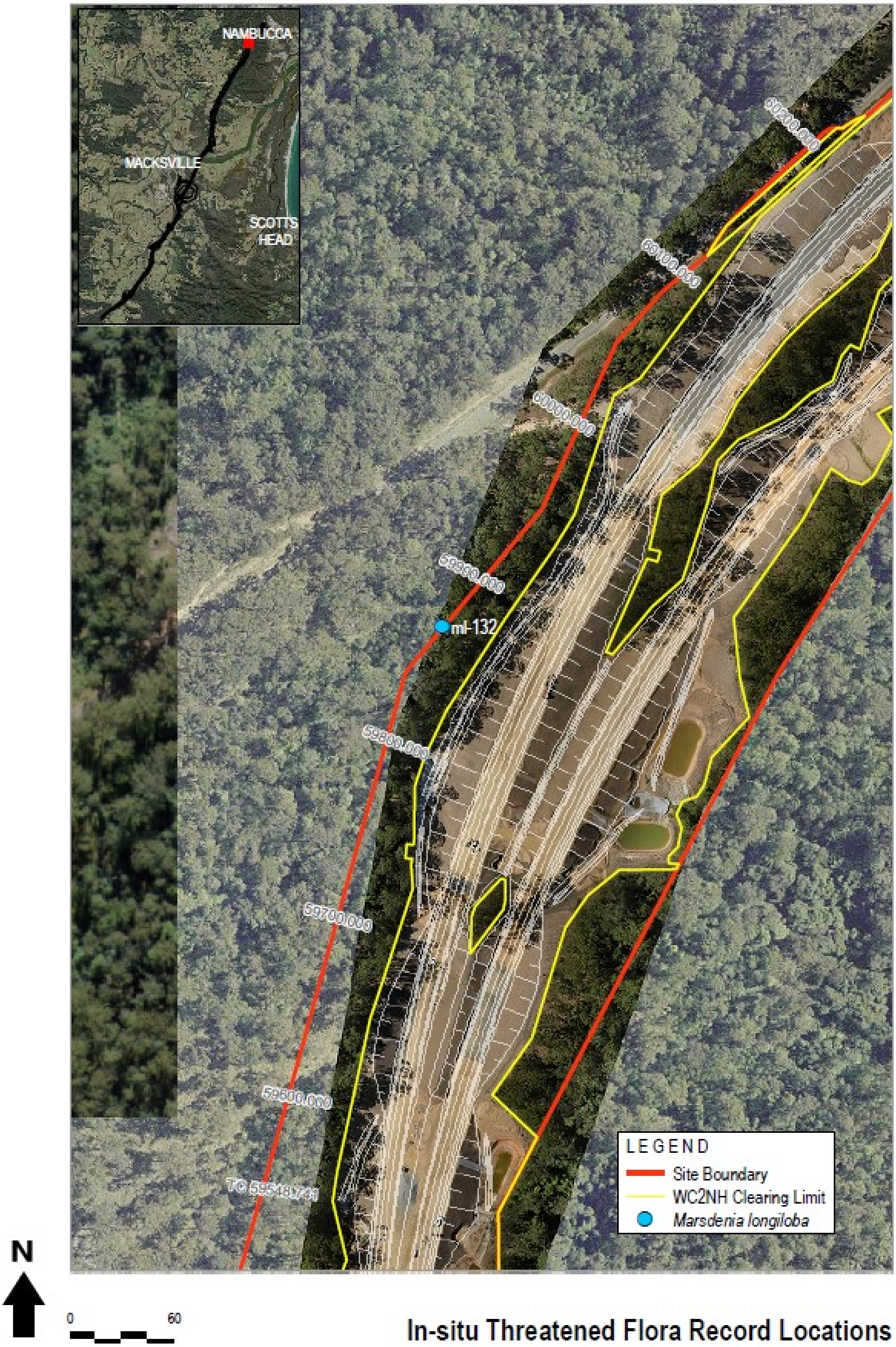

Figure 9: In-situ Slender Marsdenia, WC2NH. Map sourced from GeoLINK (2017).

3.2 Results

See Appendix 2 for photos of the in-situ threatened plant species in November 2020.

3.2.1 Maundia (*Maundia triglochinoides*)

In November 2018, Maundia had a crown cover of 40% within the monitoring plot and extended well beyond the plot, forming a large population. By November 2019, Maundia had almost disappeared from the plot (Table 11) and the surrounding area due to drought conditions. Only a few yellowing leaves were seen. There was no standing water in the swamp and it was dry enough to walk across. The main wetland plant was an *Eleocharis* species, which was unaffected by the dry conditions, as were Ludwigia and several other species. It appears that Maundia requires at least some standing water and a flooded substrate to maintain green growth, otherwise it dies off.

In November 2020, Maundia was again present in the swamp which was 30-50 cm deep and covered in dense aquatic vegetation, including Persicaria strigosa, P. orientalis, Eleocharis sp. and other species. Maundia covered about 20% of the plot and other patches were growing nearby. Several plants were observed with flower spikes.

3.2.2 Spider Orchid (*Dendrobium melaleucaphilum*)

The large Spider Orchid plant (DM03) appeared to have deteriorated. There were more dead pseudobulbs and not many with leaves. Nearly all pseudobulbs had flowered last spring, including dead ones, but no seed pods were formed. This year the plant had 70 pseudobulbs, 8 with leaves and 30 dead pseudobulbs. Sixty pseudobulbs has flowered, but no pods.

3.2.3 Rusty Plum (*Niemeyera whitei*)

All seven in-situ Rusty Plums at Cockburns Lane were alive and in reasonable condition in November 2020 (Table 13). No fruits were observed this year.

Habitat condition at the Cockburns Lane site in November 2020 was generally good. Lantana was scattered throughout the site, but did not appear to be having any negative effects on Rusty Plum or Slender Marsdenia, which also occurs at site.

3.2.4 Slender Marsdenia (*Marsdenia longiloba*)

The monitoring program includes five in-situ Slender Marsdenia occurrences (most with more than one stem including one with 15-30 stems in a small area) across three sites (Table 14). Monitoring Slender Marsdenia through time can be difficult as plants often die back and reshoot and new stems emerge from underground rhizomes away from old stems, making it appear that plants have changed location. This is part of Slender Marsdenia's natural growth pattern and life cycle rather than a response to human-related disturbances.

In November 2020, Slender Marsdenia was actively growing (i.e. green stem and leaves) in all five in-situ locations. In most locations there was more than one stem and so height and plant condition was recorded for the largest stem. The height (of the largest stem) of individuals ranged from 10 cm to 2m cm and condition score ranged from 2 to 4 (Table 14).

The largest in situ Slender Marsdenia occurrence being monitored - ML93 - consists of a clonal patch of small stem-individuals growing across the fence line along Old Coast Road in remnant forest in the road reserve and adjoining property. In November 2020, this patch consisted of about 15 stems within an area approx. 15 m x 10 m, extending from the edge of Old Coast Road to the base of a large Tallowwood (*Eucalyptus microcorys*). All stems were small (<20 cm high) and most were producing new growth (new shoots). No flowering or fruiting was observed. Recruitment in this patch is mostly likely vegetative or asexual by means of production of stems from underground tuberous roots.

At ML132 shoots remained small (<10 cm high). Stems at ml-72, ml-138 and ml-63 occur at Cockburns Lane (same site as in-situ Rusty Plum) were small and one 1.5 m high.

Table 11: In-situ threatened flora monitoring results for Maundia (*Maundia triglochinoides*) recorded by Ecos Environmental 2018 - 2020.

Maundia (*Maundia triglochinoides*)																
Population	Cover-Abundance and (Condition Class Score)			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions (Spr 2019)
	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	
Nambucca Floodplain	40% (5)	<1%	20%	Y	N	Y	Y	Y	Y	Y	N	Y	N	N	N	Canopy height 10-13 m with *Melaleuca quinquenervia* dominant species; ground stratum 100% crown cover; water to 50 cm deep; exotic grass spp. along fauna fenceline with road.

Table 12: In-situ threatened flora monitoring results for Spider Orchid (*Dendrobium melaleucaphilum*) recorded by Ecos Environmental 2018 - 2020.

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Plant ID #	Length of longest pseudobulb (cm)			Leaf Condition			Number of pseudobulbs with leaves			New Growth			Recruitment			Damage/ Disturbance			Site Conditions	GeoLINK notes (PC 2015-Spr 2017)	Ecos Environmental notes (Spr 2019)
	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020			
3	35	35	35	5	5	3	50+	50	8	N	Y	Y	N	N	N	N	N	N	Canopy height 25 m and crown cover approx 90% comprised of Eucalyptus spp.	Very healthy with signs of increased flowering activity.	Fairly healthy, effect of dry conditions evident in many dead and ratty pseudobulbs
DM Recruit	12	12	12	3	3	2	4	4	4	N	N	N	N	N	N	N	N	N		This new recruit was first observed during Spring 2016.	

Table 13: In-situ threatened flora monitoring results for Rusty Plum (*Niemeyera whitei*) recorded by Ecos Environmental 2018 - 2020.

Plant ID #	Height (cm)			Leaf Condition			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions (Spr 2020)
	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	
NW58	800	820	820	4	4	4	N	N	N	Y	Y	Y	N	N	N	N	N	N	Canopy height 20 m with crown cover 70%; some medium to large patches of Lantana scattered throught site.
NW56	120	130	130	4	4	4	N	N	N	Y	Y	Y	N	N	N	N	N	N	
NW73	700	750	750	5	4	4	Y	N	N	N	Y	Y	N	N	N	N	N	N	
NW54	600	640	640	4	4	4	N	N	N	N	Y	Y	N	N	N	N	N	N	
NW64	800	850	850	5	4	4	Y	N	N	N	N	N	N	N	N	N	N	N	
NW01-Geo	450	450	450	4	4	4	N	N	N	N	Y	Y	N	N	N	N	N	N	
NW02-Geo	500	530	530	4	4	4	N	N	N	N	Y	Y	N	N	N	N	N	N	

Table 14: In-situ threatened flora monitoring results for Slender Marsdenia (*Marsdenia longiloba*) recorded by Ecos Environmental 2018 - 2020.

Plant ID	Height (cm)			Leaf Condition			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions	GeoLINK notes (PC 2015-Spr 2017)	Ecos Environmental notes (Spr 2018-to Spr 2020)
	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	PC 2015	Spr 2018	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020	Spr 2018	Spr 2019	Spr 2020			
ML93	100	130	18	2	3	3	Spr 2018	Spr 2019	N	Y	Y	Y	N	Y	N	N	N	N	Canopy height 20 m; crown cover 100% with Eucalyptus microcorys dominant species.	15 live plants now within 1 m radius of subject plant. All range from 2 – 4 in condition class. Some plants recorded during spring 2016 have died back however new recruits have also been recorded and are now at a count of 23 flagged individual plants.	Clonal patch, no. variable 15-30 individuals in an area 15m x 10 m, from the base of E. microcorys to the edge of O)ld Coast Rd. In 2018, most plants small (<20cm high), a few >1 m high. In 2020, all small.
ML132	8	10	5	2	3	3	N	N	N	Y	Y	Y	N	N	N	N	N	N	Canopy height 25 m; crown cover 80%	During Spring 2016 partially natural die back was recorded. The plant recorded during spring 2017 is fresh, green with new growth indicating possibly a new plant to the one previously recorded.	Most shoots tagged 2018 had died off. Two small shoots (<10 cm tall) in 2020 about 1 m apart
ML72	40	10	10	2	3	3	N	N	N	N	N	N	N	N	N	N	N	N	Canopy height 20 m; crown cover 70%	Natural die back of the stem, possibly live stem bulb. No obvious signs of construction related impacts.	Died back and reshot
Ml138	90	10	10	3	3	3	N	N	N	Y	N	Y	N	N	N	N	N	N		Tall plant with mature leaves some yellowing.	Died back and reshot

ML63	10	300	250	2	4	4	N	N	N	N	Y	Y	N	N	N	N	N	N			Healthy

3.3 Conclusion

The survival rate of in-situ threatened species at the end of Year 6 (spring 2020) was 100% for Spider Orchid, Rusty Plum and Slender Marsdenia. (Table15). Maundia does not occur as discrete individuals but as a sward of stems, so its abundance was measure just as crown cover. The plot crown cover of Maundia had increased from <1% last year to 20% in Nov 2020, due the end of the 2019 drought and above average rainfall in 2020. The survival rate of Slender Marsdenia remained stable although there was evidence that stems had died back and reshot, from the same point or close-by from tuberous roots.

No signs of construction-related impacts were observed in spring 2020. The monitoring results meet the performance criteria – *survival rate at the end of Years 4-8 is >70%* and *of surviving plants at end of each year >75% are in good condition (class 3 or >)* – for Spider Orchid, Rusty Plum and Slender Marsdenia and therefore no corrective actions are required for these species. Note that >75% of in-situ Slender Marsdenia plants do not have a class score of 3 or > as they were not taller than 75 cm, but this is not of concern for this species because of its clonal habit and tendency for stems to dieback and regrow again.

Table 15: Performance measures for In-situ Threatened Flora Populations monitoring.

Species	Survival rate at finish of clearing (October 2015/ Spring 2015) is 100%, no accidental damage due to clearing	Survival rate at end of Years 1-3 is >80%	Survival rate at end of Year 4 (2018)	Survival rate at the end of Years 4-8 is >70%	Of surviving plants at end of each year >75% are in good condition (class 3 or >)			
					Year 2 - 2016	Year 3 - 2017	Year 5 - 2019	Year 6 - 2020
Spider Orchid (*Dendrobium melaleucaphilum*)	Yes - 100% survival No accidental damage due to clearing	Yes - 100% survival	Yes - 100%	Not applicable yet	Yes - 100% in good condition, with new recruit. recorded also in good condition (score 3)	Yes - 100% (including new recruit) in good condition (Score 4)	Yes - 100% with one plant reproductive	Yes - 100% with one plant reproductive
Maundia (*Maundia triglochinoides*)	Yes - 100% survival No accidental damage due to clearing	Yes - 83% survival	No - <1% survival (trace)%	Not applicable yet	Yes - 100% in good condition (score 5)	Yes - 100% of visible plants in good condition (score 3)	No – poor condition (score 1)	Yes – good recovery after the drought, flowering (score 3)
Rusty Plum (*Niemeyera whitei*)	Yes - 100% survival No accidental damage due to clearing	Yes - 100% survival	Yes - 100%	Not applicable yet	Yes - 80% in good condition (score 2 - 5)	Yes - 100% in good condition (score 3 - 5)	Yes - 100% with some plants reproductive	Yes - 100% with some shoot growth
Slender Marsdenia (*Marsdenia longiloba*)	No - 62% of plants were recorded as living But no construction related impacts were recorded	No - 60%	Yes - 100%	Not applicable yet	Yes - 100% (5 of 5 records) recorded scores 3 - 4	No - 60% (3 of 5 records) recorded scores 1 - 4	No - 40% in good condition	Yes - 70% in good condition

4 Slender Marsdenia and Woolls' Tylophora Habitat Condition

4.1 Methodology

This component of the TFMP aims to monitor Slender Marsdenia and Woolls' Tylophora habitat within the indirect impact zone – i.e. within 10 m of the edge of clearing – for potential edge effects and declines in habitat condition. The study design involves ten permanent plots along the edge of clearing in known Slender Marsdenia and Woolls' Tylophora habitat (Figures 10-12). Each plot is 10 m * 20 m with the long axis parallel to the edge of clearing. Within each plot, the following vegetation and landscape attributes are measured:

- Native vegetation structure (according to Native Vegetation Interim Type Standard)
- Level of weed incursion (measured by summing the abundance of all exotic species)
- Microclimate class (Table 16).

The plots were established by GeoLINK on 26 November 2015 around the time that clearing operations in the northern zone of the project were being completed. The plots were again monitored by GeoLINK during autumn and spring 2016 and spring 2017. See GeoLINK (2017) for more information.

Ecos Environmental carried out the first yearly operation phase monitoring of the ten plots in November 2018. The plots were located and data on the above parameters were collected. Native vegetation structure was measured according to Roads and Maritime Services (2018) which states that: "Structure consists of the height, crown cover and dominant species in each vegetation layer and will be recorded according to the current OEH vegetation standard (Native Vegetation Interim Type Standard – http://www.environment.nsw.gov.au/research/VISplot.htm)."- p27.

Ecos Environmental was sent GeoLINK (2017) after the data were collected and when it was read it became apparent that GeoLINK measured native vegetation structure differently to the Interim Type Standard. Specifically, overall crown cover was estimated for each stratum rather than individually for the three most dominant species. As Ecos Environmental followed the Interim Type Standard as per Roads and Maritime Services (2018), our vegetation structure data had to be compared qualitatively rather than quantitatively with GeoLINK's data. Appendix 4 includes GeoLINK (2017) data on vegetation structure.

Ecos Envrionmetal carried out the third yearly operation phase monitoring in November 2020, which is described in this report.

Table 16: Microclimate exposure classes for Slender Marsdenia and Woolls' Tylophora habitat.

Microclimate Class (less exposed to more exposed)	**Microclimate Type**
1	Sheltered aspect (e.g. south) and vegetation understorey slightly more open and exposed than before clearing.
2	Sheltered aspect (e.g. south) and vegetation understorey moderately more open and exposed than before clearing.
3	Sheltered aspect (e.g. south) and vegetation understorey much more open and exposed than before clearing.
4	Exposed aspect (e.g. east, north and west) and vegetation understorey slightly more open and exposed than before clearing.
5	Exposed aspect (e.g. east, north and west) and vegetation understorey moderately more open and exposed than before clearing.
6	Exposed aspect (e.g. east, north and west) and vegetation understorey much more open and exposed than before clearing.

Figure 10: Slender Marsdenia and Woolls’ Tylophora Habitat monitoring quadrats 5, 6, 7 and 8, WC2NH. Map sourced from GeoLINK (2017).

Figure 11: Slender Marsdenia and Woolls’ Tylophora Habitat monitoring quadrats 9 and 10, WC2NH. Map sourced from GeoLINK (2017).

Figure 12: Slender Marsdenia and Woolls’ Tylophora Habitat monitoring quadrats 1, 2, 3 and 4, WC2NH. Map sourced from GeoLINK (2017).

4.2 Results

Comparing (qualitatively) the vegetation structure data recorded by Ecos Enviromental (Table 18) with that recorded by GeoLINK (Appendix 4), no major changes in vegetation structure could be inferred.

It appears that since spring 2015 the level of weed incursion has increased in some plots but decreased in others (Table 17). All changes, however, are minor with weed crown cover remaining far below the performance measure threshold of 25%.

The data also indicate that the microclimate of some plots in spring 2020 differs from previous years. Specifically, that plots 6, 7, 8, 9 and 10 became more exposed. The data, however, should be interpreted cautiously as it were collected by two different observers – GeoLINK from 2015-2017 and Ecos Environmental in 2018-2020 – and therefore likely reflects observer variability. In the field, Ecos Environmental was of the impression that the vegetation understorey of plots was either moderately or much more exposed than before clearing. Consequently, no plots were assigned a microclimate class of 1 or 4 (for different aspects but both meaning only slightly more exposed than before clearing). GeoLINK, on the other hand, assigned plots 6, 7, 8, 9 and 10 either a 1 or 4 depending on their aspect.

Table 17: Weed level and microclimate class of Slender Marsdenia and Woolls' Tylophora habitat plots.

Plot	Weed Level (% crown cover)	Microclimate Class
1	Lantana	
Spring 15 (GeoLINK)	<5%	5
Autumn 16 (GeoLINK)	5	5
Spring 16 (GeoLINK)	5	5
Spring 17 (GeoLINK)	5	5
Spring 18 (Ecos)	<5%	5
Spring 19 (Ecos)	5	5
Spring 20 (Ecos)	5	5
2	Lantana, Whisky Grass	
Spring 15 (GeoLINK)	<5%	5
Autumn 16 (GeoLINK)	5	5
Spring 16 (GeoLINK)	10	5
Spring 17 (GeoLINK)	10	5
Spring 18 (Ecos)	<5%	5
Spring 19 (Ecos)	<5%	5
Spring 20 (Ecos)	5%	5
3	Lantana	
Spring 15 (GeoLINK)	<5%	1
Autumn 16 (GeoLINK)	<5%	1
Spring 16 (GeoLINK)	<5%	1
Spring 17 (GeoLINK)	<5%	1
Spring 18 (Ecos)	<5%	2
Spring 19 (Ecos)	<5%	2
Spring 20 (Ecos)	<5%	3
4	Lantana	
Spring 15 (GeoLINK)	0	2
Autumn 16 (GeoLINK)	0	2
Spring 16 (GeoLINK)	0	2
Spring 17 (GeoLINK)	0	2
Spring 18 (Ecos)	<5%	2
Spring 19 (Ecos)	<5%	2
Spring 20 (Ecos)	<5%	2
5	Lantana, Setaria, Broad-leaved Paspalum	
Spring 15 (GeoLINK)	<5%	5
Autumn 16 (GeoLINK)	<5%	5
Spring 16 (GeoLINK)	<5%	5
Spring 17 (GeoLINK)	<5%	5
Spring 18 (Ecos)	<5%	5

Plot	Weed Level (% crown cover)	Microclimate Class
Spring 19 (Ecos)	<5%	5
Spring 20 (Ecos)	<5%	5
6	Lantana	
Spring 15 (GeoLINK)	5	4
Autumn 16 (GeoLINK)	5	4
Spring 16 (GeoLINK)	5	4
Spring 17 (GeoLINK)	5	4
Spring 18 (Ecos)	<5%	5
Spring 19 (Ecos)	10	5
Spring 20 (Ecos)	10	5
7	Broad-leaved Paspalum	
Spring 15 (GeoLINK)	0	1
Autumn 16 (GeoLINK)	0	1
Spring 16 (GeoLINK)	0	1
Spring 17 (GeoLINK)	0	1
Spring 18 (Ecos)	<5%	2
Spring 19 (Ecos)	0	2
Spring 20 (Ecos)	0	2
8	Lantana	
Spring 15 (GeoLINK)	5	1
Autumn 16 (GeoLINK)	5	1
Spring 16 (GeoLINK)	7	1
Spring 17 (GeoLINK)	5	1
Spring 18 (Ecos)	<5%	2
Spring 19 (Ecos)	<5%	2
Spring 20 (Ecos)	<5%	2
9	Lantana, Broad-leaved Paspalum, Coastal Morning Glory	
Spring 15 (GeoLINK)	5	1
Autumn 16 (GeoLINK)	5	1
Spring 16 (GeoLINK)	<5%	1
Spring 17 (GeoLINK)	<5%	1
Spring 18 (Ecos)	<5%	2
Spring 19 (Ecos)	<5%	2
Spring 20 (Ecos)	<5%	2
10	Lantana, Billygoat Weed, Setaria	
Spring 15 (GeoLINK)	<5%	4
Autumn 16 (GeoLINK)	<5%	4
Spring 16 (GeoLINK)	<5%	4
Spring 17 (GeoLINK)	<5%	4
Spring 18 (Ecos)	<5%	5
Spring 19 (Ecos)	<5%	5
Spring 20 (Ecos)	<5%	5

Table 18: Vegetation structure of ten Slender Marsdenia and Woolls' Tylophora habitat monitoring plots, WC2NH. Data recorded November 2020 by Ecos Environmental.

Stratum	**Dominant species**	**Cover (% crown cover)**	**For the entire**		
Plot 1					
Upper	*Eucalyptus grandis*	10	Upper stratum Height to crown (m) min-mode-max		
Upper	*Syncarpia glomulifera*	20			
Upper			20	20	30
Mid	*Lophostemon confertus*	20	Mid stratum Height to crown (m) min-mode-max		
Mid	*Cissus hypoglauca*	65			
Mid	*Acacia binervata*	15	4	5	10
Lower	*Blechnum cartilagineum*	30	Lower stratum Height to crown (m) min-mode-max		
Lower	*Dodonaea triquetra*	15			
Lower	*Cordyline stricta*	10	0.5	2	4
Plot 2					
Upper	*Syncarpia glomulifera*	50	Upper stratum Height to crown (m) min-mode-max		
Upper	*Eucalyptus microcorys*	20			
Upper	*Allocasurina torolosa*	15	15	24	28
Mid	*Cissus hypoglauca*	40	Mid stratum Height to crown (m) min-mode-max		
Mid	*Calicoma seratifolia*	15			
Mid	*Trochocarpa laurina*	15	2	8	15
Lower	*Blechnum cartilagineum*	20	Lower stratum Height to crown (m) min-mode-max		
Lower	*Morinda jasminoides*	25			
Lower	*Cryptocarya rigida*	30	0.5	1	2
Plot 3					
Upper	*Syncarpia glomulifera*	15	Upper stratum Height to crown (m) min mode max		
Upper	*Eucalyptus grandis*	30			
Upper	*Eucalyptus anchorphylla*	10	28	28	30
Mid	*Cryptocarya rigida*	50	Mid stratum Height to crown (m) min mode max		
Mid	*Callicoma seratofolia*	30			
Mid	*Cissus hypoglauca*	40	4	5	12
Lower	*Blechnum cartilagineum*	30	Lower stratum Height to crown (m) min mode max		
Lower	*Livistonia australis*	30			
Lower	*Ripognum forcetianum*	15	0.5	1	3
Plot 4					
Upper	*Eucalyptus grandis*	30	Upper stratum Height to crown (m) min mode max		
Upper	*Eucalyptus glomulifera*	25			
Upper	*Eucalyptus acmenoides*	10	20	30	30
Mid	*Livistonia australis*	5	Mid stratum Height to crown (m) min mode max		
Mid	*Alphitonia excelsa*	20			
Mid	*Synoum glandulosum*	10	4	5	15
Lower	*Cissus hypoglauca*	50	Lower stratum Height to crown (m) min mode max		
Lower	*Gahnia sieberana*	20			

Stratum	Dominant species	Cover (% crown cover)	For the entire		
Lower	*Lepidosperma laterale*	5	0.5	1	2
Plot 5					
Upper	*Syncarpia glomulifera*	40	Upper stratum Height to crown (m) min mode max		
Upper	*Glochidion ferdinandii*	10			
Upper	*Gmelina leichhardtii*	10	15	18	20
Mid	*Livistonia australis*	15	Mid stratum Height to crown (m) min mode max		
Mid	*Guioa semiglauca*	30			
Mid	*Cissus hypoglauca*	20	7	10	12
Lower	*Cordyline stricta*	20	Lower stratum Height to crown (m) min mode max		
Lower	*Gahnia aspera*	15			
Lower	*Lomandra longifolia*	10	0.8	1	1.5
Plot 6					
Upper	*Eucalyptus pilularis*	40	Upper stratum Height to crown (m) min mode max		
Upper	*Lophostemon confertus*	20			
Upper	*Eucalyptus microcorys*	20	15	22	27
Mid	*Trochocarpa laurina*	15	Mid stratum Height to crown (m) min mode max		
Mid	*Acacia melanoxylum*	15			
Mid	*Tabernaemontana pandacaqui*	20	5	8	12
Lower	*Cordyline stricta*	20	Lower stratum Height to crown (m) min mode max		
Lower	*Livistonia australis*	20			
Lower	*Blechnum cartilagineum*	10	0.5	1	2
Plot 7					
Upper	*Eucalyptus microcorys*	80	Upper stratum Height to crown (m) min mode max		
Upper	*Eucalyptus grandis*	10			
Upper			14	20	22
Mid	*Leptospermum polygalifium*	35	Mid stratum Height to crown (m) min mode max		
Mid	*Archirhodomyrtus beckleri*	10			
Mid	*Glochidion ferdinandi*	10	1.5	3	5
Lower	*Calochlaena dubia*	80	Lower stratum Height to crown (m) min mode max		
Lower	*Lomandra longifolia*	5			
Lower	*Blechnum cartilagineum*	5	0.5	0.7	1
Plot 8					
Upper	*Eucalyptus grandis*	70	Upper stratum Height to crown (m) min mode max		
Upper					
Upper			30	24	18
Mid	*Cissus hypoglauca*	20	Mid stratum Height to crown (m) min mode max		
Mid	*Rubus moluccanus*	20			
Mid	*Guioa semiglauca*	20	12	8	7
Lower	*Blechnum cartilagineum*	25	Lower stratum Height to crown (m) min mode max		
Lower	*Oplismenus imbecilis*	30			
Lower	*Morinda jasminoides*	15	2	1	0.3

Stratum	Dominant species	Cover (% crown cover)	For the entire		
Plot 9					
Upper	*Eucalyptus grandis*	15	Upper stratum Height to crown (m) min mode max		
Upper	*Corymbia intermedia*	30			
Upper	*Eucalyptus microcorys*	10	14	25	32
Mid	*Cryptocarya rigida*	30	Mid stratum Height to crown (m) min mode max		
Mid	*Livistonia australis*	15			
Mid	*Synoum glandulosum*	10	1.5	2.5	7
Lower	*Gahnia siberana*	5	Lower stratum Height to crown (m) min mode max		
Lower	*Lastreopsis* sp.	25			
Lower	*Cordyline stricta*	2	0.1	0.5	1
Plot 10					
Upper	*Eucalyptus grandis*	70	Upper stratum Height to crown (m) min mode max		
Upper					
Upper			20	25	28
Mid	*Melaleuca stypeloides*	10	Mid stratum Height to crown (m) min mode max		
Mid	*Lophostemon confertus*	10			
Mid	*Cissus antarctica*	20	2	8	10
Lower	*Morinda jasminoides*	40	Lower stratum Height to crown (m) min mode max		
Lower	*Opplismenus imbecilis*	40			
Lower	*Cissus antarctica*	20	0.3	1.2	2

4.3 Conclusion

The monitoring plot data suggest that to date there have been no declines in Woolls' Tylophora and Slender Marsdenia habitat condition along the edge of clearing.

Applying the method specified by RMS (2018), different microclimate exposure scores were assigned for some plots than GeoLINK (2017), which most likely reflects observer variability rather than physical changes. Plot crown-cover of exotic species at the end of year 5 ranged from 0 to 10% or well below below the performance threshold of 25%, and vegetation structure appeared to have remained the same. Therefore, no corrective actions are required (Table 19).

Table 19: Performance measures for Slender Marsdenia and Woolls' Tylophora Habitat Condition monitoring.

Performance measure	**Yes/No – comments**
Plot crown-cover of exotic species is no more than 25% at the end of Years-2 to 8.	Yes – plot crown cover of exotic species at the end of year 6 is 0-10%
Baseline vegetation structure (height and crown cover) remains the same or increases in height and crown cover at the end of each year compared to the previous year.	Yes – qualitative assessment of vegetation structure data revealed no major decreases in height and crown cover at the end of year 6 compared to year 5
There is no increase in the microclimate exposure class (e.g. 1 to 2, or 4 to 5) compared to the previous year.	No – the plots 6 and 10 maintained microclimate exposure score of 5 and plots 6-9 increased from 2 to 3, but this most likely reflects observer variability rather than physical changes.

5 Recommendations

The following corrective actions (see Table 20) are recommended in relation to the results of the Floyds Grass translocation (see Section 2.3.7) recorded in Year 3 of the operational phase monitoring.

Table 20: Recommended program of corrective actions to treat decline in habitat condition and vigour of translocated Floyds Grass translocation area at the Warrell Ck TA.

Item No.	**Task**	**Personnel**	**Time**	**TfNSW response**
1	**Weed control/habitat restoration**			Agree to be adopted.
	Hand weed Broad-leaved Paspalum; set up wick wip test in sub-sample area; spray out 10 m habitat restoration zone around Area 1 and 2; remove flood debris etc.	Plant ecologist and bush regenerator.	May-June 2021	
2	**Follow-up tubestock planting and weed removal**			Agree to be adopted.
	Plant tubestock in habitat restoration zone Swamp Oak, Flooded Gum, Forest Red Gum and install 1.2 m high chicken wire tree guards to prevent wallaby grazing	Bush regenerator	Aug/Sept 2021	
3	**Follow-up weed control**	Bush regenerator	3-6 monthly to May 2022	Agree to be adopted.
4	**Monitoring** (as part of WC2NH annual translocation monitoring)	Plant ecologist	Nov/Dec 2021	Already in place

6 References

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Appendix 1: Photos Translocated Threatened Flora

Plate 1: Transplanted Rusty Plum no. 1 at Receival Site 1 Cockburns Lane showing one dead branch and new tip growth. Nov/2020.

Plate 2: Transplanted Rusty Plum no. 2 at Receival Site 1 Cockburns Lane, 4.1 metres high after 6 years. Original height approx. 8 m with a dbh of 30 cm. New stems and branches resprouted from trunk cut off about 1 m above ground. Nov/2020.

Plate 3: Rusty Plum seedling at Receival Site 7a, directed seeded Dec/2017, approx. 25 cm high Nov 2020. No increase in height in the last 12 months.

Plate 4: Transplanted Spider Orchid at Receival Site 7a. The orchid comprises a tight clump of about 50 slender pseudobulbs, most with a pair of leaves at the end. Small bristles can be seen which are the remains of orchid flower spikes produced in August-September 2020. Nov 2020.

Plate 5: Transplanted Spider Orchid at Receival Site 7a after six years. The original stem supporting the orchid was removed and attached to tree in a gully at the receival site. Nov 2020.

Plates 6 and 7: Floyds Grass translocation area – Receival Site 9, Area 1. Close-up of Floyds Grass and Ottochloa growing together and mounds with Floyds Grass underneath Ottochloa growing on top. Nov/2020.

Plate 8. Floyds Grass translocation area – Receival Site 9, Area 1. Warrell Creek on the left hand side.

Plate 9. Floyds Grass translocation area – Receival Site 9, Area 1. Floyds Grass in the foreground and encroaching Broad-leaved Paspalum. Nov/2020.

Plates 10 and 11. Floyds Grass Receival Site 9, Area 1 showing dense Broad-leaved Paspalum surrounding the translocation area, and wood chipped patches in the background (attempt at habitat restoration).

Plate 12. Floyds Grass Receival Site 9, Area 2 showing dense Broad-leaved Paspalum within the translocation area.

Plate 13. Floyds Grass Receival Site 9, Area 2. There is still a reasonable amount of Floyds Grass growing amongst Broad-leaved Paspalum which would have a much better chance of survival if the site had more maintenance, which it missed out on during the construction period.

Plates 14-16: Receival Site 1 Cockburns Lane. Upper – habitat with in situ and transplanted Slender Marsdenia; Lower – transplanted Slender Marsdenia's no. 1 and 18. Nov 2020.

Plate 17: Receival Site 3. This site was relatively open and unshaded, and usually had a SE breeze blowing through it. Slender Marsdenia transplanted to the site had a high survival rate and high mean height.

Plate 18: Receival Site 3, Slender Marsdenia no. 5. This plant flowered in Nov 2020 and the year before, the only one recorded flowering out of 164 tranplanted.

Plate 19: Receival Site 5a. This receival site had a denser 'rainforest' understory and deeper shade.

Plate 20: Small Slender Marsdenia in Receival Site 5a

Plate 21: Receival Site 7a. The survival rate and mean height of Slender Marsdenia at this site were relatively low . The habitat has a denser understory and deeper shade compared to other sites.

Plate 22: Transplanted Slender Marsdenia in Receival Site 7a. This one has left the wire cylinder and has climbed a small tree.

Plate 25: Receival Site 8a. From top left, Slender Marsdenia nos. 3, 6, 8 and 12. This receival site is relatively open on the edge of clearing and a track. Survival rate and mean height are high.

Plate 26: Receival Site 8c. This receival site was relative open and unshaded. Survival and growth rates of transplanted Slender Marsdenia were relatively high compared to other receival sites.

Plate 27: Receival Site 8c. Slender Marsdenia no. 15. Nov 2020.

Appendix 2: Photos In Situ Threatened Flora

Plate 28: In situ Rusty Plum NW 73 at Cockburns Lane, growing hard against the trunk of a Flooded Gum but in good condition. Nov 2020.

Plate 29: Maundia triglochinoides with the sword shaped leaves at in situ monitoring site on the Nambucca River floodplain. Water in swamp 0.5 m of water after 2019 drought. Nov 2020.

Plate 30: After declining from 40% to <1% crown cover in the 2019 drought (crown cover <1%), Maundia recovered quickly in 2020, which had above average rainfall, refilling the swamp at the monitoring site alongside the new highway. Photo shows Maundia flowering, Nov 2020.

Plate 31: In Situ Slender Marsdenia ML-93, Old Coast Road. Slender Marsdenia growing in a litter mound at the base of a large Tallowwood tree with stem-individuals also extending to the right into the road reserve up to edge of road.

Plate32: Close up of small Slender Marsdenia stem-individuals in photo above.

Plate 33: In Situ Spider Orchid in swampy wet sclerophyll forest on Old Coast Road. The plant had decline since last year, possibly an effect of the 2019 drought. The pseudobulbs were in poor condition. Many were discoloured, partly hollow, possibly grazed by something. Most had flowered in spring. Nov 2020.

Plate 34: In Situ Spider Orchid. Close up of above showing remains of terminal flower racemes.

Appendix F Landscape Monitoring

Warrell Creek to Nambucca Heads Landscape Rehabilitation Monitoring Operational Phase Annual Report 2019/2020




Prepared for:

Sandpiper Ecological Surveys, PO Box 401, Alstonville 2477, on behalf of

Transport for New South Wales, 21 Prince St Grafton, NSW 2460

Prepared by:

ECOS Environmental Pty Ltd

PO Box 641 Mullumbimby, NSW 2482

ph: 0487050005; email: andrewbenwell@bigpond.com

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Contents

1 Introduction

Construction of the Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrade began in February 2015 and opened to traffic mid-2018. The project saw 19.6 km of the Pacific Highway between Warrell Creek and Nambucca Heads upgraded to a dual carriageway road.

To revegetate batters, verges and other bare ground along the new highway corridor, general and targeted landscape rehabilitation treatments were implemented, as described in the project's Urban Design and Landscape Plan (RMS 2018a). The landscaping treatments were applied in 2016 as different sections of the project earthworks were completed and new drainage lines constructed.

To assess the results and effectiveness of the landscape rehabilitation treatments, 12 sites representing three different landscaping treatments are being monitored for the first four years of highway operation, as required by the *Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief* (Roads and Maritime Services 2018b) and the *Warrell Creek to Nambucca Heads Stage 2 Ecological Monitoring Program Revision C, June 2018* (Roads and Maritime Services 2018c).

The 12 monitoring sites were first recorded during the construction phase by Geolink and results are described in Geolink 2016 and Geolink 2017. Monitoring of the landscape rehabilitation sites during the first four years of highway operation is being conducted by Ecos Environmental for Sandpiper on behalf of Traffic NSW. The first year of operational phase monitoring (2018/2019) was reported in Ecos Environmental (2019). This annual monitoring report covers the second year of the monitoring program to Winter 2020.

The contents of the report are set out as follows:

Section 2 describes the landscape rehabilitation treatments applied on the WC2NH project, monitoring site locations and data collection methods.

Section 3 presents the monitoring results and

Section 4 discusses the effectiveness of the landscaping treatments in achieving goals, any issues with implementation and outcome, and suggests measures to improve landscape rehabilitation outcomes in future.

The assessments and views presented in this report are those of the author Dr Andrew Benwell who has a horticultural background (Dip Hort, Burnley Vic) and a PhD in plant ecology (UNE, Armidale, NSW). Experience in the field of highway landscaping and revegetation includes reviews of draft landscaping plans and related advice for several Pacific Highway upgrade projects for RTA/RMS, and implementation of works including seed collection, propagation, and planting. A Discussion Paper on the use of soil seedbanks for revegetation and landscaping was prepared in 2009 and updated for the Glenugie Project in 2015 and WC2NH in 2018.

2 Methods

2.1 Landscape Monitoring Sites

Twelve locations sampling the three landscape rehabilitation treatments applied on the project were selected for monitoring (see Table 1 and Figure 1). These included 5 replicates of the Seed Mix treatment, four of Bushland Reconstruction and three of Landscape Planting.

Bushland Reconstruction sites are located in the north of the road corridor (see Figure 1) as they adjoined forested areas where landscaping aimed to restore ecologically compatible vegetation, and closer to source areas for salvaging bush topsoil (RMS 2018a).

The three landscaping treatments are explained in the next section (2.2)

Table 1 Monitoring locations and landscaping treatments (RMS 2018a).

No.	Location	Treatment
1	Fill 4 Embankment East – Southern Zone	Seed Mix 1 (hydroseeding)
2	Fill 4 Embankment West – Southern Zone	Seed Mix 2 (hydroseeding)
3	Cut 2 Embankment East – Southern Zone	Seed Mix 3 (hydroseeding)
4	Ancillary Area Fill 19 West – Northern Zone	Seed Mix 4 (direct seeding)
5	Fill 5 Vegetated Drainage Swale – Southern Zone	Seed Mix 5 (hydroseeding)
6	Cut 22 Embankment East – Northern Zone	Bushland Reconstruction (see note 1 below)
7	Cut 22 Embankment West – Northern Zone	Bushland Reconstruction
8	Fill 20 Embankment East – Northern Zone	Bushland Reconstruction
9	Cut 18 Embankment East – Northern Zone	Bushland Reconstruction
10	Williamson Creek	Landscape Planting (see note 2 below)
11	Stoney Creek	Landscape Planting
12	Butchers Creek	Landscape Planting

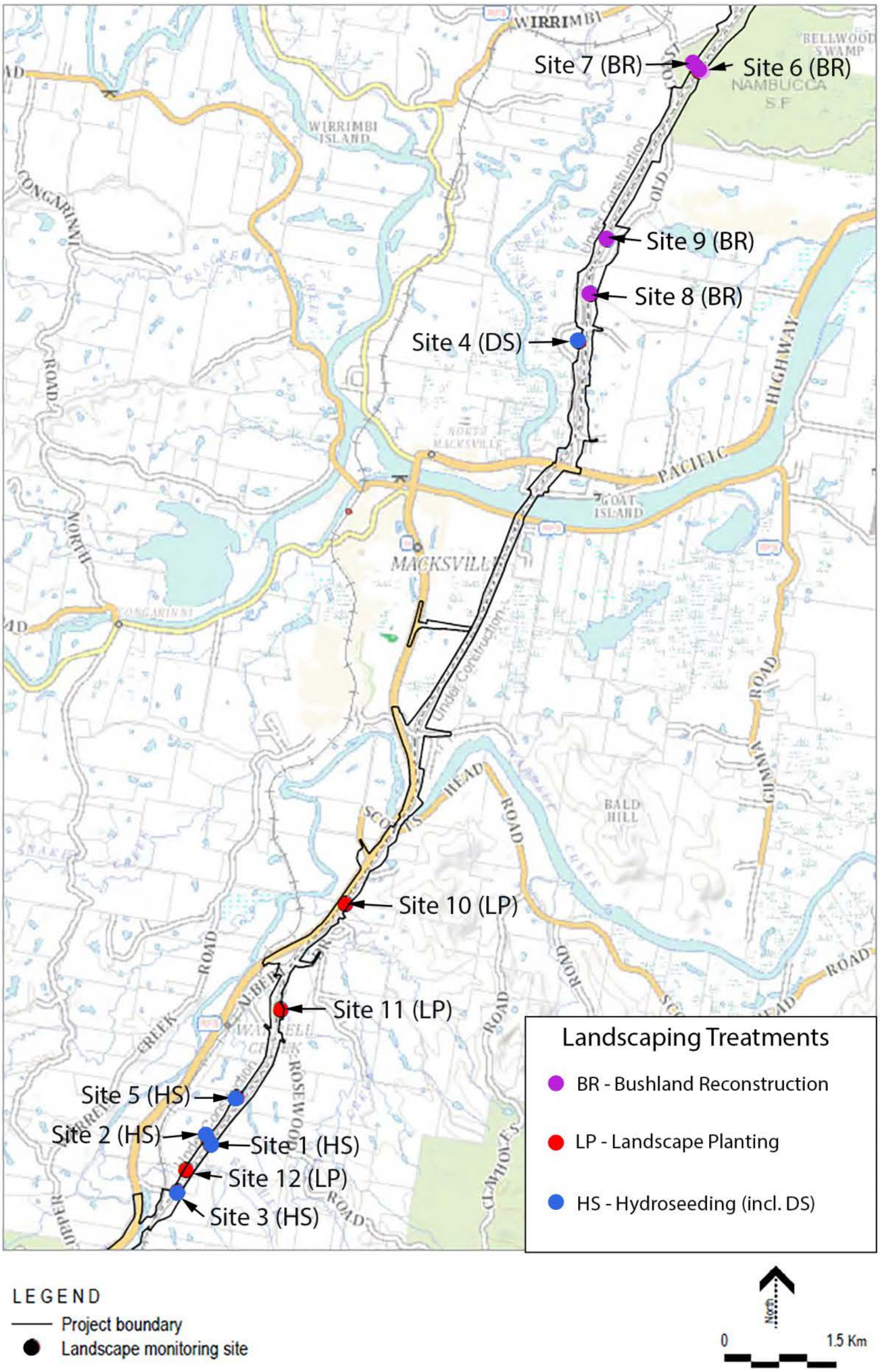

Figure 1: Monitoring Site Locations and Landscaping Treatments

2.2 Landscape Rehabilitation Methods

Landscape rehabilitation works were implemented according to The *Warrell Creek to Nambucca Heads Upgrade Project Urban Design and Landscape Plan* (RMS 2018a), which sets out the landscaping treatments to be applied on the project as earthworks and drainage line construction were completed. Three main approaches to landscaping were applied, referred to as Seed Mix, Bushland Reconstruction and Landscape Planting (RMS 2018a), as described below.

2.2.1 Seed Mix

The Seed Mix method was the main landscaping treatment applied on the WC2NH project, accounting for landscaping along about 80% of the highway corridor. In this treatment, topsoil was spread over cut and fill batters and other bare areas, and a slurry of water, seed and mulch sprayed (hydromulched) over the area from a high-pressure hose mounted on a tanker truck. This is the conventional method used on highway construction projects for broadscale landscaping and revegetation, the only difference being in the properties of the topsoil and seed mixes applied. Sites with five different seed mixes consisting of different combinations of indigenous and exotic grass, shrub and sedge species were included in this monitoring program, as indicated in Table 2.

To minimise haulage, topsoil was salvaged and stockpiled near to where it would be reapplied. It can be seen from Figure 1 that the Seed Mix treatment was applied in the southern three quarters of the road corridor, which mainly intersects cleared grazing land, so the topsoil salvaged would have had a high content of exotic grass seed.

2.2.2 Bushland Reconstruction

Bushland Reconstruction aimed to restore vegetation consisting mainly of native species reflecting the surrounding vegetation and was implemented in the north of the road corridor closer to forested habitat and source areas of topsoil with a seedbank composed of indigenous species.

Topsoil would be salvaged from bushland along the road corridor and combined with clearing mulch in the ratio of 3:2, and the topsoil seedbank of native species augmented with a seed mix consisting of Acacia species, Themeda australis, Cymbopogon refractus and Hardenbergia, as indicated at the bottom of Table 2. All the ingredients (i.e. topsoil, additional seed and clearing mulch) were combined and applied over the substrate surface. Topsoil and clearing mulch were blended prior to application and spread over the batters by machine (Clearing mulch is the woody mulch material generated from forest clearing.)

The bushland seed mix was then applied to the batter via hydromulch application (i.e. a slurry of seed and straw mulch).

Soil ameliorants were also added including Urea and Potassium (RMS 2018a), the Urea to counteract nutrient drawdown by the high C:N ratio of a 3:2 mixture of topsoil and clearing mulch.

Bushland Reconstruction aimed to reconstruct vegetation cover consisting of native species, whereas the Seed Mix approach was primarily concerned with establishing a vegetation cover appropriate for basic functions of revegetating the highway such as landscaping aesthetics, erosion control, frangibility, minimising weeds and utilising native species where possible. The key differences between the Bushland Reconstruction and Seed Mix methods are the type of soil medium (bushland topsoil includes clearing mulch 60:40 vs only site won topsoil for other areas) and different seed mixes sprayed onto the revegetation areas, which both determine the type of vegetation established on the landscaping/revegetation site.

2.2.3 Landscape Planting

Landscape Planting was carried out in areas where the aim was to restore particular habitats, particularly riparian and wetland areas. Nursery-propagated, indigenous species were planted in these areas after completion of drainage works. Although not part of the treatment, local topsoil was also present carrying a pasture seedbank of exotic species, which influenced landscaping outcomes.

Table 2. Landscaping treatments applied at monitoring sites.

