Warrell Creek to Nambucca Heads Pacific Highway Upgrade

Commonwealth Approval EPBC 2013/7101
Annual Compliance Report
February 2019 – February 2020

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NSW GOVERNMENT

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Terms and Abbreviations

BOS	Biodiversity Offset Strategy
CEMP	Construction Environmental Management Plan
Clear Milkvine	*Marsdenia longiloba*
Cryptic Forest Twiner	*Tylophora Woollsii*
DAWE	Department of Agriculture, Water and the Environment
DPIE	Department of Planning Industry and Environment
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
FFMP	Flora and Fauna Management Plan
GBF	Giant Barred Frog
GBFMP	Giant Barred Frog Management Plan
Geolink	Geolink – Project Ecologist for WC2NH Project
GHFF	Grey-headed Flying-fox
Pacifico	Acciona Ferrovial Joint Venture (the Roads and Maritime's road construction contractor for the project).
STQ	Spotted-Tail Quoll
TFMP	Threatened Flora Management Plan
WC2NH	Warrell Creek to Nambucca Heads Pacific Highway Upgrade Project

Contents

1. Introduction

1.1. Purpose of this document

The purpose of this document is to facilitate demonstration by Transport for NSW (TfNSW) of satisfactory compliance with the Commonwealth approval conditions for the Warrell Creek to Nambucca Heads Pacific Highway Upgrade project (the Project) with particular reference to Conditions 19 and 20. This report covers the forth reporting period from February 2019 to February 2020.

For each condition, one or more actions are identified which, once implemented, will achieve satisfactory compliance with the condition. Where appropriate, the timing for completion of individual actions is identified.

For each action, the minimum relevant documentation to support demonstration of compliance is identified. This documentation would inform any future compliance audit.

Where an approval condition makes reference to information being provided to the Commonwealth Minister for the Environment, the associated action(s) assumes that this information will be provided, in the first instance, to the Commonwealth Department of Agriculture, Water and the Environment.

1.2. Key dates

The timing for compliance with certain approval conditions is linked to specific dates as follows:

- Commonwealth approval: 11 Dec 2014
- Start of construction: 9 Feb 2015
- Scheduled completion of construction: mid 2019
- Expiry of Commonwealth approval 31 Dec 2064

1.3. Responsibility for compliance

Responsibility for compliance with all approval conditions sits with TfNSW.

1.4. NSW planning approval

Condition 3 and 4 (of the Commonwealth approval) provides for the use of plans, strategies or reports required under the NSW approval to satisfy the requirements of the Commonwealth approval, subject to provision of a separate document demonstrating how the document addresses the relevant Commonwealth approval requirements.

Specialists in the fields of flora and fauna have been engaged by TfNSW and the construction contractor to undertake various ecology-related management activities with regard to complying with the NSW planning approval and the CEMP.

This document contains actions relevant to compliance with the NSW planning approval that are also considered to satisfy compliance with Commonwealth approval requirements.

1.5. Definitions for action status conditions

TBA	To Be Arranged - Further works required prior to starting action.

In progress	Action initiated but not yet complete.
Ongoing	Action in place but ongoing works required to ensure compliance.
Complete	Action completed.

1.6. Non Compliances with EPBC Conditions

No non-compliances against the approval conditions were identified during the reporting period (February 2019 – February 2020).

2. Compliance Tracking

The following sections provide a compliance status for the reporting period for the 26 conditions of approval. Note: where relevant, the conditions have been amended to reflect the current approval variation and the date of the condition included.

2.1. Condition 1 – variation dated 03/10/2016

The approval holder must not clear more than:

a) 17.80 hectares (ha) of **Slender Marsdenia / Clear Milkvine and Woolls Tylophora / Cryptic Forest Twiner habitat**;

b) 106.6 ha of **Koala habitat**, including 86.50 ha critical to the survival;

c) 106.6 ha of **Grey-headed Flying-fox habitat**, comprised of 103.50 ha of foraging habitat critical to survival and 3.10 ha of roosting habitat critical to survival;

d) 114.1 ha of **Spotted-tail Quoll habitat**;

e) 0.70 ha of **Giant Barred Frog habitat**;

f) 3.40 ha of Australian Painted Snipe (*Rostratula australis*) wetland habitat;

g) 5.3 ha of habitat for the Regent Honeyeater (*Anthochaera phrygia*) and Swift Parrot (*Lathamus discolour*) wintering habitat, comprising dry schlerophyll forests containing Swamp Mahogany; and

h) 26.1 ha of Milky Silkpod (*Parsonsia dorrigoensis*) habitat, comprising Mixed Floodplain Forest, Flooded Gum Open Forest and White Mahogany/Grey Gum/Ironbark Open Forest.

Action		Timing	Status	Compliance evidence
1.1	Progressive review of area cleared	Regularly during construction	Compliant Ongoing	Record of clearing numbers provided in monthly report from Contractor to RMS. Refer to Table 1.1 below for clearing quantities for the reporting period.
1.2	Confirm clearing limitation targets have been met	Post-construction	TBA	As built survey of actual clearing area. Not able to action until after completion of clearing. Memo/short report

Table 1.1: Clearing Quantities for the reporting period.

Habitat Type	February 2019 Completed Clearing Quantities		
	Limit (ha) as per Condition 1 Approval	Clearing Quantity (ha)	Current Difference showing remaining habitat (ha) under Condition 1 Approval
Slender Marsdenia/Clear milkvine and Woolls Tylophora/Cryptic Forest Twiner habitat	17.80	17.65	0.15
Koala	106.60	83.44	23.16
Koala (Critical Habitat)	86.50	60.18	26.32
Grey-headed Flying-fox	106.60	83.44	23.17
Grey-headed Flying-fox (foraging habitat critical to survival)	103.50	81.33	22.17
Grey-headed Flying-fox (roosting habitat critical to survival)	3.10	2.10	1.00
Giant Barred Frog	0.7	0.64	0.06
Spotted –tail Quoll habitat	114.10	90.28	23.82
Australian Painted Snipe (Rostratula australis)	3.4	2.84	0.56
Regent Honeyeater (Anthochaera phrygia) and Swift Parrot (Lathamus discolour)	5.30	4.34	0.96
Parsonsia dorrigoensis (Milky Silkpod)	26.1	24.11	1.99

NOTE: The above clearing data represents clearing undertaken up to February 2020. Clearing quantities for all habitat types are below the limits as specified in condition one.

It is anticipated that minor ongoing clearing associated with property adjustments and design refinements will be undertaken until the completion of the project.

2.2. Condition 2 – original dated 11/12/2014

Within 30 days of the **complete on of construction**, the **approval holder** must:

a) notify the **Minister** in writing of the **completion of construction**; and

b) provide a report (supported by maps) that clearly shows the location of all **threatened species**, including the number of individuals of threatened flora and their **habitat cleared** as a result of **action**, which demonstrates compliance with Condition 1.

Action		Timing	Status	Compliance evidence
2.1	Prepare works as executed Environmental and Clearing Plans to show extent of clearing.	anticipated Mid – late 2020	TBA	Report & supporting mapping
2.2	Calculate final clearing quantity and include in summary table.	anticipated Mid - late 2020	TBA	Report & supporting mapping
2.3	Provide written notification (letter) of completion of construction and report to Dept. of the Environment	anticipated Mid – late 2020	TBA	Notification letter Completed document transmittal form or equivalent

Please note that while the project is open to traffic and is operational in that respect, construction is still being undertaken off the road alignment.

2.3. Condition 3 – original dated 11/12/2014

The **approval holder** must undertake the **action** and implement all mitigation measures in accordance with the **Koala Management Plan**, **Grey-headed Flying-Fox Management Plan**, **Spotted-tail Quoll Management Plan** and **Giant Barred Frog Management Plan**. These **Plans** must be implemented.