(Note – Table 1 indicates the treatment as hydroseeding, but this is more accurately describing as hydromulching,)

Site	Treatment	Application	Date of application	Media	Species seeded/planted
1	Seed Mix (Seed Mix 1)	Hydromulching	20/01/2016	Topsoil 100%	Indigenous grass species
2	Seed Mix (Seed Mix 2)	Hydromulching	7/04/2016	Topsoil 100%	Indigenous and exotic pasture grass species
3	Seed Mix (Seed Mix 3)	Hydromulching	20/01/2016	Topsoil 100%	Indigenous grass and shrub species
4	Seed Mix (Seed Mix 4)	Direct Seeding (tractor drawn)	7/11/2016	Topsoil 60%, mulch blend 40%	Indigenous and exotic pasture grass species
5	Seed Mix (Seed Mix 5)	Hydromulching	19/09/2016	Topsoil 100%	Indigenous grasses and sedges
6	Bushland Reconstruction	Hydromulching	2/04/2016	Bushland topsoil 60%, mulch blend 40%	BRC seed mix[1]
7	Bushland Reconstruction	Hydromulching	2/04/2016	Bushland topsoil 60%, mulch blend 40%	BRC seed mix[1]
8	Bushland Reconstruction	Hydromulching	16/09/2016	Bushland topsoil 60%, mulch blend 40%	BRC seed mix[1]
9	Bushland Reconstruction	Hydromulching	8/04/2016	Bushland topsoil 60%, mulch blend 40%	BRC seed mix[1]
10	Landscape Planting	Planting	14/11/2016	Topsoil 100%	Indigenous riparian and wetland species (planting mix code PM4C)[2]
11	Landscape Planting	Planting	12/09/2016	Topsoil 100%	Indigenous riparian and wetland species (planting mix code PM4A and PM4C)[2]

12	Landscape Planting	Planting	14/11/2016	Topsoil 100%	Indigenous riparian and wetland species (planting mix code PM4AA, PM4C, PM6 and PM7)[2]

[1]BRC seed mix made up of: Acacia longifolia @ 0.25 kg/ha, Acacia floribunda @ 0.25 kg/ha, Acacia fimbriata @ 0.25 kg/ha, Cymbopogon refractus @ 1 kg/ha, Hardenbergia violacea @ 1 kg/ha, Themeda australis @ 1 kg/ha.

[2]See GeoLINK (2017) for species list of each planting mix code.

2.3 Data Recording

To record the vegetation resulting from the landscape rehabilitation treatments, plant species composition was recorded in permanent/fixed 50 m belt transects at 12 locations representing the three main landscaping treatments. As indicated above, the transects were set out in 2016 during the construction phase. Monitoring for this report was carried out during the operational phase, from Spring 2018.

The monitoring program (RMS 2018b) requires collection of the following data along each transect:

- Treatment percentage cover
- Braun-Blanquet cover class score
- Weed species present
- Details on plant species present (included in mix)
- Details on plant species present (not included in mix)
- Signs of stress, predation or disease

All species on each transect were recorded and assigned a cover-abundance score according to the Braun-Blanquet scale:

1 – cover < 5% one or a few individuals;

2 - <5% more than a few individuals;

3 – 5-25%;

4 – 25-50%;

5 – 50-75%;

6 – 75-100%.

Crown cover was recorded within a 50 m long x 5 m wide area (belt transect). Photos were taken at the northern and southern transect marker stakes (or eastern and western in the case of sites 11 & 12) at each monitoring event.

In Year 1 a slightly modified method was trialled where each 50 m transect was divided into five 10 m segments and species crown cover recorded in each segment, the objective being to increase sample number and statistical precision. However, the higher level of sampling did not make trends in species composition across the landscaping treatments any clearer, so this modification was dropped in the second year in favour of single measures of species abundance by Braun Blanquet cover class. The crown cover values per segment in year 1 were combined into an overall B-B cover class value per transect.

Monitoring was carried out quarterly in spring, summer, autumn and winter. This report describes the results of the second year of monitoring, which will continue for a total of four years.

2.4 Data Analysis

The number of native and exotic species per transect, and the BB cover of natives and exotics per transect were averaged for each treatment. As the B-B scale is proportional to cover for 3-6 then drawn out in 1-2, low cover species are weighted higher than high cover species. To adjust for this distortion in assessing the overall cover of exotic and native species, the B-B cover scores of species were squared then summed. This gave a better representation of the actual relative crown cover of species. Without the adjustment the total cover of exotics and natives in Seed Mix sites was about the same, which hardly made sense when they were clearly dominated by Setaria (BB score 6) plus a few plants of native species (BB score 1 six times).

Ordination was also applied to give an overall summary of how the treatments differed in species composition. Non-metric multidimensional scaling was performed on end of monitoring year species data and plotted in ordination space. This was performed in *R* version 3.6.1 (R Core Team 2019) using the *metaMDS* function of the *vegan* package (Oksanen et al. 2019).

Treatments were compared in terms of species number and cover index of exotics and natives recorded end of monitoring year in winter 2019 and 2020. The ecological quality of the landscaping treatment results was quantified in this monitoring study as number of locally indigenous native species and degree of weed cover.

3 Results

In winter 2020, the Bushland Reconstruction treatment had the highest mean native cover (c.i. = 71.3) and lowest mean exotic cover (c.i. = 16) (Table 3). The Bushland Reconstruction treatment also had the highest mean number of native species (19.3) and lowest mean number of exotic species (3.5) per transect. Conversely, the Seed Mix treatment had the lowest mean native cover (c.i. = 11.8) and highest mean exotic cover (c.i. = 42.6) per transect.

The Seed Mix transects changed little in species composition over two years (Table 3). This reflects the rapidity with which species (Setaria and Acacia) established crown cover. Density increased but crown cover remained about the same. The dominance of Setaria was starting to become evident at the end of Year 1 (Geolink 2017) and after two more years all sites were densely covered in Setaria.

In the Bushland Reconstruction treatment, native species cover increased substantially between winter 2019 and winter 2020. Very noticeable was a large increase in the native parasitic vine Cassytha pubescens (Dodder Laurel). See Table 4 for a summary of the monitoring results for each site.

Table 3: Number of native and exotics species, and cover-abundance of native and exotic species in three landscaping treatments (seed mix; bushland reconstruction and landscape planting), recorded winter 2019 and winter 2020.

Treatment/ Transect	**Winter 2019**		**Winter 2020**		**Winter 2019**		**Winter 2020**	
	No. of natives	No. of exotics	No. of natives	No. of exotics	Native cover	Exotic cover	Native cover	Exotic cover
Seed Mix								
Transect 1	4	6	4	6	19	44	12	41
Transect 2	7	8	7	7	31	43	30	42
Transect 3	6	5	5	5	6	40	5	43
Transect 4	4	7	4	9	4	29	4	47
Transect 5	7	7	8	5	17	42	8	40
Mean	**5.6**	**6.6**	**5.6**	**6.4**	**15.4**	**39.6**	**11.8**	**42.6**
Bushland Reconstruction								
Transect 6	25	7	27	6	84	6	97	6
Transect 7	22	1	20	1	63	1	88	1
Transect 8	11	5	11	5	45	28	35	37
Transect 9	20	2	19	2	35	5	65	20
Mean	**19.5**	**3.8**	**19.3**	**3.5**	**56.8**	**10.0**	**71.3**	**16.0**
Landscape Planting								
Transect 10	9	9	9	10	30	14	16	19
Transect 11	24	15	24	12	59	18	48	38
Transect 12	3	8	3	8	6	34	9	30
Mean	**12.0**	**10.7**	**12.0**	**10.0**	**31.7**	**22.0**	**24.3**	**29.0**

The distinctive species composition of the Bushland Reconstruction treatment is evident in the ordination results, where the BRC transects occupy a separate part of the ordination space, with little overlap with the other two treatments (Figure 2). The Bushland

Reconstruction sites were characterised by native grasses, shrubs and trees, such as, *Cymbopogon refractus*, *Hakea gibbosa* and *Acacia longifolia*. The Landscape Planting sites were characterised by wetland species such as *Juncus usitatus*, *Lomandra longifolia* and *Persicaria strigosa*. The Seed Mix sites were characterised by mostly weed species such as *Setaria sphacelata, Paspalum mandiocanum* and *Conyza bonariensis*.

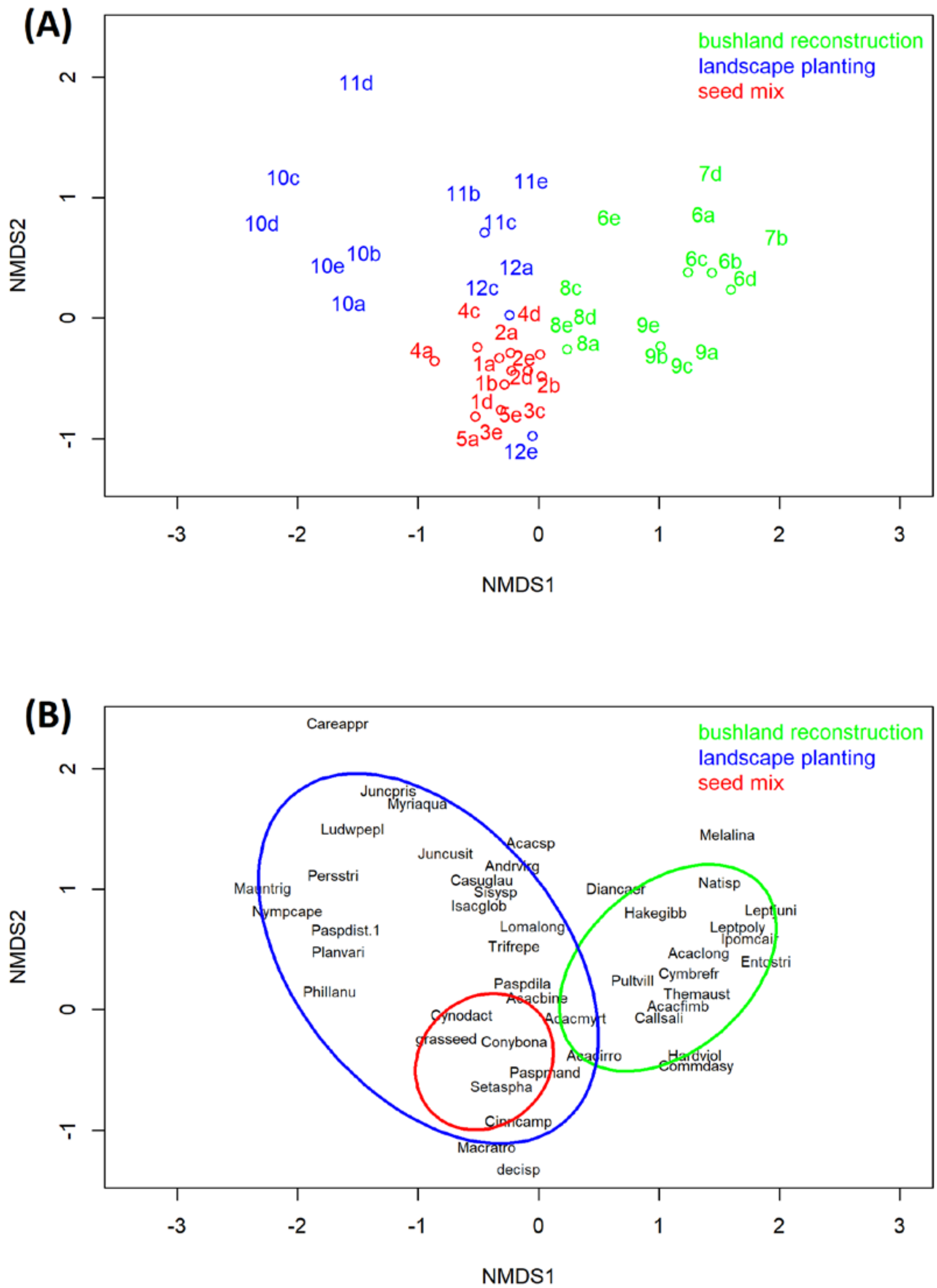

Figure 2. Non-metric multidimensional scaling of Transects of three landscape rehabilitation treatments. Stress = 0.15. Graph A shows the Transects in ordination space, where the closer Transects are in 2-d space, the more similar they are in terms of species composition.

(a to e subscripts refer to the 10 m sub-transects). To reduce clutter, the *orditorp* function of the *vegan* package was used. Graph B shows species most characteristic of each treatment. Species names are abbreviated to the first four letters of genus and species.

Table 4. Summary of Landscape Reconstruction monitoring sites.

Monitoring site no.	Treatment	Seeding/Planting mix	Annual monitoring summary (2020)
1	Seed Mix	Seed Mix 1 - Indigenous grass species	Dominated by Setaria sphacelate, open canopy of native Acacia spp., suite of natives and exotics in low abundance, minor change throughout year
2	Seed Mix	Seed Mix 2 - Indigenous and exotic pasture grass species	Dominated by Setaria sphacelate, open canopy of native Acacia spp., suite of natives and exotics in low abundance, little change throughout year
3	Seed Mix	Seed Mix 3 - Indigenous grass and shrub species	Dominated by Setaria sphacelate, open canopy of native Acacia spp., suite of natives and exotics in low abundance, little change throughout year
4	Seed Mix	Seed Mix 4 - Indigenous and exotic pasture grass species	Remained mostly bare throughout year, species present mostly exotic grasses
5	Seed Mix	Seed Mix 5 - Indigenous grasses and sedges	Dominated by Setaria sphacelate, open canopy of native Acacia spp., suite of natives and exotics in low abundance, little change throughout year
6	Bushland Reconstruction	Bushland Reconstruction	Relatively high native species richness, low cover of exotics, increase in native cover throughout year
7	Bushland Reconstruction	BRC seed mix	Relatively high native species richness, low cover of exotics, increase in native cover throughout year
8	Bushland Reconstruction	BRC seed mix	Relatively high native species richness, high Setaria sphacelate and Paslpalum mandiocanum abundance, increase in native cover throughout year
9	Bushland Reconstruction	BRC seed mix	Relatively high native species richness, moderate Paslpalum mandiocanum abundance, increase in native cover throughout year
10	Landscape Planting	Indigenous riparian and wetland species (planting mix code PM4C)[2]	Site along artificial creek, exotic grasses along bank, native sedges and rushes in water, Maundia triglochinoides (threatened species) present, minor changes throughout year
11	Landscape Planting	Indigenous riparian and wetland species (planting mix code PM4A and PM4C)[2]	Site along creek, mix of semi-aquatic and non-aquatic species, high native and exotic species richness, little change throughout year
12	Landscape Planting	Indigenous riparian and wetland species (planting mix code PM4AA, PM4C, PM6 and PM7)[2]	Site along artificial creek and adjacent natural creek, site dry throughout year, mostly bare, dominant species *Lomandra longifolia* and exotic grasses, little change throughout the year

[1]BRC – Bushland Reconstruction seed mix made up of: Acacia longifolia @ 0.25 kg/ha, Acacia floribunda @ 0.25 kg/ha, Acacia fimbriata @ 0.25 kg/ha, Cymbopogon refractus @ 1 kg/ha, Hardenbergia violacea @ 1 kg/ha, Themeda australis @ 1 kg/ha.

[2]See GeoLINK (2017) for species list of each planting mix code.

4 Discussion of the Monitoring Results

4.1 Seed Mix

Seed Mix Monitoring Sites 1, 2, 3, 4 & 5 had the highest exotic plant cover, lowest native plant cover and lowest number of native species. These sites were seeded by hydromulching (Sites 1, 2, 3 and 5) or direct seeded with a tractor (Site 4), and 100% topsoil (i.e. no clearing mulch) was applied beforehand.

After four years, vegetation at the Seed Mix sites had an open to dense canopy of Acacia species and a ground layer dominated by *Setaria sphacelata*. A small suite of exotic and native herbs and shrubs was also present in low abundance. The Acacia species grew throughout the two-year monitoring period despite long periods of below average rainfall. *Acacia fimbriata* had the highest cover-abundance across the sites followed in decreasing order by *A. irrorata, Acacia longifolia, A. falcata, A. binervata, A. myrtifolia* and *A. floribunda*. The last three species had mostly died out after four years and appear to be unsuitable for inclusion in hydromulching seed mixes.

Each site received a different seed mix. In the information provided to Ecos Environmental, apart from Acacias, indigenous grasses are listed as the main species in the seed mixes (GeoLINK 2017). No indigenous grass species were recorded by Ecos Environmental at the sites. GeoLINK (2017) also did not record indigenous grasses in their baseline 2016 and summer 2017 monitoring. Therefore, it appears that this component of the seed mixes was unsuccessful and that the understorey plant composition is instead a result of the seedbank in the topsoil applied to the sites. By contrast, the results of Bushland Reconstruction showed that hydromulched native grasses (*Themeda* and *Cymbopogon*) established well on batters of gravelly clay with little topsoil, where Setaria was absent from the seedbank.

Setaria or South African Pigeon Grass is a vigorous and dominating pasture grass common in warm, high rainfall coastal areas of the Mid and Far North Coast of NSW. In pasture it is kept down by cattle grazing (for which it was introduced). When cattle are withdrawn, it rapidly grows to over 2 m high and increases in density, smothering other native and exotic herbaceous plants (grasses, broad-leaved herbs, sedges etc). Cattle grazing increases the vigour of Setaria by increasing soil N and P. Ecologically it is a real problem as most native species are reduced or completely displaced by Setaria and plant diversity declines.

Setaria is widespread in grazing land surrounding the WC2NH project, although often not visible in paddocks along roadsides, as it is grazed down by cattle, which also allows a more mixed pasture. Topsoiling of batters with soil taken from local paddocks increases the likelihood of Setaria becoming established because the seedbank already present in the soil, the high growth potential of this species and the absence of cattle from the road corridor. Dominance of Setaria also results on any flat ground with an in-situ pasture seedbank after construction has finished. Setaria seed lacks a plume and generally falls on the ground near the parent plant, so that seed spreads slowly unless assisted by bulk movement of soil or in soil on the hooves of cattle.

Acacia species added to hydromulch (particularly A. fimbriata collected/selected from previous revegetation) were able to germinate and grow successfully in competition with Setaria, hence the resultant vegetation of tall Acacia shrubs over a dense tall Setaria grass understorey. Other species added to the mixes failed to establish because of Setaria competition (dense overtopping and smothering).

Once Setaria is established along a highway, broadscale control is usually impractical. In retrospect, measures that could potentially be used to reduce the potential of Setaria dominating revegeation on future highway projects within the region, include the following:

- Avoid topsoiling batters with soil salvaged from pasture or other weedy areas where this species is present. It is acknowledged that for most projects there is not excess topsoil and importing large quantities of topsoil would be a very significant additional cost to projects.

- Hydromulch natives directly over subsoil material on cut and fill batters, as this substrate is free of weed seed. Many natives, particularly leguminous species that fix their own nitrogen, are very hardy and if selected appropriately will grow and establish on gravelly clay. This can be seen in the results of the Bushland Reconstruction treatment, where only a very shallow depth of bush topsoil appears to have been applied (with clearing mulc) – see below. It is acknowledged that this would likely increase erosion and sedimentation risks in the short to medium term as would take longer for vegetation to stabilise cut and fill batters.

- Alternatively, apply a minimum of 100 mm (to 300 mm) of topsoil salvaged during clearing from forest with few or no weeds (including Setaria). Successful use of topsoil for revegetation along highways requires considerable planning before construction starts to (i) ensure that adequate space is provided to store topsoil as it is stripped off, (ii) tested and reliable means of storage to ensure the topsoil seedbank remains viable, (iii) data on the species that will germinate from the seedbank, their rate of growth etc. Use of native species soil seedbanks has several advantages including potentially lower landscaping costs, high species diversity, local provenance assured, low weeds and frangible species, as pointed out in RMS (2018a, p. 72).

- Greater use could be made of woody clearing mulch for Setaria suppression by blanket application (e.g. 30 cm deep) in combination with planting.

4.2 Bushland Reconstruction

The *Warrell Creek to Nambucca Heads Upgrade Project Urban Design and Landscape Plan* states: “Bushland reconstruction is an alternative revegetation methodology that is quickly becoming the Roads and Maritime’s preferred method of revegetation due to successful outcomes and environmental and project benefits. The methodology involves careful topsoil stripping and stockpiling, retention of existing seed within the topsoil, amelioration with the addition of nutrients and shredded mulch containing endemic seed and direct return of the topsoil to as near as possible to the location from where it was sourced. The methodology has been employed on other Roads and Maritime projects, including the nearby Pacific Highway precedent of Glenugie Upgrade." (p. 72, Sec. 5.6.7). This approach to landscaping/ revegetation was targeted at the northern end of the WC2NH project, closer to indigenous forest and sources of topsoil containing native species seedbank.

The Bushland Reconstruction sites had the highest native plant cover and highest number of native species. Conversely, exotic plant cover and number of exotic species were lowest at these sites. Bushland topsoil media, integrated shredded mulch (i.e. woody clearing mulch), seed and ameliorants were applied to the sites in 2016. The ratio of topsoil to mulch was 60:40. The seed mix contained the following species:

- Acacia longifolia @ 0.25 kg/ha
- Acacia floribunda @ 0.25 kg/ha
- Acacia fimbriata @ 0.25 kg/ha
- Cymbopogon refractus @ 1 kg/ha
- Hardenbergia violacea @ 1 kg/ha
- Themeda australis @ 1 kg/ha.

The results showed an increase in native plant cover at the BRC sites over the two-year period. Exotic plant cover increased slightly but remained low. All sites had low exotic plant cover, except for Site 8 which had a high abundance of *Setaria sphacelata* and *Paspalum mandiocanum*. A mistake appears to have been made with the classification of this site, as it is remarkably similar in species composition to a Seed Mix site.

All species applied as seed in the BRC seed mix (see six species listed above) were recorded by Ecos Environmental and these species dominated the vegetation at all the Bushland Reconstruction sites. In addition, 15 species most likely originating from the seedbank of bushland topsoil applied to the sites were also recorded (Table 5). However, most of these were in low abundance and contributed little to overall cover.

Several other species appear to have been added to the BRC seed mix, including four apparently non-indigenous native species (see Table 5). These are species native to NSW but probably not local ecosystems.

The Bushland Reconstruction treatment appears to have been effective in rehabilitating vegetation dominated by native species, and with a low abundance of weeds. However, the sites were dominated by species used in the BRC seed mix, not local soil seedbank species, as was intended according to the quote at the start of this section. Species from the local seedbank make up a small proportion of plant cover, with the notable exception of Hop Bush (*Dodonaea triquetra*), a soil seedbank species and probably the most common post-disturbance regenerator in the local area.

The results indicate that there are aspects of how this treatment was applied that could have been improved on. The local forest seedbank if properly salvaged, stored and reapplied should produce a dense cover of native plants. This has not occurred, as the species that dominate the sites are from the BRC seed mix. The main value of the BRC method applied was in excluding exotic species, especially Setaria.

The BRC specifications in RMS (2018a) stated: "Soil mixture (combined topsoil and mulch) depth up to 300 mm thick…..Shallower depths may be required for non-alluvial soils, or should site-won materials prove insufficient." (p. 74). The relevant Specification (R178) for topsoil reuse is 50 mm on 2:1 batters (.) Inspection of the soil at BRC sites during monitoring suggested little topsoil and mainly woody clearing mulch fragments with gravelly clay substrate visible at the surface, although this could have been due to sheet erosion or low soil humus content to begin with. The low regeneration from the soil seedbank recorded during monitoring appeared to reflect the shallow depth of topsoil applied, but could also have been due to (i) decline in seedbank viability during storage by being uncovered, or (ii) the high proportion of clearing mulch combined with the topsoil (Ecos Environmental 2015). Urea (soil ameliorant) was added to correct the soil C:N ratio, but soil chemistry and soil microflora could have been significantly altered by the inclusion of semi-decomposed mulch material, causing increased seed or seedling mortality.

Finally, a note about the parasitic vine *Cassytha pubescens* (Dodder Laurel or Cassytha), which has recorded a marked increase in cover at two of the Bushland Reconstruction Sites (6 &7). This species is a leafless vine and forms a tangled growth of stems with suckers that tap into the vascular system of virtually any plant it grows over, which it can eventually kill. It is non-host specific, growing on herbs and woody plants. It regenerates from dormant seed in the soil seedbank and its seed are dispersed by birds in small berries.

This species is present at Sites 6 and 7, where it has increased in density, so it is difficult to walk through the sites (see Winter 2020 photo on p.24). In natural bush it occasionally occurs at similar density in shrubby coastal forest and heath, particularly after fire, but usually it is much more sporadic than seen at the Bushland Reconstruction sites. (Cassytha can also be seen growing densely in landscaping along the Nambucca Heads to Urunga section, directly to the north of WC2NH.) It is possible that the hydroseeded species, or seed selections added to the BCR mix provided a particularly susceptible combination of plants for this parasite. Cassytha has weedy traits and is a significant weed overseas (apparently originating from Australian species). Local native plants may develop defences that prevent it forming dense infestations in local plant communities. This ecological balance could have been disrupted in the landscaped vegetation (using imported seed and species).

4.3 Conclusions

The Seed Mix and Landscaping treatments were successful in establishing a functional vegetation cover from a highway operation perspective, although results were marred to some degree by tall, dense, exotic Setaria grass which originated from local topsoil salvaged from pasture, cleared areas, or soil already in place on level ground. Once established it is impractical to attempt eradication of this species over large areas. Suggestions were made to reduce this grass on future projects.

With the Bushland Reconstruction method, regeneration of local native species from salvaged topsoil was limited and the vegetation dominated instead by native species in the BRC seed mix, which was hydromulched over the spread topsoil (mixed with mulch). The weak contribution of species from salvaged forest soil seedbanks to the resultant revegetation appears to be partly due to shallow depth of application, but other factors could also have been involved, including:

- Method of topsoil storage – open or covered; low or high etc
- Duration of topsoil storage
- Effects of clearing mulch on seed germination and seedling survival
- Depth of topsoil application
- Source vegetation/ecosystem type – was it suited to batters?

4.4 Recommendations

1. Continue operational monitoring program as specified (another two years to run), to record vegetation outcomes from landscaping treatments over time.

2. TfNSW consider incorporating in a future construction project, a systematic trial to evaluate the effect of methods of topsoil storage (e.g. covered and uncovered, duration time) on soil seedbank viability.

Table 5: Species composition of Bushland Reconstruction (BRC) sites including species abundance (i.e. relative establishment success) and whether the species originated from salvaged topsoil seedbank, added seed mix and seeded from adjoining forest. Origin (known or likely) is based on information provided and knowledge of the species population ecology. In some cases, interpretations may be wrong.

Species	Abundance	Origin	Comment
Acacia longifolia	Common	Seed Mix	Documented BRC seed mix
Acacia floribunda	Rare	Seed Mix	Documented BRC seed mix
Acacia fimbriata	Common	Seed Mix	Documented BRC seed mix
Cymbopogon refractus – Barb wire Grass	Common	Seed Mix	Documented BRC seed mix
Themeda Australia – Kangaroo Grass	Common	Seed Mix	Documented BRC seed mix
Acacia sp.? long leaf	Common	Seed Mix	Possibly a sub-species of A. elongata; may not be indigenous to region
Leptospermum polygalifolium var. ?	Common	Seed Mix	Leaf form unknown to author, may not be indigenous to region
Callistemon sp. ?	Common	Seed Mix	Unknown species to author, may not be indigenous to region
Melaleuca linariifolia	Rare	Seed Mix	Stores seed in capsules on branches, unlikely to be in soil seedbank
Hakea gibbosa	Occasional	Seed Mix	Stores seed in follicles, unlikely to be in soil seedbank, not in region?
Pultenaea villosa – Hairy Bush Pea	Occasional	Soil seedbank	Probably soil seedbank, also commonly used in hydroseeding
Pultenaea retusa – Bush Pea	Occasional	Soil seedbank	
Dodonaea triquetra – Hop Bush	Common	Soil seedbank	
Billardiera scandens – Apple Berry	Occasional	Soil seedbank	
Persoonia sp. – Geebung	Rare	Soil seedbank	
Davesia ulicifolia – Bitter Pea	Occasional	Soil seedbank	Probably soil seedbank, also used in hydroseeding
Kennedia rubicundaa – Coral Vine	Occasional	Soil seedbank	
Acacia binervata	Occasional	Soil seedbank	
Gonocarpus tetragynus - Raspwort	Occasional	Soil seedbank	
Commersonia dasyphylla	Rare	Soil seedbank	
Glycine clandestine	Occasional	Soil seedbank	
Ozothamnus diosmifolius – Snow Bush	Rare	Soil seedbank	
Babingtonia sylvestris – A myrtle	Rare	Soil seedbank	
Lepidosperm laterale – Sword Sedge	Occasional	Soil seedbank	
Entolasia stricta – Forest Wire Grass	Occasional	Soil seedbank	
Cassytha pubescens – Dodder Laurel	Common	Soil seedbank	
Eucalpytus piluaris, microcorys, resinifera	Occasional	Adjoining Forest	Seed blown in from adjoining forest, saplings up to 4 m high

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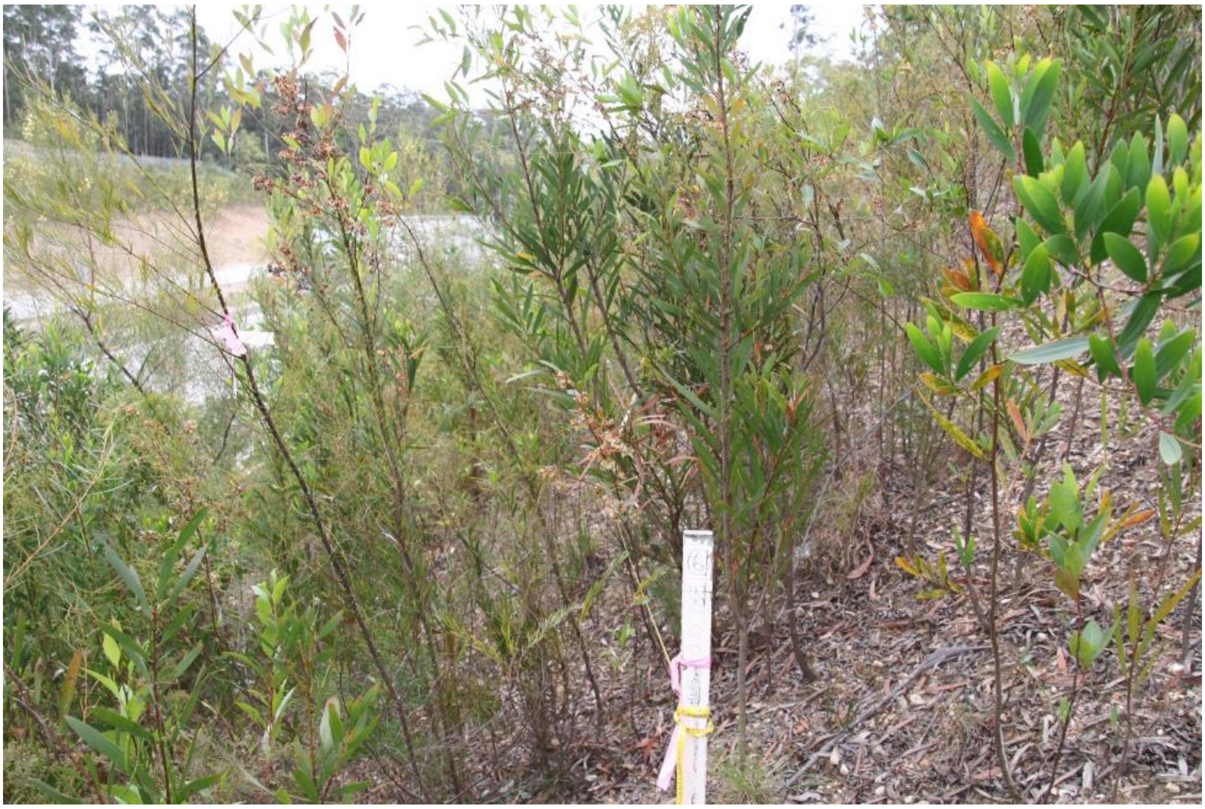
Roads and Maritime Services (2018b). Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief.

Roads and Maritime Services (2018c). Warrell Creek to Nambucca Heads Stage 2 Ecological Monitoring Program Revision C, June 2018.

Photographs of Monitoring Sites (Winter 2020)

PLOT 6 – SOUTHERN END Winter 2020



PLOT 6 – SOUTHERN END Winter 2019

PLOT 6 - NORTHERN END, Winter 2020

PLOT 6 - NORTHERN END, Winter 2019

PLOT 7 – SOUTHERN END, Winter 2020

PLOT 7 – SOUTHERN END, Winter 2019

PLOT 7 – NORTHERN END

PLOT 7 – NORTHERN END

PLOT 8 – SOUTHERN END, Winter 2020

PLOT 8 – SOUTHERN END, Wnter 2019

PLOT 8 – NORTHERN END, Winter 2020

PLOT 8, NORTHERN END., winter 2019

PLOT 9 – SOUTHERN END, Winer 2020

PLOT 9 – SOUTHERN END, Wnter 2019

PLOT 9 - NORTHERN END, Winter 2020

PLOT 9 - NORTHERN END, Winter 2019

SEED MIX (Tractor applied)

PLOT 4 – SOUTHERN END, Winter 2020

PLOT 4 – SOUTHERN END, Winter 2019

PLOT 4 – NORTHERN END, Winter 2020

PLOT 4 – NORTHERN END, Winter 2019

SEED MIX

PLOT 1 – SOUTHERN END, Winter 2020

PLOT 1 – SOUTHERN END, Winter 2019

PLOT 1 – NORTHERN END, Winter 2020

PLOT 1 – NORTHERN END, Winter 2019

SEED MIX

PLOT 3 SOUTHERN END, Winter 2020

PLOT 3 SOUTHERN END, Winter 2019

PLOT 3 NORTHERN END, Winter 2020

PLOT 3 NORTHERN END, Winter 2019

SEED MIX

PLOT 2 – SOUTHERN END, Winter 2020

PLOT 2 – SOUTHERN END, Winter 2019

PLOT 2 – NORTHERN END, Winter 2020

PLOT 2 – NORTHERN END, Winter 2019

SEED MIX

PLOT 5 – SOUTHERN END, Winter 2020

PLOT 5 – SOUTHERN END, Winter 2019

PLOT 5 – NORTHERN END, Winter 2020

PLOT 5 – NORTHERN END, Winter 2019

LANDSCAPE PLANTING

PLOT 10 – EASTERN END, Winter 2020

PLOT 10 – EASTERN END, Winter 2019

PLOT 10 – WESTERN END, Winter 2020

PLOT 10 – WESTERN END, Winter 2019

LANDSCAPE PLANTING

PLOT 11 – SOUTHERN END, Winter 2020

PLOT 11 – SOUTHERN END, Winter 2019

PLOT 11 – NORTHERN END, Winter 2020

PLOT 11 – NORTHERN END, Winter 2019

LANDSCAPE PLANTING

PLOT 12 – SOUTHERN END, Winter 2020

PLOT 12 – SOUTHERN END, Winter 2019

PLOT 12 – NORTHERN END, Winter 2020

PLOT 12 – NORTHERN END, Winter 2019

Transect Species Composition (Winter 2020)

Landscape monitoring Transect 1 – Seed Mix

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	1	490057, 6595205	490079, 6595238
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Setaria sphacelata	6		
Conyza bonariensis	1		
Acacia floribunda	3		
Senecio madagascariensis	1		
Acacia irrorata	1		
Verbena bonariensis	1		
Sida rhombifolia	1		
Acacia melanoxylum	1		
Cinnamomum camphora	2		
Kennedia rubicunda	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 2 – Seed Mix

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	2	490052, 6595299	490026, 6595259
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Setaria sphacelata	6		
Acacia floribunda	4		
Acacia irrorata	3		
Glycine clandestina	1		
Paspalum mandiocanum	1		
Verbena bonariensis	1		
Kennedia rubicunda	1		
Senecio madagascariensis	1		
Conyza bonariensis	1		
Passiflora edulis	1		
Plantago varia	1		
Acacia melanoxylum	1		
Pultenaea villosa	1		
Centella asiatica	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 3 – Seed Mix

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	3	489722, 6594721	489686, 6594689
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Setaria sphacelata	6		
Senecio madagascariensis	1		
Paspalum mandiocanum	2		
Acacia floribunda	1		
Conyza bonariensis	1		
Acacia melanoxylum	1		
Acacia fimbriata	1		
Acacia longifolia	1		
Kennedia rubicunda	1		
Macroptilium atropurpureum	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 4 – Seed Mix

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	4	494369, 6604590	494387, 6604626
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Setaria sphacelata	6		
Paspalum dilatatum	2		
Sida rhombifolia	1		
Plantago varia	1		
Conyza bonariensis	1		
Dodonaea triquetra	1		
Cynodon dactylon	1		
Centella asiatica	1		
Paspalum mandiocanum	1		
Kennedia rubicunda	1		
Plantago varia	1		
Senecio madagascariensis	1		
Hypochaeris radicata	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 5 – Seed Mix

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	5	490383, 6595788	490359, 6595741
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Setaria sphacelata	6		
Senecio madagascariensis	1		
Conyza bonariensis	1		
Acacia floribunda	1		
Cynodon dactylon	1		
Kennedia rubicunda	1		
Paspalum mandiocanum	1		
Paspalum dilatatum	1		
Glycine clandestina	1		
Centella asiatica	1		
Acacia floribunda	1		
Acacia irrorata	1		
Acacia melanoxylum	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 6 – Bushland Reconstruction

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	6	495781, 6607729	495814, 6607767
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Cassytha sp.	4		
Acacia longifolia	3		
Dodonaea triquetra	3		
Leptospermum polygalifolium	2		
Acacia fimbriata	2		
Acacia long narrow	1		
Pultenaea villosa	1		
Themeda australis	1		
Cymbopogon refractus	1		
unknown grass sp.	1		
Blechnum cartilagineum	1		
Billardiera scandens	1		
Daviesia ulicifolia	1		
Cynodon dactylon	1		
Eucalyptus microcorys	1		
Callistemon sp.	1		
Ozothamnus diosmifolius	1		
Lepidosperma laterale	1		
Senecio madagascariensis	1		
Dianella caerulea	1		
Pultenaea retusa	1		
Native Stipa sp.	1		
Lomandra longifolia	1		
Doodia aspera	1		
Babingtonia sp.	1		
Polygala multiflora	1		
Ipomea cairica	1		
Hypochaeris radicata	1		
Entolasia stricta	1		
Eucalyptus pilularis	1		
Conyza bonariensis	1		
Acacia irrorata	1		
Sida rhombifolia	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 7 – Bushland Reconstruction

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	7	495744, 6607783	495782, 6607824
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Acacia longifolia	3		
Acacia fimbriata	3		
Dodonaea triquetra	2		
Themeda australis	1		
Leptospermum juniperinum	1		
Eucalyptus pilularis	1		
Billardiera scandens	1		
Pultenaea villosa	1		
Acacia long narrow leaves	1		
Ozothamnus diosmifolius	1		
Lomandra longifolia	1		
Melaleuca linariifolia	1		
Pultenaea retusa	1		
Callistemon sp.	1		
Hakea gibbosa	1		
Conyza bonariensis	1		
Cymbopogon refractus	1		
Persoonia sp.	1		
Cassytha melantha (?)	1		
Leptospermum polygalifolium	1		
Daviesia ulicifolia	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 8 – Bushland Reconstruction

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	8	494514, 6605138	494523, 6605177
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Setaria sphacelata	3		
Acacia mrytifolia	3		
Paspalum mandiocanum	3		
Acacia fimbriata	2		
Acacia longifolia	2		
Acacia falcata	1		
Acacia floribunda	1		
Acacia irrorata	1		
Pultenaea villosa	1		
Ageratum houstonianum	1		
Kennedia rubicunda	1		
Glysine clandestina	1		
Conyza bonariensis	1		
Paspaslum dilatatum	1		
Acacia binervata	1		
Dodonaea triquetra	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 9 – Bushland Reconstruction

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	9	494703, 6605781	494721, 6605830
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Acacia fimbriata	3		
Acacia irrorata	3		
Cymbopogon refractus	3		
Acacia longifolia	2		
Paspaslum mandiocanum	4		
Themeda australis	2		
Eucalyptus microcorys	1		
Eucalyptus pilularis	1		
Acacia floribunda	1		
Billardiera scandens	1		
Gonocarpus tetragynus	1		
Kennedia rubicunda	1		
Alphitonia excelsa	1		
Daviesia ulicifolia	1		
Hardenbergia violacea	1		
Dodonaea triquetra	1		
Ozothamnus diosmifolius	1		
Callistemon salignus	1		
Hibbertia scandens	1		
Commersonia dasyphylla	1		
Setaria sphacelata	2		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 10 – Landscape Planting

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	10	491650, 6598045	491599, 6598037
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Nymphaea capensis	2		
Setaria sphacelata	2		
Paspalum urvillei	2		
Maundia triglochinoides	2		
Persicaria strigosa	1		
Baumea articulata	1		
Ludwigia peploides	1		
Schoenoplectus vallidus	1		
Paspalum distichum	1		
Sida rhombifolia	1		
Philydrum lanuginosum	1		
Verbena bonariensis	1		
white convolvulus weed	1		
Juncus sp.	1		
unknown floating aquatic sp.	1		
Cyclospermum leptophyllum	1		
Cyperus polystachyos	1		
Typha orientalis	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 11 – Landscape Planting

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	11	490895, 6596807	490897, 6596754
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Paspalum urvillei	4		
Cynodon dactylon	3		
Juncus usitatus	2		
Juncus prismatocarpus	2		
Lomandra longifolia	1		
Persicaria strigosa	1		
Acacia melanoxylum	1		
Andropogon virginicus	1		
Conyza bonariensis	1		
Setaria sphacilata	1		
Casuarina glauca	1		
Verbena rigida	1		
Ludwigia peploides	1		
Myriophyllum aquaticum	1		
Hakea gibbosa	1		
Isachne globosa	1		
Centella asiatica	1		
Senecio madagascariensis	1		
Aster subulatus	1		
Ageratum houstonianum	1		
Acacia floribunda	1		
Paspalum mandiocanum	1		
Anagallis arvensis	1		
Axonopus affinis	1		
Persicaria lapathifolia	1		
Dodonaea triquetra	1		
Ozothamnus diosmifolius	1		
Kennedia rubicunda	1		
Leptospermum polygalifolium	1		
Pultenaea villosa	1		
Themeda australis	1		
Acacia sp.	1		
Utricularia gibba	1		
Carex appressa	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Landscape monitoring Transect 12 – Landscape Planting

Date	Site no.	Stake 1 coordinates	Stake 2 coordinates
28/8/2020	12	489789, 6594939	489789, 6594909
Plant species	Braun-Blanquet scale of cover abundance (% crown cover)		
Paspalum dilatatum	3		
Setaria sphacelata	3		
Paspalum mandiocanum	2		
Lomandra longifolia	2		
Cinnamomum camphora	1		
Conyza bonariensis	1		
Acacia irrorata	1		
Centaurium erythraea	1		
Trifolium repens	1		
Senecio madagascariensis	1		
Cymbopogon refractus	1		
Lantana camara	1		
Juncus ursitatus	1		
Cyclospermum leptophyllum	1		
Gahnia aspera	1		
Geitonoplesium cymosum	1		
Phytolacca octandra	1		

Braun-Blanquet scale (% crown cover): 1 = <1%, 2 = 1-5%, 3 = 5-25%, 4 = 25-50%, 5 = 50-75%, 6 = 75-100%.

Appendix G Nest Boxes

Pacific Highway Upgrade: Warrell Creek to Nambucca Heads.

Nest box Monitoring Report – Operational Phase, Year Two (2020)

Sandpiper Ecological

1/94 Main Street
Alstonville

Sandpipereco.com

Version 2
16 September 2020

Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
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Project team:

Luke Andrews (Field survey, reporting)
Nirvarna Makings (Field survey)
Dr D. Rohweder (Project management, review)
Dr B. Taylor (image review)

Report prepared for:

Transport for New South Wales (TfNSW)

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 02 6628 3559 | E david@sandpipereco.com.au

Cover Photo: Two adult short-eared brushtail possums (*Trichosurus caninus*) in a possum box.

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1. Introduction

1.1 Background

In 2015, Transport for New South Wales (TfNSW), in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). WC2NH represents stage two of the Warrell Creek to Urunga Pacific Highway Upgrade (WC2U). WC2NH extends northward from the existing Allgomera deviation south of Warrell Creek before re-joining the existing stage one Nambucca Heads to Urunga (NH2U) project north of Nambucca heads. The WC2NH project was opened to traffic in two stages:

- Stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and
- Stage 2b - 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened on 29 June 2018.

The Ministerial Conditions of Approval (MCoA) for the WC2NH upgrade specified that appropriate actions are to be implemented to mitigate the impact of removing hollow bearing trees (HBT) on hollow dependent fauna. Such actions included the preparation of a Nest Box Plan of Management (NBPoM) in accordance to the MCoA 2.9, which states that:

"The Proponent shall, in consultation with the Office of Environment and Heritage (OEH) prepare and submit for the approval of the Director General a Nest Box Plan to provide replacement hollows for displaced fauna consistent with the requirements of SoC F7. The plan shall detail the number and type of nest boxes to be installed, which must be justified based on the number and type of hollows removed, the density of hollows in the area to be cleared and adjacent forest; and the availability of adjacent food resources."

A NBPoM was prepared to guide installation and monitoring of nest boxes for the WC2U upgrade (Lewis Ecological 2016). The NBPoM recommended 152 nest boxes be installed inside ten nest box replacement zones (NBRZs) adjacent to the WC2NH upgrade. The installation of 60% of the nest boxes was conducted prior to clearing operations (26 November to 11 December 2014) to provide temporary refuge for fauna displaced by clearing. The remaining 40% were installed following a final count of functional hollows removed during clearing. Due to limited suitable vegetation to support nest boxes within the prescribed zones a proposal to use additional and extend existing NBRZs was approved by the project Environmental Representative in August 2016. GeoLINK (2018) detailed the final calculations and numbers of nest boxes required post-clearing which led to a total of 143 nest boxes being installed across 12 NBRZs adjacent to the WC2NH alignment. The final number and type of nest boxes assigned to each area is described in Table 1 and location of nest box areas across the alignment shown in Figure 1.

As specified in the WC2NH Ecological Monitoring Program, bi-annual (winter and summer) nest box inspections are scheduled for years 3 (2016/17) and 4 (2017/18) of construction and years 2 (2020) and 4 (2022) of operation. Sandpiper Ecological Surveys (Sandpiper) was contracted to undertake operational phase monitoring. The following report presents results of nest box inspections (summer and winter) during year two of the operational phase. Results are compared with year 3 and 4 of the construction phase (GeoLINK 2018). Findings are discussed in context of the Potential Indicators of Success outlined in section 3.11.2 of the WC2NH Ecological Monitoring Program:

1. Use of nest boxes by a wide variety of hollow-using native fauna species
2. Low rates of nest box occupancy by feral species
3. Species use of nest boxes is consistent with the species targeted by the nest box design
4. High level of nest box durability, with minimal maintenance requirements.

1.2 Installation sites and nest box design

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest (Figure 1). The NBRZs were located adjacent to the WC2NH alignment and labeled A through to G (7 zones), S through to U (3 zones) and includes the two revised NBRZs (New NBRZ and OC5) (Table 1).

Eight nest box designs were installed across the WC2NH upgrade (Table 1). Nest box design dimensions were recommended based on habitat considerations for species known or considered likely to occur in the vicinity of the carriageway (Table 2). Small glider was the most common box with 30 installed across the project followed by possum with 28 and large glider with 24 (Table 1). The highest number of nest boxes was installed in zone S (28 boxes). Zones U and G were the second and third most allocated zones with 19 and 17 boxes respectively (Table 1). All nest boxes were constructed using plywood.

Table 1. Number of nest boxes and specific designs installed in the NBIZs along the WC2NH alignment. Specific Designs: MB = Microchiropteran bats, SF = Scansorial mammals (e.g. Antechinus, Phascogale), SG = Small gliders (Feather-tail Glider, Sugar Glider), Po = Possums (Common Ring-tail Possum, Common Brushtail Possum and Short-eared Brush-tail Possum), P/L = Parrots (i.e. Eastern Rosella, Lorikeets), Co = Cockatoo (Sulphur-crested Cockatoo, Yellow-tailed Black Cockatoo, Glossy Black Cockatoo), SO = Smaller Owls (Southern Boobook, Barn Owl). * Refer to Table 2 for box dimensions.

NBRZ	Chainage	Specific designs*								Total
		Co	LG	MB	P/L	Po	SF	SG	So	
A	42565-43015		2			2	2			6
B	44765-44965	1		2	2	3	1			9
C	48265-48765			1		2	1	1		5
D	56865-57465		2	2	2	3	2	2	1	14
E	58565-59065				1	1		2		4
F	59465-60015		3		1	1	4	1		10
G	60115-60915	1	4		1	4	3	4		17
New NBRZ	Not specified		3		2	1	1	3	1	11
OC5	Not specified			4			2	1		7
S	53680-54100		5	5	3	5	2	7	1	28
T	55000-55400		2	1	2	2	1	4		12
U	55500 - 55750	1	3	2	3	4	2	5		20
Total		**3**	**24**	**17**	**17**	**28**	**21**	**30**	**3**	**143**

Figure 1. Nest box locations adjacent to the WC2NH alignment.

Table 2. Design and installation specifications for nest boxes targeting specific species at WC2NH.

Box Type	Inside measurements	Chamber depth (mm)	Entrance diameter (mm)	Height above ground (m)
Scansorial Mammal (SF)	180 x 180	300	35 – 40	5-8
Microchiropteran bat (MB)	200 x 200	400	10 – 30	5-8
Small Glider (SG)	200 x 200	300	40 – 45	5-8
Large Glider (LG)	250 x 300	400	70 – 90	5-8
Possum (Po)	250 x 300	400	85 – 100	5-8
Small Owl (So)	250 x 300	500	100	8-10
Cockatoo (Co)	300 x 400	1200	200	8-10
Parrot/Lorikeet (P/L)	200 x 200	400	65	5-8

2. Methods

2.1 Nest box inspections

The first of the bi-annual operational phase (summer year 2) nest box inspections occurred over three days between 25 and 28 February 2020. The second inspection (winter) was carried out over three days between 14 and 17 July 2020. An ecologist was present during all inspections. A total of 131 nest boxes were inspected during the summer event and 141 in winter. Two boxes were destroyed prior to inspections, one via private logging (C1.10) and the other (LG4.5) due to falling from height. A further ten boxes were unable to be inspected during summer due to private property access restrictions. These boxes were inspected during the winter survey.

Nest boxes were inspected using a telescopic pole with a GoPro Hero 3+ and Knog light unit attached. The GoPro was linked wirelessly to an iPad where the contents of each box were viewed by an ecologist. The lid of each box was carefully lifted, the interior photographed, and essential data recorded using a standard datasheet. One additional box was inspected by a qualified tree climber, under supervision of an ecologist, due to tree growth restricting the lid from opening. Data recorded during all inspections included; weather conditions (i.e. rain, wind, cloud cover, ambient temperature), time and date of inspection, vertebrate fauna present, approximate age and number of fauna present, sex of the animals present (if discernible), fauna signs such as leaf nests, scats, wear or scratch marks, box condition, wire condition, and comments on any changes in surrounding habitat.

Box use was determined by direct observation of an animal or indirectly by nest characteristics. Nests were assigned an accuracy score, which included low (0-50% certain), moderate (50-75% certain), high (75-95% certain) or definite (100%). Box condition was allocated one of three ratings; good (nil or very little deterioration), minor damage (hinge deterioration, box delaminating, lid fallen off, wire or spring rusting), severe damage (box fallen, termite infestation). Evidence of feral animal occupation such as European bees (*Apis mellifera*) was also recorded. Native beehives (*Austroplebeia* and/or *Tetragonula* spp.) were recorded in the fauna column of the datasheet.

Identification of fauna and fauna nests was based on the ecologist's experience, with reference to standard field guides (e.g. Menkhorst & Knight 2004; Churchill 2008; Tyler & Knight 2009; Triggs 1996) as required. The identification of fauna signs was based on previous experience of nest characteristics of hollow dependent fauna and published information.

2.2 Nest box maintenance

Nest boxes that had minor, moderate, or severe deterioration, were assessed to determine the best ameliorative approach. Tree climbers reattached lids using new hinges and screws (n =8). Boxes where wire springs or wires had rusted and snapped (n=2) were re-installed using the existing wire minus the spring. Wire was bent several times to allow for tree growth.

3. Results

3.1 Use of nest boxes

3.1.1 Species occupancy and evidence of use rates

During summer 2020, a total of 30 (23%) nest boxes were occupied by vertebrate fauna, with 22 (16%) occupied in winter 2020 (Table 3, Figure 2). In summer, 71 (54%) nest boxes showed evidence of use, which increased to 83 (59%) in winter (Table 3, Figure 2). The combined number of boxes either occupied or showing evidence of use in summer and winter were 101 (77%) and 105 (75%) respectively (Table 3). The lower percentage recorded in winter was due to inclusion of 10 additional boxes during that sample. Active European beehives decreased from one during summer to none in winter. The number of boxes with native beehives increased from 20 (15.6%) in summer to 22 (15.5%) in winter 2020. Evidence of ants decreased from five (4%) during summer to two (1.5%) in winter (Table 3).

Table 3: Number and proportion of nest boxes (NB) occupied or showing evidence of use by vertebrate and invertebrate fauna. [A] Ten Boxes on private property unable to be accessed. [b]Two boxes destroyed.

Inspection	NB inspected	NB occupied (%)	Evidence of use (%)	Occupied or showing evidence of use (%)	European beehive (%)	Evidence of ants (%)	Evidence of Native beehives (%)	Vacant (%)
Summer 2020	131[a b]	30 (23%)	71 (54%)	101 (77%)	1 (>1%)	5 (4%)	20 (15.6%)	11 (8%)
Winter 2020	141[b]	22 (16%)	83(59%)	105 (75%)	0 (0%)	2 (1.5%)	22 (15.5%)	16 (11%)

Combined nest box use (i.e. sum of boxes occupied and those featuring evidence of use) during year two of the operational phase (i.e. winter = 105, summer = 101) increased substantially in comparison to the year three construction phase survey (i.e. winter 2016 = 62 and summer 2017 78) (Figure 1). Nest box use in year two of the operational phase was comparable to year 4 (2017/18) of the construction phase (i.e winter 95 and summer 108) (Figure 2). Occupancy rates (i.e. number nest boxes with fauna present) ranging from 22 (winter) to 30 boxes (summer) in year two of the operation phase was consistent with the range of 23 (summer year 3) to 35 boxes (winter year 4) in the construction phase (Figure 2). Vacant nest boxes exhibit a temporal decline from 72 during the initial construction phase survey to 11 in winter 2020 (Figure 2).

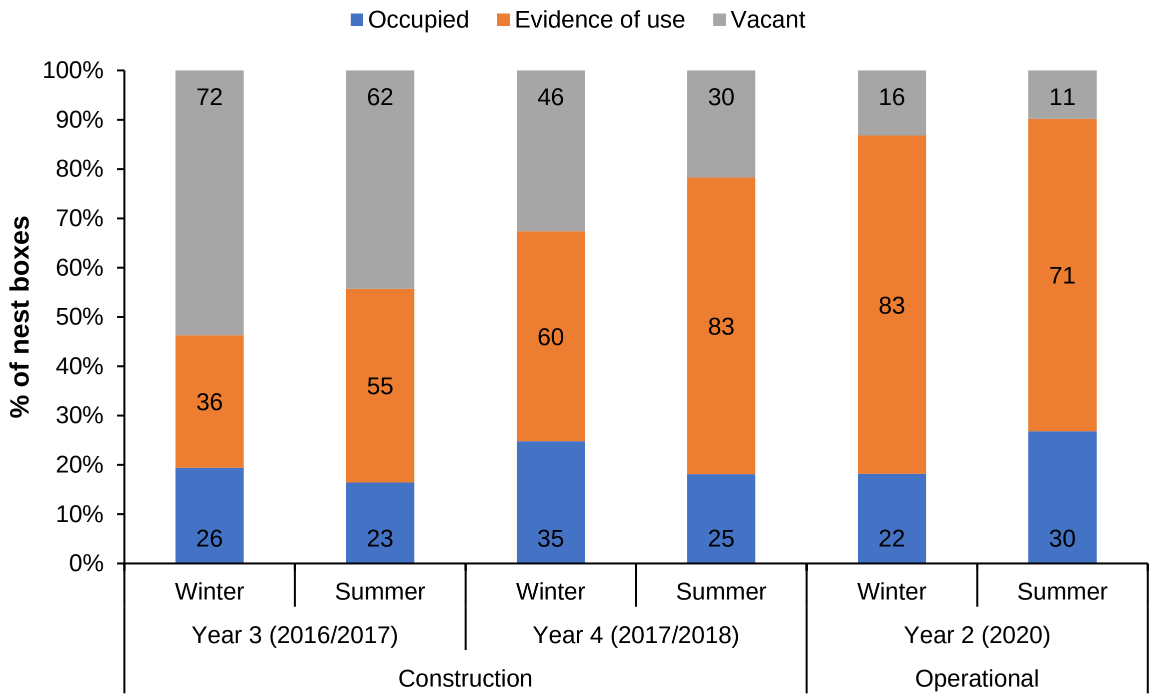

Figure 2. Nest box utilisation (occupied, evidence of use and vacant) by vertebrate fauna species at WC2NH in relation to monitoring phase (construction 2016-2018 and operational 2020 and season (winter and summer). Data labels represent number of nest boxes. Data excludes boxes not inspected or occupied by invertebrates.

3.1.2 Species diversity and fauna use

A total of nine vertebrate fauna species and six groups occupied or showed signs (i.e. scats, nests, chewed entrance) of using nest boxes during year two operational phase monitoring (Table 4). Five species were observed using or occupying nest boxes during summer and seven species during winter (Table 3). Sugar glider, short-eared brushtail possum, *Trichosurus* spp., *Antechinus* spp., *Acrobates* spp., microbat spp. and owlet-nightjar were recorded during both summer and winter (Table 4, Plate 1). A complete list of common and species names is included in Appendix A Table A1. Nest box use by rainbow lorikeet (one box), white-throated treecreeper (two boxes) and lace monitor (six boxes) were recorded in winter only, whilst common brushtail possum was recorded in summer only (Table 4, Plate 1).

Nest boxes showed limited use by introduced species (Table 4). Evidence of a black rat nest was recorded on one occasion during the summer inspection (Table 4). One active European beehive was recorded during summer in a large glider box (see Table B1 appendix B), however, the hive was abandoned and replaced by sugar glider nesting material in winter 2020. Invertebrate species recorded in nest boxes included ants, European bees and native bees (Table 3).

Of the native species, sugar gliders were the most frequently recorded, with individuals or evidence of use recorded in 50 nest boxes during summer and 46 during winter (Table 5). *Trichosurus* spp. (including short-eared and common brushtail possum) followed with evidence of use or occupancy recorded in 10 boxes during summer and eight in winter (Table 5). *Antechinus* spp. recorded lower nest box use in winter (6 boxes) than summer (11 boxes) (Table 5). Birds and reptiles displayed low use of nest boxes with five and six records respectively during operational phase monitoring (Table 5).

The eight species recorded during year two of the operational phase monitoring is comparable with year 3 (7 species) and year 4 (9 species) of the construction phase (Table 4). Species recorded in the construction phase only included green tree snake, carpet python and scaly-breasted lorikeet (Table 4). Further, white-throated treecreeper was recorded during the operational phase only (Table 4).

Table 4: Fauna species and groups which occupied or showed evidence of use of nest boxes during years three and four of construction phase monitoring (GeoLINK,2016) and years 2 of operational phase monitoring (2020). [I] = Introduced species.

Fauna	Construction phase				Operational phase	
	Year 3		Year 4		Year 2	
	Winter 2016	Summer 2017	Winter 2017	Summer 2018	Summer 2020	Winter 2020
Mammals						
Antechinus spp.	x	-	-	-	x	x
Common brushtail possum	x	x	x	x	x	-
Short-eared b'tail possum	-	-	-	-	x	x
Trichosurus spp.	-	-	-	-	x	x
Common ringtail possum	x	-	x	-	x	x
Sugar glider	x	x	x	x	x	x
Acrobates spp.	-	-	x	x	x	x
Petaurus spp.	x	x	x	x	x	x
Lesser long-eared bat	-	-	x	-	-	-
Nyctophilus spp.	-	-	-	-	-	x
Microbat spp.	-	-	-	-	x	x
Black rat[I]	-	x	-	-	x	-
Reptiles						
Lace Monitor	-	-	x	x	-	x
Green Tree Snake	x	-	-	-	-	-
Carpet Python	-	-	x	x	-	-
Birds						
Owlet-nightjar	x	x	x	-	x	x
Scaly-breasted Lorikeet	-	x	-	-	-	-
Rainbow Lorikeet	-	-	-	x	-	x
White-throated treecreeper	-	-	-	-	-	x
Invertebrates						
Native bee	x	x	x	x	x	x
European bee[I]	-	-	-	x	x	x
Ants	-	-	-	-	x	x
Totals						
Introduced sub-total	0	1	0	0	2	1
Native sub-total	8	7	10	8	11	13
Total	8	8	10	8	14	15

3.1.3 Design specific fauna use

Four of the eight box types including small glider (SG), possum (Po), scansorial mammal (SF), and microbat (MB), were used by target species (Table 5). No use by target species was recorded in the parrot/lorikeet (P/L), cockatoo (Co), small owl (So) or large glider (L/G) boxes (Table 5). Small glider boxes recorded the highest use by a target species with 63% (19 boxes in both winter and summer) being used or occupied by small gliders (either sugar glider or *Acrobates* spp.) (Table 5). Possum boxes recorded 36% (11 boxes) and 29% (9 boxes) usage by possums (short-eared brushtail possum, common brushtail possum, common ringtail possum and *Trichosurus* spp) during summer and winter respectively (Table 5). Evidence of microbats was recorded in 12% (2 boxes) of microbat boxes during summer and 30% (5 boxes) during winter (Table 5). Scansorial fauna boxes had one record of an *Antechinus* spp. nest during summer and winter (5% of all SF boxes) (Table 5).

Small gliders were found to use seven of the eight nest box designs with only one record in a So box (Table 5). Aside from SG boxes, small glider usage was recorded in a high proportion of the installed large glider boxes (46-50%), parrot/lorikeet (24-29%) and scansorial mammal boxes (48%) during the summer and winter surveys (Table 5). *Acrobates* spp. tended to show a preference towards small box designs including MB and SG types (Table 5). Whereas sugar gliders were also found in the larger glider box designs (Table 5).

Scansorial fauna (*Antechinus* spp.) were recorded in six of the eight nest box designs with no records in So and Co boxes (Table 5). Microbats and possums tended to use design specific boxes with only one *Trichosurus* spp den in a Co box (Table 5). Among the bird species, a rainbow lorikeet nest was detected in a non-design specific SG box and the white-throated treecreeper and owlet-nightjar nests were recorded in both P/L and Po box types (Table 5, Plate 1). Lace monitors were recorded occupying LG, SG, PO and P/L boxes (Table 5). No cockatoo or small owls species were recorded.

Table 5. Proportion (%) of boxes occupied or with signs of fauna use in relation to nest box design during summer and winter of year 2 operational phase monitoring (2020). Old leaf nests excluded from table summary. MB = Microchiropteran bats, SF = Scansorial mammals (e.g. Antechinus, Phascogale), SG = Small gliders (Feather-tail Glider, Sugar Glider), Po = Possums (Common Ring-tail Possum, Common Brushtail Possum and Short-eared Brush-tail Possum), P/L = Parrots (i.e. Eastern Rosella, Lorikeets), Co = Cockatoo (Sulphur-crested Cockatoo, Yellow-tailed Black Cockatoo, Glossy Black Cockatoo), SO = Smaller Owls (Southern Boobook, Barn Owl). [I] = Introduced species.

Fauna	Summer								Winter							
	Co	LG	MB	P/L	Po	SF	SG	So	Co	LG	MB	P/L	Po	SF	SG	So
Mammals																
Antechinus spp.	-	4	12	12	14	5	3	-	-	4	6	6	7	5	-	-
Common brushtail Possum	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-
Short-eared brushtail possum	-	-	-	-	11	-	-	-	-	-	-	-	4	-	-	-
Trichosurus spp.	-	4	-	6	18	-	-	67	33	-	-	-	25	-	-	-
Common ringtail possum	-	-	-	6	4	-	-	-	-	-	-	-	4	-	-	-
Sugar glider	-	46	-	24	18	48	63	33	-	50	6	29	7	48	47	67
Acrobates spp.	-	-	6	6	-	-	-	-	-	-	18	6	-	-	17	-
Nyctophilus spp.	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-
Microbat spp.	-	-	12	-	-	-	-	-	-	-	24	-	-	-	-	-
Black Rat[I]	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reptiles																
Lace monitor	-	-	-	-	-	-	-	-	-	4	-	12	7	-	-	33
Birds																
Owlet-nightjar	-	-	-	-	4	-	-	-	-	-	-	6	4	-	-	-
Rainbow lorikeet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
White-throated treecreeper	-	-	-	-	-	-	-	-	-	-	-	6	4	-	-	-
Bird spp.	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-
Invertebrates																
Ants	-	8	-	6	7	-	-	-	-	-	-	6	-	5	-	-
European bees[I]	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Native bees	-	13	-	6	4	33	27	-	-	17	-	6	7	33	27	-
Total number of boxes	**3**	**24**	**17**	**17**	**28**	**21**	**30**	**3**	**3**	**24**	**17**	**17**	**28**	**21**	**30**	**3**
Proportion (%) used by target species	**0%**	**0%**	**12%**	**0%**	**36%**	**5%**	**63%**	**0%**	**0%**	**0%**	**30%**	**0%**	**29%**	**5%**	**63%**	**0%**

Plate 1. (a) Sugar glider in a typical bowl-shaped nest observed in a scansorial mammal box. (b) *Antechinus* spp. nest with latrine deposited in corner of microbat box. (c) Lace monitor in a parrot/lorikeet box. (d) Sugar glider x 4 recorded in a small glider nest box. (e) *Nyctophilus* spp. recorded roosting in a microbat box. (f) Probable white-throated tree creeper nest indicated by layered foliage.

3.2 Nest box condition and maintenance

The majority of nest boxes (129 of 143, 90%) were in good condition, however deterioration of nest boxes was apparent. Fourteen boxes showed evidence of deterioration with requiring repairs and three exhibiting minor damage (Figure 3). A total of six nest boxes required repair of lids and hinges with a further two being reinstalled due to wire and spring failure causing detachment from trees. Two nest boxes require replacement, one as a result of wire and spring failure on a large glider box (LG4.5) and another due to private logging (C1.10). No active beehives were recorded during the latest winter inspections and evidence of ants was limited to two boxes not triggering ameliorative action

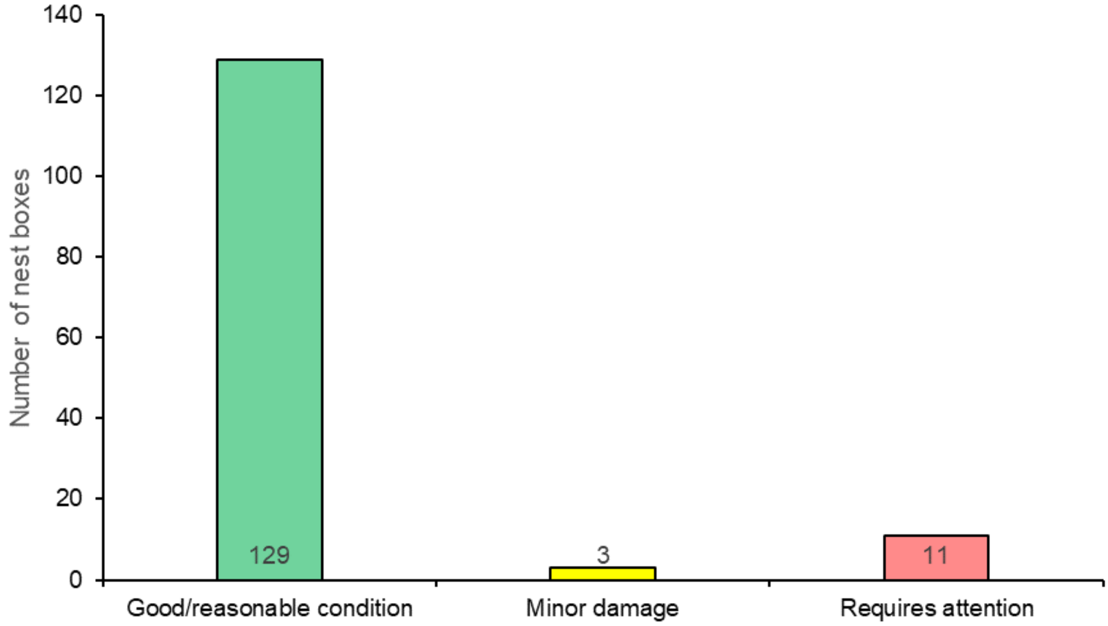

Figure 3. Nest box condition recorded during year two operational phase monitoring at WC2NH.

4. Discussion

The outcomes of the year two operational phase nest box monitoring are discussed in the context of the performance criteria outlined in section 3.11.2 of the WC2NH EMP. Key findings in relation to performance criteria are presented in Table 6.

Table 6. Summary of key findings in relation to performance criteria.

Performance criteria	Finding
Low rates of nest box occupancy by feral species	Overall, incidence of feral species occupation was very low. European bees tend to vacate nest boxes within months and vertebrate fauna species were recorded reoccupying boxes after European bee abandonment.
Use of nest boxes by a wide variety of hollow-using native fauna species	Species diversity occupying nest boxes on the WC2NH project is consistent with other Pacific Highway projects.
Species using nest boxes is consistent with the nest box design	Small and medium nest boxes, including small glider, possum, parrot, scansorial mammal and microbat designs, were used by the target species. Larger nest boxes, such as cockatoo and small owl, were not used by the target species.
High level of nest box durability with minimal maintenance requirements	7.5% of boxes required basic maintenance, which is similar to other nest box projects on the north coast. Box deterioration is predicted to increase after 5-6 years, particularly where boxes occur in moist forest.

4.1 Low rates of nest box occupancy by feral species

Rates of nest box use by feral species during the year two operational phase survey are considered very low. Two feral species were recorded, with single records of black rat and European bees during the summer survey. European bees are considered a problem for nest box programs as they occupy boxes to the exclusion of targeted species (Beyer and Goldingay 2006). The number of boxes with active hives (<1%, one hive) at WC2NH was substantially lower than the 10-11% reported at Nambucca Heads to Urunga (Sandpiper 2019) and also lower than Coopernook to Herons Creek where 2.5% of boxes were occupied by European bees (Sandpiper 2015). Further, the active European beehive recorded in summer was replaced by a sugar glider den some five months later in winter. This is consistent with findings by Goldingay *et al* (2015) who found that European bees tend to abandon nest boxes as the hive outgrows the space available, allowing arboreal fauna to occupy the abandoned box leaving little or no evidence of the hive.

The single record of a black rat nest in a large glider box was considered a probable record as no archetypal black rat nest was observed. Other feral species that commonly occupy nest boxes such as common starling (*Sturnus vulgaris*) and common myna (*Acridotheres tristis*) were not detected during year two operational monitoring (Le Roux *et al* 2016).

Non-target 'pest' arboreal ant nests were recorded in five nest boxes during summer and two during winter. Ants are commonly found in nest boxes and there is limited information regarding potential competitive interactions between them and native vertebrates (Goldingay 2006). A study by Dobson (2002 cited in Beyer and Goldingay 2006) reported that squirrel gliders were not deterred by the presence of ants and feathertail gliders have been observed in bat boxes containing ants. No ameliorative action was undertaken regarding ant occupancy based on this information in combination with the small number of active nests (2 during the final winter survey).

4.2 Use of nest boxes by a wide variety of hollow-using native fauna species

Species richness at WC2NH was comparable to or lower than other nest box projects on the north coast of NSW with a total of nine species recorded. For example, between nine and 15 species were detected during monitoring for the Hunter Expressway (Sandpiper 2013) and at Nambucca Heads to Urunga (Sandpiper 2019) while nine species were detected at Coopernook to Heron Creek and Sapphire to Woolgoolga (Sandpiper 2015, 2016), and 11 species at Oxley Highway to Kundabung (Danvers & Michniewicz 2018). The latter study sampled 514 nest boxes, which is more than triple the number monitored at WC2NH. It is also worth noting that the broader fauna classifications (i.e. Genera, Families and Groups) are likely to be species already confirmed using nest boxes. For example, *Trichosurus* spp. would be either a short-eared or common brushtail possum.

Small petaurid gliders (mostly sugar gliders) were frequent nest box users throughout both the construction and operation phase monitoring. This is consistent with findings by Goldingay *et al* (2020) and is likely a reflection of their broader habitat requirements, local abundance and high number of suitable boxes (e.g. boxes with small entrances). Reptiles were the least detected fauna group which is unsurprising given that they were not targeted by the nest box program and often do not leave obvious evidence of use (i.e. nesting material, scats).

Low use of nest boxes by birds is consistent with other nest box programs (e.g. Menkhorst 1984, Sandpiper 2016, 2017, 2018, 2019). While infrequent use of nest boxes by birds may indicate that adequate hollow resources exist in the local landscape, other limiting factors include: (1) use of nest boxes for temporary roosting (Lindenmayer *et al.* 2009); (2) box thermoregulation (Goldingay and Stevens 2009); (3) placement (nest box location) (Saunders *et al.* 2020);(4) competitive interactions with other species; and (5) rapid occupation of suitable boxes by mammals (Lindenmayer *et al* 2009). .

Certain species may prefer natural hollows to nest boxes and only use nest boxes as temporary roosting sites, making detection difficult as signs may not be readily apparent (e.g. guano/faeces) or may be covered by mammal leaf nests (Lindenmayer *et al* 2009) Further, the limited insulation capacity of nest boxes may inhibit bird use during higher summer temperatures, hence aspect is an important consideration in nest box placement (Goldingay and Steven 2009, Saunders *et al* 2020). Recently, Saunders *et al.* (2020) considered nest box placement relative to land use type as an important factor in determining use by Carnaby's Cockatoo (*Calyptorhynchus latirostris)*. These findings suggest that birds make subtle choices about where to build nests and hence nest box placement within a given landscape will effect use.

The overall rate of use (i.e. sum of boxes occupied and those featuring evidence of use) during year two of the operational phase was higher than the construction phase. Overall use rates tend to rise with time since installation as fauna find and utilise more boxes (leaving remnant nesting material) (Goldingay *et al.* 2020) in combination to increased use by invertebrate species, such as native beehives.

4.3 Species use of nest boxes is consistent with the species targeted by the nest box design

Four of eight box types, small glider, possum, scansorial mammal, and microbat, were used by the target species. Box entrance size is considered important in determining use by target species (Goldingay *et al.* 2020). Small gliders accounted for 63% of occupied SG boxes and had the highest proportional use by a target species. This finding is consistent with recent findings by Goldingay *et al.* (2020) who found that gliders were far more likely to use the small glider box due to its small diameter opening in comparison to other nest box designs (Po, Co and So). P/L and SF designs also had small diameter entries, which likely contribute to the additional small glider detections amongst those designs. Po boxes recorded 36% usage by target possum species (e.g. short-eared brushtail possum, common brushtail possum, common ringtail possum and *Trichosurus* spp). Other box types (SG, P/L, SF, MB) typically exclude possums due to their smaller entrance diameter (Goldingay *et al.* 2020).

Cockatoo, parrot/lorikeet and small owl box designs were not used by the target species. In general, cockatoo and owl nest boxes have proven ineffective for the target species (Sandpiper Ecological 2015, 2017) and there is a paucity of records of owls and cockatoos using plywood nest boxes on the east coast of Australia. Glossy-black cockatoo (*C.s lathami*) and red-tailed black cockatoo (*C. banksii*) have been recorded using round polyvinyl chloride nest boxes on Kangaroo Island and in western Victoria respectively (Goldingay & Stevens 2009), and Carnaby's black cockatoo (*C. latirostris*) has been recorded using a variety of designs in Western Australia (Groom 2010). The low use of nest boxes by black cockatoos on the north coast of NSW may be due to poor design and/or placement, both of which influence box usage by Carnaby's cockatoo (Saunders *et al* 2020). Similarly, there are few records of owls using nest boxes. During a five-year study of nest box use by a resident breeding pair of masked owls (*Tyto novaehollandiae*) in the Newcastle area Thomson (2006) recorded one immature owl roosting in a nest box for 26 consecutive nights and another individual on two nights. These results suggest irregular use of nest boxes by bird species. As mentioned previously, nest box placement, in addition to limited availability of suitable large trees, likely contribute to low use rates by birds, and use may not necessarily be related to design.

Low use may also be due to competitive interactions from other species, for instance individuals or family groups of possums and gliders may utilise several nearby boxes and exclude other species (Menkhorst 1984, Goldingay *et al.* 2020). At WC2NH use by small glider species was prevalent in the P/L and SF designs, which likely contributed to low use by small parrots and scansorial fauna. Mammal leaf nests can exclude use by Parrot/Lorikeets which require a decayed wood base for nesting (Lewis 2016). Given the high small glider abundance as seen at several sites on the north coast of New South Wales (Goldingay *et al.* 2020), leaf nests are likely to be excluding use by Parrot/Lorikeets.

4.4 High level of nest box durability with minimal maintenance requirements.

The majority of nest boxes (129 of 143, 90%) remain in good condition, however maintenance due to deterioration was undertaken on 11 (7.5%) nest boxes. These numbers are higher than other projects with nest boxes of similar design and installation habitats. For example, 3.5% of boxes required maintenance or replacement after four years at OH2K (Danvers & Michniewicz 2018) and on the neighbouring NH2U project (Sandpiper 2019).

The number of boxes requiring repair or replacement is expected to increase over time with Beyer and Goldingay (2006) suggesting that most plywood boxes will persist for ~5 years but concede a paucity of data exists in relation to how habitat type and design may affect longevity. Work on other highway upgrades compliment findings by Beyer and Goldingay (2006) with Coopernook to Heron Creek (C2HC) and Sapphire to Woolgoolga maintenance and replacement rates increasing substantially 5-6 years after installation. All of the 79 boxes installed at C2HC required maintenance or replacement seven years after installation (Sandpiper Ecological 2015). Many of the boxes were completely rotten, had major termite attack or the screws and hinges had failed (Sandpiper 2015). Screws, hinges and springs tend to weather and corrode relatively quickly (within 4-7 years) (Sandpiper 2016). This suggests the higher number of boxes requiring maintenance at WC2NH is likely attributed to the older nest boxes (85 of 143) installed prior to construction. Notwithstanding, springs represent a weak point and should be avoided in future nest box programs. Further it can be expected that the number of boxes requiring maintenance will increase over time.

Two nest boxes have been severely damaged and require replacement. Considering the ongoing maintenance requirements and limited lifespan of plywood nest boxes these boxes should be replaced with Cyplas boxes which have a suggested lifespan of 40 years. Chainsaw hollows, which have demonstrated promising results in terms of arboreal fauna usage (>75%) (Rueeger 2017) are another alternative.

5. Contingency Measures and Recommendations

5.1 Contingency Measures

Contingency measures are summarised in Table 7.

Table 7: Potential problems outlined in NBPoM and possible contingency measures. Mitigation measures applicable to the project are addressed in bold text in table below.

Problem	Contingency/Corrective Action	Proposed action
Nest boxes being used by non-target species	Review the selection and number of nest box designs.	**No immediate action required – If low uptake of target species in the larger box designs (i.e. large cockatoo and owl) continues in year four of the operational phase, options to improve the function of these boxes should be considered. This would involve consideration of the latest information on box use by the target species; box position (tree, height, location on tree); landscape position.**
Nest boxes become occupied by exotic or invasive fauna	Review/modify nest box design to exclude undesirable species, treat if applicable or relocate those nest boxes to another location.	**No immediate action required - incidence of feral species occupation was low.**
Poor uptake and usage rates by native fauna	Review the type and number of nest box designs.	**No action required – nest box occupancy and use by native species is consistent with other projects.**
Nest boxes deteriorating rapidly and requiring maintenance	Identify causes of nest box failure, modify design and construct accordingly.	**No immediate action required - continue to monitor nest box deterioration and undertake basic repairs as required.**

5.2 Recommendations

Recommendations are summarised in Table 8.

Table 8: Recommendations based on findings from operational phase monitoring and response from TfNSW.

Number	Recommendation	Transport for NSW Response
1.	Replace two damaged nest boxes to maintain the recommended nest box numbers specified in the NBPoM. Replacement boxes should be cyplas and include one large glider (LG4.5) and one scansorial mammal box (C1.10).	Agree and adopted
2.	Continue monitoring as per the NBPoM	Agree and adopted

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Appendix A – Species list

Table A1: Common and scientific names for all species recorded during nestbox inspections at WC2NH 2020.

Common Name	Scientific Name
Sugar glider	*Petaurus breviceps*
	Petaurus spp.
Feathertail glider spp.	*Acrobates spp.*
Short-eared brushtail possum	*Trichosurus caninus*
Common brushtail possum	*Trichosurus vulpecula*
Brushtail possum spp.	*Trichosurus spp.*
Common ringtail possum	*Pseudocheirus peregrinus*
Lace monitor	*Varanus varius*
Owlet-nightjar	*Aegotheles*
White-throated treecreeper	*Cormobates leucophaea*
Rainbow lorikeet	*Trichoglossus moluccanus*
Black rat	*Rattus rattus*

Appendix B – Year two operational phase nest box inspection data

Table B1: Nest box inspection data for summer and winter WC2NH 2020. CBtP = Common Brushtail Possum; SEBtP = Short-Eared Brushtail Possum; BtPoss = Brushtail Possum (Common or Short-eared); CRtP = Common Ringtail Possum; SuG = Sugar Glider; FtG = Feathertail Glider; OnJ = Owlet Nightjar; Euro = European; pet = Petaurid.

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
A	C	4.6	Large Glider	489636	6594462	28/2/20	Summer	Active euro beehive	-	Active euro beehive	Good
A	C	5.1	Possum	489707	6594598	28/2/20	Summer	-	Antechinus nest	*Antechinus* spp.	Good
A	C	5.7	Possum	489585	6594437	28/2/20	Summer	-	Antechinus nest	*Antechinus* spp.	Good
A	LG	4.11	Large Glider	489676	6594545	28/2/20	Summer	-	Old euro beehive, old SuG nest	Sugar Glider	Hinges ceased
A	SF	1.13	Scansorial Mammal	489675	6594535	28/2/20	Summer	-	Old euro beehive, old SuG nest	Sugar Glider	Good
A	SF	1.6	Scansorial Mammal	489579	6594410	28/2/20	Summer	Not Inspected	-	-	Water pooling inside
B	Cockatoo	7.2	Cockatoo	490772	6595939	No access private property	Summer	Not Inspected	Not Inspected	Not Inspected	
B	MB	2.13	Microbat	490734	6596070	No access private property	Summer	Not Inspected	Not Inspected	Not Inspected	
B	MB	2.9	Microbat	490735	6595930	No access private property	Summer	Not Inspected	Not Inspected	Not Inspected	
B	P/L	8.6	Parrot Lorikeet	490745	6595983	No access private property	Summer	Not Inspected	Not Inspected	Not Inspected	
B	P/L	8.9	Parrot Lorikeet	490757	6596026	No access private property	Summer	Not Inspected	Not Inspected	Not Inspected	

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
B	Po	5.2	Possum	490757	6595990	No access private property	Summer	Not Inspected	Not Inspected	Not Inspected	
B	Po	5.6	Possum	490740	6595944	No access private property	Summer	Not Inspected	Not Inspected	Not Inspected	
B	Po	5.9	Possum	490728	6596059	No access private property	Summer	Not Inspected	Not Inspected	Not Inspected	
B	SF	1.3	Scansorial Mammal	490744	6595991	No access private property	Summer	Not Inspected	Not Inspected	Not Inspected	
C	C	1.4	Small Glider	492506	6599227	27/2/20	Summer	-	-	Vacant	Good
C	C	5.4	Possum	492544	6599220	27/2/20	Summer	1 x SEBtP	-	Short-eared brushtail possum	Good
C	MB	2.2	Microbat	492513	6599166	27/2/20	Summer	-	Antechinus nest	Antechinus spp.	Good
C	Po	5.1	Possum	492495	6599162	27/2/20	Summer	2 x SEBtP	-	Short-eared brushtail possum	Good
C	SF	1.11	Scansorial Mammal	492443	6599106	27/2/20	Summer	Native beehive	-	Native bees	Good
D	C	1.9	Scansorial Mammal	495524	6607228	27/2/20	Summer	-	old SuG nest	Sugar Glider	Good
D	C	2.7	Microbat	495470	6607086	27/2/20	Summer	-	-	Vacant	Good
D	C	3.1	Small Glider	495377	6606930	27/02/2020	Summer	-	old SuG nest	Sugar Glider	Good
D	C	4.5	Large Glider	495465	6607081	27/2/20	Summer	-	old SuG nest	Sugar Glider	Lid completely off
D	C	5.8	Possum	495634	6607441	27/2/20	Summer	-	Old antechinus nest	Antechinus spp.	Good

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
D	C	8.4	Parrot Lorikeet	495528	6607229	27/2/20	Summer	-	antechinus nest	Antechinus spp.	Good
D	C	8.5	Parrot Lorikeet	495369	6606961	27/02/2020	Summer	-	-	Vacant	Good
D	LG	4.3	Large Glider	495613	6607394	27/2/20	Summer	-	OnJ nest	Owlet-nightjar	Good
D	MB	2.4	Microbat	495377	6606934	27/02/2020	Summer	-	-	Vacant	Good
D	PO	5.18	Possum	495470	6607148	27/2/20	Summer	-	old SuG nest	Sugar Glider	Good
D	Po	5.3	Possum	495604	6607333	27/2/20	Summer	-	Old leaf material	Trichosurus spp.	Water damage inside
D	SF	1.7	Scansorial Mammal	495407	6607000	27/2/20	Summer	-	Old antechinus nest, old termite nest	Antechinus spp.	Light damage inside
D	SG	3.11	Small Glider	495547	6607265	27/2/20	Summer	-	old SuG nest	Sugar Glider	Good
D	SO	6.2	Small Owl	495540	6607280	27/2/20	Summer	-	Old pet nest	Petaurid spp.	Good
E	C	3.8	Small Glider	496288	6608309	27/2/20	Summer	Native beehive	-	Native bees	Good
E	C	8.6	Parrot Lorikeet	496268	6608279	27/2/20	Summer	-	old SuG nest	Sugar Glider	Good
E	Po	5.8	Possum	496259	6608217	27/2/20	Summer	Native beehive	-	Native bees	Good
E	SG	3.18	Small Glider	496479	6608614	27/2/20	Summer	Native beehive	-	Native bees	Good
F	C	1.2	Scansorial Mammal	496649	6609338	26/2/20	Summer	SuG x 2	Sugar Glider nesting material	Sugar Glider	Good
F	C	4.1	Large Glider	496663	6609320	26/2/20	Summer	-	Old leaf material	Old leaf	Good
F	C	5.3	Large Glider	496640	6609618	26/2/20	Summer	-	BtPoss nest, old leaf material	Trichosurus	Good

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
										spp.	
F	LG	4.12	Large Glider	496620	6609594	26/2/20	Summer	Native beehive	-	Native bees	Lid one hinge broken
F	P/L	8.8 (Po5.4)	Parrot Lorikeet	496492	6609235	26/2/20	Summer	-	Old btposs nest	Trichosurus spp.	Good
F	Po	5.16	Possum	496488	6609157	26/2/20	Summer	-	Old btposs nest	Trichosurus spp.	Good
F	SF	1.5	Scansorial Mammal	496585	6609519	26/2/20	Summer	SuG x 2	Sugar Glider nesting material	Sugar Glider	Good
F	SF	1.9	Scansorial Mammal	496508	6609236	26/2/20	Summer	Native beehive	-	Native bees	Good
F	SF	3.6	Scansorial Mammal	496639	6609599	26/2/20	Summer	SuG x 1	Sugar Glider nesting material	Sugar Glider	Good
F	SG	3.7	Small Glider	496527	6609397	26/2/20	Summer	Native beehive	-	Native bees	Good
G	C	1.6	Scansorial Mammal	497427	6610227	26/2/20	Summer	Sug x 2	Sugar Glider nesting material	Sugar Glider	Good
G	C	3.1	Small Glider	497304	6610070	26/2/20	Summer	Sug x 2	Sugar Glider nesting material	Sugar Glider	Good
G	C	3.6	Small Glider	496924	6609701	26/02/2020	Summer	-	Antechinus nest	Antechinus spp.	Good
G	C	4.3	Large Glider	496957	6609729	26/2/20	Summer	Native beehive	-	Native bees	Good
G	C	4.8	Large Glider	497036	6609788	25/02/2020	Summer	-	old SuG nest	Sugar Glider	Good
G	C	7.1	Cockatoo	496872	6609668	25/2/20	Summer	-	Old btposs nest	Trichosurus spp..	Lid loose
G	C	8.7	Parrot Lorikeet	496948	6609702	26/02/2020	Summer	-	BtPoss nest- otherwise antechinus nest	Trichosurus spp..	Good

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
G	HMP	HMP	Possum	497205	6609967	25/02/2020	Summer	-	old SuG nest	Sugar Glider	Lid, broken
G	LG	4.1	Large Glider	497371	6610146	26/2/20	Summer	Ant nest	-	Ant nest	Good
G	LG	4.9	Large Glider	496917	6609683	26/2/20	Summer	-	old SuG nest, antechinus nest, old ants	Sugar Glider	Good
G	Po	5.11	Possum	497068	6609857	25/02/2020	Summer	-	BtPoss nest	Trichosurus spp.	Good
G	Po	5.12	Possum	497253	6610029	26/2/20	Summer	-	BtPoss nest	Trichosurus spp.	Good
G	Po	5.15	Possum	497212	6609983	25/2/20	Summer	Ants	old SuG nest, possum nest	Sugar Glider	Good
G	SF	1.1	Scansorial Mammal	497245	6610013	26/2/20	Summer	-	old SuG nest	Sugar Glider	Good
G	SF	1.14	Scansorial Mammal	497037	6609831	25/02/2020	Summer	Native beehive	-	Native bees	Good
G	SG	3.13	Small Glider	496853	6609671	26/2/20	Summer	-	old SuG nest	Sugar Glider	Good
G	SG	3.17	Small Glider	497272	6610048	26/2/20	Summer	Native beehive	-	Native bees	Good
New NBRZ	C	3.13	Small Glider	497511	6610415	25/02/2020	Summer	Sug x 3	Sugar Glider nesting material	Sugar Glider	Good
New NBRZ	C	3.2	Small Glider	497399	6610581	25/02/2020	Summer	-	old SuG nest	Sugar Glider	Good
New NBRZ	C	4.1	Large Glider	497404	6610590	25/02/2020	Summer	-	old SuG nest	Sugar Glider	Good
New NBRZ	C	4.2	Large Glider	497299	6610324	25/02/2020	Summer	-	old SuG nest	Sugar Glider	Good
New NBRZ	C	4.7	Large Glider	497501	6610327	25/02/2020	Summer	-	old antechinus nest, old SuG nest	Antechinus spp.	Good
New NBRZ	C	5.12	Possum	497338	6610385	25/02/2020	Summer	-	Owlet nightjar nest	Owlet-nightjar	Good

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
New NBRZ	C	5.5	Small Glider	497486	6610313	25/2/20	Summer	-	old SuG nest	Sugar Glider	Good
New NBRZ	C	6.1	Small Owl	497371	6610443	25/02/2020	Summer	-	BtPoss nest	Trichosurus spp.	Good
New NBRZ	C	8.1	Parrot Lorikeet	497177	6610264	25/02/2020	Summer	-	old SuG nest	Sugar Glider	Good
New NBRZ	P/L	8	Parrot Lorikeet	497511	6610340	25/02/2020	Summer	-	FtG nest	Acrobates spp.	Good
New NBRZ	SF	1.1	Scansorial Mammal	497515	6610408	25/02/2020	Summer	Native beehive	-	Native bees	Good
OC5	C	1.1	Scansorial Mammal	494366	6604916	26/02/2020	Summer	Not inspected	Not inspected	Not inspected	Tree Cut down??
OC5	C	1.5	Scansorial Mammal	494351	6605047	26/2/20	Summer	Sug x 3	Sugar Glider nesting material	Sugar Glider	Good
OC5	C	2.1	Microbat	494364	6604984	26/02/2020	Summer	-	Microbat scat	Microbat spp.	Good
OC5	C	2.3	Microbat	494367	6604964	26/02/2020	Summer	-	Microbat scat	Microbat spp.	Good
OC5	C	2.5	Microbat	494361	6604949	26/02/2020	Summer	-	Antechinus nest	Antechinus spp.	Good
OC5	C	2.6	Microbat	494365	6605000	26/2/20	Summer	-	-	Vacant	Good
OC5	C	3.5	Small Glider	494378	6604909	26/2/20	Summer	-	old SuG nest	Sugar Glider	Good
S	C	3.12	Possum	494316	6604201	26/2/20	Summer	Ants	old SuG nest	Ants	Good
S	C	3.9	Small Glider	494328	6603870	26/2/20	Summer	-	Baby SuG skeleton	Sugar Glider	Good
S	C	4.4	Large Glider	494326	6604196	26/2/20	Summer	-	Old black rat nest, Btposs nest	Black Rat	Good
S	C	5.6	Possum	494325	6604137	26/2/20	Summer	CBtP x 1	-	Common Brushtail	Good

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
										Possum	
S	C	8.3	Parrot Lorikeet	494350	6604355	26/2/20	Summer	-	old SuG nest	Sugar Glider	Good
S	LG	4.1	Large Glider	494337	6604315	26/2/20	Summer	-	old pet nest	Small Petaurid spp.	Good
S	LG	4.14	Large Glider	494325	6603868	26/2/20	Summer	Euro beehive	-	Euro beehive	Good
S	LG	4.2	Large Glider	494337	6603901	26/2/20	Summer	-	Old leaf material	Old leaf	Water pooling inside
S	LG	4.6	Large Glider	494336	6604005	26/2/20	Summer	-	old SuG nest	Sugar Glider	Good
S	MB	2.1	Microbat	494354	6604286	26/2/20	Summer	-	-	Vacant	Good
S	MB	2.12	Microbat	494325	6604064	26/2/20	Summer	-	-	Vacant	Good
S	MB	2.3	Microbat	494340	6603983	26/2/20	Summer	-	-	Vacant	Good
S	MB	2.5	Microbat	494328	6604164	26/2/20	Summer	-	-	Vacant	Good
S	MB	2.8	Microbat	494330	6604122	27/2/20	Summer	-	-	Vacant	Good
S	P/L	8.1	Parrot Lorikeet	494342	6604258	26/2/20	Summer	-	Old termite nest	Ants	Termite damage inside
S	P/L	8.11	Parrot Lorikeet	494316	6604003	26/2/20	Summer	-	RtPoss nest	Ringtail possum	Good
S	Po	5.1	Possum	494363	6604313	26/2/20	Summer	CBtP x 1	-	Common Brushtail Possum	Good
S	Po	5.13	Possum	494318	6603797	26/2/20	Summer	SEBtP x 2	-	Short-eared brushtail	Good

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
										possum	
S	Po	5.17	Possum	494343	6604199	26/2/20	Summer	-	BtPoss nest	Trichosurus spp.	Good
S	SF	1.2	Scansorial Mammal	494331	6604135	26/2/20	Summer	-	old SuG nest	Sugar Glider	Good
S	SF	1.4	Scansorial Mammal	494313	6603990	26/2/20	Summer	Native beehive	-	Native bees	Good
S	SG	3.1	Small Glider	494333	6604235	26/2/20	Summer	SuG x 2	Sugar Glider nesting material	Sugar Glider	Good
S	SG	3.1	Small Glider	494340	6604165	26/2/20	Summer	SuG x 3	Sugar Glider nesting material	Sugar Glider	Good
S	SG	3.12	Small Glider	494331	6604346	26/2/20	Summer	Sug x3	Sugar Glider nesting material	Sugar Glider	Good
S	SG	3.9	Small Glider	494317	6604020	26/2/20	Summer	-	old SuG nest	Sugar Glider	Good
S	Sg	3.3	Small Glider	494321	6604041	26/2/20	Summer	SuG x 1	-	Sugar Glider	Good
S	Sg	3.4	Small Glider	494325	6603917	26/2/20	Summer	-	old SuG nest	Sugar Glider	Good
S	So	6.1	Small Owl	494314	6604203	26/2/20	Summer	Ants	old Btposs nest	Trichosurus spp.	Good
T	C	1.3	Scansorial Mammal	494611	6605257	27/2/20	Summer	Native beehive	-	Native bees	Good
T	C	3.3	Small Glider	494655	6605389	28/2/20	Summer	Native beehive	-	Native bees	Good
T	C	3.4	Small Glider	494619	6605294	29/2/20	Summer	-	old SuG nest, large reptile scat	Sugar Glider	Good
T	C	4.9	Large Glider	494634	6605322	1/3/20	Summer	-	old SuG nest	Sugar Glider	Good
T	C	5.9	Possum	494664	6605431	2/3/20	Summer	-	old SuG nest	Sugar Glider	Good