Action		Timing	Status	Compliance evidence
3.1	Implement the Koala Management Plan	Pre-construction, Construction and Operation	Compliant Ongoing	Sensitive Area Plans Ecological Monitoring Report Roadkill Quarterly Reports Completed Pre-clearing Checklists Fauna Relocation Register Habitat Tree Hollow Register Environmental Work Method Statements (EWMS) for Activities Project Induction

				Biodiversity Offset Strategy Urban Design and Landscape Plan Fauna Connectivity Report See summary Table 3.1
3.2	Implement the Grey-Headed Flying Fox Management Plan	Pre-construction, Construction and Operation	Compliant Ongoing	Sensitive Area Plans Ecological Monitoring Report Roadkill Quarterly Reports Completed Pre-clearing Checklists Fauna Relocation Register Habitat Tree Hollow Register Environmental Work Method Statements (EWMS) for Activities Project Induction Biodiversity Offset Strategy Urban Design and Landscape Plan Fauna Connectivity Report See summary Table 3.2
3.3	Implement the Spotted-tail Quoll Management Plan	Pre-construction, Construction and Operation	Compliant Ongoing	Sensitive Area Plans Ecological Monitoring Report Roadkill Quarterly Reports Completed Pre-clearing Checklists Fauna Relocation Register Habitat Tree Hollow Register Environmental Work Method Statements (EWMS) for Activities Project Induction

				Biodiversity Offset Strategy Urban Design and Landscape Plan Fauna Connectivity Report See summary Table 3.3
3.4	Implement the Giant Barred Frog Management Plan	Pre-construction, Construction and Operation	Compliant Ongoing	Sensitive Area Plans Ecological Monitoring Report Roadkill Quarterly Reports Completed Pre-clearing Checklists Fauna Relocation Register Habitat Tree Hollow Register Environmental Work Method Statements (EWMS) for Activities Project Induction Biodiversity Offset Strategy Urban Design and Landscape Plan Fauna Connectivity Report See summary Table 3.4

Compliance Tracker

Table 3.1: Compliance with the Koala Management Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Design Phase/Pre-construction	Minimise areas of Koala habitat to be cleared where feasible and reasonable during the detailed design phase.	The Project design has minimised clearing quantities as much as possible by ensuring the construction corridor is as narrow as possible. Ancillary sites were located in areas where clearing is minimal.	Design Drawings

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Pre-construction	All ancillary sites were located outside of mapped Koala habitat.	Ancillary sites were located in areas of minimal clearing and have minimised clearing of Koala habitat trees.	Sensitive Area Plans Ancillary Facility Register
Pre-Construction	Prior to any clearing taking place, the Project Ecologist undertook an inspection of vegetation, to be cleared, to determine if work activities do not constitute “Construction” as defined in the planning approval under the NSW EP&A Act and are excluded from the Referral under the Federal EPBC Act.	Prior to construction commencing, only minor clearing (<150mm DBH) was undertaken. The Project Ecologist inspected all areas of clearing to ensure no Koala habitat was removed during Pre-construction activities.	Early Works Permits
Pre-Construction/ Construction	The limits of clearing are clearly marked on all relevant work plans and protective fencing erected to mark these limits (i.e. ‘no-go’ areas).	The clearing limits have been included on the Sensitive Area Plans and marked in the field using yellow flagging.	Sensitive Area Plans Early Works Permits Pre-clearing and Ground Disturbance Permits
Detailed Design/Pre-construction	Areas for habitat restoration / connectivity were identified and included in the detailed design.	Habitat connectivity planting has been included in the Urban Design and Landscape Plan	Urban Design and Landscape Plan
Pre-construction/ Construction	Preparation of an EWMS would be undertaken for all work/construction activities and would include where necessary measures to minimise risk to Koalas.	An EWMS has been prepared for all work activities which includes measures to protect flora and fauna in accordance with the Flora and Fauna Management Plan (FFMP)	EWMS
	Induction of all personnel involved with pre-construction/construction activities would be undertaken to advise on Koala management requirements	Project Induction includes information about identification of Koala’s on site.	Project Induction

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	For any areas of vegetation to be cleared during the pre-construction stage of the Project, a suitably qualified ecologist undertook a search for native fauna (including Koalas) in the vicinity of clearing immediately prior to clearing commencing. During the construction stage, pre-clearing surveys will be undertaken within 48 hours of any clearing commencing (These are to include spotlighting surveys within suitable habitat on the night prior to clearing operations commencing in a given area.) In the event that a Koala is identified within 50 metres of a works area, works will be rescheduled until the construction stage of the Project. During the construction phase clearing works, the suitably qualified expert or an experienced wildlife handler under the supervision of the suitably qualified expert will be available to retrieve and provide appropriate care of any displaced matters of NES and release the fauna into adjacent habitats safe from construction work. Immediately prior to (within 2 hours) of clearing commencing in a given area, an additional ecologist inspection is to be undertaken to confirm that clearing areas remain free of fauna (including Koalas). Where Koalas are identified no works would be undertaken within 50 metres of the animal and the measures within the Fauna Management Protocol for Koalas (refer to Table 4.1 of	The Project Ecologist undertakes inspections of all areas to be cleared and signs off on the Pre-clearing Inspection Checklist prior to commencement. No Koala's have been identified on site during clearing operations.	Pre-clearing and Ground Disturbance Permit

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	Koala Management Plan) would be implemented. Should relocation of Koalas be required, a Koala Relocation Strategy included in Appendix C of the Koala Management Plan would be implemented.		
Pre-construction and Construction	Koala Management Protocol to be implemented requiring all personnel to report Koalas (including road kill). An assessment of future road kill risks including adaptive management actions is to be provided by the Project Ecologist where: - A Koala is detected within/near the site, or - Koala road kill is detected. Prior to the construction of fauna passage locations and installation of fauna fence, where continuous lines of jersey barriers are to be installed, gaps are to be provided to allow escape of any animals off the highway. Where gaps cannot be provided, a suitable material will be placed over the barrier to allow Koalas to climb over the barrier.	No Koala roadkill has been identified on the Project during Pre-construction, Construction and Operational Phases of the Project. No concrete barriers have been placed through Koala habitat areas.	Roadkill records and quarterly report.
Pre-construction/ Construction/ Operation	Appropriate habitat offsets to be identified by including targeted Koala surveys (GeoLINK 2014) using recognised survey approaches to confirm usage of potential offset properties.	Offset properties set up Koala's identified on Norton Property. Refer to CoA 14 for further details	Monitoring Records
Construction Operation	Progressive rehabilitation of identified areas (refer to Appendix B of the Koala Management Strategy) during the construction stage using collected topsoil and seed at specific sites and to develop different successional stages of	Progressive rehabilitation of the site has commenced. The koala connectivity landscaping will be undertaken in accordance with the Urban Design and Landscape Plan.	Urban Design and Landscape Plan Site Inspection Records

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	rehabilitation. Key rehabilitation measures would include: - Progressive revegetation / rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation. - Planting of locally occurring species, including plants representative of groundcover, understorey and canopy strata. - Planting of preferred food trees for native fauna, including appropriate eucalypt species for the Koala. - Plantings are to be undertaken around fauna crossing structures to optimise utilisation of these structures. - Monitoring and maintenance of plantings. - Managing and controlling weeds.	A Landscape Maintenance Plan has been finalised for implementation that will include the rehabilitation and monitoring koala connectivity landscaping. Weed management is undertaken in accordance with the Weed and Pathogen Management Plan (WPMP).	
Pre-Construction Detailed Design/ Construction	EPA was consulted during the detailed design phase on fauna crossing structure specific requirements for fauna furniture and treatments in and around fauna crossing structures. This included, but not necessarily be limited to requirements for refuge poles and/or horizontal rails, pathways and appropriate plantings and/or \sizing /placement of scour rock & treatment of the substrate e.g. soil and/or mulch over the concrete floor and apron. Advice was provided by the project ecologist on fauna furniture to be installed within fauna crossing structures.	The EPA/Fisheries have been consulted with and have provided input into the detailed design of the fauna crossing structures including the fauna furniture design. The Fauna Connectivity Report prepared by TfNSW includes detailed information of the consultation process undertaken with the EPA and Fisheries in relation to the fauna crossing structures. The Project made prototype panels to demonstrate different types of stone pitching that was to be placed in the low flow channel of Butchers Creek.	Detailed Design Drawings ERG Minutes Fauna Connectivity Report

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
		The prototype panels were shown to the EPA and Fisheries to determine the preferred option for frog and fish passage in this waterway. The fauna furniture design has been demonstrated on site using a prototype and shown to the EPA. The EPA are satisfied with the general arrangement. The fauna drop down design has been demonstrated on site using a prototype and shown to the EPA. The EPA are satisfied with the general arrangement.	

Table 3.2: Compliance with Grey Headed Flying Fox Management Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Pre-construction	Identify exclusion zones and install exclusion fencing or marking. Exclusion fencing or marking is intended to exclude construction activities from occurring in flying-fox habitat.	Orange flagging and no-go zone signage placed prior to the commencement of construction activities. Flagging was removed when confirmation received that the flying foxes were not utilising the roost on site.	Inspection records Sensitive Area Plans
Detailed Design/ Pre-construction	Minimise through detailed design the incidence of clearing vegetation containing Swamp Mahogany, *Melaleuca quinquenervia, Banksia integrifolia* and *Eucalyptus tereticornis* that contribute to foraging habitat particularly through winter.	The width of the road corridor through the GHFF roost area has been minimised. The total quantity of clearing foraging habitat for GHFF has been minimised.	Sensitive Area Plans Detailed Design Drawings
Pre-construction/ Construction	Construction related infrastructure to be planned and sited within cleared or disturbed areas of the ancillary site. Particularly away from water	Ancillary sites have been located away from the GHFF roost area and potential habitat.	Consistency review documents for Ancillary site facilities.