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
T	LG	4.8	Large Glider	494730	6605488	27/2/20	Summer	Ants	Old leaf material	Ants	Good
T	MB	2.1	Microbat	494672	6605442		Summer	-	-	Vacant	Good
T	P/L	8.1	Parrot Lorikeet	494733	6605511	27/2/20	Summer	-	old SuG nest	Sugar Glider	Good
T	P/L	8.4	Parrot Lorikeet	494615	6605318		Summer	Native beehive	-	Native bees	Good
T	Po	5.5	Possum	494600	6605317	27/2/20	Summer	Ants	Old BtPoss nest	Ants	Good
T	SG	3.14	Small Glider	494744	6605507	27/2/20	Summer	Native beehive	-	Native bees	Good
T	SG	3.2	Small Glider	494755	6605557	27/2/20	Summer	-	old SuG nest	Sugar Glider	Box slid right down tree
U	C	1.1	Scansorial Mammal	494766	6605817	27/2/20	Summer	5 x SuG	Sugar Glider nesting material	Sugar Glider	Good
U	C	3.11	Small Glider	494663	6605631	27/2/20	Summer	-	old SuG nest	Sugar Glider	Good
U	C	3.7	Small Glider	494815	6605915	27/2/20	Summer	-	old SuG nest	Sugar Glider	Good
U	C	5.1	Possum	494677	6605595	27/2/20	Summer	-	Antechinus nest	Antechinus spp.	Good
U	C	5.2	Possum	494800	6605875	27/2/20	Summer	-	Old SuG nest	Sugar Glider	Good
U	C	7.1	Cockatoo				Summer	Not inspected	Not inspected	Vacant	Requires new bottom installed missing base
U	C	8.2	Parrot Lorikeet	494705	6605641	27/2/20	Summer	-	Antechinus nest	Antechinus spp.	Good
U	LG	4.5	Large Glider	494749	6605782	27/2/20	Summer	-	Beehive possible - can’t get lid open	Native bees	Lid damaged
U	LG	4.4	Large Glider	494775	6605856	27/2/20	Summer	-	Pet nest, old ants	Petaurid spp.	Good

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
U	LG	4.7	Large Glider	494703	6605653	27/2/20	Summer	-	old SuG nest	Sugar Glider	Good
U	MB	2.11	Microbat	494792	6605863	27/2/20	Summer	-	FtG nest	Acrobates spp.	Good
U	MB	2.7	Microbat	494766	6605815	27/2/20	Summer	-	-	Vacant	Good
U	P/L	8.3	Parrot Lorikeet	494804	6605885	27/2/20	Summer	-	old ant nest, old leaf material	Old leaf	Good
U	P/L	8.7	Parrot Lorikeet	494736	6605739	27/2/20	Summer	-	Old leaf nest	old leaf	Box down off tree, just need new wire, remains on site
U	Po	5.14	Possum	494743	6605760	27/2/20	Summer	-	RtPoss nest	Ringtail possum	Good
U	Po	5.7	Possum	494691	6605660	27/2/20	Summer	-	BtPoss nest	Trichosurus spp.	Good
U	SF	1.12	Scansorial Mammal	494726	6605715	27/2/20	Summer	Native beehive	-	Native bees	Good
U	SG	3.15	Small Glider	494750	6605817	27/2/20	Summer	-	Old euro beehive	Vacant	Good
U	SG	3.5	Small Glider	494785	6605876	27/2/20	Summer	Native beehive	-	Native bees	Good
U	SG	3.8	Small Glider	494740	6605718	27/2/20	Summer	Native beehive	-	Native bees	Good
A	C	4.6	Large Glider	489636	6594462	16/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
A	C	5.1	Possum	489707	6594598	16/7/20	Winter	-	Antechinus nest	Antechinus spp.	G
A	C	5.7	Possum	489585	6594437	16/7/20	Winter	-	Old BtPoss nest	Trichosurus spp.	G

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
A	LG	4.11	Large Glider	489676	6594545	16/7/20	Winter	-	Old leaf, old euro beehive	Sugar Glider	Lid on ground
A	SF	1.13	Scansorial Mammal	489675	6594535		Winter	-	Fresh SuG nest	Sugar Glider	G
A	SF	1.6	Scansorial Mammal	489579	6594410	16/7/20	Winter	Ants	-	Ants	G
B	Cockatoo	7.2	Cockatoo	490772	6595939	16/7/20	Winter	-	-	Vacant	G
B	MB	2.13	Microbat	490734	6596070	16/7/20	Winter	-	Microbat scat	Microbat spp.	G
B	MB	2.9	Microbat	490735	6595930	16/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
B	P/L	8.6	Parrot Lorikeet	490745	6595983	16/7/20	Winter	-	Old leaf nest	Sugar Glider	G
B	P/L	8.9	Parrot Lorikeet	490757	6596026	16/7/20	Winter	-	Chewing of entrance, Old leaf, old euro beehive	Old leaf	G
B	Po	5.2	Possum	490757	6595990	16/7/20	Winter	-	-	Vacant	G
B	Po	5.6	Possum	490740	6595944	16/07/2020	Winter	-	mud wasp nests	Vacant	G
B	Po	5.9	Possum	490728	6596059	16/7/20	Winter	-	-	Vacant	G
B	SF	1.3	Scansorial Mammal	490744	6595991	16/7/20	Winter	-	Old leaf nest	Old leaf	G
C	C	1.4	Small Glider	492506	6599227	16/7/20	Winter	-	-	Vacant	G
C	C	5.4	Possum	492544	6599220	16/7/20	Winter	-	Old BtPoss nest	Trichosurus spp.	G
C	MB	2.2	Microbat	492513	6599166	16/7/20	Winter	-	Fresh Antechinus nest	Antechinus spp.	G
C	Po	5.1	Possum	492495	6599162	16/7/20	Winter	-	Old BtPoss nest	Trichosurus	G

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
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C	SF	1.11	Scansorial Mammal	492443	6599106	16/7/20	Winter	-	Old native beehive	Native bees	G
D	C	1.9	Scansorial Mammal	495524	6607228	17/7/20	Winter	Sugar Glider x 1	Sugar Glider nesting material	Sugar Glider	G
D	C	2.7	Microbat	495470	6607086	17/11/20	Winter	-	-	Vacant	G
D	C	3.1	Small Glider	495377	6606930	17/1/21	Winter	-	Old Leaf nest	Sugar Glider	G
D	C	4.5	Large Glider	495465	6607081	15/7/20	Winter	-	Old Leaf nest	Sugar Glider	Requires new lid
D	C	5.8	Possum	495634	6607441	17/5/20	Winter	-	Old BtPoss den	Antechinus spp.	G
D	C	8.4	Parrot Lorikeet	495528	6607229	17/9/20	Winter	-	Antechinus nest	Antechinus spp.	G
D	C	8.5	Parrot Lorikeet	495369	6606961	15/7/20	Winter	-	Old euro beehive decomposed	Vacant	G
D	LG	4.3	Large Glider	495613	6607394	17/7/20	Winter	-	Owlet NightJar	Owlet-nightjar	G
D	MB	2.4	Microbat	495377	6606934	15/7/20	Winter	Nyctophilus spp.	-	Nyctophilus spp.	G
D	PO	5.18	Possum	495470	6607148	17/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
D	Po	5.3	Possum	495604	6607333	17/7/20	Winter	-	Old Leaf nest	Trichosurus spp.	G
D	SF	1.7	Scansorial Mammal	495407	6607000	15/7/20	Winter	-	Old antechinus nest	Antechinus spp.	G
D	SG	3.11	Small Glider	495547	6607265	17/7/20	Winter	-	Acrobates spp. leaf nest	Acrobates spp.	G

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
D	SO	6.2	Small Owl	495540	6607280	17/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
E	C	3.8	Small Glider	496288	6608309	14/7/20	Winter	-	Native beehive	Native bees	G
E	C	8.6	Parrot Lorikeet	496268	6608279	14/7/20	Winter	Lace monitor	-	Lace monitor	G
E	Po	5.8	Possum	496259	6608217	14/7/20	Winter	-	Native beehive	Native bees	G
E	SG	3.18	Small Glider	496479	6608614	14/7/20	Winter	-	Native beehive	Native bees	G
F	C	1.2	Scansorial Mammal	496649	6609338	14/7/20	Winter	Sugar Glider	Sugar Glider nesting material	Sugar Glider	G
F	C	4.1	Large Glider	496663	6609320	14/7/20	Winter	-	Old leaf material	Old leaf	G
F	C	5.3	Large Glider	496640	6609618	14/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
F	LG	4.12	Large Glider	496620	6609594	14/7/20	Winter	-	Old euro beehive	Native bees	Lid fallen off lid on site
F	P/L	8.8 (Po5.4)	Parrot Lorikeet	496492	6609235	14/7/20	Winter	-	-	Vacant	G
F	Po	5.16	Possum	496488	6609157	14/7/20	Winter	SEBtP	-	Short-eared brushtail possum	G
F	SF	1.5	Scansorial Mammal	496585	6609519	14/7/20	Winter	-	Acrobates spp. leaf nest	Sugar Glider	G
F	SF	1.9	Scansorial Mammal	496508	6609236	14/7/20	Winter	-	Native beehive	Native Bees	G
F	SF	3.6	Scansorial Mammal	496639	6609599	14/7/20	Winter	Sugar Glider x 2	Sugar Glider nesting material	Sugar Glider	G
F	SG	3.7	Small Glider	496527	6609397	14/7/20	Winter	-	Old euro beehive	Native bees	G
G	C	1.6	Scansorial Mammal	497427	6610227	14/7/20	Winter	3 x Sugar glider	Sugar Glider nesting material	Sugar Glider	G

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
G	C	3.1	Small Glider	497304	6610070	14/7/20	Winter	Sugar Glider	Sugar Glider nesting material	Sugar Glider	G
G	C	3.6	Small Glider	496924	6609701	14/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
G	C	4.3	Large Glider	496957	6609729	15/7/20	Winter	-	Native beehive	Native bees	G
G	C	4.8	Large Glider	497036	6609788	14/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
G	C	7.1	Cockatoo	496872	6609668	15/7/20	Winter	-	Old BtPoss nest	Trichosurus spp.	One hinge broken
G	C	8.7	Parrot Lorikeet	496948	6609702	14/7/20	Winter	-	Owlet nightjar	Owlet-nightjar	G
G	HMP	HMP	Possum	497205	6609967	14/7/20	Winter	Lace Monitor	-	Lace monitor	Fair
G	LG	4.1	Large Glider	497371	6610146	14/7/20	Winter	Lace monitor	-	Lace monitor	G
G	LG	4.9	Large Glider	496917	6609683	15/7/20	Winter	Not inspected	Not inspected	Vacant	Box on ground, need full box replacement
G	Po	5.11	Possum	497068	6609857	14/7/20	Winter	-	BtPoss nest	Trichosurus spp.	G
G	Po	5.12	Possum	497253	6610029	14/7/20	Winter	Lace monitor	-	Lace monitor	G
G	Po	5.15	Possum	497212	6609983	16/7/20	Winter	-	Beehive	Native bees	G
G	SF	1.1	Scansorial Mammal	497245	6610013	14/7/20	Winter	Sugar Glider	Sugar Glider nesting material	Sugar Glider	G
G	SF	1.14	Scansorial Mammal	497037	6609831	15/7/20	Winter	-	Native beehive	Native bees	G
G	SG	3.13	Small Glider	496853	6609671	14/7/20	Winter	-	Acrobates spp. leaf nest	Acrobates spp.	G
G	SG	3.17	Small Glider	497272	6610048	16/7/20	Winter	-	Native bees	Native bees	G

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
New NBRZ	C	3.13	Small Glider	497511	6610415	15/7/20	Winter	-	Fresh small pet nest	Sugar Glider	One lid hinge broken
New NBRZ	C	3.2	Small Glider	497399	6610581	14/7/20	Winter	-	Acrobates spp. leaf nest	Acrobates spp.	Hinge semi broken
New NBRZ	C	4.1	Large Glider	497404	6610590	14/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
New NBRZ	C	4.2	Large Glider	497299	6610324	14/7/20	Winter	-	Small glider nest	Small Petaurid spp.	G
New NBRZ	C	4.7	Large Glider	497501	6610327	14/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
New NBRZ	C	5.12	Possum	497338	6610385	14/7/20	Winter	-	Owlet nightjar possible	Owlet-nightjar	G
New NBRZ	C	5.5	Small Glider	497486	6610313	14/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
New NBRZ	C	6.1	Small Owl	497371	6610443	14/7/20	Winter	Lace monitor	-	Lace monitor	G
New NBRZ	C	8.1	Parrot Lorikeet	497177	6610264	14/7/20	Winter	-	Old small glider nest	Small Petaurid spp.	G
New NBRZ	P/L	8	Parrot Lorikeet	497511	6610340	14/7/20	Winter	-	Old antechinus nest	Acrobates spp.	G
New NBRZ	SF	1.1	Scansorial Mammal	497515	6610408	14/7/20	Winter	-	Native beehive	Native bees	G
OC5	C	1.1	Scansorial Mammal	494366	6604916	15/7/20	Winter	Not inspected	Not inspected	Vacant	Tree cut down, need new box
OC5	C	1.5	Scansorial Mammal	494351	6605047	16/7/20	Winter	-	Fresh SuG nest	Sugar Glider	G
OC5	C	2.1	Microbat	494364	6604984	16/7/20	Winter	-	FtG nest	Acrobates spp.	G
OC5	C	2.3	Microbat	494367	6604964	16/7/20	Winter	-	Mb scat	Microbat spp.	G
OC5	C	2.5	Microbat	494361	6604949	16/7/20	Winter	-	SuG nest	Acrobates spp.	G

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
OC5	C	2.6	Microbat	494365	6605000	16/7/20	Winter	-	Old mb scat	Microbat spp.	G
OC5	C	3.5	Small Glider	494378	6604909	16/7/20	Winter	-	SuG nest	Sugar Glider	G
S	C	3.12	Possum	494316	6604201	15/7/20	Winter	-	Old BtPoss nest	Trichosurus spp.	G
S	C	3.9	Small Glider	494328	6603870		Winter	Sugar Glider x 2	Sugar Glider nesting material	Sugar Glider	G
S	C	4.4	Large Glider	494326	6604196	15/7/20	Winter	-	Old bird nest material w scat	Bird spp.	G
S	C	5.6	Possum	494325	6604137	15/7/20	Winter	-	-	Vacant	G
S	C	8.3	Parrot Lorikeet	494350	6604355	15/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
S	LG	4.1	Large Glider	494337	6604315	15/7/20	Winter	-	Sugar Glider nesting material	Small Petaurid spp.	G
S	LG	4.14	Large Glider	494325	6603868	15/7/20	Winter	-	Old Leaf nest	Old leaf	G
S	LG	4.2	Large Glider	494337	6603901	15/7/20	Winter	-	-	Vacant	Vines starting to grow over box/Water
S	LG	4.6	Large Glider	494336	6604005	15/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
S	MB	2.1	Microbat	494354	6604286	15/7/20	Winter	-	-	Vacant	G
S	MB	2.12	Microbat	494325	6604064	15/7/20	Winter	-	-	Vacant	G
S	MB	2.3	Microbat	494340	6603983	15/7/20	Winter	-	-	Vacant	G
S	MB	2.5	Microbat	494328	6604164	15/7/20	Winter	-	-	Vacant	G
S	MB	2.8	Microbat	494330	6604122	15/7/00	Winter	-	-	Vacant	G

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
S	P/L	8.1	Parrot Lorikeet	494342	6604258	15/7/20	Winter	Ants	-	Ants	G
S	P/L	8.11	Parrot Lorikeet	494316	6604003	15/7/20	Winter	-	White-throated treecreeper	White-throated treecreeper	G
S	Po	5.1	Possum	494363	6604313	15/7/20	Winter	-	-	Vacant	G
S	Po	5.13	Possum	494318	6603797	15/7/20	Winter	-	Old BtPoss nest	Trichosurus spp..	G
S	Po	5.17	Possum	494343	6604199	15/7/20	Winter	-	Old BtPoss nest	Trichosurus spp..	G
S	SF	1.2	Scansorial Mammal	494331	6604135	15/7/20	Winter	Sugar Glider	Sugar Glider nesting material	Sugar Glider	G
S	SF	1.4	Scansorial Mammal	494313	6603990	15/7/20	Winter	-	Native beehive	Native bees	G
S	SG	3.1	Small Glider	494333	6604235	15/7/20	Winter	Sugar Glider x 2	Sugar Glider nesting material	Sugar Glider	G
S	SG	3.1	Small Glider	494340	6604165	15/7/20	Winter	-	Acrobates spp. leaf nest	Acrobates spp.	G
S	SG	3.12	Small Glider	494331	6604346	15/7/20	Winter	Sugar Glider x 3	Sugar Glider nesting material	Sugar Glider	G
S	SG	3.9	Small Glider	494317	6604020	15/7/20	Winter	-	Old lorikeet nest	Rainbow lorikeet	G
S	Sg	3.3	Small Glider	494321	6604041	15/7/20	Winter	-	Acrobates spp. leaf nest	Acrobates spp.	G
S	Sg	3.4	Small Glider	494325	6603917	15/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
S	So	6.1	Small Owl	494314	6604203	15/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
T	C	1.3	Scansorial Mammal	494611	6605257	15/7/20	Winter	-	Native beehive	Native bees	G

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
T	C	3.3	Small Glider	494655	6605389	15/7/20	Winter	-	Native beehive	Native bees	G
T	C	3.4	Small Glider	494619	6605294	14/7/20	Winter	Sugar Glider x 2	Sugar Glider nesting material	Sugar Glider	G
T	C	4.9	Large Glider	494634	6605322	15/7/20	Winter	-	Native beehive	Native Bees	G
T	C	5.9	Possum	494664	6605431	15/7/20	Winter	-	Old SuG nest	Sugar Glider	G
T	LG	4.8	Large Glider	494730	6605488	15/7/20	Winter	-	Old leaf material	Small Petaurid spp.	G
T	MB	2.1	Microbat	494672	6605442	15/7/20	Winter	-	-	Vacant	Lid hinge broken one side
T	P/L	8.1	Parrot Lorikeet	494733	6605511	15/7/20	Winter	-	Old leaf nest	Small Petaurid spp.	G
T	P/L	8.4	Parrot Lorikeet	494615	6605318	15/7/20	Winter	-	Native beehive	Native bees	G
T	Po	5.5	Possum	494600	6605317	13/7/20	Winter	-	BtPoss nest	Trichosurus spp..	G
T	SG	3.14	Small Glider	494744	6605507	15/7/20	Winter	-	Native beehive	Native bees	G
T	SG	3.2	Small Glider	494755	6605557	15/7/20	Winter	-	-	Vacant	Fallen down
U	C	1.1	Scansorial Mammal	494766	6605817	15/7/20	Winter	Sugar Glider x 4	Sugar Glider nesting material	Sugar Glider	G
U	C	3.11	Small Glider	494663	6605631	15/7/20	Winter	Sugar Glider	Sugar Glider nesting material	Sugar Glider	G
U	C	3.7	Small Glider	494815	6605915	15/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G
U	C	5.1	Possum	494677	6605595	15/7/20	Winter	-	White-throated treecreeper	White-throated treecreeper	G

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
U	C	5.2	Possum	494800	6605875	15/7/20	Winter	-	Old BtPoss nest	Trichosurus spp.	G
U	C	7.1	Cockatoo				Winter	-	-	Vacant	Requires new bottom installed missing base
U	C	8.2	Parrot Lorikeet	494705	6605641	15/7/20	Winter	Lace monitor	Old Leaf nest	Lace monitor	G
U	LG	4.5	Large Glider	494749	6605782	30/7/20	Winter	-	Old Leaf nest	Native bees	G
U	LG	4.4	Large Glider	494775	6605856	15/7/20	Winter	-	Antechinus nest	Antechinus spp.	G
U	LG	4.7	Large Glider	494703	6605653	15/7/20	Winter	-	Old Leaf nest	Sugar Glider	G
U	MB	2.11	Microbat	494792	6605863	15/7/20	Winter	-	Sugar Glider nesting material	Acrobates spp.	G
U	MB	2.7	Microbat	494766	6605815	15/7/20	Winter	Microbat spp. x 2	-	Microbat spp.	G
U	P/L	8.3	Parrot Lorikeet	494804	6605885	15/7/20	Winter	Ants	Old leaf material	Small Petaurid spp.	Lid damaged
U	P/L	8.7	Parrot Lorikeet	494736	6605739	15/7/20	Winter	-	Old Leaf nest	Old leaf	On ground can put back up
U	Po	5.14	Possum	494743	6605760		Winter	-	Owlet Nightjar	Ringtail possum	G
U	Po	5.7	Possum	494691	6605660	15/7/20	Winter	-	Old Btp den	Trichosurus spp..	G
U	SF	1.12	Scansorial Mammal	494726	6605715	15/7/20	Winter	-	Native beehive	Native bees	G
U	SG	3.15	Small Glider	494750	6605817	15/7/20	Winter	-	Sugar Glider nesting material	Sugar Glider	G

Zone	Box ID	Code	Box Type	Easting	Northing	Inspection Date	Season	Fauna occupying	Fauna signs	Fauna recorded	Box condition
U	SG	3.5	Small Glider	494785	6605876	15/7/20	Winter	-	Native beehive	Native bees	G
U	SG	3.8	Small Glider	494740	6605718	15/7/20	Winter	-	Native beehive	Native bees	G

Appendix H Green-Thighed Frog

Warrell Creek to Nambucca Heads

Green-thighed Frog Monitoring Report – year two operational phase 2019-2020

Transport for New South Wales | July 2020

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Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
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Project team:

David Rohweder (Project management, field survey, reporting)
Luke Andrews (Field survey)
Brendan Taylor (Report review)

Report prepared for:

Transport for NSW

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 02 6628 3559 | E david@sandpipereco.com.au

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1. Introduction

In 2015, Transport for NSW (TfNSW), in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages:

- Stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and
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Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala, spotted-tailed quoll, grey-headed flying-fox, yellow-bellied glider, giant barred frog, green-thighed frog breeding ponds, fauna underpasses, vegetated median, road-kill, exclusion fencing, and threatened flora. Sandpiper Ecological Surveys (Sandpiper) was contracted by TfNSW to deliver the WC2NH operational ecological and water quality monitoring program.

The following report details surveys conducted to monitor use of ponds constructed for green-thighed frog (*Litoria brevipalmata*) breeding. The aim of monitoring is to confirm use of the subject ponds by the target species.

1.1 Background

During pre-construction surveys green-thighed frogs were recorded at two locations within/adjoining the WC2NH alignment (Lewis 2013). The locations were:

- Chainage 60065 within the road corridor where two male frogs were recorded; and
- Chainage 60865 eastern side of road corridor where one male frog was recorded.

Low-lying, periodically inundated forest between chainages 57365 and 59365 was identified as potential habitat (Lewis 2013). Based on this information Lewis (2013) recommended that breeding ponds be constructed at five locations within the WC2NH section (Table 1). Each site was to contain five (approximately) 4x3m ponds with a maximum depth of 400mm, and a 250m section of permanent frog exclusion fence was to be installed between the ponds and carriageway. Site 2N was initially situated on the north side of the alignment at chainage 60065 but was moved to chainage 59440 due to concern about vehicle strike on Old Coast Road.

Table 1: Location and features of frog ponds. * green-thighed frog recorded during pre-construction surveys.

Site	Chainage	Easting	Northing	No. ponds	Retention period (days)	Topographic position
1E	58015	495912	6607879	5	60-80	Adjacent to drainage line; staggered upslope
1W	58165	495921	6608056	5	60-70	Upper slope/ridgeline
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2N	59440	496465	6609092	5	Not specified	Not specified
3	60865*	497383	6610179	5	60-70	Ridge

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest. Green-thighed frog breeding ponds are situated at the northern end of the alignment, adjoining Nambucca State Forest (Figure 1).

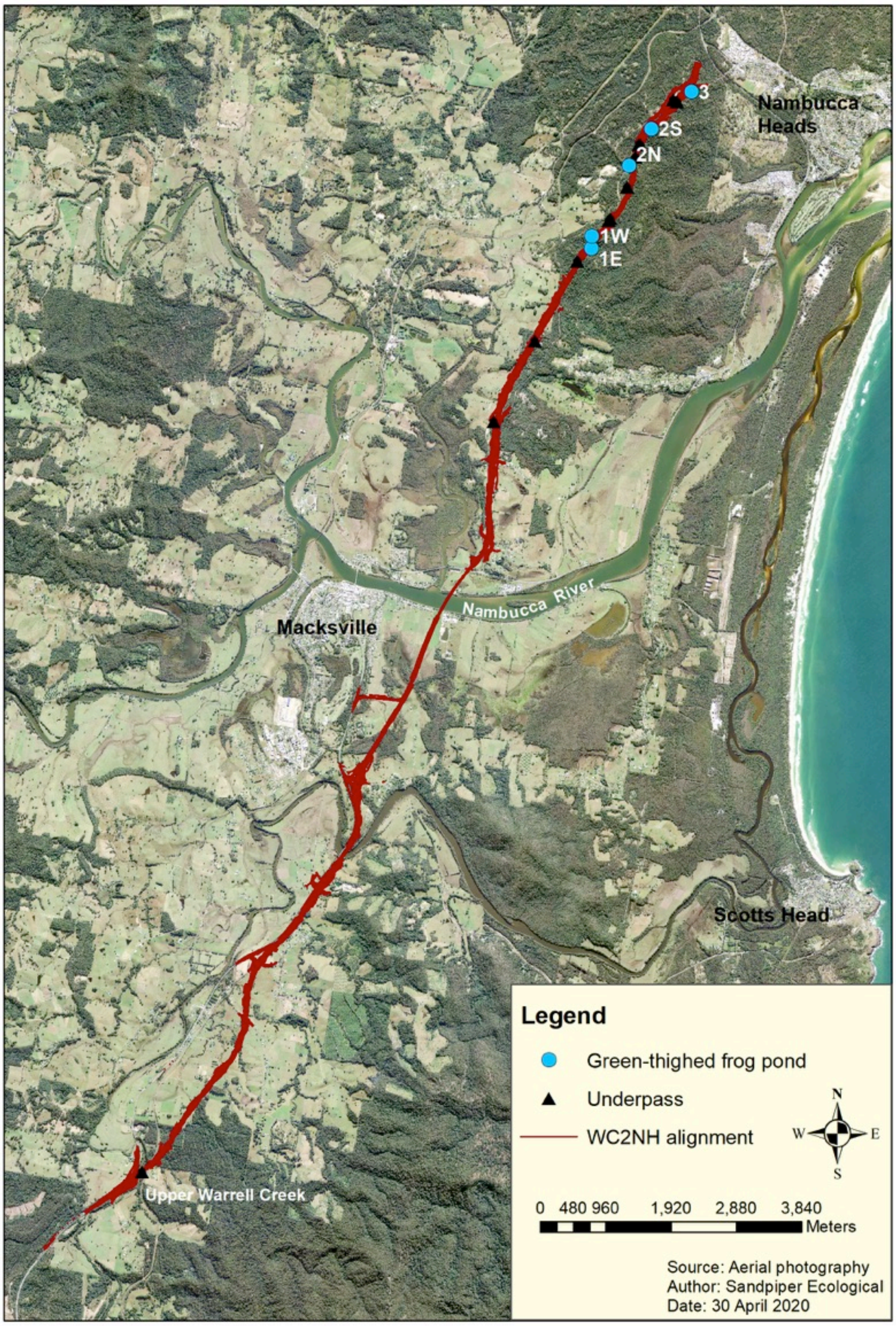

Figure 1: Location of constructed green-thighed frog ponds in relation to the WC2NH alignment.

2. Methods

2.1 Weather conditions

Frog surveys were based on two rainfall triggers:

- 75mm in 24hrs; or
- 150mm in 72hrs.

In accordance with the project brief the WC2NH project weather station was initially monitored for rainfall totals. Once that station was decommissioned in late January 2020 monitoring switched to the Bellwood weather station (N$^{o.}$ 059150), which is managed by the Bureau of Meteorology (BoM). According to the Bellwood weather station the rainfall trigger was exceed on two occasions between October 2019 and March 2020:

- 19 January = 85mm.
- 7-13 February = 338mm.

Unfortunately the project weather station recorded less than 70mm of rain for the mid-January event and as a consequence no sampling occurred at that time. Surveys occurred during the 7-13 February rainfall event.

2.2 Site inspection

To determine the quality of habitat present all frog ponds were inspected on 7 February. The inspection revealed variable water depth and vegetation cover between and within sites, however the majority of ponds contained water and had between 50 and 90% vegetation cover of the littoral zone and were therefore deemed satisfactory for monitoring. No ponds were located at site 1W. At the time of report preparation, TfNSW had, in consultation with an ecologist, constructed ponds at site 1W and installed clay lining in defective ponds at site 2N. Landscaping of these ponds is underway to meet the requirements of the Green-thighed Frog management strategy.

2.3 Reference site

The reference site referred to in the project brief was sampled during the February 2020 surveys. The site did not contain standing water during the survey and it seems likely that potential breeding habitat was removed during construction and drainage/remediation work along Old Coast Road. Surveys will be undertaken to identify an alternate breeding site during subsequent annual surveys. The mid-February rain event triggered green-thighed frog breeding to the north (Glenugie) and south (Kundabung) of the subject site and there is no reason to expect that breeding would not occur on-site.

2.4 Frog survey

Breeding ponds were sampled on two occasions, 7 February, following 69mm of rain, and 9 February following 170mm over three days. Surveys were conducted by two personnel and involved a 30 minute active search at each site, including peripheral habitats within 100m of a site. During a survey the littoral zone of each pond was carefully inspected and all calling and observed frogs were recorded. Surveys were conducted between 1951 and 2339 hours. Upon arrival at a site 5 minutes was spent listening for calling frogs and, on 7 February, the call of green-thighed frog was broadcast for 3 minutes through a 5watt megaphone.

2.5 Tadpole survey

Tadpole surveys were conducted on 27 March 2020, 47 days after 10 February, which represents the mid-point of the February rain event. Tadpole surveys included: a 20-minute traverse of each site focussing on pond edges and immediate surrounds; and dip-netting each pond (10 scoops/pond). Other data collected were: water depth at post; and photo of each pond array. A map of each site was prepared showing the location of ponds in relation to the forest edge, highway and drainage lines. Frog exclusion fence at each site was inspected for evidence of gaps or deterioration. Site 1W was not revisited during the tadpole survey as ponds were not present during the initial rain event.

Captured tadpoles were transferred to an aquarium for identification using Anstis (2017). Fish were identified with reference to Allen *et al.* (2002) and dytiscid larvae with reference to the Centre for Freshwater Ecosystems (undated) and CSIRO (2004). All captured fauna were released at the point of capture and all sample equipment was disinfected between sites.

3. Results

3.1 Frog survey

Weather conditions during both surveys were suitable for frog breeding (Table A1, Appendix A). Air temperature ranged from 22 to 26 ^{0}C and relative humidity 78 to 100%. Rain occurred during survey of sites 1E and 2N on 9 February and cloud cover >50% was recorded during surveys at most sites during both samples.

No green-thighed frogs were recorded during the field survey. Nine species of frog were recorded across both surveys (Table 2). The highest species richness at a single site was five, recorded at site 1E, 2S and 3. The lowest species richness recorded at a site was one at the Reference site. *Pseudophryne coriacea* was the most widespread species and was recorded at five sites, followed by *Crinia signifera* and *Litoria fallax*, recorded at three sites each. Five species were recorded within breeding ponds, including *Lit. fallax*, *Lit. gracilenta*, *C. signifera*, and *Limnodynastes peronii*.

Table 2: Frogs recorded during surveys of constructed breeding ponds adjoining the WC2NH upgrade. * species recorded in ponds.

Group	Species	Site 1E		Site 2N		Site 2S		Reference site		Site 3	
		7/2	9/2	7/2	9/2	7/2	9/2	7/2	9/2	7/2	9/2
Tree frogs	*Litoria caerulea*				X						
	Litoria fallax	X	X		X					X*	X*
	Litoria gracilenta	X					X*				X*
	Litoria nasuta	X*	X*			X*	X*				
	Litoria revelata						X				
	Litoria tyleri	X	X								
Burrowing frogs	*Crinia signifera*			X*	X*	X*	X*			X*	X*
	Pseudophryne coriacea		X		X		X	X			X
	Limnodynastes peronii									X*	X*

3.2 Tadpole survey

Four species of frog were recorded during tadpole surveys (Table 3), all of which were recorded during previous frog surveys. Sites 2S and 3 had the highest diversity with three species at each. Site 3 had the highest abundance with 57 tadpoles recorded from the 50 dip net scoops. Dytiscid larvae were recorded at sites 2N and 2S and no fish were recorded (Table 3).

Table 3: Results of tadpole survey conducted on 27 March 2020. St = development stage; P = pond#

Group	Species	Site 1E	Site 2N	Site 2S	Site 3
Amphibians	*Litoria fallax*			P4=9 (St 37)	
	Litoria gracilenta				P2=6 (St 30-40)
	Litoria nasuta	P2=18 (St 30-42); P4=11 (St 30-37)		P2=1 (St 25)	P3=6 (St 25-39); P4=25 (St25-30); P5=9 (St 25-39)
	Crinia signifera		P5=5 (St 25-40)	P4=2 (St 25)	P1=7 (St 30-42); P2=3 (ST 35-40); P3=1 (St 30)
Dytiscid larvae			P5	P2 & P4	
Fish		Nil	Nil	Nil	Nil

Water depth ranged from 0 to 316mm, (Table 4). Three of five ponds at site 2N were dry whilst two of five at site 1E and two of six at site 2S were dry. All ponds at site 3 contained water. Three ponds at site 2N were modified to improve water retention during the sample period. Stands of bulrush (*Typha orientalis*) were recorded in two ponds, one at site 1E and one at site 2S, suggesting semi-permanent water. A picture of each pond, taken from the north side, is included in Appendix A.

Table 4: Water depth and notable features of each pond.

Site	Pond Nº	Water Depth (mm)	Comment
1E	1	0	Grassy; no measuring post
	2	175	Typha present; no measuring post
	3	0	No measuring post
	4	250	No measuring post
	5	0	No measuring post
2N	1	0	Pond modified (clay added) after rain event
	2	0	Pond modified (clay added) after rain event
	3	0	Pond modified (clay added) after rain event
	4	202	
	5	222	
2S	1	0	
	2	124	
	3	108	
	4	223	Typha present – suggesting semi permanent water
	5	49	Grassy
	6	0	Grassy
3	1	46	Good condition
	2	32	Good condition
	3	165	Good condition
	4	316	Good condition
	5	312	Good condition

3.2.1 Fence condition

Frog exclusion fence was generally in good condition. A gap in the fence was recorded on a gate at site 2S (Plate 2), and minor lifting of fine mesh was evident at several sites (Plate 3). Lifting of fine mesh is not considered a major issue at this stage. The effectiveness of fine mesh exclusion was evident with two species of frog recorded on the fence during the survey (Plates 4 and 5).

Plate 1: Gap in fine mesh exclusion at Site 2S

Plate 2: Lifting of fine mesh exclusion.

Plate 3: *Pseudophryne coriacea* recorded on the outer side of exclusion fence at the reference site.

Plate 4: *Litoria tyleri* recorded on the outer side of exclusion fence at site 1E.

4. Discussion

4.1 Performance indicators

4.1.1 Continued presence of green-thighed frogs at breeding ponds or individuals calling from the edge of constructed ponds

No green-thighed frogs were recorded in the vicinity of breeding ponds or at the reference site during the field survey. Indeed, potential breeding habitat did not develop in the remaining area of the reference site situated between the alignment and Old Coast Road during the sample period. Future surveys of the reference site will need to include habitat west of Old Coast Road, and elsewhere in Nambucca State Forest. The absence of green-thighed frogs following a prolonged dry period is not cause for concern. A substantive breeding event may not have occurred in the study area since autumn 2018 and it is likely that the abundance of green-thighed frogs has declined since that time. It may take several successive breeding events before frog numbers increase sufficiently to warrant use of constructed ponds. The breeding strategy of green-thighed frogs mean that the species may be more prone to the effect of drought than congeneric species that breed in permanent water bodies and/or breed after smaller volume rain events.

Variable breeding activity, even within a small geographic area, is not unusual (Lewis 2018) and variability may increase in cases where population size is small. Lewis (2013) recorded three male frogs at two sites during targeted surveys of the WC2NH alignment, which is low compared to other north coast breeding sites (Lewis 2018), although equivalent to the majority of sites sampled by Lemckert *et al.* (2006). The fact that baseline surveys occurred in January to March 2012, following successive wet years, means that frog abundance may have been elevated at that time. Successive wet years may be required before the continued presence of frogs and success of breeding ponds can be evaluated.

The ability of green-thighed frogs to successfully breed in artificial ponds and preference for sites with ground vegetation and/or leaf litter (Lemkert & Slatyer 2002) means it will take time for individuals to encounter the subject ponds. Although sample sites are gradually rehabilitating areas surrounding the ponds have sparse leaf litter and ground vegetation, two important breeding habitat features (Lemkert & Slatyer 2002). The small number of individuals recorded during baseline surveys and likely presence of breeding habitat elsewhere in NSF reduces the likelihood that frogs will readily utilise the subject ponds.

4.1.2 The presence of tadpoles, juveniles or metamorphs during follow up surveys

The absence of tadpoles, juveniles or metamorphs is likely due to the reasons discussed in the previous section and is consistent with the absence of adult frogs. Pond condition varied between sites. Ponds at site 3 were in good condition and are likely to retain water for the prescribed 60-80 day period. In contrast, site 1W did not contain any ponds at the time of the monitoring, and three of five ponds at each of sites 2N, 1E and three of six at 2S did not support water for the required period. Pond issues at sites 1W and 2N were resolved during the sample period. Remediation work at sites 1E and 2S is warranted given that the majority of ponds at both sites don’t retain water for a sufficient period of time.

The presence of bulrush in single ponds at sites 1E and 2S suggests they may retain water for longer than 90 days. Inspection of these ponds several months after substantive rainfall will be required to confirm water retention periods. It was noted that the location of ponds at site 3, on the midslope, is inconsistent with Lewis (2013), who recommended they be installed on the ridgeline. According to TfNSW ponds were not installed on the ridgeline due to concern about receiving sufficient runoff.

4.2 Corrective actions

Lewis (2013) listed five corrective actions:

1. Absence of green-thighed frogs from sites 2S, 2N and 3 - implement additional surveys of adjacent areas to confirm green-thighed frogs remain in that general area, and secondly, undertake a review and if deemed necessary modify the ponds to improve any site suitability problems.

Additional surveys are not considered necessary. The need for such surveys should be assessed following annual monitoring in year 3 of the operational phase. The presence of successive good quality breeding years will be an important consideration.

2. Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis - review and if deemed necessary, modify the ponds by placing a semi permeable layer or further excavation.

Issues with pond condition at sites 1W and 2N were rectified during the sample period. Revegetation of pond margins, as per the management strategy, will be required before these sites are included in subsequent monitoring events. Remediation work is warranted at sites 1E and 2S. This should involve installation of a clay liner in three ponds at each site.

3. Ponds holding water for too long and representing unsuitable habitat (i.e. permanent versus ephemeral). The corrective action for this would be to improve drainage to ensure the ponds dries out.

Based on presence of bulrush, single ponds at sites 1E and 2S may retain water for longer than the prescribed period. Neither pond supported fish, which suggests that water may not be permanent, or conversely, that fish have not been able to colonise the ponds. Remediation work at ponds that retain water on a semi-permanent basis is warranted but should be based on results of an inspection in winter 2020.

4. Exotic fish fauna recorded in breeding ponds. The corrective action for this would be to improve drainage to ensure the pond dries out.

Exotic fish were not recorded in any of the subject ponds.

5. Recommendations

Recommendations relating to the year 2 operational phase green-thighed frog monitoring program are summarised in Table 5.

Table 5: Recommendations following year 2 operational phase threatened mammal monitoring and Transport for NSW response.

Number	Recommendation	Transport for NSW Response
1.	Continue annual monitoring of breeding ponds following suitable rainfall events. Searches for a suitable reference site should be conducted as part of the next monitoring event	Agree & to be adopted
2.	Inspect breeding ponds containing bulrush in June 2020 to confirm water retention and advise on the need for remediation	A review of the ponds has been undertaken with several options being considered in consultation with the project ecologist to reduce water retention times. Rectification works are expected to be undertaken in the coming months.
3.	Undertake remediation of 3 ponds at site 1E and 3 ponds at site 2S to improve water retention.	Remediation works at the 3 ponds has been initiated with some further minor works to be undertaken in the coming months. Water retention holding times will be confirmed during future monitoring events.
4.	Ensure appropriate revegetation (as per Lewis 2013) has occurred at recently constructed or modified ponds at sites 1W and 2N.	Revegetation works has been completed at sites 1W and 2N. This will continue to be monitored and maintained as required during the construction contractor's landscape maintenance period.

6. References

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Appendix A

Table A1: Weather conditions recorded during field survey.

Variable	Site 1E		Site 2N		Site 2S		Reference site		Site 3	
	7/2	9/2	7/2	9/2	7/2	9/2	7/2	9/2	7/2	9/2
Air temperature (^{0}C)	26.1	NR	26.1	22.6	26.1	22.5	26.1	22.8	26.1	22.8
Dew Point (^{0}C)	22.7	NR	22.5	22.6	22.5	22.5	22.5	23.3	22.5	23.9
Relative humidity (%)	78.5	NR	80.5	98.1	80.5	100	80.5	100	80.5	100
Cloud cover (%)	100	100	100	100	75	40	60	100	60	40
Rainfall (P/A)	A	P	A	P	A	A	A	A	A	A
Wind	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Photo-points

Site 2N

Pond 1

Pond 2


Pond 3


Pond 4


Pond 5

Site 2S


Pond 1


Pond 2


Pond 3

Pond 4

Pond 5

Pond 6

Site 1E

Pond 1

Pond 2

Pond 3


Pond 4


Pond 5

Site 3


Pond 1

Pond 2

Pond 3

Pond 4

Pond 5

Warrell Creek to Nambucca Heads

Green-thighed Frog Monitoring Report – year three operational phase 2020-2021

Transport for New South Wales | March 2021

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8/3/2021	2	Final	S. Walker & K. Hincks	TfNSW	MSW & PDF	D. Rohweder

Project team:

David Rohweder (Project management, field survey, reporting)
Luke Andrews (Field survey)

Report prepared for:

Transport for NSW

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 02 6628 3559 | E david@sandpipereco.com.au

Table of contents

List of tables

List of figures

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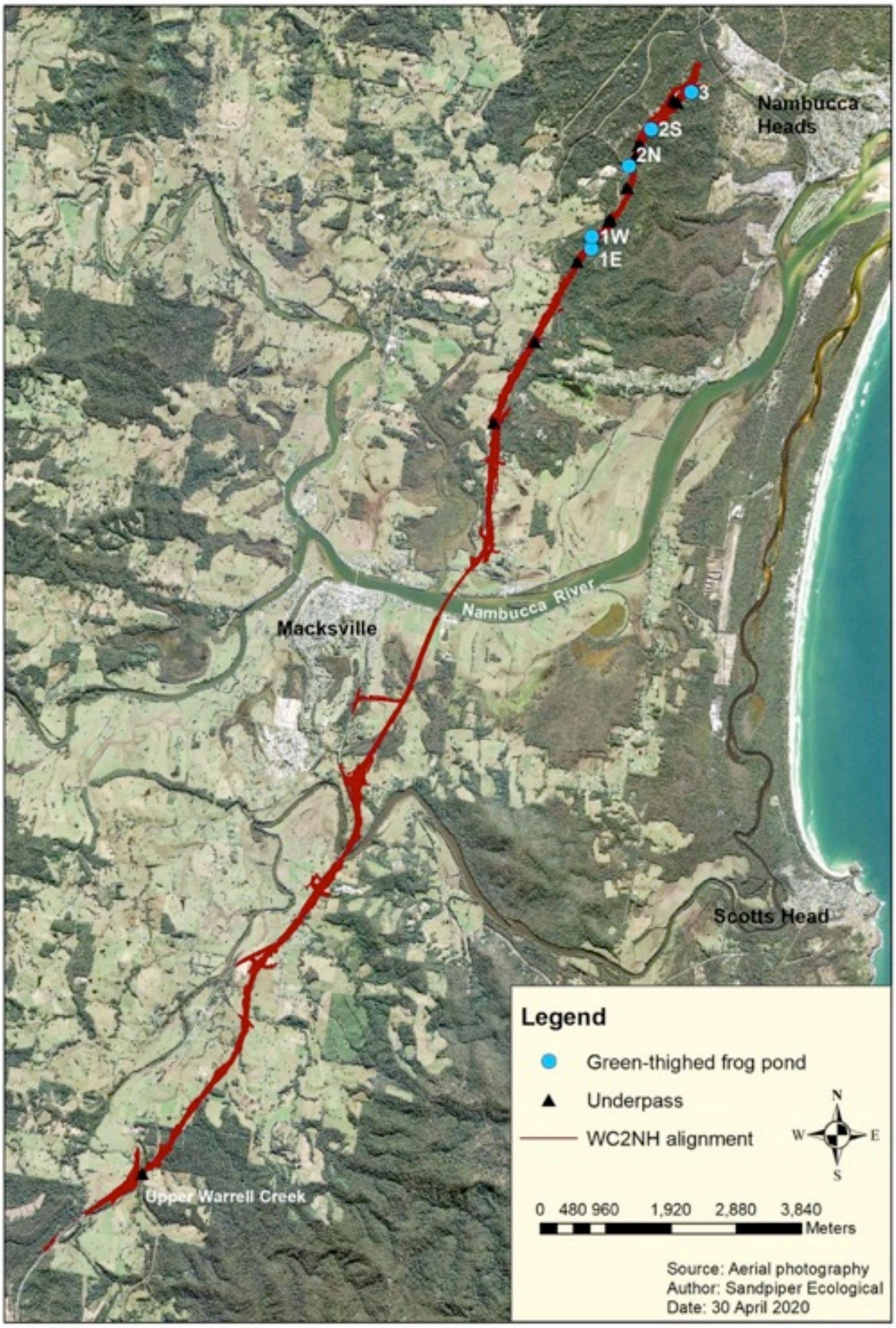

Figure 1: Location of constructed green-thighed frog ponds in relation to the WC2NH alignment.

2. Methods

2.1 Weather conditions

Frog surveys were based on two rainfall triggers:

- 75mm in 24hrs; or
- 150mm in 72hrs.

Since the project weather station was decommissioned in late January 2020 monitoring of rainfall switched to the Bellwood (N$^{o.}$ 059150) and Coffs Harbour Airport (N$^{o.}$ 095151) weather stations, which are managed by the Bureau of Meteorology (BoM). In mid-December 2020 a large rain event occurred in north-eastern NSW. Recording of rainfall by the Bellwood station for the period 12-18 December differs substantially to that observed during the rain event and recorded by the Coffs Airport station. The decision to commence surveys was based on observation of rainfall totals at various gauges near the sample sites (see http://www.bom.gov.au/nsw/flood/index.shtml?ref=hdr), all of which showed that the 24hr total of 75mm was exceeded on 12/13 December. For the period 12-14 December the Bellwood station recorded 31mm, with no value shown for 12 December. In contrast, the Coffs Airport station recorded 189mm for the same period with 150mm recorded on 12 December. Frog surveys occurred on 14 December.

2.3 Reference site

The reference site referred to in the project brief was sampled during the December 2020 surveys. The site did not contain standing water during the survey and it seems likely that potential breeding habitat was removed during construction and drainage/remediation work along Old Coast Road. As per the year 2 monitoring report (Sandpiper Ecological 2020) the reference site survey was expanded to include the ridgeline east and west of the alignment at 2S, and the ridge north of site 3 (Figure 2). These surveys included a slow traverse of management trails by two ecologists searching flooded wheel ruts and depressions. The December 2020 rain event triggered green-thighed frog breeding to the north (Glenugie) and south (Clybucca and Colombatti) of the subject site (pers comm M. Stephens), and there is no reason to expect that breeding would not occur on-site.

2.4 Frog survey

Breeding ponds were sampled on 14 December 2020. Surveys were conducted by two personnel and involved a 30 minute active search at each site, including peripheral habitats within 100m of a site. During each survey the littoral zone of each pond was carefully inspected and all calling and observed frogs were recorded. Surveys were conducted between 1915 and 2315 hours. Upon arrival at a site 5 minutes was spent listening for calling frogs.

2.5 Tadpole survey

Tadpole surveys were conducted on 21 January 2021, 37 days after the December rain event. Tadpole surveys included: a 20-minute traverse of each site focussing on pond edges and immediate surrounds; and dip-netting each pond (10 scoops/pond). Other data collected were: water depth at post; and photo of each pond array. A map of each site was prepared showing the location of ponds in relation to the forest edge, highway and drainage lines. Frog exclusion fence at each site was inspected for evidence of gaps or deterioration.

Captured tadpoles were transferred to an aquarium for identification using Anstis (2017). Fish were identified with reference to Allen *et al.* (2002) and dytiscid larvae with reference to the Centre for

Freshwater Ecosystems (undated) and CSIRO (2004). All captured fauna were released at the point of capture and all sample equipment was disinfected between sites.

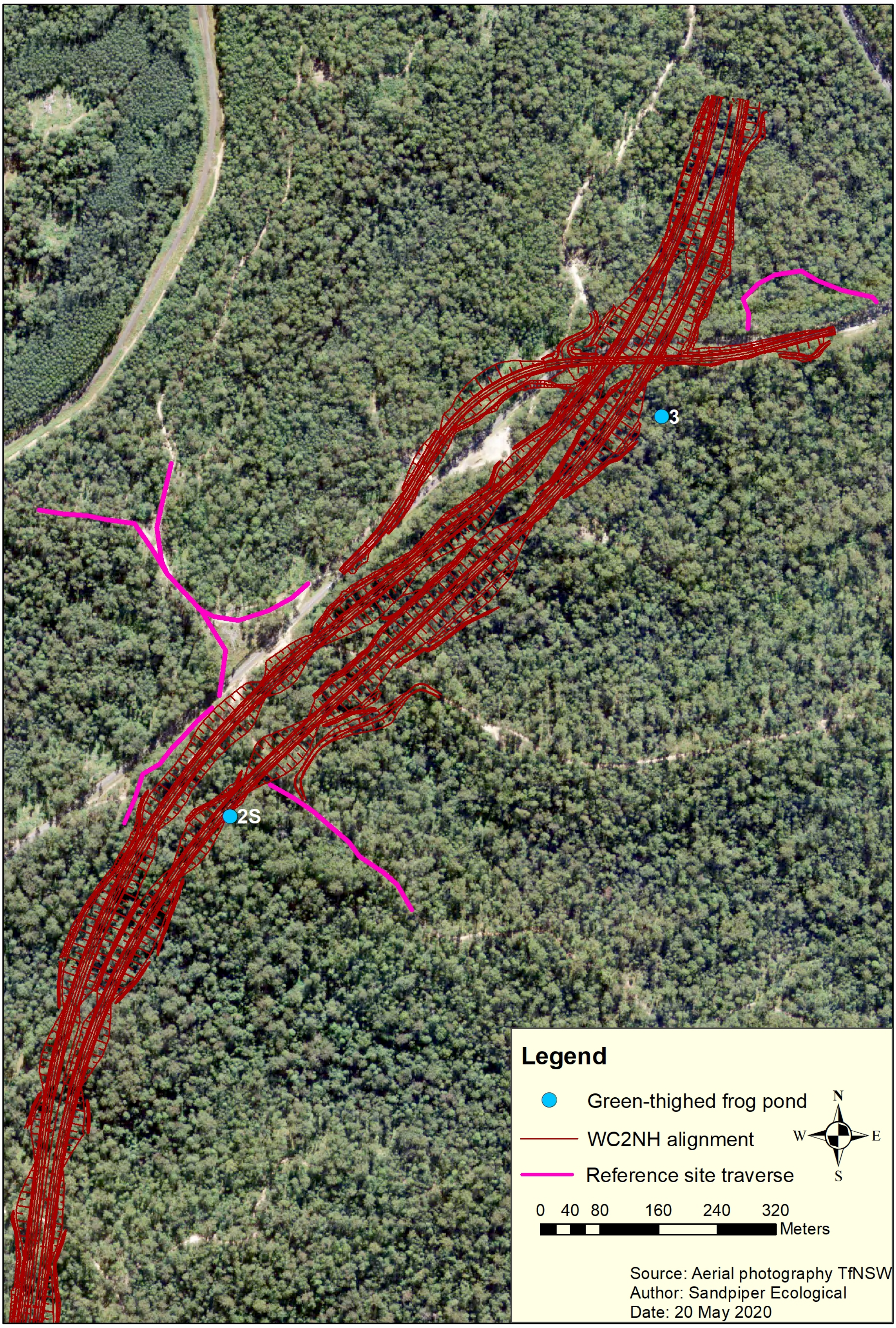

Figure 2: Location of reference site traverses in vicinity of sample sites 2S and 3.

3. Results

3.1 Frog survey

Weather conditions were suitable for frog breeding (Table A1, Appendix A). Air temperature ranged from 20 to 21.6 ^{0}C and relative humidity 92 to 100%. Continuous light rain occurred during the survey and cloud cover was 100%. Wind was moderate throughout the survey.

No green-thighed frogs were recorded during the field survey. Ten species of frog were recorded (Table 2). The highest species richness at a single site was five, recorded at site 2S and 3. The lowest species richness recorded at a site was two at the Reference site. *Crinia signifera and Limnodynastes peronii* were the most widespread species, with each recorded at four sites, followed by *Litoria gracilenta*, recorded at three sites each. Seven species were recorded within breeding ponds, including *Lit. fallax*, *Lit. gracilenta*, *Lit. nasuta*, *Lit. tyleri*, *C. signifera*, *Adelotus brevis* and *Limnodynastes peronii*.

Table 2: Frogs recorded during surveys of constructed breeding ponds adjoining the WC2NH upgrade in December 2021. * species recorded in ponds.

Group	Species	Site 1E	Site 2N	Site 2S	Reference site	Site 3
Tree frogs	*Litoria caerulea*		X			
	Litoria fallax					X*
	Litoria gracilenta	X*		X*		X*
	Litoria nasuta	X*				
	Litoria tyleri					X*
	Litoria peronii	X				
Burrowing frogs	*Crinia signifera*		X*	X*	X	X*
	Pseudophryne coriacea			X		
	Adelotus brevis		X	X*		
	Limnodynastes peronii		X	X*	X	X*

3.2 Tadpole survey

Five species of frog were recorded during tadpole surveys (Table 3), all of which were recorded during the previous frog survey. Sites 2S and 3 had the highest diversity with four species at each. Site 3 had the highest abundance with 90 tadpoles recorded from the 50 dip net scoops. Dytiscid larvae were recorded at sites 1E, 2N and 2S and no fish were recorded (Table 3).

Table 3: Results of tadpole survey conducted on 21 January 2021. St = development stage; P = pond#

Group	Species	Site 1E	Site 2N	Site 2S	Site 3
Amphibians	*Litoria gracilenta*			P2=5 (St 41)	P3=2 (St 23-29)
	Litoria nasuta	P4=38 (St 25)	P2=28 (St 31-41) P4=6 (St 30)	P2=10 (St 30)	P2=43 (St 31-41) P4=7 (St 30-44) P5=12 (St 31-42)
	Crinia signifera	P2=10 (St 30)		P2=5 (St 30+)	
	Litoria peronii	P2=3 (St 31-38)			P5=8 (St 23/24)
	Limnodynastes peronii			P2=9 (St 41) P5=1 (St 30)	P4=15 (St23/24) P5=2 (ST23)
Dytiscid larvae		Pond 2	Ponds 2 & 4	Pond 5	
Fish		Nil	Nil	Nil	Nil

Water depth ranged from 0 to 316mm, (Table 4). Three of five ponds at site 2N were dry whilst two of five at site 1E and two of six at site 2S were dry. All ponds at site 3 contained water. Three ponds at site 2N were modified to improve water retention during the sample period. Stands of bulrush (*Typha orientalis*) were recorded in two ponds, one at site 1E and one at site 2S, suggesting semi-permanent water. A picture of each pond, taken from the north side, is included in Appendix A.

Table 4: Water depth and notable features of each pond recorded on 21 January 2021.

Site	Pond N^{o}	Water Depth (mm)	Comment
1E	1	0	Grassy; no measuring post
	2	60	Typha present
	3	0	
	4	160	
	5	0	
2N	1	130	Pond modified (clay added) after rain event
	2	60	Pond modified (clay added) after rain event
	3	70	Pond modified (clay added) after rain event
	4	35	
	5	20	
2S	1	0	
	2	20	
	3	0	
	4	0	Typha present – suggesting semi permanent water
	5	150	Grassy
	6	0	Grassy
3	1	0	Good condition – no water at post; shallow water elsewhere
	2	0	Good condition – no water at post; shallow water elsewhere
	3	70	Good condition
	4	210	Good condition
	5	180	Good condition

3.2.1 Fence condition

Frog exclusion fence was generally in good condition. A gap in the fence was recorded on a gate at site 2S, and minor lifting of fine mesh was evident at several sites. Lifting of fine mesh is not considered a major issue at this stage.

4. Discussion

4.1 Performance indicators

4.1.1 Continued presence of green-thighed frogs at breeding ponds or individuals calling from the edge of constructed ponds

No green-thighed frogs were recorded in the vicinity of breeding ponds or at the reference site during the field survey. Potential breeding habitat did not develop in the remaining area of the reference site situated between the alignment and Old Coast Road during the rain event. The expansion of reference site surveys to include habitat west of Old Coast Road identified small areas of potential habitat, in the form of flooded wheel ruts and a flooded drainage line, yet no frogs were detected. Small areas of potential habitat (i.e. flooded depressions on a track) were also recorded along the ridge east of the Reference site. The expanded reference site survey suggests there is limited potential breeding habitat in proximity to the alignment, which may explain the small number of individuals recorded during the baseline surveys. The study area certainly lacks the expansive areas of habitat typical of other breeding sites. During other work in NSF potential breeding habitat has been recorded in the northeast forest block and along Rosewood Road in the southeast block.

The breeding strategy of green-thighed frogs may mean they are more prone to the effect of drought than congeneric species that breed in permanent water bodies and/or breed after smaller volume rain events. The population in the study area may take several years to rebound following a severe drought, such as occurred in 2019. This is likely exacerbated by the small extent of breeding habitat in the study area and the small baseline population. The non-quantitative nature of the baseline survey means it is difficult to make definitive statements on population size. The baseline surveys coincided with successive good quality breeding events that may have enabled frogs to expand their range. This is supported by summary of rainfall and breeding events (i.e. rain events of >75mm in 24hrs or 150mm in 72 hours) for the period 2008/2009 to 2019/2020 (Figure 3).

Rainfall data from the Bellwood weather station shows there has been a reduction in the number of annual breeding events since 2013/2014 (Figure 3). The baseline survey was conducted between January and March 2012 following the three highest years of rainfall recorded for the period 2008 to 2020 and years when there were 2-3 breeding events in the period October to March (Figure 3). In comparison, two of the three lowest rainfall totals between 2008 and 2020 have occurred since 2014/15 and four of the last five breeding seasons have had single breeding events only.

Variable breeding activity by green-thighed frog, even within a small geographic area, is not unusual (Lewis 2018) and variability may increase in cases where population size is small. Lewis (2013) recorded three male frogs at two sites during targeted surveys of the WC2NH alignment, which is low compared to other north coast breeding sites (Lewis 2018), although equivalent to the majority of sites sampled by Lemckert *et al.* (2006). The fact that baseline surveys occurred in January to March 2012, following successive wet years, means that frog abundance may have been elevated at the time of survey.

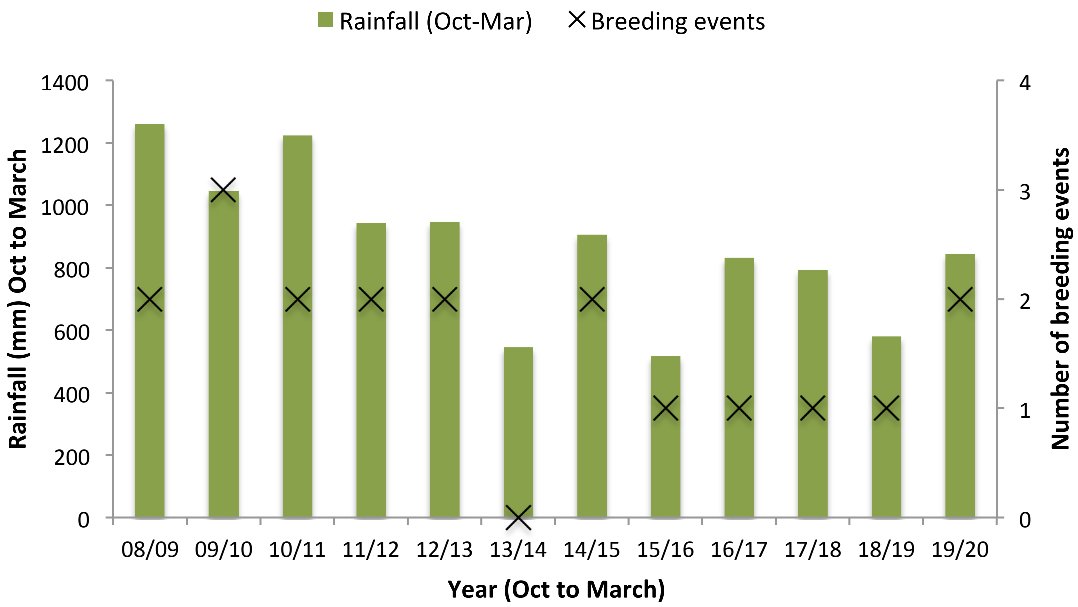

Figure 3: Cumulative rainfall totals recorded at the Bellwood weather station for each breeding year (i.e. October to March) from 2008 to 2020, and the number of breeding events (i.e. 75mm in 24hrs or 150mm in 72hrs) in each breeding year.

Expansion and contraction of green-thighed frog populations and local distribution is possible given the species breeding behaviour. The species breeding strategy combined with modifications to habitat associated with the highway and local roadwork may explain the recent absence of frogs from the study area. Assuming lower abundance and restricted distribution due to climatic conditions it may take several successive breeding years before frog numbers increase sufficiently to warrant use of constructed ponds.

The preference of green-thighed frogs for sites with ground vegetation and/or leaf litter (Lemkert & Slatyer 2002) means it will take time for individuals to encounter the subject ponds. Although sample sites are gradually rehabilitating areas surrounding the ponds have sparse leaf litter and ground vegetation, two important breeding habitat features (Lemkert & Slatyer 2002). The likely small population, as shown by the baseline survey, presence of breeding habitat elsewhere in Nambucca State Forest, and low quality of habitat surrounding ponds, reduces the likelihood that frogs will readily encounter and utilise the subject ponds for breeding.

4.1.2 The presence of tadpoles, juveniles or metamorphs during follow up surveys

The absence of tadpoles, juveniles or metamorphs is likely due to the reasons discussed in the previous section and is consistent with the absence of adult frogs. Pond condition varied between sites and was different to that recorded in 2020. Most ponds contained less water during the 2021 tadpole survey than the equivalent survey in 2020, a result attributed to less follow-up rainfall in summer 2020/21.

Ponds at site 3 were in good condition, although pond numbers one and two are unlikely to retain water for the prescribed 60-80 day period without follow-up rainfall. All ponds at site 2N contained water during the tadpole survey, whilst four of six at 2S and 3 of five at 1E did not contain water for the required period. Pond remediation at site 2N following the 2020 survey (see Sandpiper Ecological 2020) was successful and those ponds should retain water for the prescribed period. Water retention at site 2S differed between 2020 and 2021, with four of six sites containing water in 2020. Water retention is strongly influenced by climate and particularly follow-up rainfall between the initial breeding event and tadpole survey. Concern about permanent water retention in ponds with bulrush at sites 2S and 1E (see Sandpiper Ecological 2020) is unwarranted as the subject pond at site 2S was dry during the 2021 tadpole survey and the subject pond at 1E contained shallow water.

4.2 Corrective actions

Lewis (2013) listed five corrective actions:

1. Absence of green-thighed frogs from sites 2S, 2N and 3 - implement additional surveys of adjacent areas to confirm green-thighed frogs remain in that general area, and secondly, undertake a review and if deemed necessary modify the ponds to improve any site suitability problems.

Sandpiper Ecological (2020) suggested that the need for additional surveys should be assessed following annual monitoring in year 3 of the operational phase. The absence of frogs is not surprising given the low probability that a small number of frogs would find small breeding ponds situated in cleared, largely unsuitable, habitat. Uptake of constructed ponds, by green-thighed frogs, has been low even when ponds occur close to good quality breeding habitat. There is justifiable doubt about the viability and demand for constructed breeding ponds.

2. Ponds not holding water for a sufficient time to enable tadpoles to reach metamorphosis - review and if deemed necessary, modify the ponds by placing a semi permeable layer or further excavation.

Fourteen of the 21 ponds sampled during the tadpole survey contained water, with at least two inundated ponds present at each site. Pond remediation work conducted at site 2N in autumn 2020 was successful with all ponds at that site containing water during the 2021 tadpole survey.

3. Ponds holding water for too long and representing unsuitable habitat (i.e. permanent versus ephemeral). The corrective action for this would be to improve drainage to ensure the ponds dries out.

The 2021 survey has confirmed that ponds at sites 1E and 2S are unlikely to retain water for longer than the prescribed period.

4. Exotic fish fauna recorded in breeding ponds. The corrective action for this would be to improve drainage to ensure the pond dries out.

Exotic fish were not recorded in any of the subject ponds.

5. Recommendations

Recommendations relating to the year 3 operational phase green-thighed frog monitoring program are summarised in Table 5.

Table 5: Recommendations following year 3 operational phase green-thighed frog monitoring and Transport for NSW response.

Number	Recommendation	Transport for NSW Response
1.	Continue annual monitoring of breeding ponds following suitable rainfall events. Searches for a suitable reference site should continue during the next monitoring event	Agree and to be adopted.

6. References

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Appendix A

Table A1: Weather conditions recorded during the green-thighed frog survey on 14 December 2020.

Variable	Site 1E	Site 2N	Site 2S	Reference site	Site 3
Air temperature (^{0}C)	20	21.3	21.6	21.4	21.6
Relative humidity (%)	100	93	92	94	94
Cloud cover (%)	100	100	100	100	100
Rainfall (P/A)	P	P	P	P	P
Wind	RL	MLB	MLB	MLB	MLB

Table 6: Frogs recorded during surveys of constructed breeding ponds adjoining the WC2NH upgrade in February 2020. * species recorded in ponds.

Group	Species	Site 1E		Site 2N		Site 2S		Reference site		Site 3	
		7/2	9/2	7/2	9/2	7/2	9/2	7/2	9/2	7/2	9/2
Tree frogs	*Litoria caerulea*				X						
	Litoria fallax	X	X		X					X*	X*
	Litoria gracilenta	X					X*				X*
	Litoria nasuta	X*	X*			X*	X*				
	Litoria revelata						X				
	Litoria tyleri	X	X								
Burrowing frogs	*Crinia signifera*			X*	X*	X*	X*			X*	X*
	Pseudophryne coriacea		X		X		X	X			X
	Limnodynastes peronii									X*	X*

Table 7: Results of tadpole survey conducted on 27 March 2020. St = development stage; P = pond#

Group	Species	Site 1E	Site 2N	Site 2S	Site 3
Amphibians	*Litoria fallax*			P4=9 (St 37)	
	Litoria gracilenta				P2=6 (St 30-40)
	Litoria nasuta	P2=18 (St 30-42); P4=11 (St 30-37)		P2=1 (St 25)	P3=6 (St 25-39); P4=25 (St25-30); P5=9 (St 25-39)
	Crinia signifera		P5=5 (St 25-40)	P4=2 (St 25)	P1=7 (St 30-42); P2=3 (ST 35-40); P3=1 (St 30)
Dytiscid larvae			P5	P2 & P4	

Photo-points

Site 2N


Pond 1 – 2020


Pond 1 - 2021


Pond 2 – 2020


Pond 2 - 2021


Pond 3 – 2020


Pond 3 - 2021


Pond 4 – 2020


Pond 4 - 2021


Pond 5 – 2020


Pond 5 - 2021

Site 2S


Pond 1 – 2020


Pond 2 - 2021


Pond 2 – 2020


Pond 2 - 2021


Pond 3 – 2020


Pond 3 - 2021


Pond 4 – 2020


Pond 4 - 2021


Pond 5 – 2020


Pond 5 - 2021


Pond 6 – 2020


Pond 6 - 2021

Site 1E


Pond 1 – 2020


Pond 1 - 2021

Pond 2 – 2020

Pond 2 - 2021

Pond 3 – 2020

Pond 3 - 2021

Pond 4 – 2020

Pond 4 - 2021


Pond 5 – 2020


Pond 5 - 2021

Site 3


Pond 1 2020


Pond 1 - 2021


Pond 2 – 2020


Pond 2 - 2021


Pond 3 – 2020


Pond 3 - 2021


Pond 4 – 2020


Pond 4 - 2021


Pond 5 – 2020


Pond 5 - 2021

Appendix I Koala

Warrell Creek to Nambucca Heads Koala Monitoring Operational phase

Koala Monitoring Interim Report

Year 3 operational phase

Transport for NSW | October 2020

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Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
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Project team:

Dr D. Rohweder (project management, survey, report review)
Dr B. Taylor (reporting, survey)
Mr L. Andrews (survey)
Ms N. Makings (survey)

Report prepared for:

Transport for NSW

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 02 6628 3559 | E **david@sandpipereco.com.au**

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1. Introduction

In 2015, Transport for New South Wales (TfNSW), in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages: stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and stage 2b 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala, yellow-bellied glider, giant barred frog, green-thighed frog breeding ponds, underpasses, vegetated median, roadkill, exclusion fence, and threatened flora. Sandpiper Ecological Surveys (SES) has been contracted by TfNSW to deliver the WC2NH operational ecological and water quality monitoring program.

The following interim report details the methods and results of spring year three operational phase koala population monitoring. Year one operational phase monitoring was conducted in spring 2018 (Sandpiper 2018). The aim of koala monitoring is to identify changes in resident koala activity (abundance, home range and movements) in response to construction of WC2NH and the effectiveness of koala habitat connectivity mitigation measures (i.e. fauna underpasses and exclusion fencing). The following report focuses on targeted koala surveys on replicate transects and nearby management trails and includes general comment on the effectiveness of mitigation measures. Detailed analysis of koala use of underpasses and a summary of all koala records will be provided in the annual (year 3 operational phase) koala report, which is due in August 2021.

1.1 Background

The impact of the upgrade on koala (*Phascolarctos cinereus*) was assessed in the Project Environmental Assessment (Sinclair Knight Merz [SKM] 2010a, SKM 2010b), and following its listing on the *Environment Protection and Biodiversity Conservation Act 1999*, a supplementary assessment in accordance with the *EPBC Act Policy Statement 1.1 Significant Impact Guidelines* (Geolink 2016). The supplementary assessment found that the Proposal would have negative impacts on koalas utilising the Nambucca State Forest/ Old Coast Road area, mainly through habitat removal and fragmentation.

The Project, with effective implementation of proposed mitigation measures, was found to be unlikely to result in a significant impact to the local koala population. Notwithstanding, as the Project adversely affected habitat that satisfied the SEWPaC (2012) definition of ‘habitat critical to the survival of the species’ (including direct removal of approximately 86.5 ha of vegetation that satisfies this criteria); the Project was considered to constitute a significant impact on the Koala as per the DSEWPaC (2012) and DoE (2013a) guidelines.

Measures implemented to minimise impacts on koalas include:

- Ecological monitoring to determine the effectiveness of mitigation measures undertaken as part of the Project.
- Installation of fauna crossings, and fauna exclusion fencing to allow for safe passage of fauna (including the koala) crossing the Pacific Highway.
- Installation of 'floppy-top' fauna exclusion fencing to minimise road strike

Prior to construction a pre-clearance baseline koala monitoring methodology was prepared and baseline surveys conducted in autumn and spring 2014 (SKM 2014). Construction phase koala monitoring surveys were conducted in spring 2015 (year 1) and spring 2017 (year 3) (Geolink 2017). Operational phase koala monitoring surveys were conducted in spring 2018 (year 1) (Sandpiper Ecological 2018).

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest. Koala population monitoring surveys occur within Nambucca State Forest at the northern end of the upgrade.

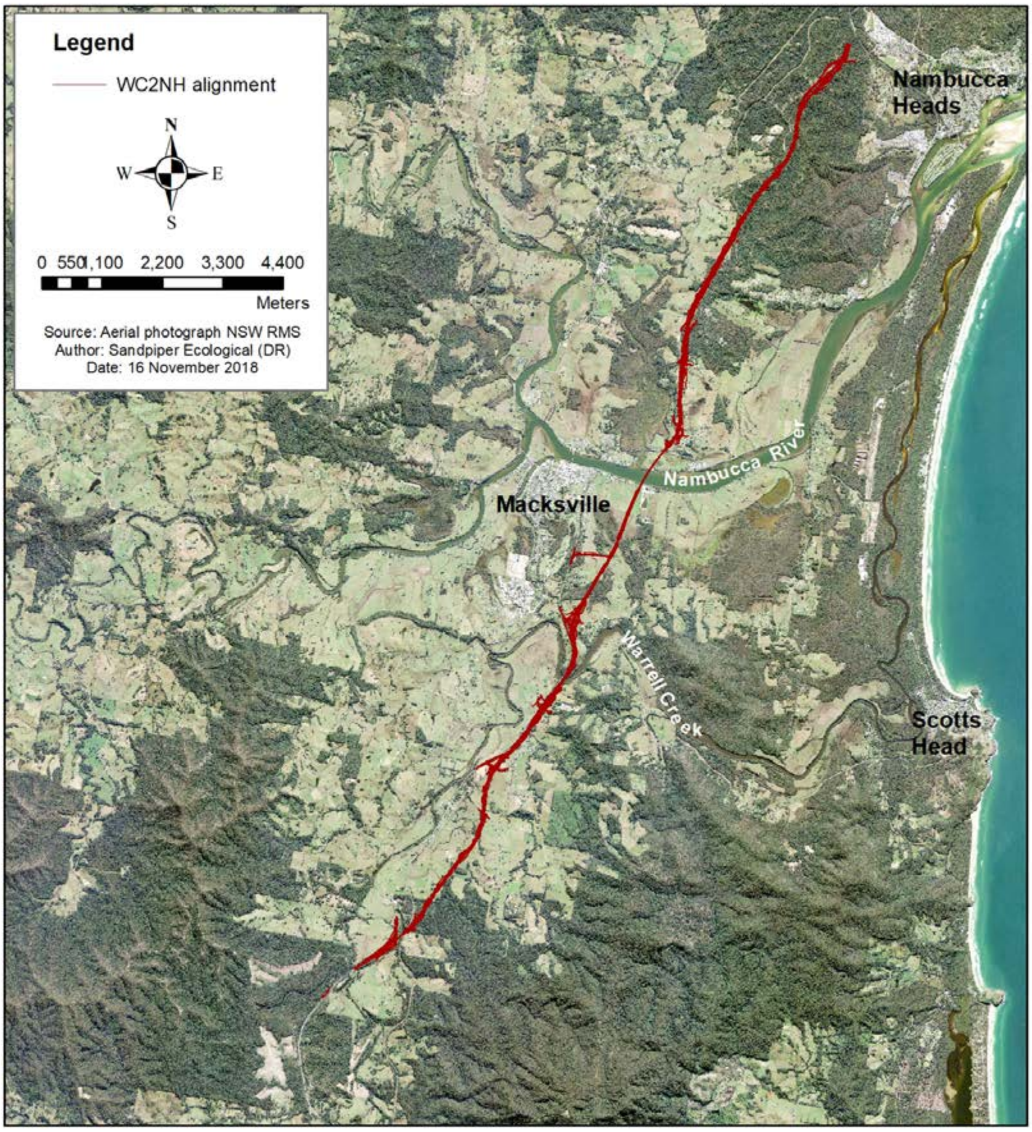

Figure 1: Location of the WC2NH alignment.

2. Methodology

2.1 Transect surveys

Twenty-five paired transects were established perpendicular to the alignment within the Nambucca State Forest/Old Coast Road area between chainages 15600 and 19500. Transects ranged in length from 34m to 500m and were approximately 150m apart (Figure 2). Shorter transects terminated at the forest edge, or at a private property boundary. Each transect was surveyed by one ecologist during the day and night. All surveys were conducted on foot at a speed of 0.5 to 1kph. At night, the male koala call was broadcast for five minutes through a 5-8 watt speaker or megaphone from the approximate centre-point of each transect. Additional spotlighting was conducted along tracks and roads whilst moving between transects. All nocturnal surveys were conducted using 200+ lumen spotlights.

Four ecologists conducted surveys between 7 and 9 September. Weather conditions during the survey were suitable for sampling koalas with mild to warm temperatures and light winds recorded. Survey time for 500m transects ranged from 26 to 39 minutes/transect.

The following data were collected for each koala detected:

- Location (using global positioning system GPS).
- Distance from transect (GIS).
- Occupied tree species.
- Habitat type.
- Height of occupied tree.
- Diameter at breast height of occupied tree.
- Sex.
- Behaviour.
- Evidence of disease.
- Reproductive status.

2.2 Survey limitations

The survey design has substantial limitations when considered in the context of the monitoring aim. The aim of monitoring is to identify changes in resident koala activity (abundance, home range and movements) in response to construction of WC2NH and the effectiveness of koala habitat connectivity mitigation measures (i.e. fauna underpasses and exclusion fencing). The second part of the aim “the effectiveness of koala habitat connectivity mitigation measures” is addressed in a separate component of the WC2NH operational phase monitoring program and is not a focus of population monitoring. The first part of the aim “to identify changes in resident koala activity (abundance, home range, and movements) in response to construction” is covered by the transect surveys and addressed in this report.

The survey design is unsuitable to obtain information on abundance, home range or movement. As noted by Geolink (2017) the dense mid-storey vegetation present on many transects substantially reduces koala detectability. The detection probability on some transects is likely to be less than 25%. The difficult terrain also means that a substantial amount of time is spent looking at the ground rather than the canopy. In addition, transects are not independent and there is a strong likelihood that the same koala could be recorded on adjoining transects making estimates of abundance difficult. Individuals moving beneath the highway exacerbate this problem.

Detection limitations were noted during previous surveys and sampling along tracks was included to supplement transect surveys (Geolink 2017). However, the lack of well-defined spatial and temporal survey effort for the supplementary surveys introduces another potential bias.

3. Results

3.1 Transect surveys

No koalas were recorded while completing transect surveys during the spring 2020 sample event (Table 1; Figure 2). Koala scats were recorded beneath a tallowwood tree (*Eucalyptus microcorys*) on transects E7, E11, E13, E22, W5, and W16 (Table 2; Figure 2).

3.2 Tracks and easements

One koala was observed inside (i.e. within road corridor) the exclusion fence near E11 during spotlight surveys of tracks and easements on 8/9/2020 (Table 1; Figure 2). The individual was captured and relocated to forest habitat adjacent E11. The male koala was a healthy sub-adult in good condition with no signs of disease. It is likely the individual breached the exclusion fencing via a nearby gate that featured a ~200mm gap between the gate bottom and the ground. The gap was remedied after relocating the individual to the adjoining east forest.

Scats were recorded while surveying the edge of the forest from fence line easements. Scats were detected at three locations near transects E5, E6, and E11. All scat records were beneath tallowwoods.

3.3 Habitat use and distribution

Based on the location of scat records, koala use of adjoining forest was largely evident on ridges and mid-slope within Open Blackbutt Forest. While it is unknown what part of the forest the individual outside the exclusion fence emerged from, it was observed near E11, which is positioned on mid-slope.

The distribution of 2020 records suggest that koalas continue to be distributed quite broadly across the study area albeit at low densities (Figure 2). When combined with underpass crossing records (Sandpiper 2019), evidence of habitat use extends from W5/E5 through to W24/E24. Scat records around E10-E13 show a similar distribution to 2018 scat records. Further, scat records around W5/E5-E7 are consistent with 2018/19 records of nearby underpass use (Figure 2). The combination of scat and underpass records confirms use of both sides of the highway particularly in the vicinity of W11/E11 and W6/E6.

Table 1: Details of koala recorded during the spring 2020 survey. M = male.

Date	Easting	Northing	Time of observation	Closest transect & distance (m)	Survey type	Habitat type	Sex	Behaviour	Reproductive & disease status	Side of carriage way
8/9/2020	496638	6609355	Night	E11; 12m	Track & easement	Open Blackbutt Forest	M	On ground inside exclusion fence	Healthy	East

Table 2: Location of koala scats recorded during spring 2020 transect and track/easement surveys. Datum – GDA 94.

Transect	Evidence	Distance from alignment (m)	Easting	Northing	Date
E5 (fence line nearby)	Old scat beneath tallowwood	fence line	497273	6610075	9/9/2020
E6 (fence line nearby)	Old scat beneath tallowwood	fence line	497131	6609905	9/9/2020
E7	Old scat beneath tallowwood	72	497073	6609803	9/9/2020
E11	Old scat beneath tallowwood	205	496805	6609244	9/9/2020
E11 (fence line nearby)	Old scat beneath tallowwood	fence line	496693	6609399	9/9/2020
E13	Old scat beneath tallowwood	466	496995	6608780	9/9/2020
E22	Old scat beneath tallowwood	32	495923	6607876	9/9/2020
W5	Old scat beneath tallowwood	352	496872	6610275	8/9/2020
W16	Old scat beneath tallowwood	162	496266	6608680	8/9/2020

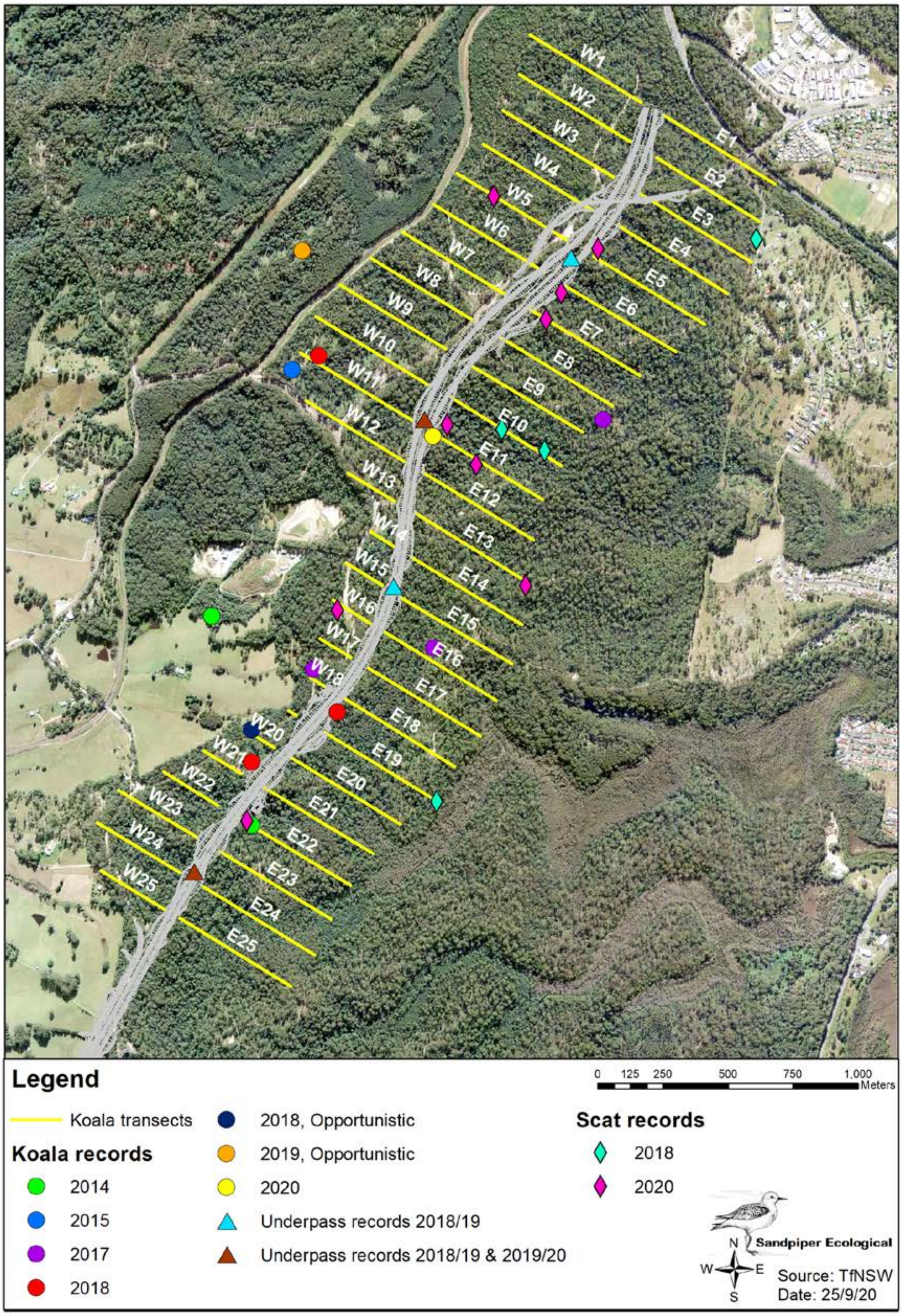

Figure 2: Location of koala observations and scat records between 2014 and 2020.

4. Discussion

4.1 Koala population

Fewer koalas were recorded during current surveys (1 individual) compared to spring 2018 and spring 2017 surveys (3 individuals; Table 3). A single individual was recorded on tracks/easements during baseline surveys and year one of the construction phase (Table 3). However, inconsistencies in survey method, particularly the effort expended on tracks and easements where most koalas have been recorded, precludes a robust assessment of possible changes in koala abundance and whether this is associated with the WC2NH upgrade. Notwithstanding, this report is interim and additional koala data will be collected throughout year 3 whilst conducting underpass and adjacent habitat surveys and yellow-bellied glider surveys. The entire year 3 dataset will enable a more robust analysis of koala abundance in the locality.

Table 3: Comparison of koala records during the baseline, construction, and operational phases of the WC2NH upgrade. * individual recorded on four occasions.

Phase & year	Transect Surveys (diurnal & nocturnal)		Track & Easement Surveys (nocturnal)	Total koalas recorded
	Koalas observed	Koala evidence (scats)	Koalas observed	
Baseline autumn 2014	0	0	1	1
Baseline spring 2014	0	0	1	1
Construction spring 2015	1	1	1	1*
Construction spring 2017	0	2	3	3
Operation spring 2018	1	3	2	3
Operation spring 2020	0	6	1	1

Results of 2017 construction phase surveys and 2018 operation phase showed that at least three koalas were residing within the survey area which was estimated to be approximately 104 ha (Sandpiper Ecological 2019). Home range areas of koalas residing in moderate to high habitat quality habitat on the north coast is reportedly in the range of 23-37 ha (see Lassau *et al.* 2008; Goldingay & Dobner 2014). Home range areas of koalas residing in Nambucca State Forest (NSF) would likely be larger than these estimates due to the lower habitat quality and NSF's forest management history. As such, the study area probably supports few individuals.

Detection of fewer koalas during the current survey may be an artefact of several exogenous factors outside of the control of the upgrade project. Indeed, the broader area has suffered an extended period of drought up until the early part of this year as well as wildfire in the east part of the forest and logging operations in the south-east. While the direct effect of these events is largely unknown, it is expected that they may have adversely affected the local koala population.

Despite fewer koala observations during the current surveys, the detection of scats at nine spatially spread locations suggests there is more than one individual residing in the study area. The distribution of scat records and underpass crossings confirms the findings of 2018/19 monitoring (Sandpiper Ecological 2018, 2019) that some individuals are re-establishing home ranges to the new forest edge and some home ranges include both sides of the highway. These results also support the notion that the study area supports a low-density koala population (Geolink 2017).

The impact of clearing for the upgrade on the local koala population is difficult to ascertain. As discussed above, clearing impacts are both compounded and confounded by several exogenous factors acting concurrently on the local koala population. Positive signs of koala persistence include the broad distribution of scats across the study area especially adjacent to the upgrade corridor, and the presence of at least one young, healthy individual.

4.2 Habitat use and distribution

It is evident from the distribution of current and 2018/19 monitoring records that koalas are utilising both sides of the highway corridor, particularly in forest areas featuring stands of tallowwood. Encouragingly, koalas have used underpasses to cross the highway corridor at four locations spread along the study area (Figure 2). This suggests that the highway corridor is not a barrier to movement between the forest blocks. The ability to move beneath the highway is particularly important in areas of poor habitat quality or during times of drought or even bushfires when individuals need to extend or shift their home range area.

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Customer feedback
Roads and Maritime
Locked Bag 928,
North Sydney NSW 2059

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Appendix J Widened Median

Warrell Creek to Nambucca Heads

Vegetated Median Monitoring Report – year two operational phase 2019-2020

Transport for New South Wales | May 2020 | Final report

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Document Review

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Project team:

David Rohweder (Project management, reporting)
Luke Andrews (Field survey)
Nirvarna Makings (Field survey)
Nick Priest (Field survey)

Report prepared for:

Transport for NSW

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 02 6628 3559 | E david@sandpipereco.com.au

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1. Introduction

In 2015, Transport for NSW (TfNSW), in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages:

- Stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and
- Stage 2b - 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened on 29 June 2018.

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species and mitigation measures targeted include koala (*Phascolarctos cinereus*), spotted-tailed quoll (*Dasyurus maculatus*), grey-headed flying-fox (*Pteropus poliocephalus*), yellow-bellied glider (*Petaurus australis*), giant barred frog (*Mixophyes iteratus*), green-thighed frog (*Litoria brevipalmata*) breeding ponds, fauna underpasses, vegetated median, road-kill, exclusion fencing, and threatened flora. Sandpiper Ecological Surveys (Sandpiper) was contracted by TfNSW to deliver the WC2NH operational ecological and water quality monitoring program.

The following report details surveys conducted to monitor use of a vegetated median by threatened gliders. The aim of monitoring is to confirm use of the vegetated median by yellow-bellied glider (*Petaurus australis*).

1.1 Background

Nambucca State Forest (NSF) is known to support a population of yellow-bellied glider and the WC2NH upgrade was considered likely to divide this population with adverse consequences if not adequately mitigated (Goldingay 2014a). To minimise impacts on yellow-bellied glider a 1.1km section of alignment through NSF was separated to allow for retention of a vegetated median. Three rope bridges and a pair of glide poles were installed to further facilitate glider movement across the road corridor. Rope bridges and glide poles are not included in this monitoring program.

Yellow-bellied gliders were recorded in proximity to the vegetated median during clearing and on both sides of the alignment during baseline, construction phase and operational phase population monitoring (Figure 1; Sandpiper Ecological 2020a). Population monitoring has recorded a decline in the number of glider family groups between 2014/15 and 2019/20 (Sandpiper Ecological 2020a). This decline is consistent across reference and impact sites and is not due to the WC2NH upgrade.

Vegetated medians have proven effective in enabling both sugar and squirrel gliders (*P. breviceps* & *P. norfolcensis*) to cross the Pacific Highway (Taylor & Rohweder 2013; Sandpiper Ecological 2018, 2020b). Whilst there is, as yet, no confirmation that yellow-bellied gliders utilise vegetated medians crossings by congeneric species with similar glide capability (e.g. sugar & squirrel gliders) suggests that it is feasible. Indeed, yellow-bellied gliders have only recently been recorded using glide poles to cross a dual carriageway (Taylor & Rohweder 2020). The rarity of the species means that longer duration studies at more sites may be required before use of medians is confirmed.

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 2). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest. The vegetated median is situated near the northern end of the alignment, adjoining Nambucca State Forest (Figure 2).

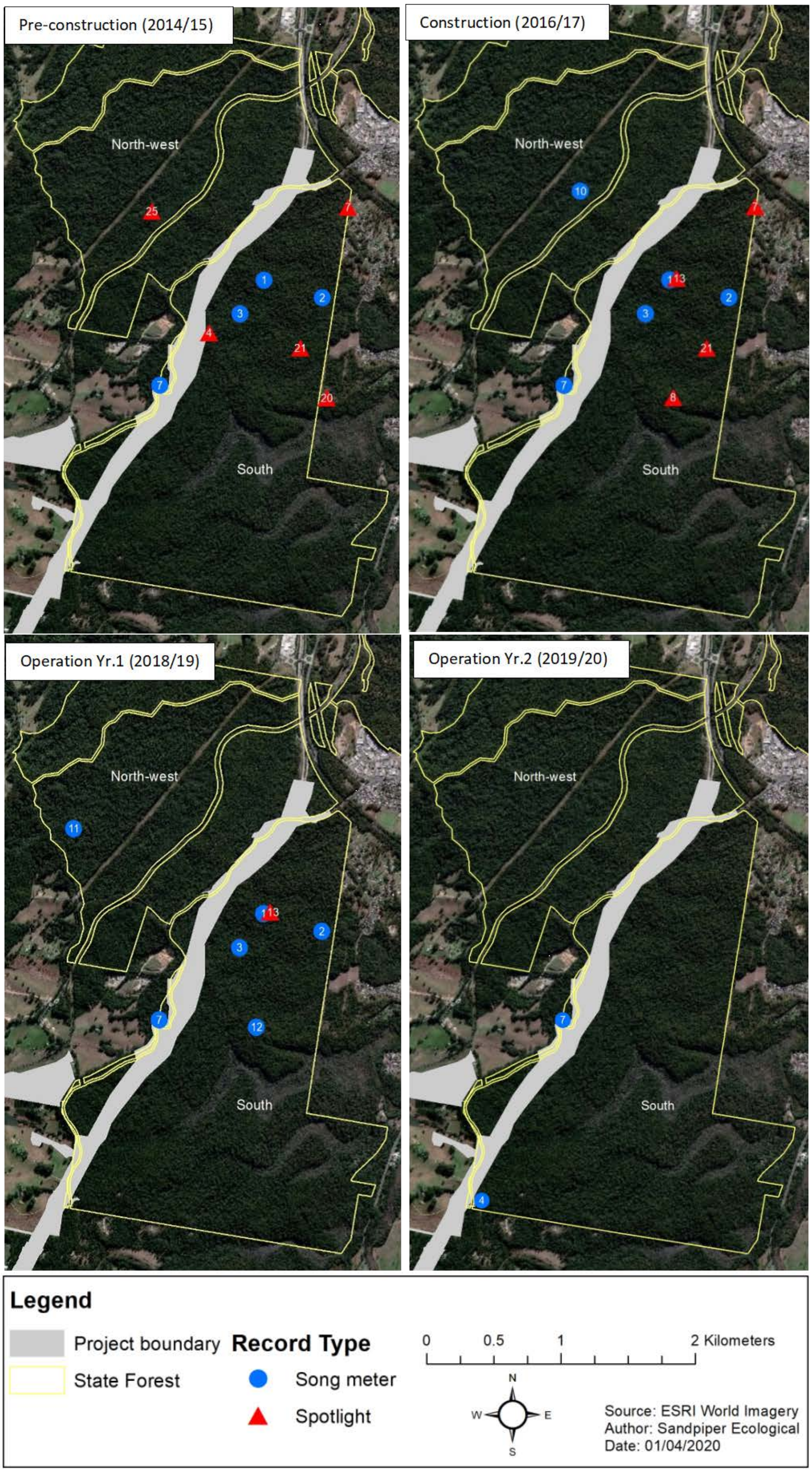

Figure 1: Location of yellow-bellied glider song meter and spotlight records in relation to the WC2NH alignment since baseline surveys in 2014

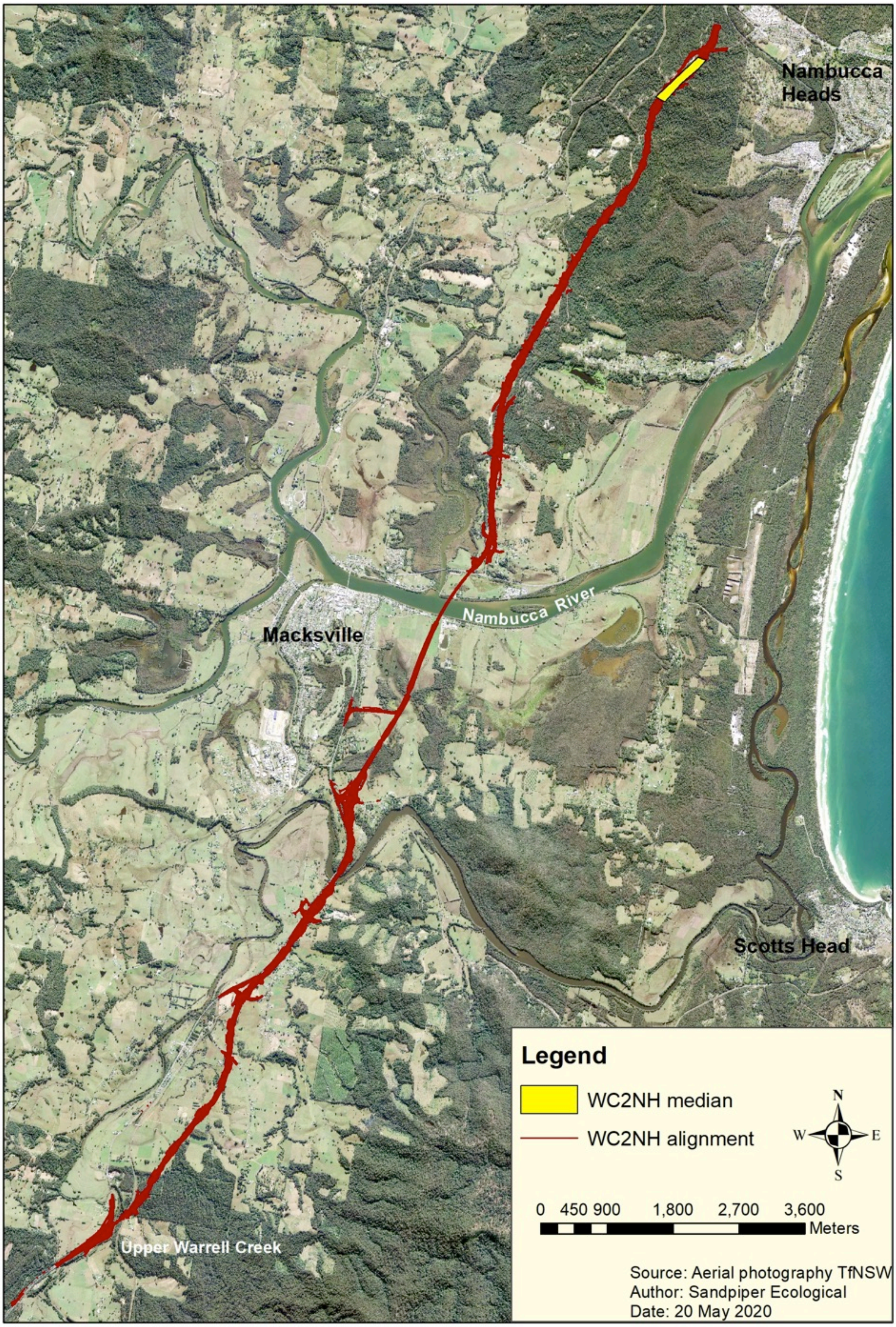

Figure 2: Location of the vegetated median in relation to the WC2NH alignment.