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	sources and flying-fox movements areas.		Ancillary Facility Register
Construction	Pre-clearing and clearing surveys of all vegetation within the clearing footprint conducted as per protocol. If necessary, develop and implement a contingency plan for moving flying-fox out of the clearing corridor during vegetation clearing and construction, refer to Appendix C of the GHFF Management Plan.	Pre-clearing and ground disturbance permits have been signed off by the Project Ecologist prior to commencing clearing activities. Project Ecologist present during clearing operations in GHFF habitat. No GHFF have been moved from the Project site for clearing operations	Pre-clearing and ground disturbance checklists.
Detailed Design	To minimise the risk of flying-fox vehicle strike during take-off from roosting/foraging, revegetation close to carriageways is not to include plants that flower prolifically and produce nectar food sources likely to attract flying-foxes.	The Urban Design and Landscape Plan has considered revegetation that is suitable for the GHFF. Tree species have been located away from the sides of the roadway. Fauna exclusion fencing has been designed for this area.	Urban Design and Landscape Plan Road Furniture Design Package (RF01)
Construction	Exclusion zones fenced off and/or clearly marked. Fencing and marking monitored with breaches repaired.	The clearing limits were been clearly marked with yellow flagging and no-go zone signage. Rural fencing has been installed to prevent access beyond the Project Boundary into the exclusion zone.	Inspection records
Construction	Installation of temporary exclusion fencing around ancillary facilities.	Ancillary sites have been located in areas where clearing is minimal and avoids GHFF habitat.	Sensitive Area Plans
Construction	Impacts to the flying-fox camp from construction noise, vibration and light would be managed through maintaining exclusion zone buffers and fencing. Only low noise / low disturbance construction activities to occur within the exclusion zone buffer during mid-September to the following	No GHFF have been detected using the camp since prior to the commencement of construction. The GHFF colony has been detected using an alternative roost location and have not returned to the roost adjacent to the worksite.	GHFF Monitoring Reports

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	April. Inclusion of cross drainage and the provision of a permeable, free draining rock platform in the vicinity of the camp. Implement contingency plan for moving flying-fox out of the clearing corridor and 100 metre buffer during vegetation clearing/ construction.	The GHFF Management Plan has been updated to permit the project to undertake activities such as haulage through the site buffer zone if the GHFF population returns to the roost site. This update was approved in January 2017.	
Construction	Implement water quality procedures from the CEMP.	Regular inspections of the erosion and sediment controls in the area was ongoing throughout construction. Water quality monitoring is currently ongoing.	Inspection records Water Quality Monitoring Records

Table 3.3: Compliance with Spotted-tail Quoll Management Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Detailed Design and Construction	Minimise areas of vegetation (STQ habitat) to be cleared where feasible and reasonable during the detailed design and construction phase. Design changes (e.g. additional ancillary facilities, batch plants etc. to avoid clearing of vegetation (STQ habitat)).	The Project design has minimised clearing quantities as much as possible by ensuring the construction corridor is as narrow as possible. Ancillary sites have been located in areas where clearing is minimal and avoids STQ habitat.	Detailed Design Ancillary Facility Register
Pre-construction	All ancillary sites to be located outside of STQ habitat.	Ancillary sites have been located in areas where clearing is minimal and avoids STQ habitat.	Ancillary Site Facility Consistency Reviews Ancillary Facility Register
Pre-construction	Prior to any clearing taking place, the Project Ecologist will undertake an inspection of vegetation to be cleared to determine if work activities do not constitute “Construction” as defined in the planning approval under the NSW EP&A Act and	Prior to construction commencing, only minor clearing (<150mm DBH) was undertaken. The Project Ecologist inspected all areas of clearing to ensure no STQ habitat was removed during Pre-construction activities.	Early Works Permits

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	are excluded from the Referral under the Federal EPBC Act.		
Construction	The limits of clearing are to be clearly marked on all relevant work plans and protective fencing erected to mark these limits (i.e. no-go areas). Fauna habitat resources for the STQ to be marked by the ecologist and retained within areas adjacent to the clearing footprint and within the Project boundary where appropriate.	The clearing limits have been included on the Sensitive Area Plans and marked in the field using yellow flagging. Habitat resources are marked by the Project Ecologist where appropriate	Sensitive Area Plans Pre-clearing and Ground Disturbance Permit
Detailed Design	Areas for habitat restoration / connectivity were identified and included in the detailed design.	Habitat connectivity planting has been included in the Urban Design and Landscape Plan	Urban Design and Landscape Plan
Construction	Preparation of an EWMS is undertaken for all work activities and would include where necessary measures to minimise risk to the STQ.	An EWMS has been prepared for all work activities which includes measures to protect flora and fauna in accordance with the Flora and Fauna Management Plan (FFMP).	EWMS
	Induction of all personnel involved with activities would be undertaken to advise of STQ management requirements.	Project Induction includes information about identification of STQ on site.	Project Induction
	For any area of vegetation to be cleared during the pre-construction stage of the project, a suitably qualified ecologist undertook a search for native fauna (including STQ) in the vicinity of clearing immediately prior to clearing commencing. During construction a suitably qualified ecologist will undertake pre-clearing surveys for threatened fauna species (including STQs) prior to (within 48 hours) any clearing commencing. For the STQ, these would focus on dens, large hollow-bearing trees, scats and any other potential habitat features such	The Project Ecologist undertakes inspections of all areas to be cleared and signs off on the Pre-clearing Inspection Checklist prior to commencement. No STQ have been identified on site during clearing operations.	Pre-clearing and ground disturbance Permit

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	as rock formations. Immediately prior to (within 2 hours) of clearing commencing within a given clearing area an additional ecologist inspection is to be undertaken to confirm that clearing areas remain free of fauna (including STQs). In the event that a STQ is identified, no works would be undertaken within 200 metres of the animal and the measures within the Fauna Management Protocol for STQs (refer to Table 4.1) would be implemented. For any STQ detected on/near the site the protocol shown in Table 4.1 is to be implemented.		
Construction	STQ Management Protocol (Table 4-1) to be implemented requiring all personnel to report STQs (including road kill). Assessment of future road kill risk including adaptive management actions to be provided by Project Ecologist where STQ road kill is detected.	No STQ roadkill has been identified on the Project.	Roadkill records and quarterly reports.
Construction	Progressive rehabilitation of identified areas refer to Appendix C) during the construction stage using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation. Key rehabilitation measures would include: - Progressive revegetation /rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation. -Planting of locally occurring species, including plants representative of groundcover, understorey and canopy strata.	Progressive rehabilitation of the site has commenced. The site will be rehabilitated in accordance with the Urban Design and Landscape Plan which includes habitat connectivity planting around the fauna passage structures.	Inspection records Urban Design and Landscape Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	- Plantings are to be undertaken around fauna crossing structures to optimise utilisation of these structures. - Monitoring and maintenance of plantings. Managing and controlling weeds.		
Detailed Design and Construction	EPA will be consulted during the detailed design phase on fauna crossing structure specific requirements for fauna furniture and treatments in and around fauna crossing structures. This will include, but not necessarily be limited to requirements for refuge poles and/or horizontal rails, pathways and appropriate plantings and/or sizing and placement of scour rock & treatment of the substrate e.g. soil and/or mulch over the concrete floor and apron. Advice will be provided by the project ecologist on fauna furniture to be installed within fauna crossing structures.	The EPA/Fisheries has been consulted with and have provided input into the detailed design of the fauna crossing structures including the fauna furniture design. The fauna furniture design has been demonstrated on site using a prototype and shown to the EPA. The EPA are satisfied with the general arrangement. The fauna drop down design has been demonstrated on site using a prototype and shown to the EPA. The EPA are satisfied with the general arrangement.	Detailed design drawings

Table 3.4 Compliance with the Giant Barred Frog Management Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Pre-construction	No areas of Giant Barred Frog habitat to be cleared during preconstruction	No areas of GBF were cleared during pre-construction	Early Works Permits
Pre-construction/ Construction	All ancillary sites to be located outside of mapped Giant Barred Frog habitat.	Ancillary sites are located outside of the mapped GBF habitat.	Sensitive Area Plans Ancillary Facility Register
Pre-construction/ Construction	Perform field surveys at nominated biodiversity offset sites.	Offset properties have been surveyed and area of potential habitat assessed	Shown on draft offset management plans