2. Methods

2.1 Spotlighting

Three parallel transects were established, one within the vegetated median and one each on the east and west sides. Each transect was 500m in length and was sampled by one or two observers on six occasions, three each in winter/spring and summer/autumn. Each transect was sampled on-foot for 30 minutes using a 200-lumen spotlight. The call of yellow-bellied glider was broadcast for five minutes through a 10-watt megaphone prior to commencement of the east and west transect spotlight survey. Data collected during each survey included, weather conditions, species present, behaviour of gliders, and flowering trees and shrubs.

2.2 Hair funnels

Three parallel hair funnel transects were established, one within the median and one on the east and west sides of the median. Thirty hair funnels were installed on each transect at 20-25m spacing. Hair funnels were baited with peanut butter, honey and oats and a honey water solution was sprayed on the tree trunk above each funnel. Funnels were installed at approximately 5m above ground and left insitu for a minimum of six weeks during each sample session, with bait and wafers changed after three weeks. Hair samples were sent to recognised hair analysts (R. Carter or G. Story) for identification.

3. Results

3.1 Spotlighting

Weather conditions during the six sample periods were suitable for detecting gliders with light or no wind and good visibility (Table 1). Rain occurred (10mm) in the 24hrs preceding the survey on 30 March 2020.

Table 1: Weather conditions recorded during each spotlight survey of the WC2NH vegetated median. * 24hrs prior to survey

Season	Site	Date	Moon	Wind	Rain	Visibility	Air Temperature ^{0}C	Humidity %
Winter/Spring	East	14/8/19	Full	RL	Nil	Good	13.5	91
		5/9/19	New	RL	Nil	Good	14.6	90
		3/10/19	1/4	RL	Nil	Good	18.4	73
	Median	14/8/19	Full	RL	Nil	Good	14	85
		5/9/19	New	RL	Nil	Good	15.5	88
		3/10/19	1/4	RL	Nil	Good	18.9	74
	West	14/8/19	Full	RL	Nil	Good	16.9	76
		5/9/19	New	RL	Nil	Good	17.1	83
		3/10/19	1/4	RL	Nil	Good	18.9	74
Summer/Autumn	East	25/2/20	New	Nil	Nil	Good	23.6	76
		27/2/20	New	Nil	Nil	Good	23.3	87
		30/3/20	1/4	RL	10mm*	Moderate	19.3	87
	Median	25/2/20	New	Nil	Nil	Good	23.6	76
		27/2/20	New	Nil	Nil	Good	23.3	87
		30/3/20	1/4	RL	10mm*	Moderate	19.3	87
	West	25/2/20	New	Nil	Nil	Good	23.6	76
		27/2/20	New	Nil	Nil	Good	23.3	87
		30/3/20	1/4	RL	10mm*	Moderate	19.3	87

Two species of mammal were recorded during the spotlight surveys (Table 2). Sugar glider was recorded during three surveys in winter/spring and grey-headed flying-fox was recorded during two surveys in winter/spring, and two surveys in summer/autumn. No yellow-bellied gliders were recorded during the survey. Sugar gliders were recorded within the median on 14 August and 5 September, east of the median on 3 October, and west of the median on 5 September (Table 2). The sugar glider recorded in the median on 5 September was observed foraging in a flowering blackbutt.

Table 2: Species recorded during spotlight surveys of the WC2NH vegetated median. GHFF = grey-headed flying-fox; SuG = sugar glider; SE = southeast, m = meters, s = south, n = north, e = east, w = west.

Season	Site	Date	Obs	Start	End	Species	Comments	Flowering
Winter/ Spring	East	14/8/19	NP	1910	1940	GHFF		Tallowwood, Blackbutt
		5/9/19	NP	1920	1950	Nil		
		3/10/19	NP	1930	2000	SuG.SE@490ms3e	Preening	Blackbutt
	Median	14/8/19	NP	1835	1905	SuG.SE@420mn2e, GHFF		Tallowwood
		5/9/19	NP	1847	1917	SuG.SE@75mn10e, GHFF	Feeding in flowering Blackbutt	Tallowwood, Blackbutt
		3/10/19	NP	1900	1930	GHFF		
	West	14/8/19	NP	18:00	18:30	Nil		Tallowwood
		5/9/19	NP	1815	1845	SuG.SE@230s2w	Feeding on acacia sap	Tallowwood, Blackbutt
		3/10/19	NP	1830	1900	GHFF	SuG off transect	
Summer/ Autumn	East	25/2/20	LA	2025	2055	GHFF		Blackbutt
		27/2/20	LA	2010	2040	GHFF		Blackbutt
		30/3/20	LA	2025	2055	Nil		
	Median	25/2/20	LA/NM	2100	2115	GHFF		Blackbutt
		27/2/20	LA/NM	2045	2100	GHFF		Blackbutt
		30/3/20	LA	2100	2130	Nil		*Acacia* spp.
	West	25/2/20	NM	2025	2055	GHFF		Grey gum
		27/2/20	NM	2010	2040	GHFF		Grey gum
		30/3/20	LA	1945	2015	Nil		

3.2 Hair funnels

Three species, and two genera were identified from hair samples. Confirmed species were sugar glider, bush rat (*Rattus fuscipes*) and house mouse (*Mus musculus*). Genera were brushtail possum (*Trichosurus* spp.) and sugar/squirrel glider (*Petaurus* spp.). *Petaurus* spp. is most likely sugar glider, as squirrel glider has not been recorded in the study area during crossing structure or yellow-bellied glider population monitoring (Sandpiper Ecological 2019, 2020a).

A total of 176 sugar glider (incl *Petaurus* spp.) records were obtained during hair funnel sampling, 56 in winter/spring and 120 in summer/autumn (Table 3). The number of sample nights and hair funnel sample nights (i.e. Nº nights * Nº funnels) was 42 / 3780 in winter/spring and 50 / 4500 in summer/autumn (Table 3). Sugar gliders were recorded on all hair funnel transects.

Table 3: Number of sugar glider hair sample records from the WC2NH vegetated median. HF = hair funnel.

Season	East	Median	West	Total	Sample nights	HF nights
Winter/spring	17	18	21	56	42	3780
Summer/autumn	33	52	35	120	50	4500

The number of sugar glider records per sample night was substantially higher on all transects in summer/autumn than winter/spring. In summer/autumn the highest number of records/sample night was recorded in the median where, on average, sugar gliders were recorded at 1.04 funnels per night (Figure 2).

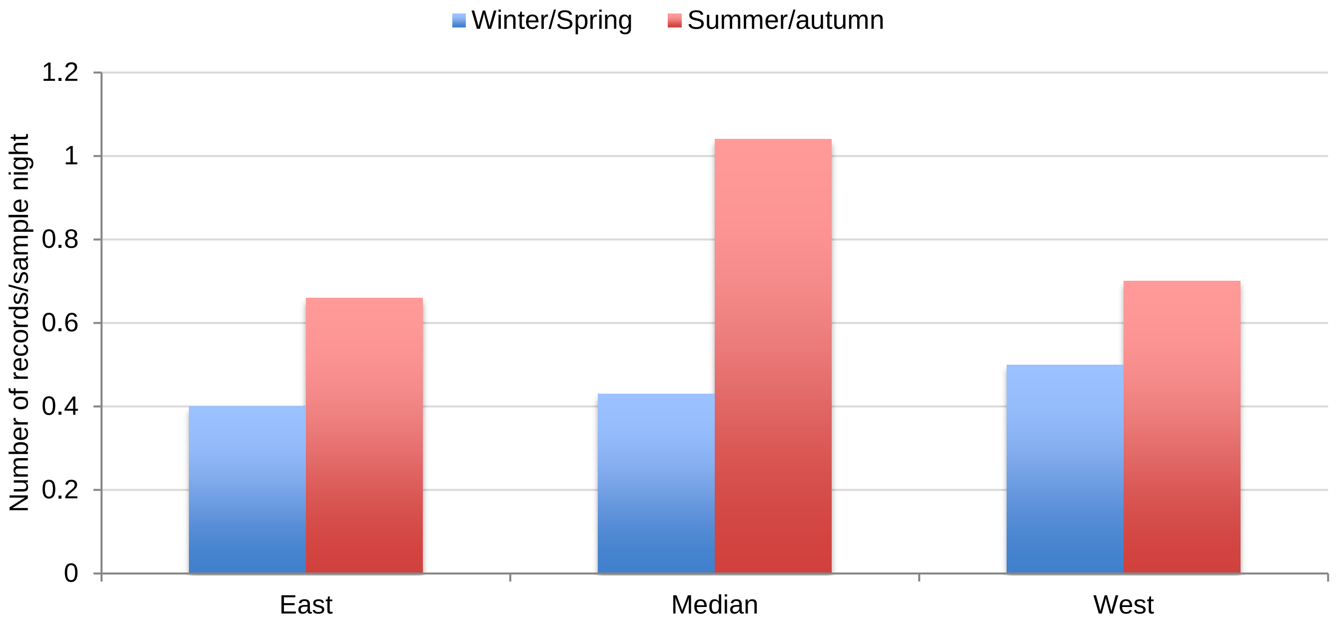

Figure 3: Number of sugar glider records per sample night during winter/spring and summer/autumn.

4. Discussion

4.1 Use of vegetated median by target species

The absence of yellow-bellied gliders in the vegetated median is not unexpected given recent evidence of population declines in NSF and at several other locations on the New South Wales north coast (Sandpiper Ecological 2020a, c). Habitat within and adjoining the median is suitable for yellow-bellied glider, however, use of the median may only occur when the population recovers. Successive years of above average rainfall and good blossom events may assist recovery, although the exact reason for decline is unknown and could be due to landscape issues and particularly long-term forest management (Eyre & Smith 1997; Eyre 2007). Logging in the southeast section of NSF in winter 2020 may inhibit recovery.

The confirmed presence of sugar gliders in the vegetated median means it is likely that yellow-bellied gliders could utilise the median to cross the highway. Published information suggests that yellow-bellied gliders have slightly poorer glide performance than sugar gliders and tend to launch and land higher on trees (Goldingay 2014b; Jackson 2002). Nonetheless, the gap width is in the order of 20-25m and adjoining trees are between 25 and 30m tall. The forest gap from edge to median and tree height is similar to Halfway Creek where yellow-bellied gliders have been crossing the alignment using a central (median) glide pole (Taylor & Rohweder 2020).

Spotlighting and playback are suitable methods for detecting yellow-bellied gliders in forested situations, although most individuals are detected by call rather than spotlight. In a roadside situation call detection, and the effectiveness of playback, is compromised by traffic noise. Whilst yellow-bellied glider can be identified from hair samples (see DSEWPaC 2011) there are few confirmed records from hair funnels. Sandpiper Ecological (2019) recorded yellow-bellied glider from two hair samples on the Nambucca Heads to Urunga Upgrade out of a total 960 samples over two years. In summary, the likelihood of spotlighting a yellow-bellied glider is low, call playback is limited by highway noise, and hair funnels infrequently record the species. These limitations, coupled with low population density, reduce the likelihood of confirming if yellow-bellied gliders utilise the vegetated median.

4.2 Corrective actions

RMS (2018) identify the following problem and contingency measure relating to the vegetated median:

- **Problem** - No evidence of use of the vegetated median or glider crossing structures by the target glider species
- **Contingency measure** - Modify or install alternative crossing structures (e.g. glider poles and/or rope bridges).

Rope bridges and glide poles are not the subject of this monitoring program and no comment can be made on the effectiveness of those structures. It is too early to make conclusions on the effectiveness of the vegetated median for yellow-bellied glider apart from stating that the median is suitable to facilitate movement of gliders, if present, across the highway. The approach adopted in the adjoining section of upgrade (i.e. Nambucca Heads to Urunga) was to continue with spotlight and hair funnel sampling in year three and consider alternatives prior to year five.

5. Recommendations

Recommendations relating to the year 2 operational phase vegetated median monitoring program are presented in Table 4.

Table 4: Recommendations based on findings from year three spring/summer operational phase monitoring and response from TfNSW.

Number	Recommendation	Transport for NSW Response
1.	Continue monitoring the vegetated median in accordance with the brief and EMP in year three of the operational phase.	Agree and adopted
2.	Following the spring year 3 monitoring event re-evaluate survey methods in light of results from cameras installed in vegetated medians as part of the W2B vegetated median monitoring program.	Agree and adopted

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Appendix K Road Kill

Pacific Highway Upgrade: Warrell Creek to Nambucca Heads

Year 2 Operational phase road-kill monitoring – annual report 2020

Sandpiper Ecological

1/94 Main Street
Alstonville

December 2020

Document Review

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Project team:

Mr. L. Andrews (field work, reporting)
Dr D. Rohweder (project management, field work reporting)
Ms.N.Makings (Field work, mapping)
Dr B. Taylor (review)

Report prepared for:

Transport for NSW

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 0401 195 480 | E **david@sandpipereco.com.au**

Cover Photo:

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1. Introduction

1.1 Background

In 2015, Roads and Maritime Services (RMS) NSW, in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages: stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and stage 2b 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

The upgrade included a number of road-kill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate road-kill included:

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including culverts, bridges, rope bridges and glide poles.

Several fauna fence designs were installed to target threatened species including:

- **Type 1** - Chainmesh fence 1.8 m tall with floppy top feature, which is designed to exclude a range of native mammal species such as macropods, possums, spotted-tail Quoll (*Dasyurus maculatus*) and koala (*Phascolarctos cinereus*). 18.03 km of this fence type occurs at the site.
- **Type 3** - Small gauge mesh fence with sheet metal return angled away from the highway (combined with fauna floppy top fence), which is designed to exclude green-thighed frog (*Litoria brevipalmata*) from the road corridor. 1.32 km of type 3 fauna fence occurs at the site, overlapping with the type 1 fencing.
- **Type 4** - Chainmesh fence 4 m tall through the Macksville Flying-fox camp Paperbark Swamp Forest community designed to discourage grey-headed flying-fox (*Pteropus poliocephalus*) from flying within range of passing traffic when exiting or entering the roost. 1km of type 4 fence occurs at the site.

Sandpiper Ecological Surveys (SES) has been engaged by Transport for NSW (TfNSW) to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal road-kill surveys over the entire upgrade length.

Monitoring of road kill is a requirement of the approved WC2NH koala, spotted-tailed quoll and grey-headed flying-fox management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for road-kill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog (*Mixophyes iteratus*). Monitoring is required for the first five years of operation, and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Seasonal surveys are scheduled for October, January, April, and July. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced monitoring in October 2018. Previous road-kill monitoring was conducted by Geolink (2018a, b, c, d).

The aim of monitoring is to:

- report on any vertebrate road-kill following opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

The following report details the methods used to monitor road-kill in 2020 (Year 2 operational phase) and compares road-kill data from 2020 with 2019 (Sandpiper Ecological 2018, 2019a).

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the North (Figure 1).

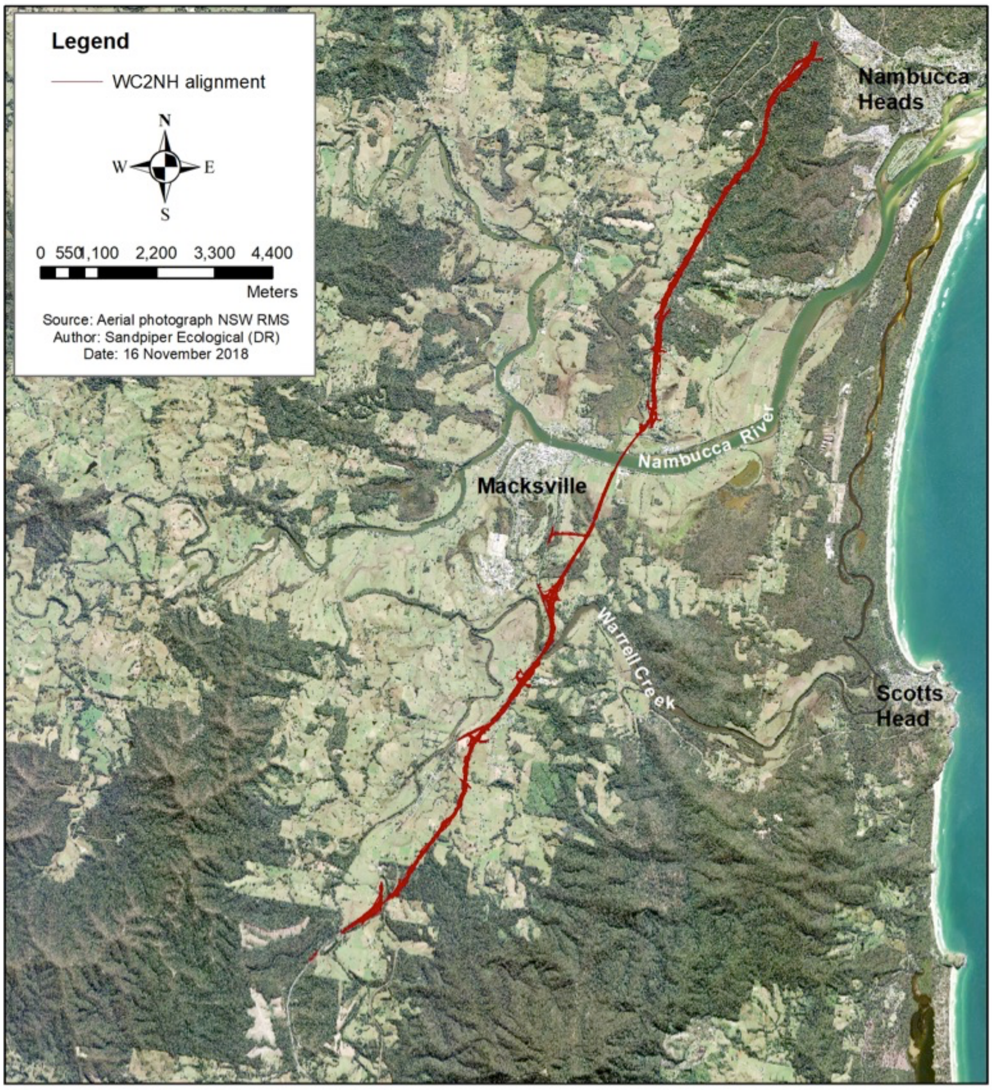

Figure 1: Location of the WC2NH alignment.

2. Methodology

2.1 Road-kill surveys

Surveys were conducted by a two-person team from a vehicle driven at 80-90km/hr in the left lane. The vehicle was equipped with an amber (flashing) light and warning sign (Plate 1). The team consisted of a driver, and ecologist, with experience identifying road-killed fauna. Surveys were undertaken weekly and commenced within three hours of sunrise. During each survey, all personnel scanned the road surface and road shoulder for fauna. When road-killed fauna were detected the vehicle was pulled onto the shoulder/parking bay and the ecologist inspected the subject animal from the closest perpendicular position behind wire rope. Fauna that could not be identified immediately were photographed and images sent to colleagues for assessment. Carcasses were removed from the road surface when safe to do so.

Plate 1: Work vehicle with signage, flashing amber light and indicators.

The April 2020 road-kill survey coincided with government imposed restrictions on social distancing to manage the spread of COVID-19. As part of these restrictions Sandpiper Ecological reviewed its fieldwork practices and initiated a one-person/vehicle restriction unless persons were from the same household. These restrictions meant that one person (an ecologist) conducted the first two road-kill surveys in April 2020, with the second two samples conducted by two operators (including one ecologist) from the same household. Limitations associated with a single operator were overcome by reducing vehicle speed (70-80km/hr) during surveys one and two, and conducting two surveys of the alignment, one immediately after the other, during survey two.

Data collected on each road-kill included (Appendix A1):

- Geographic coordinate
- Presence/absence of fauna exclusion fence
- Species/fauna group
- Date of survey
- Road-kill location – north or southbound carriageway

Data collected for threatened species listed on the Commonwealth *Environment Protection and Biodiversity Conservation Act* (EPBC) *1999* and/or the NSW *Biodiversity Conservation Act* (BC) *2016*, included, where possible: sex and age (juvenile/adult); presence of pouch young if applicable; presence of flightless young (flying-foxes); distance to a fauna connectivity structure; distance to a drop-down structure if applicable; damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation. Mammal groups were defined as: small (rodent, small dasyurid, phascogale, small glider etc); medium (possum, bandicoot, quoll, etc); large (wallaby and kangaroo).

All road-kills were cross-referenced with the previous survey results to identify possible duplicates. Using, at a minimum, one team member consistently across all surveys, GPS coordinates of each specimen, looking at carcass age and location on the carriageway, and detailed location description assisted with identification of duplicates. Distance to connectivity structure, and distance to escape structure was determined via GIS. All other data were entered on an iPad in the field.

2.2 Data summary and analysis

Data from the October 2020 survey were uploaded to Microsoft Excel and compared with results from July 2020 to identify duplicate records. The location of October road-kills were then overlaid on the WC2NH alignment to show distribution and compared to road-kills recorded in summer, autumn, and winter 2020 (Table 2). Graphs were produced showing the total number of road-kills in relation to sample periods (years, season and sample weeks), taxonomic groups (i.e. reptile, mammal and bird) and unfenced vs fenced sections of the highway.

2.2.1 Statistical analysis

The primary aim of statistical analysis was to determine if there is a statistical difference in the frequency of road-kill between fenced and unfenced sections of the alignment. Road-kill data were summarised by removing species/groups that would not (under normal circumstances) be stopped by exclusion fence from accessing the road alignment e.g. birds, small reptiles, frogs, small mammals and flying-foxes. Species/groups of fauna likely to be stopped by exclusion fence and therefore included in the analysis are listed in Table 1. Introduced species were included in the analysis. Freshwater turtles were included, as exclusion fence with a ground return should stop this group. Small lace monitors could move through exclusion fence, however, individuals of that size are rarely recorded in open habitats and that species has been included.

The location of each road-kill in relation to exclusion fence was determined by overlaying road-kill records on a plan of exclusion fence extent using ArcGIS. If exclusion fence occurred on one side only the record was classified as “No fence”. Further, road-kill records on bridges were considered unfenced unless exclusion fence extended 100 m beyond both ends of the bridge. Sections of the alignment with a single fence may be included as a separate category in future analysis as sample size increases.

Data were pooled across all samples and divided into “fenced” and “unfenced”. Expected proportions were based on the proportion of highway with fence on both sides (“fenced”) and proportion with a single fence, or no fence (“no fence”). The proportion of fenced verses unfenced was 0.55 to 0.45. Data were analysed using a two-tailed G-test as per the equation of McDonald (2013), and a Kruskal-Wallis test in Systat 13.

Table 1: Fauna groups included in comparison of fenced and unfenced sections of alignment.

Group	Species included
Large Dasyurid	Spotted-tailed quoll
Macropods	Red-necked wallaby, swamp wallaby & eastern grey kangaroo
Bandicoots	Long-nosed & northern brown bandicoots
Possum	Brushtail & ringtail possums
Canid	Fox & dog
Feline	Cat
Leporidae	Hare & rabbits
Freshwater turtles	Long-necked, saw-shelled and Macleay river turtles
Goanna	Lace monitor
Barred frog	Giant barred frog

3. Results

3.1 October 2020 sample

3.1.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses on the road surface (Table 2). Light rain (3.8mm) occurred on 23 October prior to the fourth sample with a negligible effect on carcasses retention.

Table 2: Weather conditions in the 24hrs preceding each sample event. Data obtained from BoM Bellwood and Coffs Harbour Weather stations.

Date	Average Relative Humidity (%)	Rainfall (mm)	Max Temperature (^{0}C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
2/10/20	63	0.4	23.2	20	Good	Nil
9/10/20	61	0	25.9	15	Good	Nil
16/10/20	60	0	27.5	35	Good	Nil
23/10/20	68	3.8	25.4	56	Good	Nil

3.1.3 Opportunistic road-kill information

No opportunistic road-kill records were obtained during the October 2020 sample period.

3.1.2 Species richness and abundance

A total of 25 road-killed fauna were recorded during the October 2020 sample period. This included twelve native species (two introduced – European hare and goose) and five fauna groups (Table A1, Appendix A). Birds were the most diverse group represented with six species and one group recorded (Table 3). Mammals were the next most diverse group recording three species and three groups (Table 3). Reptile records included two species (eastern-long necked turtle, eastern bearded dragon) and one group (*Chelidae* sp.). A masked owl, listed as vulnerable under the NSW *Biodiversity Conservation (BC) Act* 2016, was recorded north of Upper Warrell Creek. No frogs were recorded during October surveys.

Mammals accounted for 40% of road-kill detections (ten individuals) followed by birds (nine individuals), reptiles (four individuals) and introduced species (two individuals) (Table 3). Wallabies were the most frequently detected group with seven individuals recorded (Table 3). This included three red-necked wallabies, two swamp wallabies and two wallaby spp (Table 3). Degradation, and location of carcasses on the carriageway made identification to species level difficult in some cases (Table 3).

Of the 25 road-kill records, 13 (54%) were individuals that should be blocked by exclusion fence. The remaining 12 records, predominantly birds (8 individuals), were species that readily move through or over exclusion fencing (others included rodent spp and a bearded dragon).

Table 3: Species of vertebrate fauna recorded during seasonal road-kill surveys throughout the operational phase of the WC2NH upgrade. * denotes threatened species; ** = stage 2a only.

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Total
Birds													
Australian magpie	6	1		1				2	2	1			13
Grey butcherbird			1										1
Magpie-lark	2		1		1		1		1		1	1	8
Australian white ibis			1						1				2
Cattle egret				1						1			2
Little pied cormorant					1								1
Buff-banded rail					1								1
Purple swamphen	3		2	2		1		2	3		1	1	15
White-headed pigeon										1			1
Crested pigeon	2												2
Galah	7				1			3					11
Rainbow lorikeet								1					1
Eastern grass owl*				1									1
Australian boobook			1	1			1				1		4
Masked owl*	1				1		1					1	4
Eastern barn owl			11	3		1	5	2	1				23
Tawny frogmouth	1	3	1	2		6		4		1		1	19
Australian owlet-nightjar					1					1			2
Laughing kookaburra	3		2	1		2		3	1	1	2	1	16
Forest kingfisher	1												1
Australian wood duck	20			2	2		1	2				2	29

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Total
Pacific black duck	2		1										3
Whistling kite				1									1
Black-shouldered kite					1	1							2
Torresian crow					1								1
Pied currawong				1									1
Black-faced cuckoo-shrike								1					1
Dollarbird					2								1
Green catbird					1								1
Australasian figbird										1			1
Black bittern*						1							1
Eastern yellow robin						1							1
Pheasant coucal							1		1				2
Masked lapwing							1						1
Welcome swallow								1					1
Red-browed finch										1			1
Duck spp.						1				1			2
Tyto spp.										1			1
Small bird								2					2
Medium bird				1	2	2	2	2	6	1	1		16
Unidentifiable bird	5	4	1		3						2	2	17
Total birds	53	8	22	17	18	16	13	25	16	11	8	9	214
Mammals													
Short-beaked echidna				3				2		1	2	1	9

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Total
Black flying-fox	2	1			7	1	1						11
Grey-headed flying-fox*					8			5	2				15
Pteropus spp.					3	8	1		1	1			14
Common brushtail possum			1	2						1			4
Trichosurus spp.									1	1	1		3
Common ringtail possum					1			1					2
Eastern grey kangaroo				3			1						4
Red-necked wallaby			6		8	2	8	3	7	1	8	3	46
Swamp wallaby	2	1		1		1	1			1	1	2	10
Wallaby spp.						2			3			2	7
Macropod spp.	3		2	1	1					2	1		10
Northern brown bandicoot	1		1		1	1	1	2	2	3	3		15
Bandicoot spp.						1		4				1	6
Chalinolobus spp. (microbat)				1									1
Microbat spp.					1								1
Rodent spp.						2						1	3
Small mammal					2						1		3
Medium mammal				2	4	2	4	5	2	2	2		23
Large mammal				1	1			1			1		4
Unidentified Mammal	1			3									4
Total mammals	10	2	10	17	36	20	17	23	18	13	20	10	196
Reptiles													
Common blue-tongued	1			2	1				2				6

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Total
skink													
Carpet python	1			2	1	1		1					6
Common tree snake	1	2						1					4
Eastern long-neck turtle	1			6						1		2	10
Macquarie river turtle	5	1					1						7
Unidentified *Chelidae* spp.	6							1				1	8
Red-bellied black snake	1												1
Eastern water dragon	1			1									2
Eastern bearded dragon												1	1
Blackish blind snake						1							1
Yellow-faced whipsnake				1									1
Unidentified reptile								2		1			3
Total reptiles	17	3	0	12	2	2	1	5	2	2	0	4	50
Frogs													
Green tree frog	2												2
Striped marsh frog	3												3
Medium frog				3									3
Large frog				1									1
Total frogs	5	0	0	4	0	0	0	0	0	0	0	0	9
Introduced species													
Cat	1												1
European fox	3	1	1	2	1	1	2						11
European hare	2			1						1		1	5

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Total
Rabbit	1												1
Black rat	1					1							2
House mouse					1								1
Rock pigeon			1	1									2
Domestic goose				1								1	2
Total introduced species	8	1	2	5	2	2	2	0	0	1	0	2	25
Total	93	14	34	55	57	40	33	53	36	27	28	25	495

The number of road-kill recorded each week in October 2020 varied during the sample period. There was a substantial difference in road-kill abundance between the first two surveys and the third and fourth surveys (Figure 2). Nineteen road-killed fauna were recorded in week one (9 individuals) and two (10 individuals) with the remaining during weeks three and four (three individuals each survey). Week one is not representative of the number of individuals killed in the preceding week as it includes the period between the July and October sample periods.

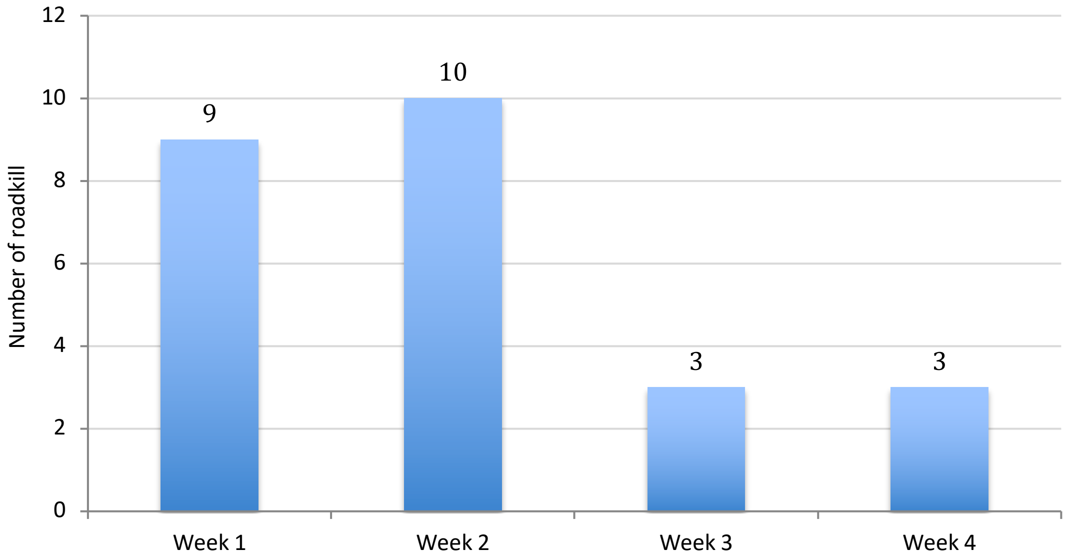

Figure 2: Number of road kills recorded in each sample week during the October (spring) sample period.

The abundance of road-killed fauna in the four vertebrate groups varied over the sample period (Figure 3). The number of road-killed mammals ranged from five in week two to one in week three with detections (>1) occurring throughout the sample period. The number of road-killed birds ranged from four during week two to none during week four. Two reptiles were recorded in week one with single records occurring during weeks two and four (Figure 3).

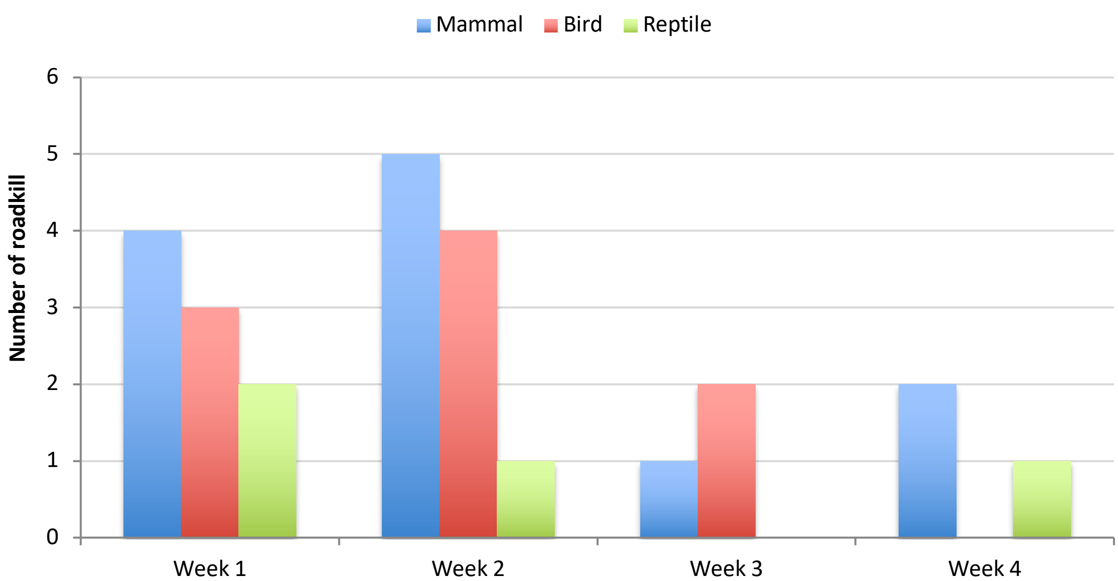

Figure 3: Number of road-killed fauna from four vertebrate classes during each sample week in October 2020.

3.1.4 Distribution of road-kill

In October 2020, road-killed fauna was recorded over the entire WC2NH alignment (Figure 4-8), although the majority of records (68%) occurred south of Mattick Road. Of the eight road-kills recorded north of Mattick Road, 50% were birds. Despite the broad distribution of road-kill a distinct cluster was evident between the Nambucca River and Mattick Road (Five individuals; 2.5 ind/km). Four of the five individuals were wallabies with one bird (domestic goose) recorded (Figure 6 & 7). Clusters of two or more individuals were also recorded to the south of Lower Warrell Creek Bridge and around Nambucca Floodplain Bridge 1 (Figure 5 & 6).

In October 2020, 14 road-kills were recorded in areas with exclusion fence, and 11 were recorded in areas without exclusion fence (Figures 4-8). Road-kills in areas with exclusion fence on one side of the carriageway were classed as fence absent. Five records (or 36%) in sections with fence were species that should have been blocked by the fence (i.e. medium and large mammals and reptiles). In contrast, eight individuals (or 72%) of road-kills in sections without fence were of species that should be blocked by a fence.

Figure 4: Location of road-killed fauna recorded in 2020. Note: only October 2020 records are labeled.

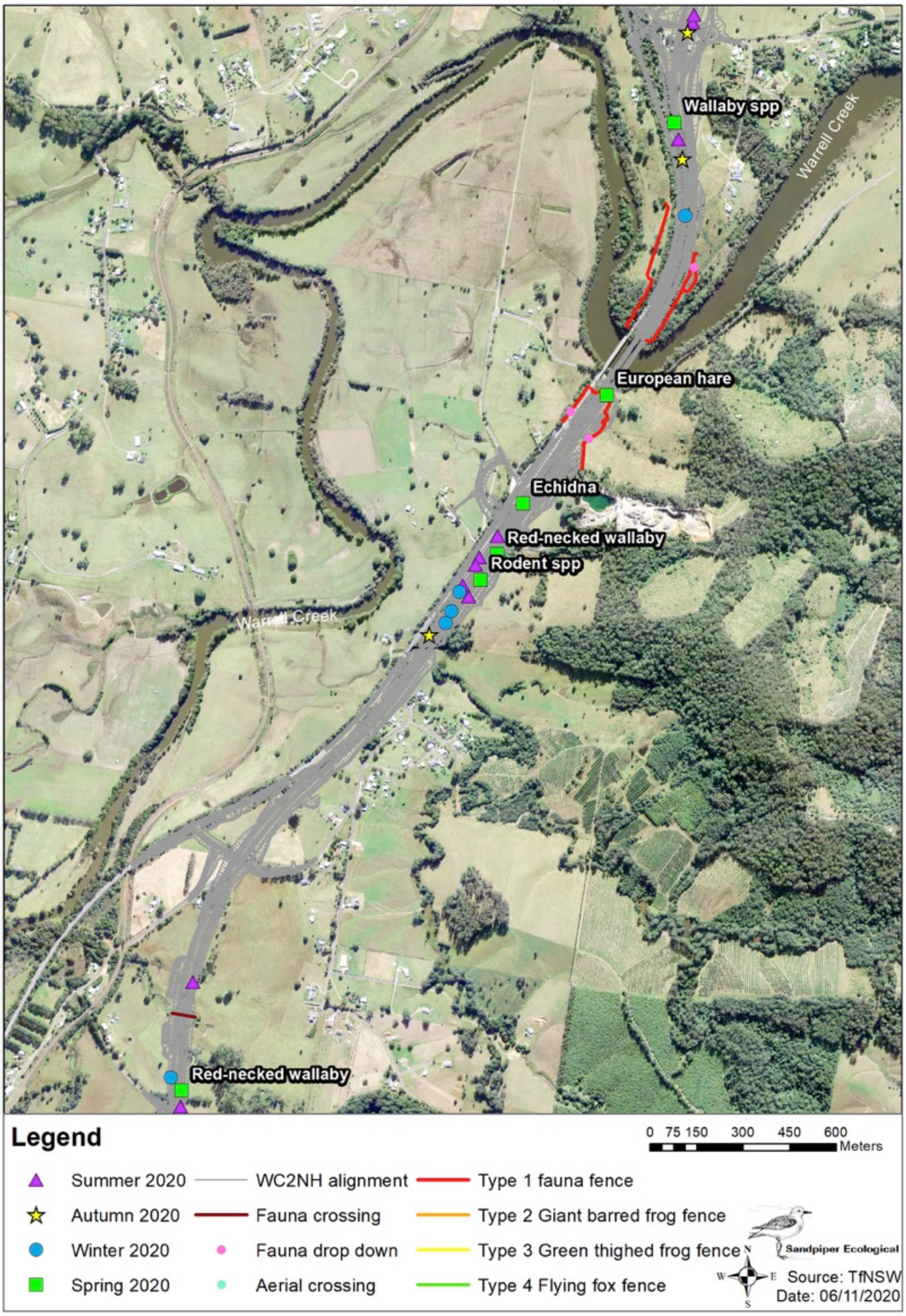

Figure 5: Location of road-killed fauna recorded in 2020. Note: only October 2020 records are labeled

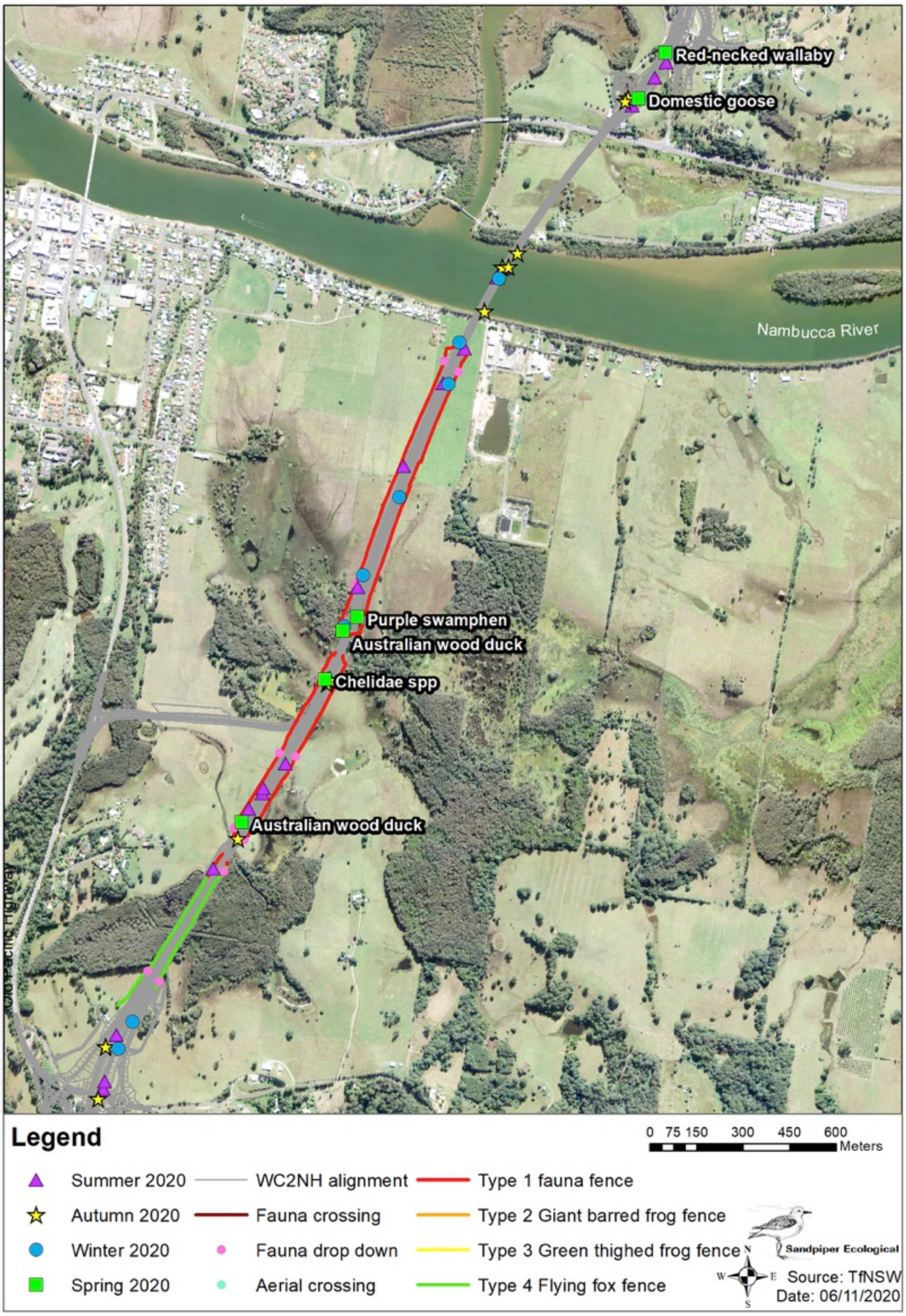

Figure 6: Location of road-killed fauna recorded in 2020. Note: only October 2020 records are labeled.

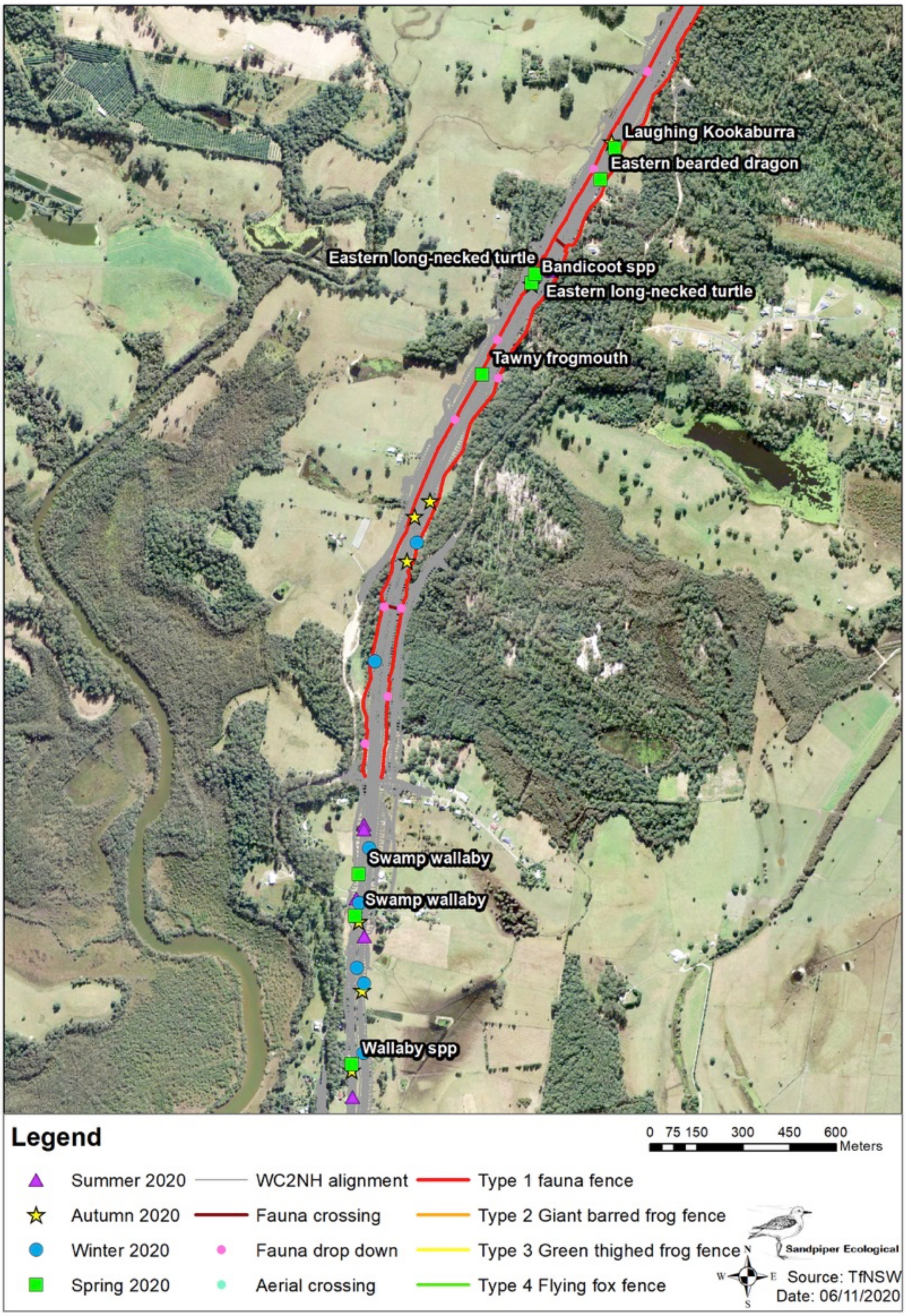

Figure 7: Location of road-killed fauna recorded in 2020. Note: only October 2020 records are labeled.

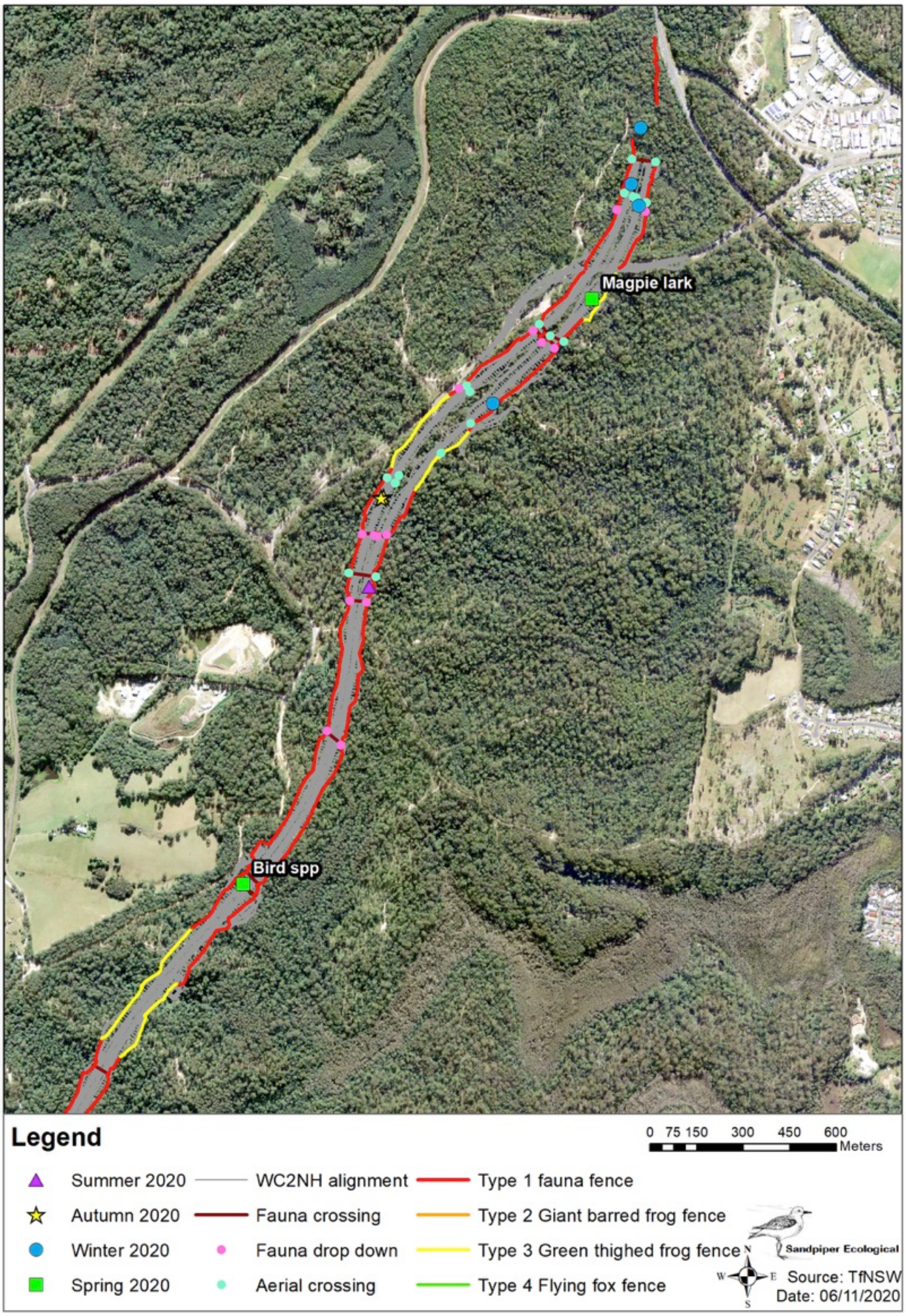

Figure 8: Location of road-killed fauna recorded in 2020. Note: only October 2020 records are labeled.

3.2 Annual results 2020

3.2.1 Species richness and abundance

A total of 30 species and a further 13 fauna groups were recorded during road-kill surveys in 2020, including two threatened species, masked owl and grey-headed flying-fox (Table 3). Both threatened species are listed as vulnerable under the *BC Act* 2016 grey-headed flying-fox is also listed as vulnerable under the Commonwealth *Environment protection and Biodiversity Conservation Act* 1999.

The highest species richness of road-kill was recorded in autumn (14 native species; 5 groups), followed by spring (12 native species; 7 groups), summer (11 native species; five groups) and winter (8 species; 7 groups). The most commonly recorded species were red-necked wallaby (18 records), northern brown bandicoot (8 records), laughing kookaburra (4 records), and swamp wallaby (4 records; Table 3). There were a further six records of medium mammal, which could have been bandicoots or possums.

3.2.2 Temporal comparisons

In 2020 a total of 116 individuals were recorded across the 16 road-kill samples (Table 3). Native mammals were the most commonly recorded group with 61 records, followed by birds (44 records), reptiles (8 records) and introduced mammals (3 records). Road-kill abundance fluctuated between sample weeks (Figure 9). The number of road-kill typically peaked in the first sample week/season (Figure 9) as that sample includes road-kills over a longer period than one week. A more accurate indication of road-kills/week is provided by weeks two, three and four in each sample period.

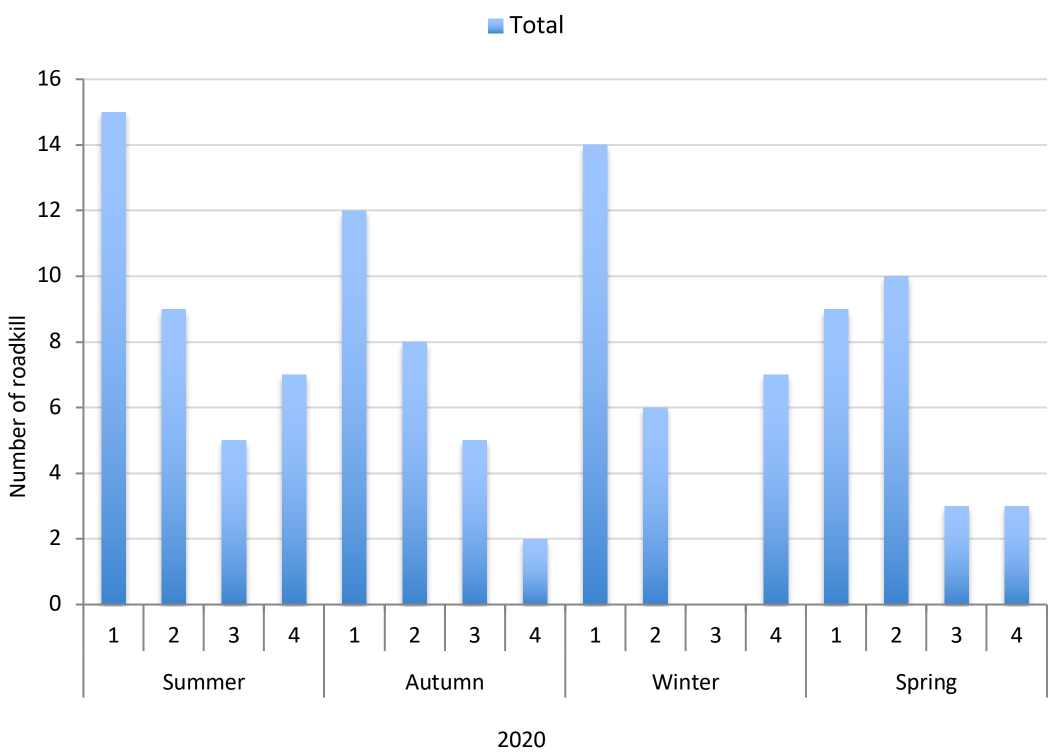

Figure 9: Total number of road-kill recorded each week during 2020.

In comparing the number of road-kills in each sample period (2019 and 2020 combined) the data show a declining trend from spring through summer and autumn to a low in winter (Figure 10). The large standard deviations reflect variations in road-kill numbers between weeks and the higher number recorded in the first week of each sample period.

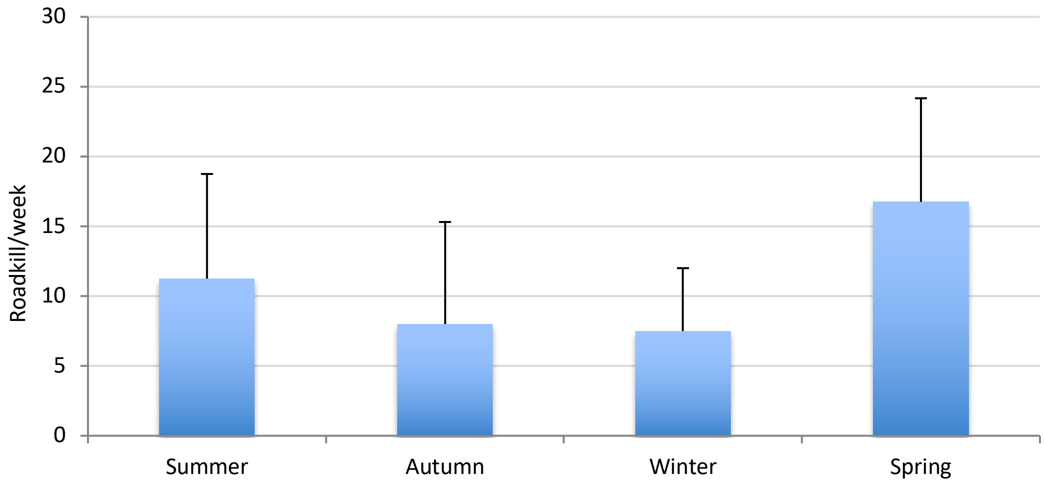

Figure 10: Mean (+SD) number of road-kill per week (n=8) recorded during each sample period (2019 and 2020 combined).

A comparison between 2019 and 2020 data showed a general decline in the number of road-kill (Figure 11). Substantially fewer birds and mammals were recorded in 2020 in comparison to 2019 (Table 4). Whereas the number of introduced individuals also decreased and reptile records remained relatively consistent (Table 4).

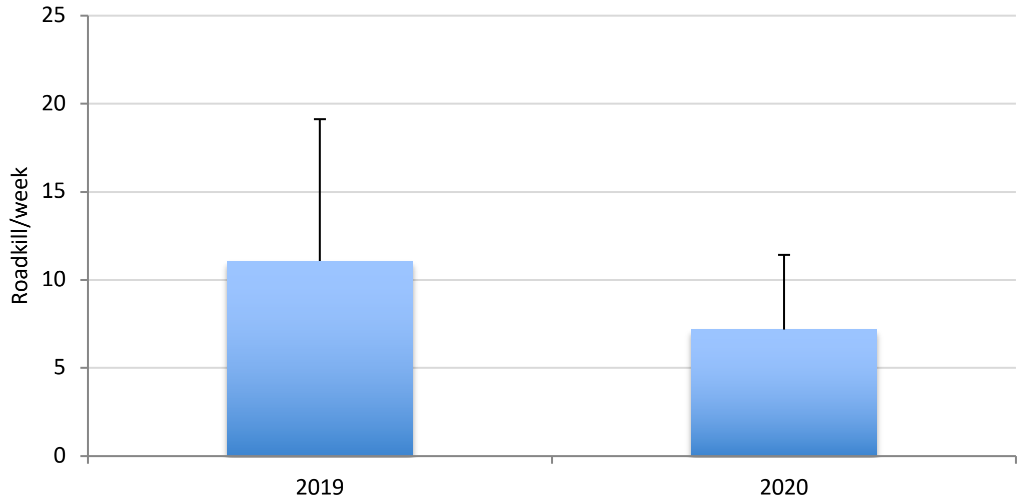

Figure 11: Mean (+SD) number of road-kill per week (n=16) recorded during operational phase monitoring (2019 and 2020).

Table 4: Comparison of road-kill numbers between 2019 and 2020 sample periods.

Year	Total	Birds	Mammals	Reptiles	Amphibians	Introduced
2019	183	72	96	10	0	6
2020	115	45	60	8	0	2

3.2.3 Flying-foxes (*Pteropus* spp.)

Four flying-foxes, including two confirmed as grey-headed flying-fox, were recorded in 2020, with three recorded in summer and one in autumn.

3.2.3 Distribution of road-kill

Road-killed fauna have been recorded over the entire study area (Figures 4-8). There were substantially fewer road-kills in areas with continuous fauna fence north of Mattick Road and the southern extent to just north of Rosewood Road. Road-kill density between the southern extent and just north of Rosewood Road was 3.3 ind/km, which is similar to the 3.57 ind/km recorded north of Mattick Road, but less than the 9.18 ind/km recorded between Warrell Creek and Nambucca river (inc. Gumma floodplain) and 26.7 ind/km on the Nambucca Bridge. Notable road-kill hotspots include:

- Warrell Creek to Nambucca river (inc. the Gumma floodplain) (34 records).
- Nambucca River to Mattick Road (23 records).
- Scotts Head Road to Williamsons Creek (12 records).
- Nambucca River Bridge (8 records).

3.2.4 Fenced vs unfenced

In both 2019 and 2020 the number of road-kills of species that should be blocked by exclusion fence varied between sections of alignment with or without fauna exclusion fence (Figure 12). The number of road-kill was higher in sections where exclusion fence was absent and lower along fenced areas of the alignment (Figure 12). The distribution of species recorded in 2019 and 2020 that should be blocked by the fence is shown on Figures 13 to 20. These figures highlight the clustering of records in areas without fence such as south of Mattick Road (Figure 15), north and south of Bald Hill Road (Figure 17), and between Upper Warrell creek and Warrell creek (Figures 18 & 19).

A G-test was run on two sets of data, 2020, and 2019 + 2020 (Table 5). A statistically significant difference in the number of road-kill between fenced and unfenced areas was recorded for both data sets (Table 5), with a significantly higher number of road-kills in unfenced sections of the alignment. The Kruskal-Wallis test did not record a statistically significant difference between fenced and unfenced sections of the alignment ($n=16$, $df=1$, $P=0.054$), although the result was very close to being significant.

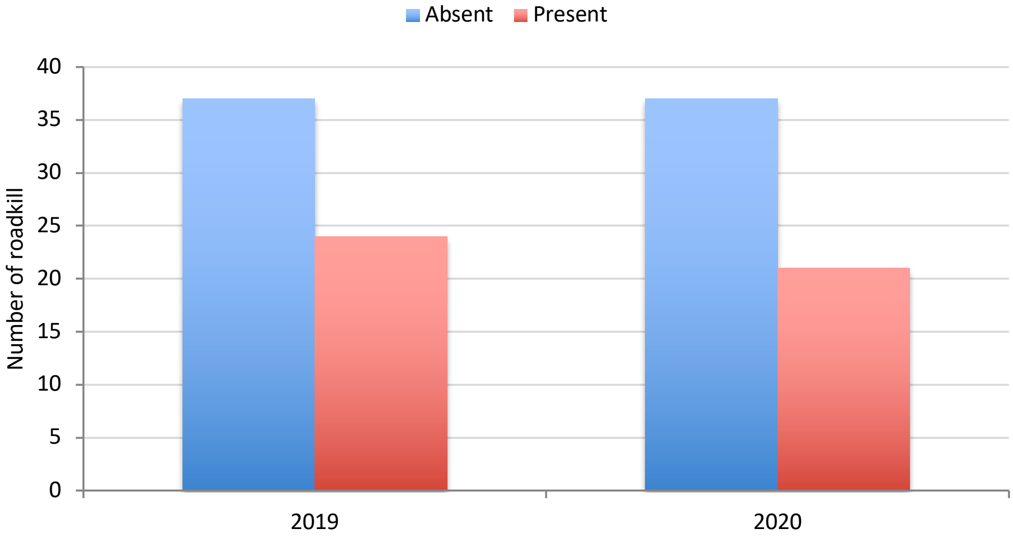

Figure 12: Annual comparison in the number of road-kill reported along the WC2NH alignment where fauna fence is present or absent. Only includes fauna that is likely to be excluded by the fauna fence (see Table 1).

Table 5: Results of G-test on road-kills in fenced and unfenced sections of the alignment.

Group	Category	Nº. road-kill	Expected proportion	Expected Nº.	Df	G statistic	P (2-tail)
All species (2020)	Fence	19	0.55	33.55	1	14.12	0.0001
	No fence	42	0.45	27.45			
All species (20+19)	Fence	40	0.55	68.75	1	26.86	<0.0001
	No fence	85	0.45	56.25			

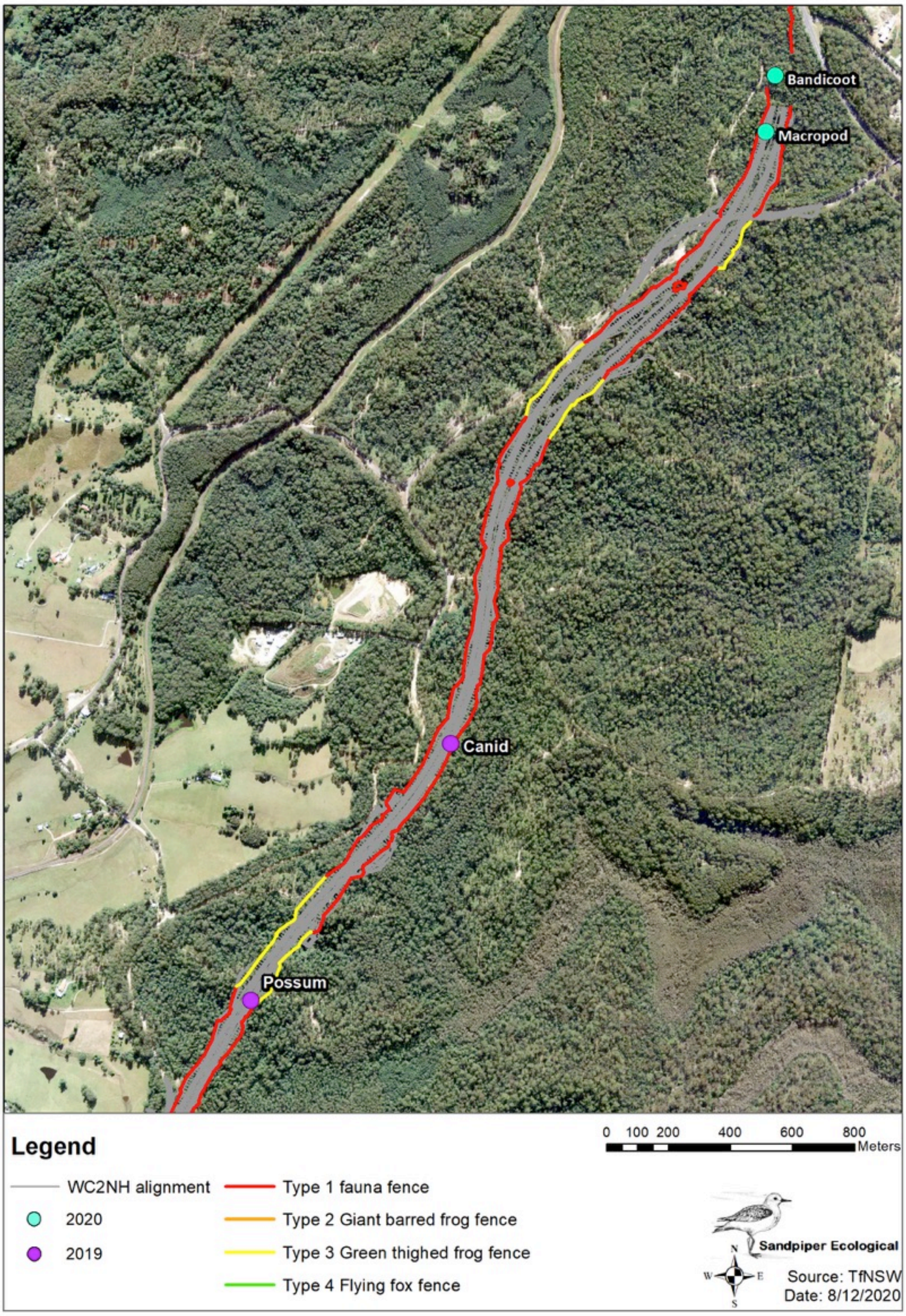

Figure 13: Distribution of fauna groups recorded in 2019 and 2020 that should be blocked by exclusion fence.

Figure 14: Distribution of fauna groups recorded in 2019 and 2020 that should be blocked by exclusion fence.

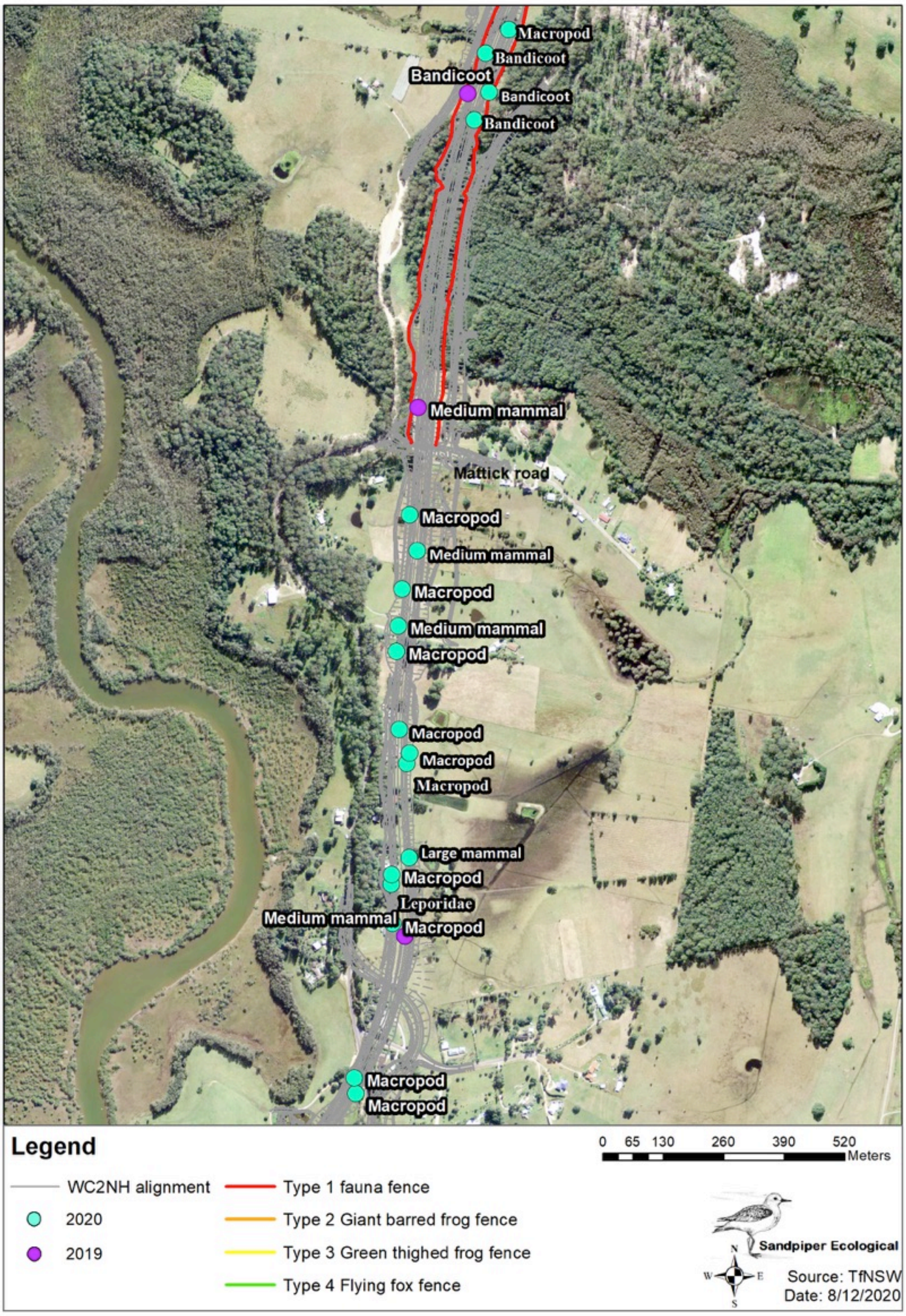

Figure 15: Distribution of fauna groups recorded in 2019 and 2020 that should be blocked by exclusion fence.

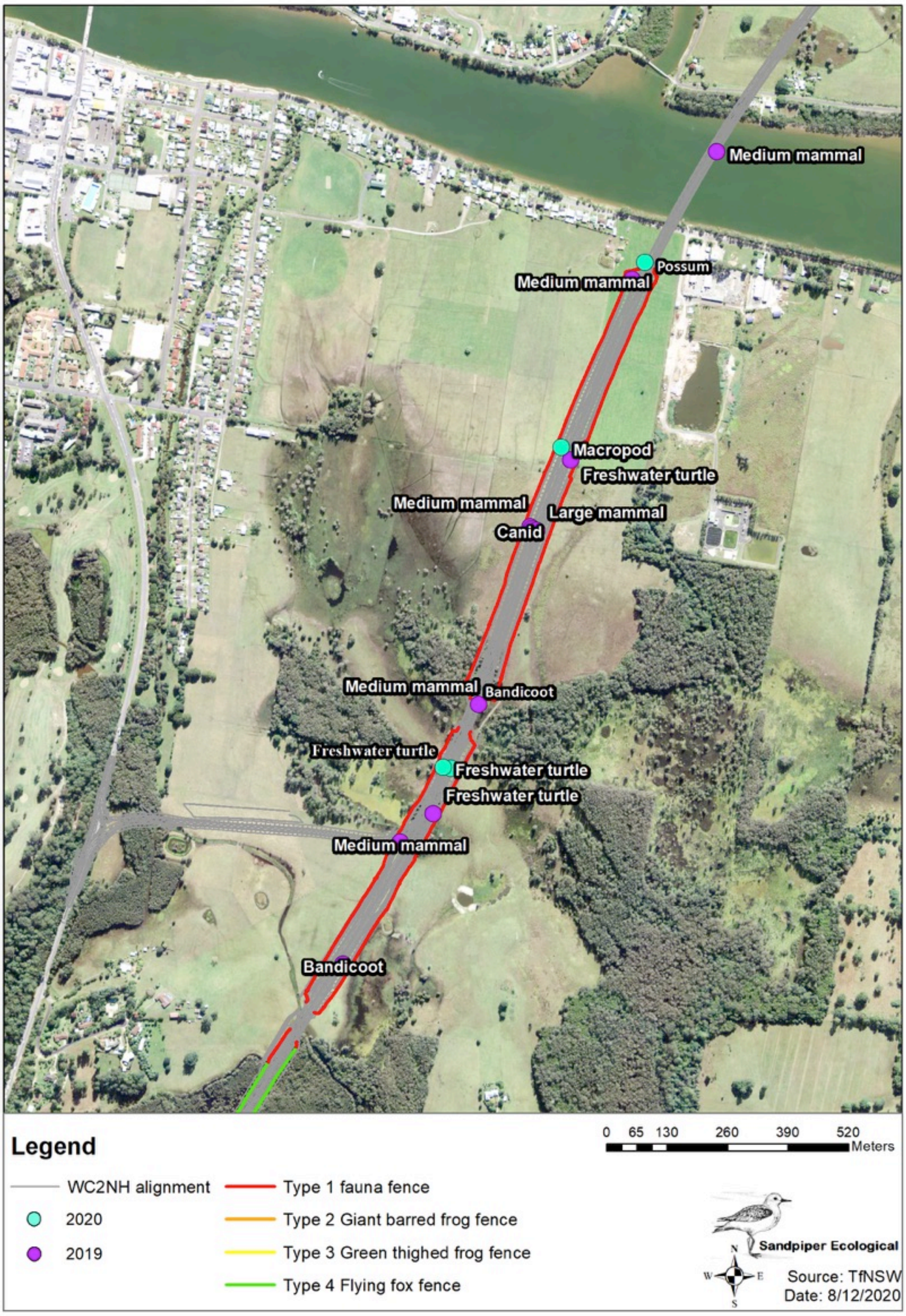

Figure 16: Distribution of fauna groups recorded in 2019 and 2020 that should be blocked by exclusion fence.

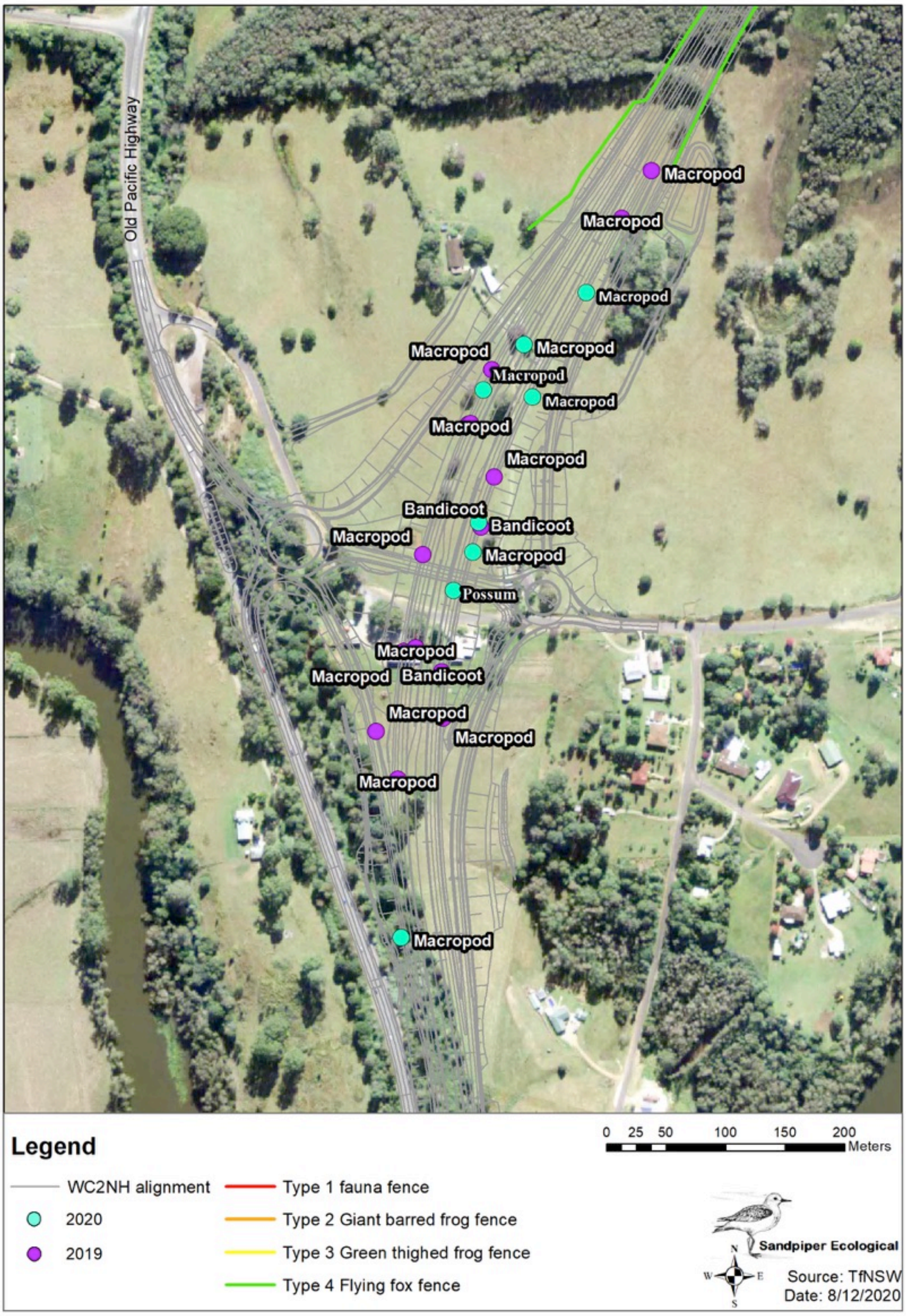

Figure 17: Distribution of fauna groups recorded in 2019 and 2020 that should be blocked by exclusion fence.

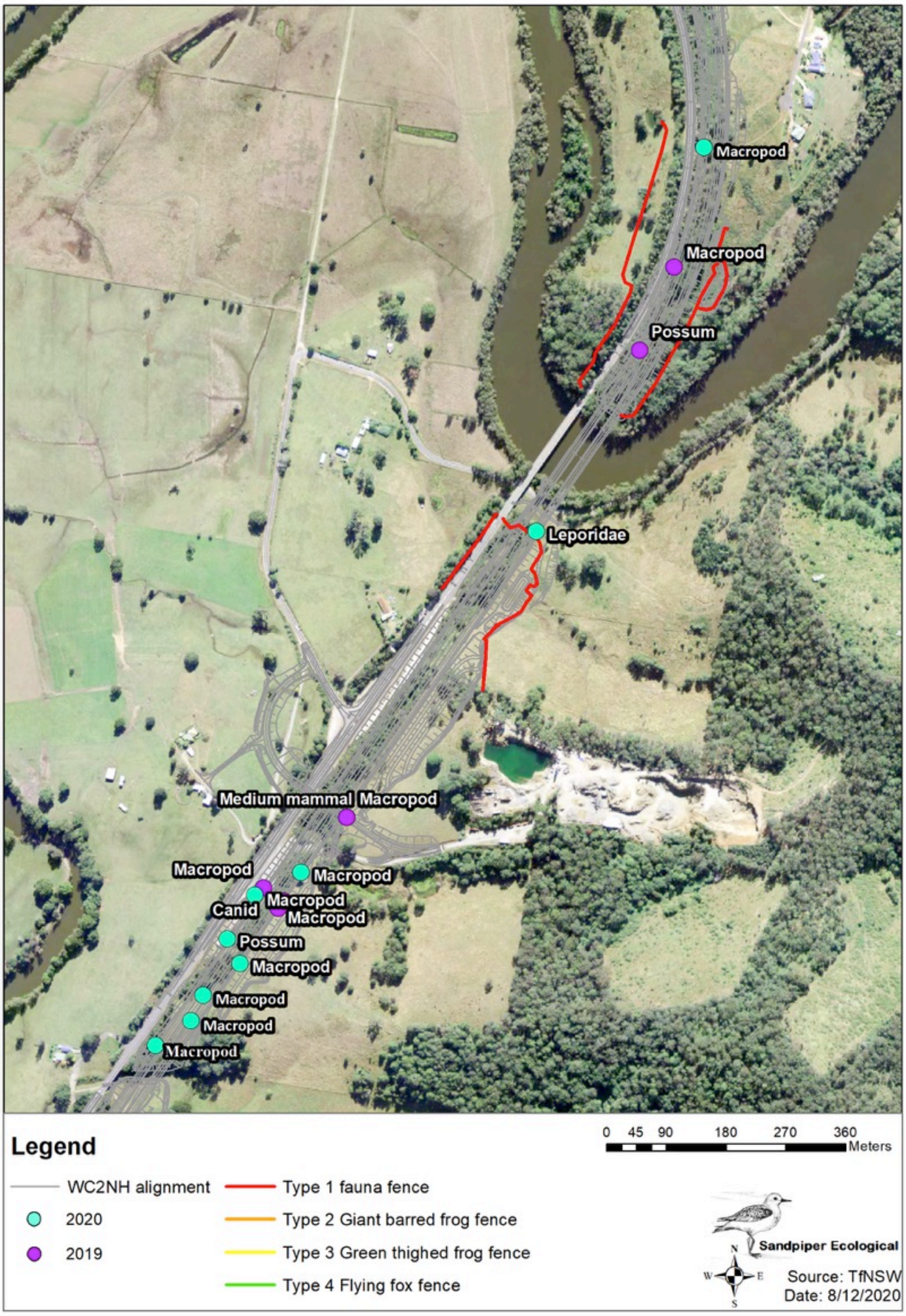

Figure 18: Distribution of fauna groups recorded in 2019 and 2020 that should be blocked by exclusion fence.

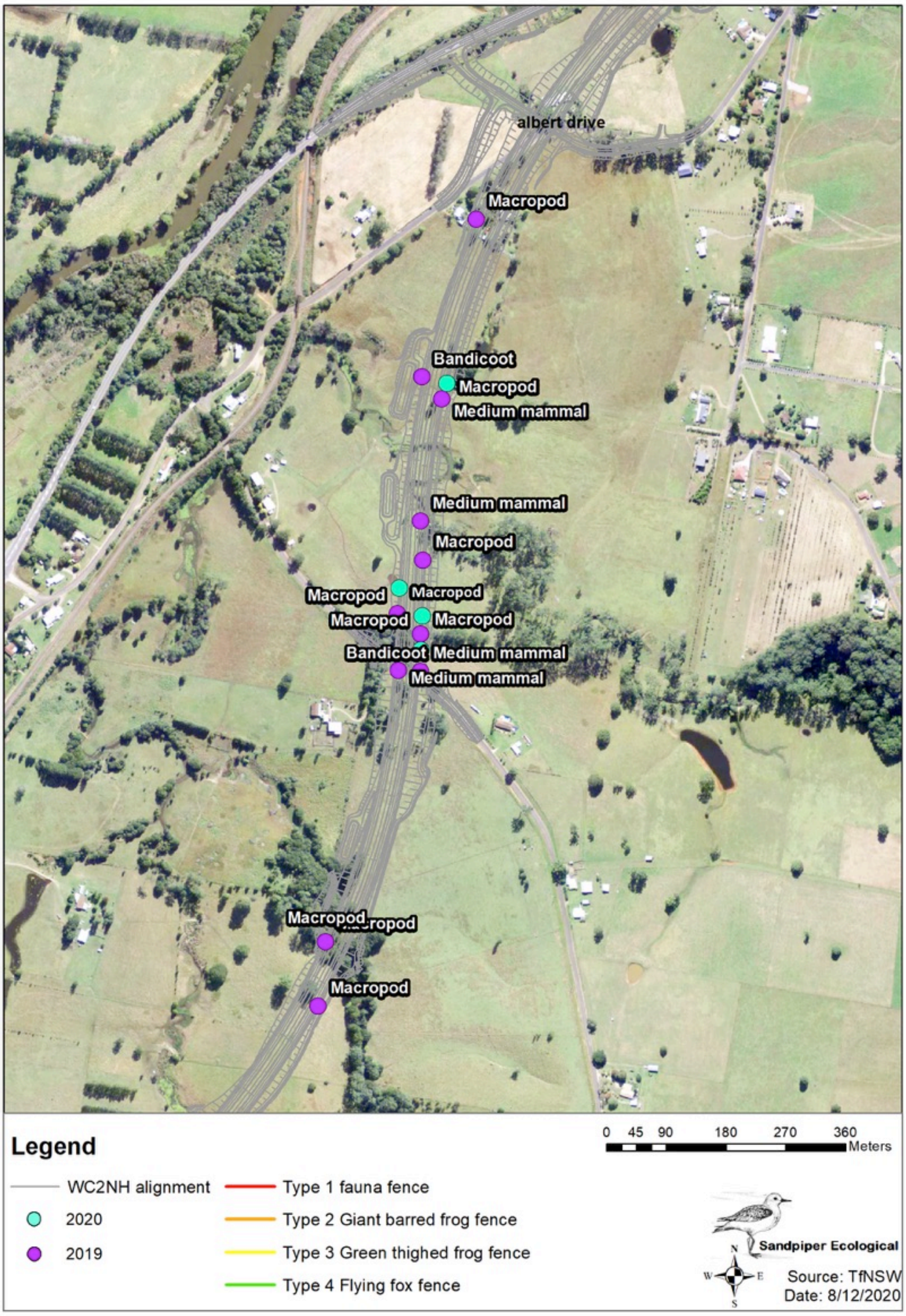

Figure 19: Distribution of fauna groups recorded in 2019 and 2020 that should be blocked by exclusion fence.

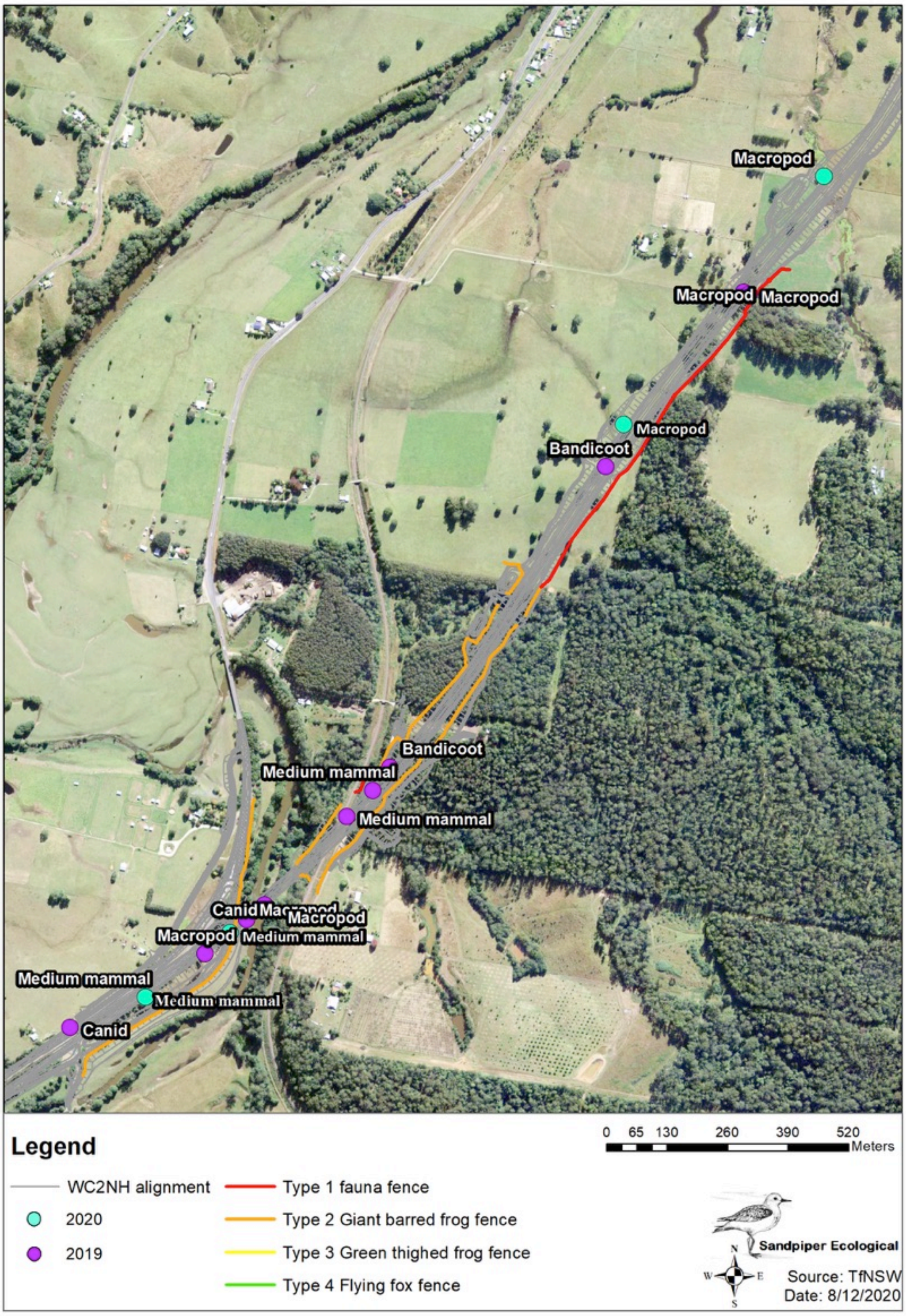

Figure 20: Distribution of fauna groups recorded in 2019 and 2020 that should be blocked by exclusion fence.

4. Discussion

4.1 October 2020

Road-kill monitoring over the entire WC2NH alignment in October 2020 indicated that fauna continue to be killed by vehicles 27 months after the entire alignment was opened to traffic. Road-kill abundance decreased slightly from 28 individuals in winter to 25 individuals in spring (October). Species richness increased from 10 to 15 over the same period. Unlike previous samples the number of road-kill peaked in week two rather than week one. This is contrary to the trend recorded in previous surveys and may be due to a failure to detect some records during the first survey. This likelihood is supported by a noticeable decline in road-kill abundance during weeks two and three.

Monitoring identified a distinct clustering of road-kill consistent with previous samples (see Sandpiper Ecological 2018, 2019a). Sections of alignment between the Nambucca River and Mattick Road, Gumma Floodplain, and between upper and lower Warrell Creeks featured clusters of road-kill. These areas are consistent with most previous quarterly surveys. No amphibians were recorded in October 2020, which is consistent with previous surveys and further emphasises the difficulty identifying road-killed amphibians during vehicle-based surveys.

4.2 Temporal and spatial variation

The distinct seasonal effect recorded in 2018 and 2019 of peaks in spring and summer was less pronounced in 2020 when road-kill abundance peaked in summer (36 individuals) and then remained reasonably consistent in autumn (27), winter (28) and spring (25). The spring/summer peak has been attributed to seasonal changes in breeding cycles and foraging demands (Sandpiper Ecological 2019a). The pattern recorded in 2020 may be influenced by better climatic conditions, which reduced the need for herbivores to forage along the road edge and the need to move larger distances to forage. Further monitoring will assist in determining if the 2020 trend continues.

There have been some notable increases and decreases in abundance of some species between 2018 and 2020. Decreases identified in 2019 for Eastern barn owl, Australian magpie, Australian wood duck, freshwater turtles, and amphibians continued in 2020. Decreases between 2019 and 2020 are evident for carpet python, flying-foxes, European red fox, galah, and tawny frogmouth. These decreases are attributed to a combination of improved climatic conditions from 2018/19 to 2020 (eastern barn owl, amphibians, freshwater turtles, flying-foxes), changes in habitat within the road corridor (Australian wood duck, freshwater turtles), and possibly reduced population size near the alignment (Australian magpie, carpet python). Habituation to the highway is also likely to have influenced road-kill abundance of some species. Introduced species are often the first group to regularly utilise underpasses (Sandpiper Ecological 2015) and it is not surprising to see fox numbers decline and very few cats recorded.

Both short-beaked echidna and bandicoots displayed possible increases in road-kill abundance in 2020. Whilst the abundance of macropods remained high in 2020 (31 road-kills) numbers were consistent with 2019 (27 road-kills). This result is surprising as the 2019 findings were attributed to increased movement and use of the highway corridor for foraging due to drought conditions (Sandpiper Ecological 2019a). A suggestion supported by the findings of Klocker *et al.* (2006), who also recorded elevated road-kill during drought. Continued road-kill at present rates is likely to reduce the abundance of macropods, particularly red-necked wallaby in habitat adjoining the road (Huijser &

Bergers 2000). If macropod road-kill continues at 2019/20 rates in 2021, mitigation measures should be considered at key hotspot sites.

Whilst bandicoots are not grazers they may be attracted to the highway to forage on mulch bunds and batters. Numerous bandicoot diggings have been observed on mulch bunds in some sections of the alignment. Bandicoots are capable of getting through small gaps in fauna fence and it is possible that some road-kill records are due to this. An inspection of the fauna exclusion fence in winter 2020 identified several points where bandicoots could gain access to the alignment (Sandpiper Ecological 2020). TfNSW has commenced repairing these gaps.

Sandpiper Ecological (2018) suggested that the occurrence of birds in road-kill might decline as individuals habituate to the highway. This suggestion is supported by the data with a 30% decline in the number of road-killed birds between 2018 and 2019 and a further 40% decline from 2019 to 2020. It is difficult to determine if the decline in bird abundance is due to population decline or avoidance of the highway. Whilst the highway may represent a population sink for resident territorial species, such as frogmouths, owls, and kookaburras, which may affect populations of some species over time (Loss *et al.* 2014), habituation to the highway cannot be discounted.

4.3 Fenced vs unfenced

The two methods used to compare road-kill abundance between fenced and unfenced sections recorded similar results. The G-test identified a highly statistically significant difference ($P<0.01$) and the Kruskal-Wallis test record a slightly non-significant difference ($P=0.054$). The data suggest an obvious difference with twice the number of road-kills recorded in unfenced or single fence sections, and the disparity between statistical methods may be due to the influence of zero values on the Kruskal-Wallis test. The G-test result suggests that fauna are being killed at a significantly higher frequency in unfenced sections, which is consistent with the hypothesis that exclusion fence reduces road mortality. Results of both methods are consistent with the 2019 findings and both 2020 and 2019 data differ to 2018 when no significant difference between fenced and unfenced was recorded.