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Construction	Any design changes required during the construction stage would minimise clearing of Giant Barred Frog habitat where feasible and reasonable.	The clearing of GBF habitat has been minimised where possible. Only necessary infrastructure has been placed in the GBF habitat area.	Sensitive Area Plans
Construction	Preparation of an EWMS would be undertaken for all construction activities to clearly communicate relevant measures within this plan to work crews . Ongoing induction of all personnel involved with construction activities would be undertaken to advise of Giant Barred Frog management requirements. Early Works – Establishing Site Controls (Temporary Frog Fencing). Pre-clearing Survey for Giant Barred Frogs. Clearing Supervision in Giant Barred Frog areas. Dewatering Procedures in Giant Barred Frog areas. Permanent Frog Fencing. Unexpected Finds Procedure. All mitigation measures applied during construction as per Table 5-1.	An EWMS has been prepared for all work activities which includes measures to protect flora and fauna in accordance with the Flora and Fauna Management Plan (FFMP). Project Induction includes information about identification of GBF on site. Temporary frog fencing was installed prior to the commencement of clearing. The Project Ecologist undertakook inspections of all areas to be cleared and signs off on the Pre-clearing Inspection Checklist prior to commencement. The Project Ecologist has supervised the clearing operations in the GBF habitat. Surveys were undertaken with input sought from the Project Ecologist when the frog fencing is reinstated after a flood event.	EWMS Project Induction Pre-clearing and Ground Disturbance Permit Site Inspection Record Urban Design and Landscape Plan
Construction	Giant Barred Frog road kill to be reported to the Project Ecologist and TfNSW. An assessment of future road kill risks including adaptive management actions is to be provided by the Project Ecologist where: - A Giant Barred Frog is detected within/ near the site; or	No GBF roadkill has been identified on the Project.	Roadkill records and quarterly reports.

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	- Giant Barred Frog road kill is detected		
Construction Operation	Progressive rehabilitation of identified areas (refer to Appendix C of the GBF Management Plan). Key rehabilitation measures will include planting of the northern bank of Upper Warrell Creek on either side of the bridge Progressive revegetation and rehabilitation during construction. Use of locally endemic native species representative of those currently growing along Upper Warrell Creek. Monitoring and maintenance of plantings. Managing and controlling weeds.	Progressive rehabilitation of the site was undertaken. The site has been rehabilitated in accordance with the Urban Design and Landscape Plan which considers GBF habitat in the rehabilitation of Upper Warrell Creek.	Urban Design and Landscape Plan

The Ecological Monitoring Annual Report 2019-2020 provided in Appendix 1 contains the results of the monitoring required for the **Plans** during the reporting period.

2.4. Condition 4 – original dated 11/12/2014

To mitigate impacts to **threatened species**, the **approval holder** must submit the Flora and Fauna Management Sub Plan and Construction Environment Management Plan to the **Department** for approval prior to **commencement**. The Plans must include the additional mitigation measures not included in the **management plans** and as described in the **Biodiversity Offset Strategy**. The approved **plans** must be implemented.

Action		Timing	Status	Compliance evidence
4.1	Submit Flora and Fauna Management Plan and Construction Environment Management Plan to the Department	Prior to commencement	Compliant Complete	The CEMP and FFMP were submitted to DoEE on the 17 & 22 December 2014.
4.2	Plans must include the additional mitigation measures not included in the management plans as described in the Biodiversity Offset Strategy.	Prior to commencement	Compliant Complete	The plans were accepted by DoEE on the 9 January 2015.
4.3	Implement the FFMP and CEMP	Construction	Compliant Ongoing	Compliance with the FFMP and CEMP is monitored on site. The Project team included an independent Environmental Representative to monitor compliance with these documents.

Compliance with the CEMP and FFMP is reviewed regularly by TfNSW and Pacifico. There were no non-compliances relating to the FFMP. The Project is continuing to implement the CEMP during construction activities.

2.5. Condition 5 – original dated 11/12/2014

In the event of any inconsistency, ambiguity or discrepancy between the **management plans** and the Flora and Fauna Management Plan or the Construction Environmental Management Plan, the **management plans** have precedence.

Action		Timing	Status	Compliance evidence
5.1	Identify discrepancies in the CEMP/FFMP and Management Plans	Construction Operation	Compliant Ongoing	No discrepancies noted

2.6. Condition 6 – original dated 11/12/2014

Prior to commencement, the approval holder must amend the monitoring program proposed in the **Threatened Flora Management Plan** to:

a) include detailed monitoring methodology designed to monitor the success of the management and mitigation measures proposed for pre-construction, construction and operations; and
b) ensure all performance thresholds, corrective actions and monitoring/timing frequency are specific, measurable, auditable, enforceable and time-bound to monitor the success of the management and mitigation measures proposed.

Action	Timing	Status	Compliance evidence
6.1 Update the TFMP to include detailed monitoring methodology designed to monitor the success of the management and mitigation measures	Prior to commencement	Compliant Complete	The TFMP has been approved by DoEE on the 9 January 2015;
6.2 Update the TFMP to ensure all performance thresholds, corrective actions and monitoring/timing frequency are specific, measurable auditable, enforceable and time-bound	Prior to commencement	Compliant Complete	The TFMP has been approved by DoEE on the 9 January 2015.

2.7. Condition 7 – original dated 11/12/2014

The **approval** holder must not **commence** the **action** until the **Threatened Flora Management Plan** has been approved by the **Minister.** The approved **Threatened Flora Management Plan** must be implemented.

Action		Timing	Status	Compliance evidence
7.1	The action must not commence until the TFMP is approved by the Minister	Prior to commencement	Compliant Complete	The TFMP was approved by DoEE on the 9 January 2015.
7.2	Implement the TFMP	Construction Operation	Compliant Ongoing	Translocation Annual Report Ecological Monitoring Report

Further details on the monitoring undertaken are provided in the Annual Ecological Monitoring Report in Appendix 1.

2.8. Condition 8 – original dated 11/12/2014

The **approval holder** must monitor all mitigation measures until they are demonstrated to be successful, and with written agreement from the **Department**.

Action		Timing	Status	Compliance evidence
8.1	Monitor implementation of the mitigation measures	Construction and Operation	Compliant Ongoing	Ecological Monitoring Annual Report This Report
8.2	Obtain written agreement from the Department that all mitigation measures have been demonstrated as successful	Completion of construction and operation	Compliant TBA	Written agreement with the Department

2.9. Condition 9 – original dated 11/12/2014

If **MNES** not previously identified and reported to the **Department**, are found in the **action** area, the **approval holder** must notify the **Department** in writing within five business days of finding the **MNES**, and within a further 30 business days, the **approval holder** must outline in writing how **impacts** to these **MNES** will be avoided, mitigated and/or **offset**.

Action		Timing	Status	Compliance evidence
9.1	Notify the Department in writing within five business days of finding MNES	Pre-Construction, Construction, Operation	Ongoing	No additional EPBC listed species have been identified during the reporting period.
9.2	Outline in writing within 30 business days how the impacts to MNES will be avoided, mitigated and/or offset	Pre-Construction, Construction, Operation	Ongoing	No additional EPBC listed species have been identified during the reporting period.

2.10. Condition 10 – variation dated 21/08/2019

Prior to **commencement**, all **management plans** must be made publicly available on the **approval holder's website**, and these must remain available for 10 years following **commencement**. The monitoring results must also be made available on request for the duration of the **approval**.

Action		Timing	Status	Compliance evidence
10.1	Upload Management Plans on to the public website	Construction Operation	Compliant Complete	All management plans uploaded to the TfNSW website at this link at Note 1.
10.2	Monitoring results must be made available on request for the duration of the approval	Construction Operation	Compliant Ongoing	Monitoring results are available on request.

Note 1: https://www.pacifichighway.nsw.gov.au/document-library/warrell-creek-to-nambucca-heads-upgrade-species-management-plans.

2.11. Condition 11 – variation dated 21/08/2019

The **approval** holder must make all monitoring results required by the **management plans** publicly available on the **approval holder's website** within two months of the monitoring event, and these must remain publically available for 10 years following **commencement**. The monitoring results must also be made available on request for the duration of the **approval.**

Action		Timing	Status	Compliance evidence
11.1	All monitoring results to be uploaded to the Project website	Construction Operation	Compliant Ongoing	Monitoring data has been published on the project website in accordance with the timeframes at the link at Note 1. Monitoring results are available on request.