The difference between 2019/20 and 2018 is attributed to greater numbers of macropods and bandicoots killed in unfenced sections (in 2019/20), and lower numbers of turtles killed in fenced sections in 2019. Sandpiper Ecological (2018) found that a significantly higher frequency of road-kill occurred in unfenced areas when reptiles were removed from the analysis. Geolink (2018a) attributed the high incidence of road-killed turtles, during Stage 2A monitoring, to individuals trapped on the roadside of the exclusion fence following fence construction. The 2019 and 2020 results support this observation, although it is worth noting that turtles continue to be struck on the Gumma Floodplain, albeit in lower numbers than in 2018.

Despite the higher incidence of road-kill in unfenced areas the results do not show how many individuals are blocked from entering the carriageway by exclusion fence. Exclusion fence corresponds with vegetated areas that have a higher abundance of fauna and without exclusion fence road-kill would be substantially higher in these areas (de Carvalho *et al.* 2014). The lower incidence of mortality through the Nambucca State Forest shows that the exclusion fence is limiting the frequency of road-kill in that area.

At this stage of monitoring no modifications to exclusion fence design or extent is recommended. Due to the likely influence of temporal changes in climate on road-kill further monitoring is recommended to confirm the presence of hotspots and the overall frequency of road-kill within the WC2NH alignment. Bandicoots and macropods stand out as requiring particular scrutiny due to evidence of increasing road-kill rates. As the road-kill monitoring program extends for five years it may be worth considering corrective actions early in year four should present trends continue in year three.

Data suggest that species likely to be blocked by exclusion fence are killed regardless of whether a drop-down occurs nearby. Whilst the influence of drop-downs on road-kill rate requires further analysis this observation is consistent with drop-down monitoring which showed negligible use by native fauna (Sandpiper Ecological 2019b).

4.4 Threatened fauna

Two threatened species were recorded during road-kill surveys in 2020, grey-headed flying fox (2 individuals), and masked owl (1 individual), with a total of four threatened species recorded since monitoring commenced. Importantly, no additional threatened species were recorded in 2020. Masked owls are susceptible to vehicle strike due to their habitat of foraging along forest edges (see Higgins 1999) and they are likely to be regularly recorded in low numbers. Flying-foxes are also susceptible to vehicle strike when foraging close to traffic or traversing bridges over large waterways. Mortality of flying-foxes on the WC2NH upgrade in 2019 was attributed to both situations, with effects compounded by drought (Sandpiper Ecological 2019a). The substantial decline in flying-fox mortality recorded in 2020 is most likely due to improved foraging conditions associated with higher summer and autumn rainfall and less reliance on road-side vegetation.

Vehicle strike is not identified as a major threat to grey-headed flying foxes (DotEE 2017). Scheelings and Frith (2015) found that 2.4% of individuals presented at clinics in Victoria were due to vehicle strike, and 84.6% of these were euthanised. As noted above vehicle strike may be more prevalent during times of heat and food stress. The suggestion that road-strike at the Nambucca River Bridge could be due to barrier effect (see Sandpiper Ecological 2019a) is not supported by the 2020 survey results.

5. Conclusion and recommendations

Contrary to 2018 and 2019 results the 2020 road-kill monitoring program for the WC2NH upgrade identified a decline in road-kill abundance and no distinct seasonal trend. Easing of drought conditions in 2020 has contributed to lower flying-fox road-kill, although road-kill of macropods and bandicoots remained high, and there is some evidence of increasing incidence of echidna road-kill. Whilst mortality rates for these groups are of concern further monitoring is required to confirm the trend. In 2020 there was notable declines in occurrence of Australian wood duck, freshwater turtles, barn owl, magpies, carpet pythons, fox, and galah, a result attributed to the combined effects of habitat condition, species abundance in adjacent habitat, and habituation. Continued high rates of mortality between the Nambucca River Bridge and Mattick Road, the Gumma Floodplain, and in vicinity of Upper Warrell Creek requires further assessment and future monitoring will assist in determining if mitigation is warranted. Importantly, no spotted-tailed quoll, koala, or giant barred frog was recorded as road-kill during the 2020 sample period. Whilst two grey-headed flying-foxes were confirmed, no individuals were recorded near the former camp, or inside the flying-fox exclusion fence.

Recommendations for future monitoring are presented in Table 6.

Table 6: Recommendations based on findings of the year 2 operational phase road-kill monitoring program.

Number	Recommendation	Transport for NSW Response
1.	Continue seasonal road-kill surveys during year three (2021) of the operational phase using the same methods applied in year one and two	Agree and adopted

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Appendix A – Field Survey Data

Table A1: October 2020 road-kill results. NB = northbound; SB = southbound; C'way = carriageway; Prox = proximity

Date	Obs	Start time	End time	C'way	Species	Sex & age class	Pouch or back young	RK general location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Prox to xing structure	Proximity to drop-down
2/10/20	LA &SR	730	845	SB	Magpie lark	Adult		100m s old coast road	497311	6610162	No	Present	Good	NA	NA
				SB	Unid bird	Unknown	N/A	300m N Cockburn's lane	489782	6594832	No	Present	Good	NA	NA
				NB	Wallaby spp.	Adult		300 S bald hill Road	492436	6599742	No	Absent	NA	NA	NA
				NB	Eastern long-necked turtle	Adult		100 m south C3	494984	6606393	no	Present	Good	NA	NA
				NB	Wood duck	Adult	N/A	Bridge floodway 1	493269	6601543	no	Present	Good	NA	NA
				NB	Wallaby spp.	Adult	N/A	700 m S Mattick Road	494391	6603844	no	Absent	NA	NA	NA
				NB	Swamp wallaby	Adult		400M s Mattick road	494401	6604324	no	Absent	NA	NA	NA
				NB	Bandicoot spp	Adult		Above C3	494972	6606364	no	Present	Good	161m	215m
				NB	Eastern long-necked turtle	Adult		Above C3	494984	6606393	no	Present	Good	NA	NA
9/10/20	LA/NM			SB	Laughing Kookaburra	Adult		200m North C3	495239	6606798	Yes	Present	Good	NA	NA
				SB	Eastern bearded dragon	Adult		200m North C4	495194	6606697	Yes	Present	Good	NA	NA
				SB	Domestic goose	Adult		North side of Nambucca bridge	494224	6603259	no	Absent	NA	NA	NA
				SB	Purple swamphen	Adult		500m South Nambucca bridge	493317	6601587	no	Present	Good	NA	NA
				SB	Red-necked wallaby	Adult		100m south of Quarry access road	491865	6598351	no	Absent	NA	NA	NA
				SB	Rodent spp	Adult		100m south of Quarry access road	491812	6598268	no	Absent	NA	NA	NA
				SB	Red-necked wallaby	Adult		150 N rosewood road	490846	6596622	no	Absent	NA	NA	NA
				NB	Masked owl	Adult		250m S Rosewood road	490777	6596352	no	Absent	NA	NA	NA
				NB	Red-necked wallaby	Adult		600 m north of Nambucca bridge	494311	6603407	no	Absent	NA	NA	NA
				NB	Swamp wallaby	Adult		150m s Mattick Rd	494413	6604458	no	Absent	NA	NA	NA
16/10/20	LA/KT			SB	European hare	Adult		50m south of Lower Warrell Creek bridge	492219	6598864	no	Absent	NA	NA	NA
				NB	Australia wood duck	Adult		Flood plain bridge 2	492944	6600925	no	Present	Good	NA	NA
				NB	Bird spp	Unknown		Above C5/6	496185	6608276	no	Present	Good	NA	NA
23/10/20	LA/KT			SB	Echidna	Adult		80 n of Quarry access road	491948	6598514	no	Absent	NA	NA	NA
				NB	Chelidae spp.	Adult		Flood plain bridge 1	493212	6601386	no	Present	Good	NA	NA
				NB	Tawny frogmouth	Adult		500 m south C3	494811	6606069	no	Present	Good	NA	NA

Pacific Highway Upgrade Warrell Creek to Nambucca Heads

Operational phase road-kill monitoring – summer 2021.

Sandpiper Ecological

1/101 Main Street
Alstonville

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Project team:

Ms. N. Makings (reporting)
Dr D. Rohweder (project management)
Dr B. Taylor (field work, report review)
Mr. L. Andrews (field work)

Report prepared for:

Transport for NSW

ABN: 82 084 096 828

PO Box 401
ALSTONVILLE NSW 2477
P 02 6628 3559 | E david@sandpipereco.com.au

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1. Introduction

1.1 Background

In 2015, Transport for NSW (formerly NSW Roads and Maritime Service), in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages: stage 2a – 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and stage 2b – 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

The upgrade included a number of mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate road-kill included:

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna drop-down structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including underpasses, bridges, rope bridges and glide poles.

Several fauna fence designs were installed to target threatened species including:

- **Type 1** - Chainmesh fence 1.8 m tall with floppy top feature which is designed to exclude a range of native mammal species such as macropods, possums, spotted-tail quoll (*Dasyurus maculatus*) and koala (*Phascolarctos cinereus*). A total of 18.03km of this fence type occurs at the site.
- **Type 3** - Small gauge mesh fence with sheet metal return angled away from the highway (combined with fauna floppy top fence) which is designed to exclude green-thighed frog (*Litoria brevipalmata*) and giant barred frog (*Mixophyes iteratus*) from the road corridor. A total of 1.32km of type 3 fauna fence occurs at the site, overlapping with the type 1 fencing.
- **Type 4** - Chainmesh fence 4 m tall through the Macksville Flying-fox camp Paperbark Swamp Forest community designed to discourage grey-headed flying-fox (*Pteropus poliocephalus*) from flying within range of passing traffic when exiting or entering the roost. A total of 1km of type 4 fence occurs at the site.

Sandpiper Ecological Surveys (SES) has been engaged by Transport for NSW (TfNSW) to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal road-kill surveys over the entire upgrade length.

Monitoring of road-killed fauna is a requirement of the approved WC2NH koala, spotted-tailed quoll and grey-headed flying-fox management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for road-kill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog. Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced seasonal monitoring in October 2018. Previous road-kill monitoring was conducted by Geolink (2018a, b, c, d).

The aim of road-kill monitoring is to:

- report on any vertebrate road-kill following opening to traffic; and
- assess the effectiveness of fauna fence in preventing fauna being killed by vehicles while attempting to cross the WC2NH upgrade.

The results of monitoring in 2018, 2019 and 2020 have been previously reported on (Sandpiper Ecological 2018, 2019, 2020). The following report covers the summer 2021 monitoring event and includes the entire WC2NH alignment.

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1).

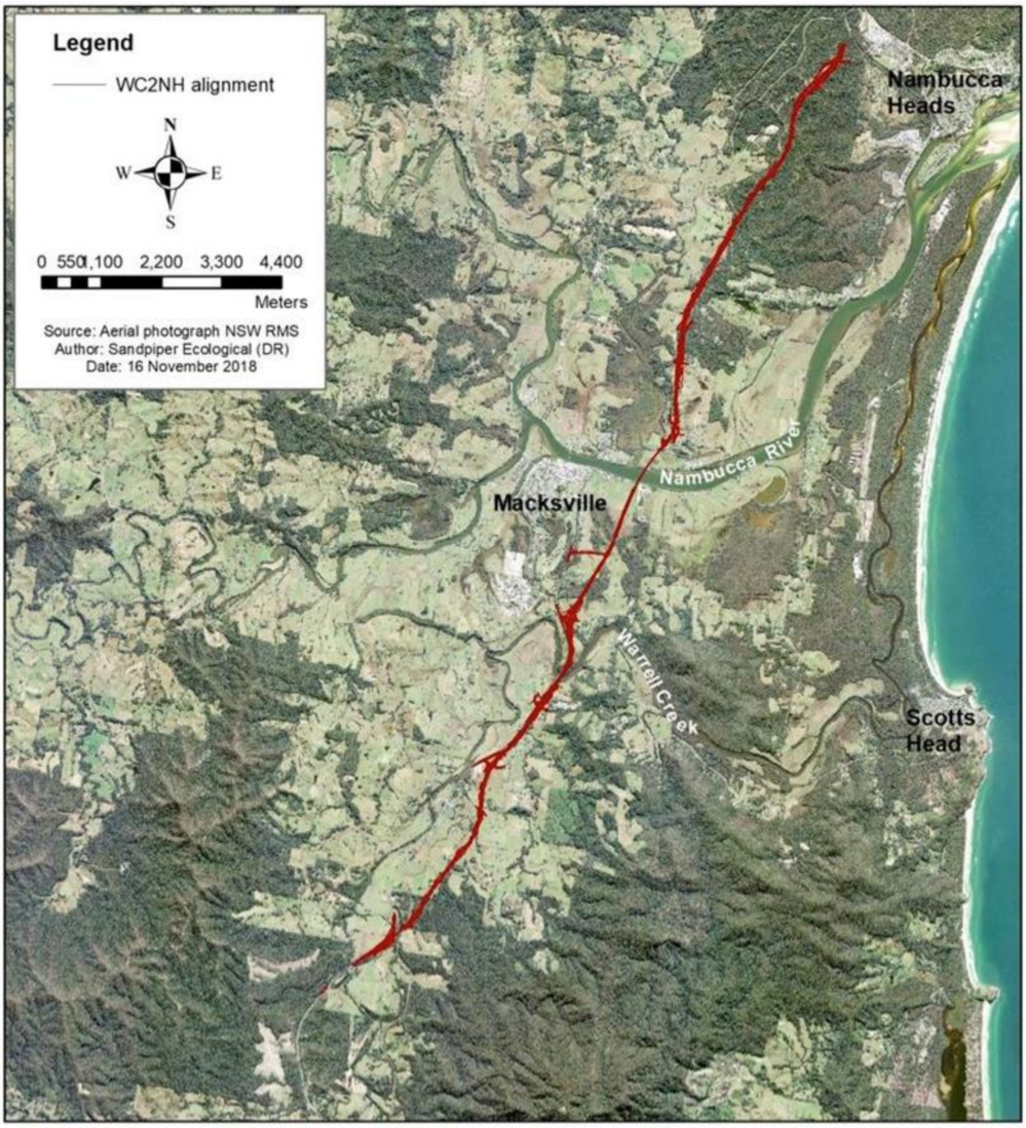

Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Road-kill surveys

Surveys were conducted by a two-person team from a vehicle driven at 80-90km/hr in the left lane. The vehicle was equipped with an amber (flashing) light and warning sign (Plate 1). The team consisted of a driver and an ecologist passenger with experience identifying road-killed fauna. Surveys were undertaken weekly and commenced within three hours of sunrise. During each survey, the ecologist scanned the road surface and road shoulder for fauna. When road-killed fauna were detected the vehicle would pull onto the shoulder/parking bay and the ecologist would exit the vehicle, move along the roadside behind the wire rope and inspect the subject animal from the closest perpendicular position behind the wire rope. Fauna that could not be identified immediately were photographed and images were sent to colleagues for assessment. Carcasses were removed from the road surface when safe to do so.

Plate 1: Work vehicle with signage, flashing amber light and indicators.

Data collected on each road-kill included:

- Geographic coordinate
- Presence/absence of fauna exclusion fence adjacent the record
- Species/fauna group
- Date of survey
- Road-kill location – north or southbound carriageway

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and/or the *Biodiversity Conservation (BC) Act 2016*, included, where possible: sex and age (juvenile/adult); presence of pouch young if applicable; presence of flightless young (flying-foxes); distance to a fauna connectivity structure; distance to a drop-down structure if applicable; damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

All road-kills were cross referenced with the previous survey data to identify possible duplicates. The consistent use of at least one team member across all surveys, GPS coordinates of each specimen, detailed carcass descriptions, and detailed location descriptions assisted with identifying duplicates. Distance to connectivity structure, and distance to escape structure was determined via GIS. All other data were uploaded to an iPad in the field.

2.2 Data summary and analysis

Data from the summer 2021 survey were uploaded to Microsoft Excel. The summer data were compared with results from Spring 2020 to further assist in identifying duplicate records. Data were then plotted to show the total number of road-kills in summer 2021 and the number of road-kills in different fauna groups each week of the survey. The location of summer 2021 road-kills was overlaid on the WC2NH alignment to show distribution, and the data compared to road-kills recorded in summer, autumn, winter and spring 2018, 2019 and 2020 (Sandpiper Ecological 2018, 2019, 2020).

3. Results

3.1 Weather conditions

Light rain occurred in the 24-hour period prior to the second and third samples, however no rain occurred during a survey (Table 1). Visibility was good during all surveys (Table 1).

Table 1: Weather conditions during each sample event. *preceding 24 hours. All data was obtained from the Bureau of Meteorology Coffs Harbour weather station except for rainfall data which was obtained from Bellwood station.

Date	Average Relative Humidity (%)	Rainfall (mm)*	Max Temperature (^{0}C)	Max Wind Speed (km/h)	Visibility during survey	Rain during survey
18/1/21	69	0	27.5	54	Good	Nil
22/1/21	62	2	28.0	50	Good	Nil
29/1/21	87	1	27.4	30	Good	Nil
5/2/21	77	0	28.0	30	Good	Nil

3.2 Species richness and abundance

A total of 20 road-killed fauna were recorded during the summer 2021 sample period. Fauna included 12 native species and one introduced species (dog), as well as three fauna groups (Table 2). Birds were the most diverse group represented with seven species and one fauna group. Mammals were represented by five species and one fauna group and reptiles featured two species and one fauna group.

Noisy miner was the most frequently detected species with three records, followed by two records each for Chelidae spp. and wallabies (one swamp wallaby and one red-necked wallaby) (Table 2). Degradation and location of carcasses on the carriageway made identification to species level difficult in some cases (Table 2). No frogs or threatened species were recorded during the summer year 3 surveys.

Of the 20 road-kill records, seven (35%) were species expected to be blocked by exclusion fence (i.e. medium and large mammals). The remaining 13 records, including birds, a small mammal, a common blue-tongued skink and a carpet python are species that readily move through or over exclusion fencing.

Table 2: Species of vertebrate fauna recorded during seasonal road-kill surveys throughout the operational phase of the WC2NH upgrade. * denotes threatened species; ** = stage 2a only; Sum = summer; Aut = autumn; Win = winter; Spr = spring.

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Total
Birds														
Australian magpie	6	1		1				2	2	1			1	14
Grey butcherbird			1											1
Magpie-lark	2		1		1		1		1		1	1		8
Australian white ibis			1						1					2
Cattle egret				1						1				2
Little pied cormorant					1									1
Buff-banded rail					1									1
Purple swamphen	3		2	2		1		2	3		1	1		15
White-headed pigeon										1				1
Crested pigeon	2													2
Galah	7				1			3						11
Rainbow lorikeet								1						1
Eastern grass owl*				1										1
Australian boobook			1	1			1				1			4
Masked owl*	1				1		1					1		4
Eastern barn owl			11	3		1	5	2	1					23
Tawny frogmouth	1	3	1	2		6		4		1		1	1	20
Australian owlet-nightjar					1					1				2
Laughing kookaburra	3		2	1		2		3	1	1	2	1		16
Forest kingfisher	1													1

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Total
Australian wood duck	20			2	2		1	2				2	1	30
Pacific black duck	2		1											3
Whistling kite				1										1
Black-shouldered kite					1	1								2
Torresian crow					1								1	2
Pied currawong				1									1	2
Black-faced cuckoo-shrike								1						1
Noisy miner													3	3
Dollarbird					2									1
Green catbird					1								1	2
Australasian figbird										1				1
Black bittern*						1								1
Eastern yellow robin						1								1
Pheasant coucal							1		1					2
Masked lapwing							1							1
Welcome swallow								1						1
Red-browed finch										1				1
Duck spp.						1				1				2
Tyto spp.										1				1
Small bird								2						2
Medium bird				1	2	2	2	2	6	1	1			16
Unidentifiable bird	5	4	1		3						2	2	1	18
Total birds	53	8	22	17	18	16	13	25	16	11	8	9	10	214

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Total
Mammals														
Short-beaked echidna				3				2		1	2	1		9
Black flying-fox	2	1			7	1	1							11
Grey-headed flying-fox*					8			5	2					15
Pteropus spp.					3	8	1		1	1				14
Short-eared brushtail possum													1	1
Common brushtail possum			1	2						1				4
Trichosurus spp.									1	1	1			3
Common ringtail possum					1			1						2
Eastern grey kangaroo				3			1							4
Red-necked wallaby			6		8	2	8	3	7	1	8	3	1	47
Swamp wallaby	2	1		1		1	1			1	1	2	1	11
Wallaby spp.						2			3			2		7
Macropod spp.	3		2	1	1					2	1			10
Northern brown bandicoot	1		1		1	1	1	2	2	3	3		1	16
Bandicoot spp.						1		4				1		6
Chalinolobus spp. (microbat)				1										1
Microbat spp.					1									1
Rodent spp.						2						1		3
Small mammal					2						1		1	4
Medium mammal				2	4	2	4	5	2	2	2			23
Large mammal				1	1			1			1			4

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Total
Unidentified Mammal	1			3										4
Total mammals	10	2	10	17	36	20	17	23	18	13	20	10	5	196
Reptiles														
Common blue-tongued skink	1			2	1				2				1	7
Carpet python	1			2	1	1		1					1	7
Common tree snake	1	2						1						4
Eastern long-neck turtle	1			6						1		2		10
Macquarie river turtle	5	1					1							7
Unidentified *Chelidae* spp.	6							1				1	2	10
Red-bellied black snake	1													1
Eastern water dragon	1			1										2
Eastern bearded dragon												1		2
Blackish blind snake						1								1
Yellow-faced whipsnake				1										1
Unidentified reptile								2		1				3
Total reptiles	17	3	0	12	2	2	1	5	2	2	0	4	4	50
Frogs														
Green tree frog	2													2
Striped marsh frog	3													3
Medium frog				3										3
Large frog				1										1
Total frogs	5	0	0	4	0	0	0	0	0	0	0	0	0	9
Introduced species														

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Total
Cat	1													1
Dog													1	1
European fox	3	1	1	2	1	1	2							11
European hare	2			1						1		1		5
Rabbit	1													1
Black rat	1					1								2
House mouse					1									1
Rock pigeon			1	1										2
Domestic goose				1								1		2
Total introduced species	8	1	2	5	2	2	2	0	0	1	0	2	1	25
Total	93	14	34	55	57	40	33	53	36	27	28	25	20	515

Over the summer 2021 sample period the number of road-kill recorded each week declined from 13 in week one to three in week two, and two in weeks three and four (Figure 2).

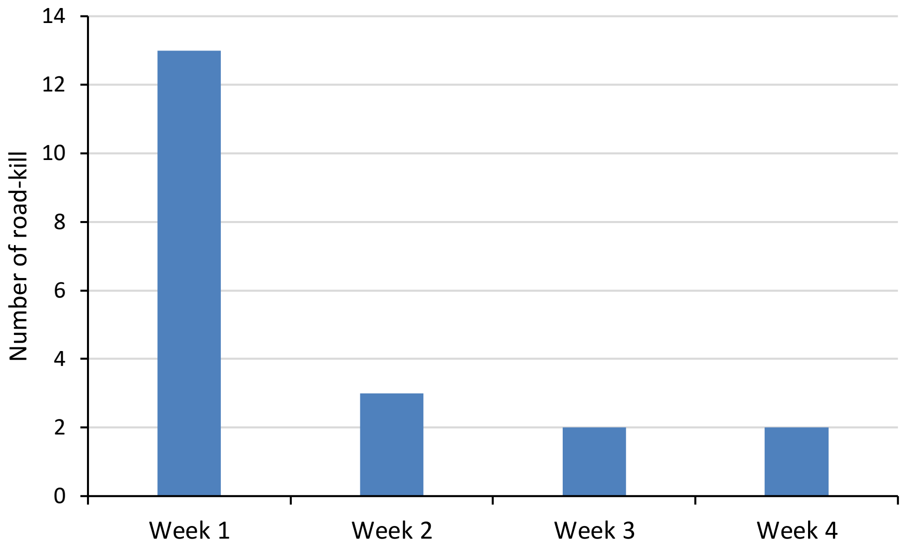

Figure 2: Number of road-kills recorded in each sample week during the summer 2021 sample period.

The abundance of road-killed fauna in the three vertebrate groups varied during the sample period (Figure 3). Birds and mammals were recorded in three weeks, and reptiles in two. The number of road-killed birds decreased from six in week one to three in week two, none in week two and one in week four. The number of road-killed mammals decreased from four in week one to none in week two, and one each in week three and four. The number of road-killed reptiles decreased from three in week one to none in week two, increasing to one in week three, and were absent in week four.

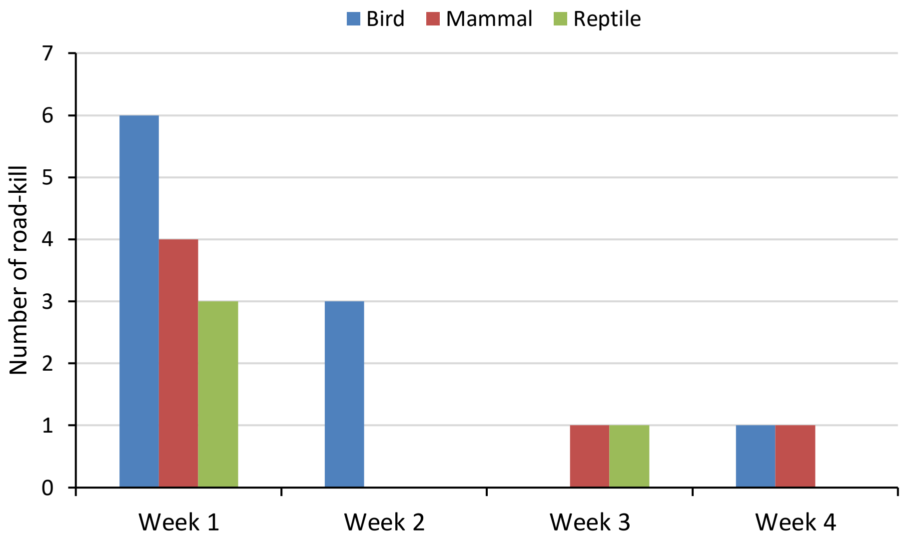

Figure 3: Number of road-killed fauna from three vertebrate classes during each sample week in summer 2021.

The number of road-killed flying-foxes has varied over the monitoring period (Figure 4). Black flying-fox, grey-headed flying-fox and total number of flying-foxes peaked during summer 2019 with seven, eight and 18 road-kills, respectively. Numbers have fluctuated and largely declined since then, with no flying-foxes recorded in winter and spring 2020, and summer 2021 (Figure 4).

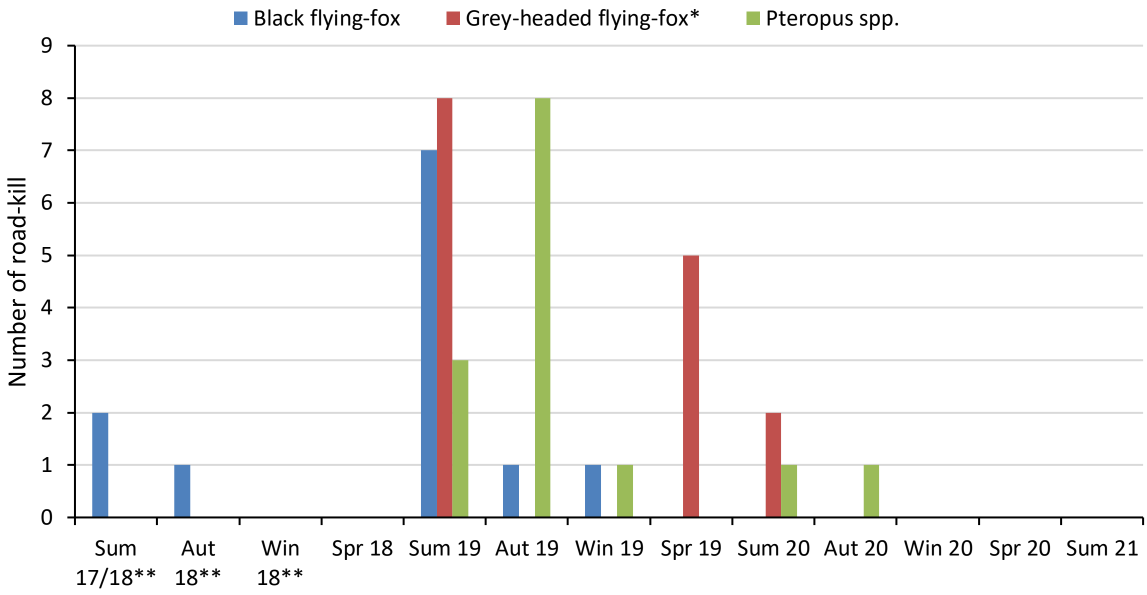

Figure 4: Number of road-killed flying-foxes from all sample periods. * denotes threatened species. **Stage 2a only.

3.3 Opportunistic road-kill information

No opportunistic road-kill was recorded during summer 2021.

3.4 Distribution of road-kill

Fauna road-kills were recorded across the entire WC2NH alignment during summer 2021 (Figures 5-8). Half of the records (50%) were situated between Mattick Road and Bald Hill Road., with the remaining half occurring south of Bald Hill Road (25%), and north of Mattick road (25%) which is entirely fenced with type 1 and 3 exclusion fence. The section between Mattick Road and Bald Hill Road traverses predominantly cleared land and includes the Nambucca River and Gumma floodplain. Approximately 50% of that area is fenced with Type 1 and Type 4 exclusion fence.

During the summer 2021 period, 10 road-kills were recorded in areas without exclusion fence, eight in areas with an exclusion fence and two in an area with an exclusion fence on only one side of the carriageway (Figures 5-8). One of the fenced section records (5% of all records) was a species that was expected to be blocked by the fence (i.e. medium and large mammals). Six records (30% of all records) in sections without fence or with an exclusion fence only on one side, were of species expected to be blocked by an exclusion fence on both sides of the carriageway.

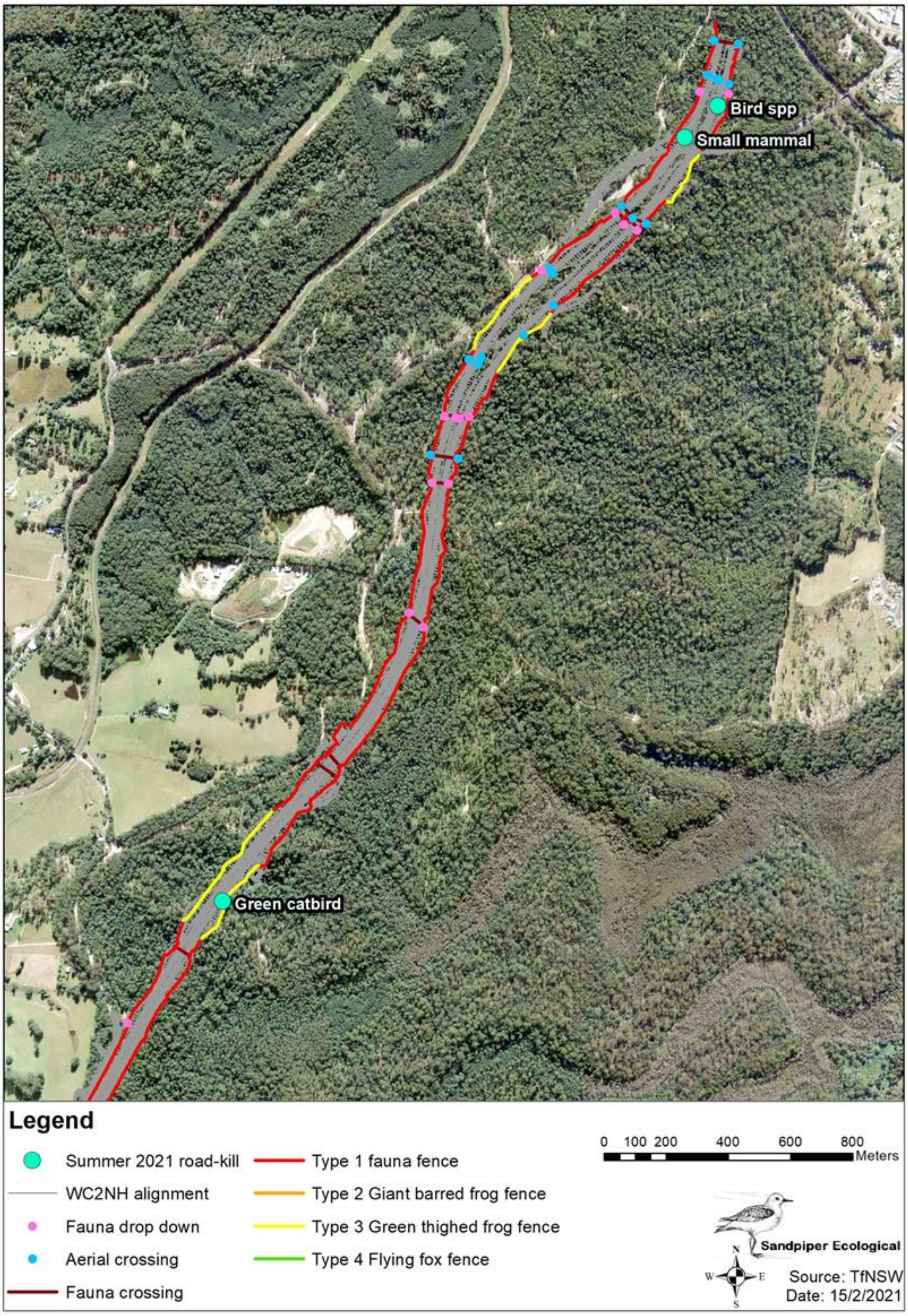

Figure 5: Location of road-killed fauna recorded in summer 2021.

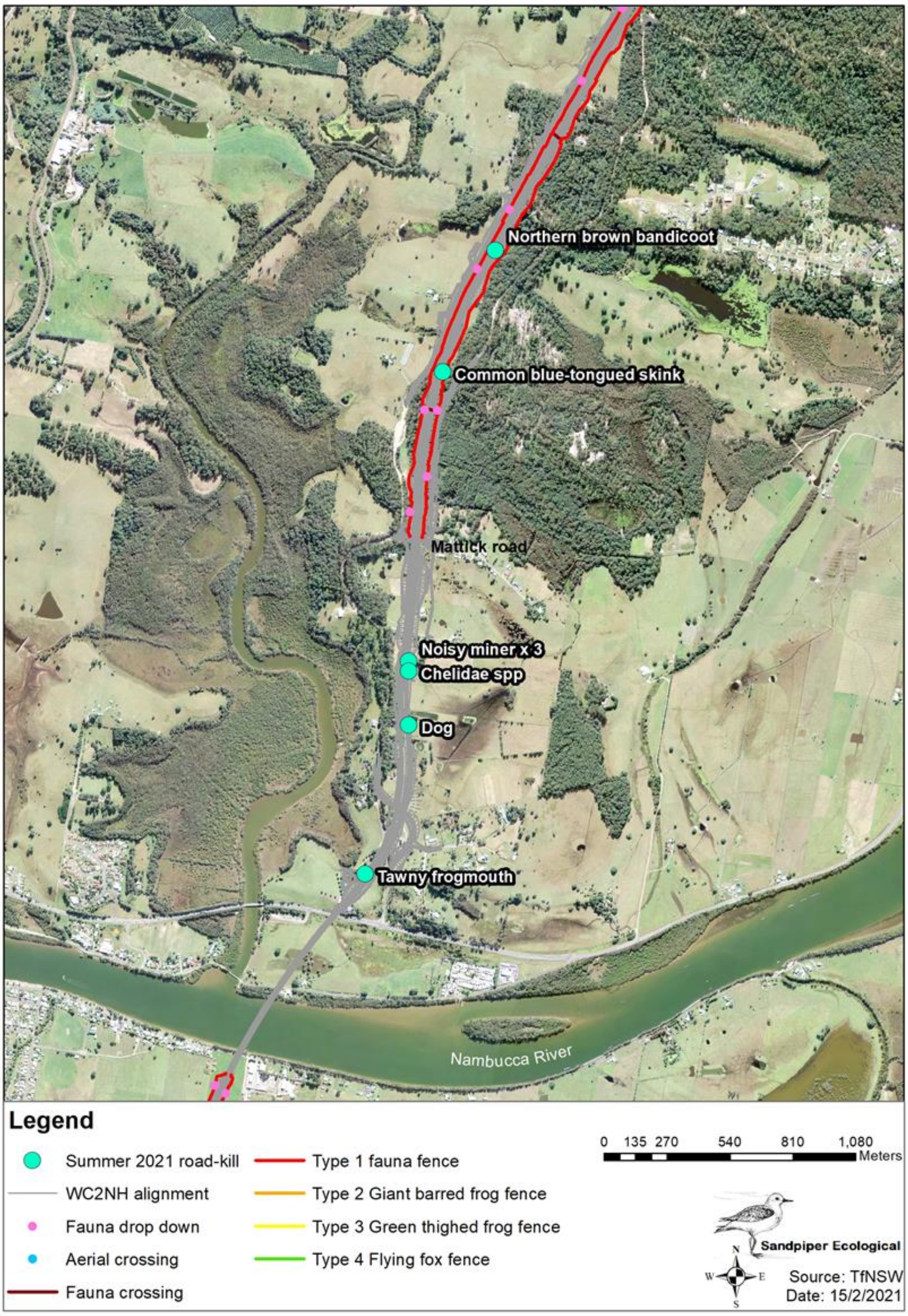

Figure 6: Location of road-killed fauna recorded in summer 2021.

Figure 7: Location of road-killed fauna recorded in summer 2021.

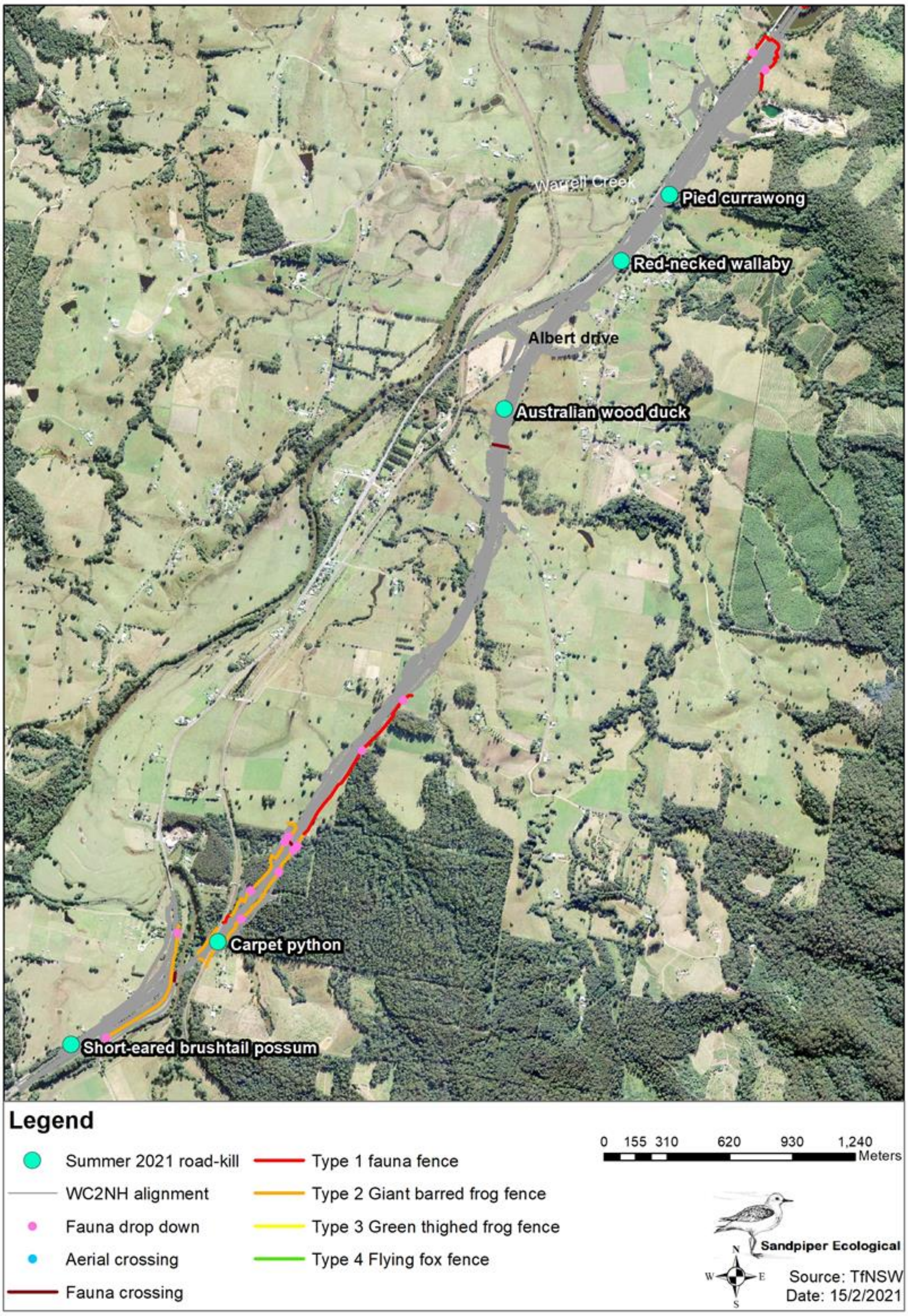

Figure 8: Location of road-killed fauna recorded in summer 2021.

4. Discussion

4.1 Summer 2021

Road-kill monitoring of the WC2NH alignment in summer 2021 indicates that fauna continue to be killed by vehicles 2.5 years after the entire alignment was open to traffic. However, the number of road-kills recorded in summer 2021 is the lowest for any road-kill sample period since seasonal sampling commenced in spring 2018. Indeed, the summer 2021 total was 16 individuals fewer than the summer sample in 2020. Importantly, no threatened species listed under the *EPBC Act 1999*, or the *BC Act 2016* were recorded during the summer 2021 survey.

Unlike 2018 and 2019, the distinct seasonal peaks in spring and summer were not evident during the 2020-2021 period, with 27 individuals recorded in autumn 2020, 28 individuals in winter 2020, 25 individuals in spring 2020, and 20 individuals in summer 2021. Most fauna groups have demonstrated reductions in road-kill numbers. In particular, summer red-necked wallaby road-kill numbers have decreased by six between 2020 and 2021. This is a positive result, as concerns have previously been raised about the effect of road-kill on the local red-necked wallaby population.

The reduction in road-kill numbers may be an artefact of improved local conditions which reduced the need for herbivores, such as red-necked wallabies, to both forage along the road edge and move larger distances to source food. It may also reflect reduced local abundance after a period of protracted drought and bushfires during 2019. While the reduction in road-kill numbers is encouraging, temporal fluctuations in the number and species of road-kill are evident (Sandpiper Ecological 2018, 2019 and 2020). Further monitoring will assist in determining if this trend continues.

As in previous samples, the number of road-kill peaked in week one. This largely reflects the period over which carcasses can accumulate. This trend is likely to occur in seasonal sample periods and it means that the number of road-kills recorded during a month overestimates the actual number of animals killed in that month.

Road-kill hotspots identified in summer 2021 are consistent with previous surveys. The area from Mattick Road to Bald Hill Road (50% of road-kills), which includes the Nambucca River and Gumma Floodplain has consistently recorded a high incidence of road-kill (Sandpiper Ecological 2018, 2019, 2020). Birds and mammals comprised the majority of road-kills in all surveys to date.

4.2 Flying-fox impacts

No road-killed flying-foxes were recorded during summer 2021. This is consistent with the substantial decline in flying-fox road mortality recorded in 2020. It likely reflects the improved foraging conditions during 2020/21 and thereby less reliance on road-side vegetation. It may also reflect a reduction in local population abundance due to the bushfires and extreme drought conditions of 2019.

4.3 Effectiveness of fauna fencing

The spatial pattern of road-kill occurrence is largely consistent with that of previous samples, excluding autumn 2020. The road-kill rate of species expected to be blocked by the fence is lower in areas with exclusion fence than in areas without exclusion fence. Importantly, no mortality of targeted threatened species was recorded in summer 2021. Monitoring continues to show that where present, exclusion fencing is effective in mitigating road-strike for target species.

5. Recommendations

Recommendations relating to the summer 2021 operational phase road-kill monitoring are summarised in Table 3.

Table 3: Recommendations following the summer 2021 operational phase road-kill monitoring and Transport for NSW response.

Number	Recommendation	Transport for NSW Response
1.	Continue seasonal road-kill surveys using the same methods applied in year one and two	Agreed and adopted.

6. References

Geolink (2018a). *Roadkill monitoring report: WC2NH Stage 2A*. Report prepared for NSW Roads and Maritime Services.

Geolink (2018b). *Roadkill monitoring summary report: autumn (April) 2018*. Letter report prepared for NSW Roads and Maritime Services.

Geolink (2018c). *Roadkill monitoring summary report: winter (July) 2018*. Letter report prepared for NSW Roads and Maritime Services.

Geolink (2018d). *Roadkill monitoring report - initial 12 weeks WC2NH Stage 2B*. Report prepared for NSW Roads and Maritime Services.

Roads and Maritime (2018). *Warrell Creek to Nambucca Heads Stage 2 Ecological Monitoring Program*. Report prepared by NSW Roads and Maritime Services.

Sandpiper Ecological (2018). *Pacific Highway Upgrade, Warrell Creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2018*. Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2019). Pacific Highway Upgrade, Warrell Creek to Nambucca Heads: operational phase road-kill monitoring- annual report 2019. Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2020). Pacific Highway Upgrade, Warrell Creek to Nambucca Heads: Year 2 operational phase road-kill monitoring- annual report 2020. Report prepared for Transport for NSW.

Appendix A – Field Survey Data

Table A1: Summer 2021 roadkill results. Obs = Observers; LA = Luke Andrews, KT = Katie Stevens, BT = Brendan Taylor; xing = crossing

Date	Observers	Start time	End time	Carriageway	Species	Sex & age class	Presence of pouch or back young	RK general location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to xing structure	Proxmity to drop-down	If FlyFox, proximity to camp; prox. to canopy veg, prox. to food
18/1/21	LA/KS	830	930	SB	Bird spp.	Unknown	Nil	100m north of old coast road	497451	6610405	Yes	NA	NA	NA	NA	NA
				SB	Noisy miner x 3	Adult	Nil	200m north of Macksville exit	494429	6604236	Yes	NA	NA	NA	NA	NA
				SB	Chelidae spp.	Unknown	Nil	200m north of Macksville exit	494428	6604193	Yes	Absent	NA	NA	NA	NA
				SB	Dog	Adult	Nil	On Macksville ramp exit	494430	6603962	No	Absent	NA	NA	NA	NA
				SB	Chelidae spp.	Unknown	Nil	On Macksville/Scott's head exit	492649	6600389	No	One side	NA	NA	NA	NA
				SB	Red-necked Wallaby	Sub adult	Nil	100m South of black snake creek	491450	6597779	No	Absent	NA	NA	NA	NA
				SB	Carpet python	Unknown	Nil	Under Upper Warrell creek railway bridge	489459	6594413	No	NA	NA	NA	NA	NA
				NB	Australian wood duck	Adult	Nil	200m South of Albert drive	490873	65970474	No	NA	NA	NA	NA	NA
				NB	Swamp wallaby	Adult	Nil	Macksville on ramp	492623	6600411	No	One side	NA	NA	NA	NA
				NB	Australian magpie	Unknown	Nil	Floodwaters bridge 1	493273	6601534	UK	NA	NA	NA	NA	NA
				NB	Small mammal	Unknown	Nil	50m past old coast road	497343	6610303	No	NA	NA	NA	NA	NA
22/1/21	BT/LA	815	915	SB	Green catbird	Adult	Nil	Above c7	495855	6607840	UK	NA	NA	NA	NA	NA
				SB	Torresian crow	Adult	Nil	100 m north of Gumma floodplain bridge 2	493075	6601108	UK	NA	NA	NA	NA	NA
				NB	Tawny frogmouth	Adult	Nil	100M north NB bridge	492241	6603321	UK	NA	NA	NA	NA	NA
29/1/21	LA/KS	8:30	9:30	SB	Common blue-tongued skink	Adult	Nil	800m North of Mattick Road	494575	6605480	UK	NA	NA	NA	NA	NA
				NB	Short-eared brushtail possum	Adult	Nil	500Ms Upper Warrell creek	488733	6593904	UK	Absent	NA	NA	NA	NA
5/2/21	LA/BT	815	10:00	SB	Northern brown bandicoot	Adult	Nil	1Km north of Mattick Road	494802	6606002	UK	Present	Good	553m	82m	NA
				SB	Pied currawong	Adult	Nil	On Williamson's creek bridge	491688	6598105	UK	NA	NA	NA	NA	NA