Note 1: https://www.pacifichighway.nsw.gov.au/document-library?keyword=Warrell%20Creek%20to%20Nambucca%20Heads&date_from=&date_to=

2.12. Condition 12 - original dated 11/12/2014

To compensate for the loss of threatened species habitat, within 12 months of the approval of the action, the approval holder must submit to the Minister for approval a Biodiversity Offset Package. The Package must:

a) provide known **habitat** and compensate for the residual significant **impacts** on the **threatened species** and their **habitat** in Condition 1a) to e);

b) demonstrate consistency with and meets the requirements of the **EPBC Act Environmental Offsets Policy**;

a) detail the **offset attributes** (including maps in electronic Geographic Information System (GIS) format with accompanying **shapefiles**), site descriptions environmental values relevant to **threatened species** being **offset**, connectivity with other **habitat** and biodiversity corridors;

b) include detailed surveys and quantitative and qualitative descriptions of any proposed **offset areas** which clearly identify **baseline** conditions. This must include:

   i. a **baseline** description (prior to any management activities) of the current **quality** of the **habitat** for each relevant **threatened species** in each **offset area**, including the location of survey points (GPS reference);

   ii. the quantity (in hectares) of suitable **habitat** present within the **offsets areas** for the **threatened species** the **quality** of the **habitat** for the relevant **threatened species** found within the **offset areas**;

   iii. vegetation condition mapping; and

   iv. photo reference points.

c) be prepared by a **suitably qualified ecologist**;

d) include conservation and management measures for long-term protection and adaptive management of the **offsets** to improve **habitat** for **threatened species** within the **offset areas** from **baseline** conditions, including but not limited to:

   i. a map showing **offset areas** to be managed;

   ii. conservation management actions for each **offset area** and the details of methods to be used;

   iii. **offset** management must be consistent with **threat abatement plans** for **threatened species**;

   iv. the timing of management activity for each **offset area** and anticipated timeframes for achieving performance objectives;

   v. clear performance measures and performance indicators for each **offset area** including contingency actions, criteria for triggering contingency actions and a commitment to the implementation of these actions in the event that performance objectives are not met that will enable maintenance and enhancement of **habitat** within the **offset area**, as well as contribute to the better protection of individuals and/or populations of **threatened species** and their **habitat**;

      i. a monitoring program to assess the effectiveness of the management actions measured against the **baseline** condition. This must include, but not be limited to, control sites and periodic ecological surveys to be undertaken by a **suitably qualified ecologist**;

      ii. a risk assessment and a description of the contingency measures that would be implemented to mitigate these risks;

      iii. details of the various parties responsible for the management, monitoring and implementing the management activities,

including their experience and qualifications and employment or engagement status; and

iv. details of qualifications and experience of persons responsible for undertaking monitoring, review, and implementation of the Biodiversity Offset Package, including the role of the **independent expert** in preparing, reviewing, and implementing the Biodiversity Offset Package; and

a description of protection and funding arrangements or agreements including work programs and responsible entities

Action	Timing	Status	Compliance evidence
12.1 Submit a BOP to Minister of DoEE for approval	Within 12 months of the approved action	Compliant Complete	The action was approved on 11 December 2014. The Biodiversity Offset Package was submitted for approval on 11 December 2015.

2.13. Condition 13 – original dated 11/12/2014

The **approval holder** must implement the approved Biodiversity Offset Package within 24 months of the date of this **approval**.

Action	Timing	Status	Compliance evidence
13.1 Implement the actions approved under the BOP	Within 24 months off approval	Compliant –	The BOP was approved by DoEE on 5/7/2017 and is currently being implemented. BioBanking applications for two sites were submitted to OEH on the 25 February 2018. The Norton offset site was secured on 18 February 2019 and the Swain offset site was secured on 22 February 2019.

A revised draft was submitted to DoEE for approval in November 2016. The revised Plan was approved by DoEE on 5 July 2017.

2.14. Condition 14 – original dated 11/12/2014

If an **offset** site proposed as a part of the Offset Package is already required to be protected as a result of a separate **EPBC Act** approval, only the management actions which can be demonstrated to be additional to those required for the separate approval, can be considered as an **offset** for this project. The legal protection of the site and management action required for separate approvals cannot be considered a part of the **offsets**, in accordance with the **Environmental Offsets Policy**.

Action	Timing	Status	Compliance evidence
14.1 Allocate offsets under the BOP from one section of a designated property. No cross over of allocation to occur.	Pre During and post construction	Compliant	There is no overlap between the WC2NH offset areas and any other project's offset areas.

To comply with the EPBC Act offset policy, Transport has allocated separate areas of the Norton property (503 ha in total) to each project as follows:

NH2U: 281 ha (includes 5 ha domestic exclusion area)

WC2NH: 185 ha

OH2K: 37 ha

A map showing the area dedicated to each property was included in the revised draft of WC2NH OMP (submitted for approval November 2016) and the NGOMP for NH2U. This will give DoEE confidence that no doubling or cross over of allocations between the approved projects has or will occur.

To-date in assessing the OH2K OMP and earlier drafts of the NGOMP and WC2NH OMP, DAWE have not raised any concerns with this approach.

2.15. Condition 15 – variation dated 25/09/2018

The **approval holder** must, within 36 months of the **approval** of the Biodiversity Offset Package, register a legally binding conservation mechanism to provide long-term protection to the **offsets** approved by the **Minister** in the Biodiversity Offset Package, which prohibits any activities that are not conservation activities from being undertaken in the **offsets.**

Action	Timing	Status	Compliance evidence
15.1 Register within 36 months of the approval of the Biodiversity Offset Package, a legally binding conservation mechanism to provide long-term protection to the offsets approved by the Minister in the Biodiversity Offset Package, which prohibits any activities that are not conservation activities from being undertaken in the offsets	36 months from BOP approval date	Ongoing due 5 July 2020	The BOP was approved by DoEE on 5 July 2017 and is currently being implemented.

The WC2NH Biodiversity Offset Package was approved by DoEE in July 2017. Transport is progressing with securing the offset properties as follows:

Offset property (tenure)	Offset mechanism	Status
Norton (TfNSW)	Bio Banking Agreement (provides a legally binding conservation mechanism under the Threatened Species Conservation Act)	BioBanking Agreement have been executed by OEH and registered on title on 18 February 2019.
Boambee now known as the Yuraarla Flora Reserve (Forestry Corporation NSW)	Newly declared Flora Reserve which provides a legally binding conservation mechanism under the Forestry Act.	Forestry Corporation NSW (FCNSW) supplied their compensation terms for this site which were approved by TfNSW in April 2018. FCNSW have advised TfNSW that are in the process of briefing their Minister to gazette the conservation agreement for the Yuraarla Flora Reserve by 5 July 2020.
Swain (private)	Bio Banking Agreement.	BioBanking Agreement have been executed by OEH and registered on title on 22 February 2019.

Transport sought a variation to this condition, providing detail on the progress with implementing the package and requesting a further 24 months to finalise the protection mechanisms on the 3 offset sites. This variation was approved by DoEE on 25 September 2018.

2.16. Condition 16 – variation dated 21/08/2019

If within 6 years, after impacts to **Grey-headed Flying-fox habitat**, the results of the monitoring required in the **Grey-headed Flying-fox Management Plan**, show that the Macksville Grey-headed Flying-fox Camp is abandoned by the Grey-headed Flying-fox, between September and May for two consecutive years, the **approval holder** must then offset within 48 months the entire 23.50 ha roosting habitat critical to survival, rather than 3.10 ha required by Condition , by a means approved by the **Minister**.

Note: The provision of the additional offset, if required, would be additional to the requirements of Condition 13-16.

Action	Timing	Status	Compliance evidence
16.1 Monitoring GHFF camp. From monitoring results, determine if camp unoccupied continually for 2 consecutive years within a 6 year monitoring period. If unoccupied provide for the full 23.50 Ha offset area else provide for the 3.1 Ha.	Completion by 1 May 2023	Ongoing	Monitoring of the Macksville Grey-headed Flying-fox Camp found it to be abandoned by the Grey-headed Flying-fox, between September and May for two consecutive years on 31 May 2017. TfNSW is in the process of investigating suitable offset habitat.

2.17. Condition 17 – original dated 11/12/2014

Within 14 days after the **commencement** of the **action**, the person taking the **action** must advise the **Department** in writing of the actual date of **commencement**.

Action		Timing	Status	Compliance evidence
17.1	Advice in writing to be provided to DoEE 14 days after the commencement of the action.	14 days after the commencement of the action	Complete	A letter was provided to DoEE by TfNSW on the 17 February 2015. The Commencement date for the action was the 9 February 2015.

2.18. Condition 18 – original dated 11/12/2014

The **approval holder** must notify the **Department** in writing of potential non-compliance with any condition of this **approval** as soon as practical and within no later than two business days of becoming aware of the non-compliance. The notice provided to the **Department** under this condition must specify:

a) the condition which the **approval holder** has potentially breached;

b) the nature of the non-compliance; and

c) when and how the **approval holder** became aware of the non-compliance.

Further to providing any such notice, the **approval holder** must provide the following information within 10 business days of becoming aware of a potential non-compliance:

a) how the non-compliance will affect the anticipated impacts of the **approved action**, in particular how the non-compliance will affect the impacts on the **MNES**;

b) the measures the **approval holder** will take to address the impacts of the non-compliance on the **MNES** and rectify the non-compliance; and

c) the time by when the **approval holder** will rectify the non-compliance.

Action	Timing	Status	Compliance evidence
18.1 Details of any non-compliance to be reported to DoEE within 2 business days of being made aware of the non-compliance	Construction	Compliant Ongoing	No non-compliances were reported to the Department during the reporting period.

2.19. Condition 19 – variation dated 21/08/2019

Within three months of every 12 month anniversary of the **commencement** of the **action**, the **approval holder** must publish a report on its **website** addressing compliance with each of the conditions of this **approval**, including implementation of any **management plan, package** as specified in the conditions. **Documentary** evidence providing proof of the date of publication must be included in the published **compliance report**. The **compliance report** must remain on the **website**, for 10 years following **commencement**. The monitoring results must also be made available on request for the duration of the **approval**. Reports of any non-compliance must also be included in the annual **compliance report.** The **approval holder** must continue to publish the report until such time as agreed in writing by the **Minister**.

Action		Timing	Status	Compliance evidence
24.1	Prepare compliance report and upload to project website	By 9 May 2016	Compliant 9 May 2019	Report uploaded to project website. Advice provided to Dept. on date of publication.
24.2	Prepare compliance report and upload to project website	By 9 May 2017	Compliant 4 May 2019	Report uploaded to project website. Advice provided to Dept. on date of publication.
24.3	Prepare compliance report and upload to project website	By 9 May 2018	Compliant 4 May 2019	Report uploaded to project website. Advice provided to Dept. on date of publication.
24.4	Prepare compliance report and upload to project website	By 9 May 2019	Compliant 9 May 2019	Report uploaded to project website. Advice provided to Dept. on date of publication.
24.5	Prepare compliance report and upload to project website	By 9 May 2020	Compliant 30 Mar 2020	Report uploaded to project website. Advice provided to Dept. on date of publication.

Compliance reports are published at https://www.pacifichighway.nsw.gov.au/document-library/warrell-creek-to-nambucca-heads-upgrade-epbc-compliance-reports

2.20. Condition 20 – variation dated 21/08/2019

The **approval holder** must maintain accurate **compliance records** substantiating all activities associated with or relevant to the conditions of **approval**, including measures taken to implement the **management plans** and **package** required by this **approval**, and make them available upon request to the **Department**. Such **compliance records** may be subject to audit by the **Department** or an independent auditor in accordance with section 458 of the **EPBC Act**, or used to verify compliance with the conditions of **approval**. Summaries of audits will be posted on the **Department's website**. The results of audits may also be publicised through the general media.

Action	Timing	Status	Compliance evidence
20.1 Maintain compliance records for the management plans	Construction, operation	Ongoing	Compliance records are maintained on the relevant TfNSW document management systems or available on the Project Website.
20.2 Maintain compliance records for the Biodiversity Offset Strategy	Construction, operation	Ongoing	Throughout the reporting period, TfNSW has undertaken routine property inspections and maintenance of the Norton property. This has included weed control, cattle exclusion and track maintenance. TfNSW reports to the Biodiversity Conservation Trust to demonstrate compliance with the management plan. The Swain property is protected under stewardship agreement management by the Biodiversity Conservation Trust. This involves monitoring and reporting to ensure that the land owner is managing the property in accordance with the management action plan attached to the stewardship agreement.

2.21. Condition 21 – original dated 11/12/2014

Upon the direction of the **Minister**, the **approval holder** must ensure that an independent audit of compliance with the conditions of **approval** is conducted and a report submitted to the **Minister**. The audit must not commence unless and until the **Minister** has approved the independent auditor and audit criteria. The audit report must address the criteria to the satisfaction of the **Minister.**

Action		Timing	Status	Compliance evidence
21.1	Prepare independent audit of compliance with the conditions of approval if directed by the Minister to do so.	When Directed	TBA	An independent audit of the conditions of approval has not been required during the reporting period.

2.22. Condition 22 – variation dated 21/08/2019

If the **approval holder** wishes to carry out any activity otherwise than in accordance with a **management plan** or **package** as specified in the conditions, the **approval holder** must submit to the **Department** for the **Minister's** written approval a revised version of that **management plan** or **package**. The varied activity must not commence until the **Minister** has approved the varied **management plan** or **package** in writing. The **Minister** will not approve a varied **management plan** or **package** unless the revised **management plan** or **package** would result in an equivalent or improved environmental outcome over time. If the **Minister** approves the revised **management plan** or **package** that **management plan** or **package** must be implemented in place of the **management plan** or **package** originally approved.

Action		Timing	Status	Compliance evidence
22.1	Provide updated management plan or package for approval	Construction Operation	Compliant Ongoing	Activities are undertaken in accordance with approved management plans. The GHFF Management Plan, STQ Management Plan and Koala Management Plan were updated to change the road kill monitoring program prior to the partial opening of Stage 2A. The updated plans were approved by DoEE on 12 of January 2018.

2.23. Condition 23 – variation dated 21/08/2019

If the **Minister** believes that it is necessary or convenient for the better protection of **MNES** to do so, the **Minister** may request that the **approval holder** make specified revisions to a **management plan** or **package** required by the conditions and submit the revised **management plan** or **package** for the **Minister's** written approval. The **approval holder** must comply with any such request. The revised **management plan** or **package** must be implemented. Until the **Minister** has approved a revised **management plan** or **package**, the **approval holder** must continue to implement the previously approved **management plan** or **package**, as specified in the conditions.

Action	Timing	Status	Compliance evidence
23.1 Update the Management Plan or Package in response to a direction from the Minister and provide for approval.	As directed	TBA	No updates to the management plans or package have been required.

2.24. Condition 24 – original dated 11/12/2014

If, at any time after five years from the date of this **approval**, the **approval holder** has not **commenced** the **action**, then the **approval holder** must not **commence** the **action** without the written agreement of the **Minister.**

Action		Timing	Status	Compliance evidence
24.1	Notify the Minister of the commencement of the action	Prior to Commencement	Compliant Complete	TfNSW notified the Minister of the commencement of the action on the 17 February 2015.

2.25. Condition 25 – variation dated 21/08/2019

Unless otherwise agreed to in writing by the **Minister**, the **approval holder** must publish the **management plans, package** and **monitoring data** in these conditions of approval on its **website**. Each **management plan** and **package** and **monitoring data** must be published on the **website** within one month of being approved (unless otherwise specified in these conditions) or within one month of data collection.

Action	Timing	Status	Compliance evidence
25.1 Publish management plans on the Project Website	Construction Operation	Compliant Complete	Management Plans uploaded onto the project website
25.2 Publish the Biodiversity Offset Package on the Project Website	Construction Operation	Compliant Complete	The Biodiversity Offset Package has been published on the project website
25.3 Publish monitoring data onto the website	Construction Operation	Compliant Ongoing	Monitoring data has been published on the project website in accordance with the timeframes.

2.26. Condition 26 – variation dated 21/08/2019

The **approval holder** must notify the **Department** within 5 business days of publishing the **management plan, package** or **monitoring data** on their website and the **management plan, package,** and **monitoring data** must remain on the **website** for 10 years following the final monitoring event required by this approval or **management plan**.

Action		Timing	Status	Compliance evidence
26.1	Management plans uploaded on TfNSW website	With 5 days	Compliant	The CEMP TFMP and FFMP were uploaded on the project web site on 17 February 2015. Plan revisions have been uploaded onto the project website with notification provided to DoEE within 5 business days of publication.
26.2	Monitoring data uploaded on TfNSW website	In accordance with approval	Compliant	TfNSW provides email notification to the Department's 'EPBC Monitoring' mailbox within 5 days of publishing relevant information onto the project website

Appendix 1 Management Plan Reports for the reporting period 2018-2019

Transport
Roads & Maritime
Services

Warrell Creek to Nambucca Heads Koala Monitoring

Annual report 2018-19

Roads and Maritime Services | September 2019

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Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
30/9/2019	1	Draft	S. Hardiman	RMS	MSW	D. Rohweder

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Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
10/10/2019	2	Final	S. Hardiman	RMS	MSW	D. Rohweder

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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, underpasses, vegetated median, roadkill, 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.

The following report details the results pertaining to koala in the first year of operation. The report summarises results obtained from three monitoring tasks: koala population surveys; monitoring of underpasses and adjacent habitats and yellow-bellied glider population monitoring in Nambucca State Forest. 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).

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 the species 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 satisfied that criteria); the Project was considered to constitute a significant impact on the Koala as per SEWPaC (2012) and DoE (2013a) guidelines. A Koala Plan of Management (KMP) was prepared to manage impacts on koalas during the pre-construction, construction, and operational phases of the project (Geolink 2017a).

Measures implemented to minimise impacts on koalas include:

- Population monitoring to determine the effectiveness of mitigation measures and project impacts.
- Construction phase pre-clearing surveys, staged clearing, project inductions, Environmental Work Method Statements, rescue procedure, and installation of temporary barriers.

- 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.
- Habitat offsets.

The objective of the baseline koala population monitoring was to determine the pre-impact (baseline) densities, distribution and usage of habitats within proximity to the WC2NH project. Ongoing monitoring aims 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).

Baseline surveys were 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 2017b) and year one operational surveys were conducted in spring 2018 (Sandpiper Ecological 2018a).

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.

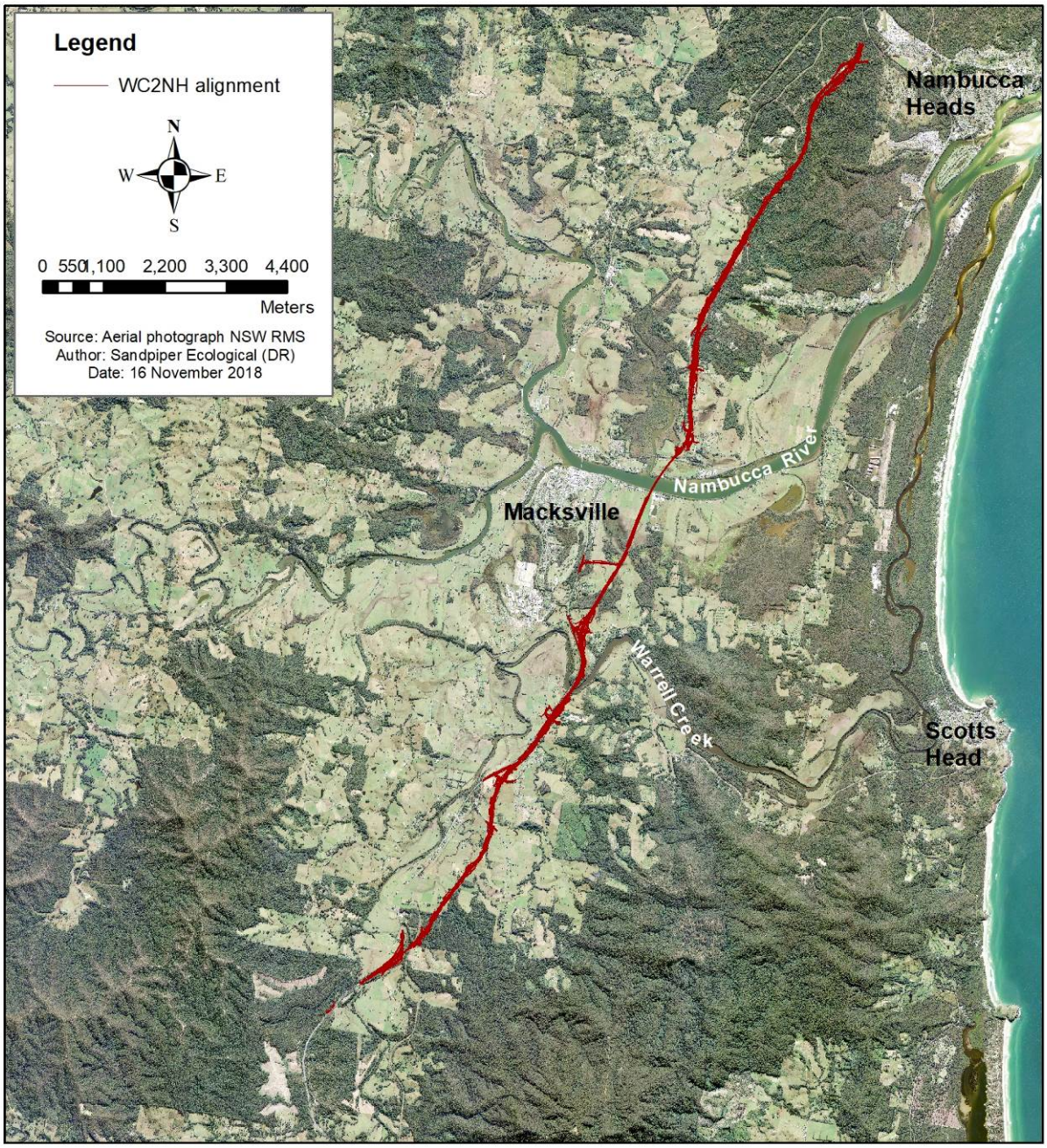

Figure 1: Location of the WC2NH alignment.

2. Methods

Methods used to sample koalas are summarised in the year one operational phase koala population monitoring report (Sandpiper 2018a), year 1 operational phase underpass monitoring report (Sandpiper 2019a), year one operational phase yellow-bellied glider population monitoring report (Sandpiper 2019b).

3. Results

3.1 Koala population surveys

3.1.1 Transect surveys

One koala was recorded on transect W11 during the spring 2018 sample event (Table 1; Figure 2). An unconfirmed koala call was heard west of transect W7 on 12 November 2018 but the location of that call remains unconfirmed. Koala scats were recorded beneath three tallowwood trees (*Eucalyptus microcorys*), two on transect E10, and one on transect E19 (Table 2; Figure 2).

3.1.2 Tracks and easements

Two confirmed koala records were obtained during surveys of tracks and easements, one during the day between transects E18 and E19, and one at night between transects W20 and W21 (Table 1; Figure 2). Two individuals appeared healthy (dry bottom and clear eyes) and diagnostic features could not be determined for the third individual. One individual was a female and the sex of the other two individuals could not be determined. The individual recorded on 13/11/2018 was recorded in the same tree during the day and night surveys.

3.1.3 Habitat use and distribution

Koalas were recorded using both Open Blackbutt Forest on ridges and midslope, and Flooded Gum Moist Open Forest in gullies. Occupied tree species included flooded gum (*Eucalyptus grandis*), tallowwood (*Eucalyptus microcorys*), and white mahogany (*Eucalyptus* spp). Scats were recorded beneath tallowwoods only.

In 2018, koala records occurred in the southern third and centre of the study area (Figure 2). Records near transects 19, 20 and 21 were in a similar area to records in 2017 and 2014 (Figure 2). The 2018 record on transect W11 was within 150m of a record in 2015. Koala scats recorded on E10 were near a koala record from 2017. The scats recorded at the east end of E19 may be from the individual recorded adjacent to the alignment between E18 and E19 in spring 2018 (Figure 2).

3.2 Underpass monitoring

Koalas were detected using underpasses, by cameras and sandpads, in both the spring/summer and winter sample periods (Table 3). In spring/summer, cameras detected koalas making 15 complete crossings of the carriageway distributed across four sites. In winter, cameras detected a koala making a complete crossing at one site. Site 4 was the most regularly used underpass with 11 complete crossings recorded in year one of the operational phase (Figure 2). Koala tracks were detected in sandpads on 4 occasions at site 4 in spring/summer (Table 3). No koala tracks were recorded during

sandpad monitoring in winter 2019, however tracks were recorded at sites 4, 9 and 10 during the scat and track surveys. Koalas were recorded moving both east and west.

3.3 Opportunistic records

Opportunistic records of koalas were collected whilst conducting year one and two spotlight surveys for yellow-bellied glider and fox baiting at selected underpasses. Five koalas were recorded during these surveys, four adults, and one back young. During yellow-bellied glider surveys one individual, was recorded on 28/11/2018, close to the alignment at chainage 58,400, and three individuals, two adults and one back young, were recorded on 2 September 2019. Both of the latter records were west of the north coast rail line. One koala was recorded crossing culvert 9 / 10 on 18 September 2019 during feral pest control baiting (Plate 1).

Plate 1: Koala recorded at underpass 9/10 on 18 September 2019.

3.4 Koala distribution

Koala records obtained during year one of the operation phase show that the species continues to use habitat on both sides of the carriageway and records obtained from underpass monitoring prove that individuals are utilising dedicated underpasses to move across the carriageway. Koalas have been sighted in Nambucca State Forest within 650m of underpasses at chainages 57700, 59100, and 59740 but not near the northern underpass (Site 11 & 12) at chainage 60500. Apart from a record during the baseline population surveys koalas have not been recorded during construction or operation phase spotlight surveys near Site 4 at chainage 57700. This is despite 11 complete crossings in year one of the operation phase. Comparison between spotlight and underpass records suggests that individuals are moving distances of at least 650m between feed trees and the highway. It is likely that some of the koalas detected in underpasses are additional to those individuals detected during spotlight surveys.

3.5 Road kill surveys

No koalas were recorded during roadkill surveys conducted quarterly between October 2018 and August 2019 (Sandpiper 2018b, 2019c, 2019d, 2019e).

Table 1: Koalas recorded during the spring 2018 population monitoring surveys in Nambucca State Forest. Uk = unknown; F = female

Date	Easting	Northing	Time of observation	Closest transect & distance (m)	Survey type	Occupied tree	Habitat type	Tree height (m)	Tree diameter (mm)	Sex	Behaviour	Disease status	Reproductive status	Side of carriageway
12/11/2018	496198	6609663	Night	W11; 26	Transect	Flooded gum	Flooded Gum Moist Forest	35	340	Uk	Resting on lateral branch	Healthy	Uk	West
13/11/2018	496270	6608294	Day	E18; 59	Track & easement	Tallowwood	Open Blackbutt Forest	18	440	Uk	Resting – curled in tight ball; recorded during following night survey	Uk	Uk	East
20/11/2018	495941	6608102	Night	W21; 59	Track & easement	White mahogany	Open Blackbutt Forest	8	150	F	Resting on branch	Healthy	Uk	West

Table 2: Location of koala scats recorded during spring 2018 koala population monitoring surveys in Nambucca State Forest. Datum – GDA 94.

Transect	Evidence	Distance from alignment (m)	Easting	Northing	Date
E10	Old scats beneath tallowwood	241	496903	6609380	14/11/2018
E10	Old scats beneath tallowwood	424	497068	6609298	14/11/2018
E19	Very old scats beneath tallowwood	540	496652	6607950	13/11/2018

Table 3: Koalas recorded during underpass monitoring in year one operational phase monitoring for the WC2Nh upgrade. P = present.

Site	Complete crossings (cameras)		Sand pad detections	
	Spring/Summer 2018	Winter 2019	Spring/Summer 2018	Winter 2019
C4	10	1	4	P
C7	2			
C9 & 10	1			P
C11 & 12	2			
Total	15	1		

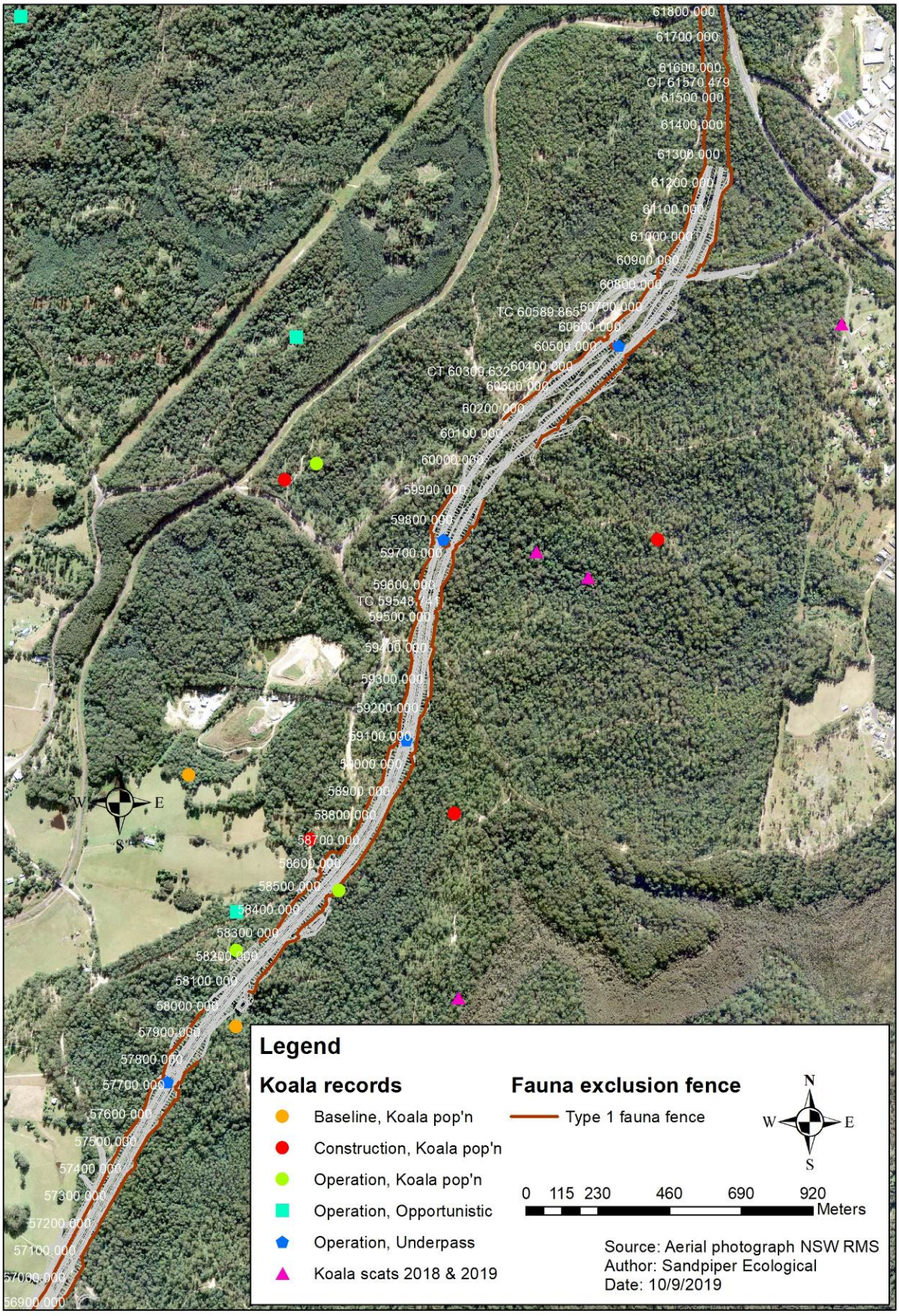

Figure 2: Location of koala records obtained between 2014 and 2019 during surveys for the WC2NH Pacific Highway Upgrade.

4. Discussion

4.1 Koala population

The same number of koalas (3 individuals) was recorded during the spring 2018 and spring 2017 population surveys. This was substantially more than the single individual recorded during baseline surveys and year one of the construction phase (Table 4). Possible variation in methods between surveys, particularly effort expended on tracks and easements where most koalas are recorded, makes it impossible to draw conclusions on whether koala abundance has increased or decreased due to the WC2NH upgrade.

Table 4: 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

The results show that koalas continue to reside in habitat immediately adjoining the highway and, based on the distribution of koala records in underpasses, it is likely that additional koalas reside near the alignment. The presence of an advanced back young in September 2019 shows that the population is breeding. The year one operational phase monitoring results support the suggestion that the study area has a low-density koala population (Geolink 2017).

Spotlight surveys sampled approximately 104ha of habitat. Three koalas within an area of 104ha is broadly consistent with published home range estimates for males in northern NSW of 22.7ha at Bonville to 37.4ha at Lismore (Lassau *et al.* 2008; Goldingay & Dobner 2014). Home range size of koalas in Nambucca State Forest is expected to be larger than at nearby Bonville due to the lower quality of habitat and forest management history.

Whilst it is impossible to confirm the impact that clearing for the upgrade had on the local koala population the continued presence of individuals around the alignment suggests that impacts have been managed and at this stage do not seem irreversible. Another positive sign is that two of the three individuals observed in spring 2018 appeared healthy, and the health status of the third individual could not be determined.

4.2 Habitat use and distribution

Koala sightings and scat records obtained over the course of monitoring are beginning to reveal a pattern of koala habitation. Koalas have consistently been recorded over a 1km long section of the alignment, between chainages 57900 and 58900, with fewer but consistent records between chainages 59700 and 60700. Underpass monitoring has confirmed use of four culverts with regular use in the southern cluster of records (i.e. Site 4) and occasional use in the

northern cluster. The pattern of underpass use may reflect home range extent and differences in movement patterns between male and female, or areas of varying habitat quality.

The presence of koalas in habitat immediately adjoining the highway and several confirmed crossings of underpasses in spring/summer 2018 and winter 2019 (Sandpiper Ecological 2019a) suggests that some individuals have re-established home ranges to the new forest edge and others have home ranges that encompass the highway.

4.3 Compliance with koala plan of management

The WC2NH upgrade has complied with goals one and two of the KMP (Table 5). Monitoring has shown that connectivity has been maintained with koalas making complete crossings at four sites over a 2.9km section of upgrade, and moving both east and west. The available data do not enable a robust temporal comparison of koala density, however, numbers recorded have been consistent between construction and operation, and greater than baseline. No koalas have been recorded during quarterly roadkill surveys and fauna exclusion fence is in good condition.

Goal 3 has been partially achieved. Plantings were undertaken around culvert entrances to improve connectivity with adjacent forest. Ongoing defect work, drought, and cattle (1 site) have had a negative impact on plants. Now that construction work has ceased it is essential that greater emphasise be placed on ensuring underpass plantings become established in the short-term (i.e. 2-3yrs).

Table 5: Compliance with Table 6.1 from the Koala Management Plan.

Main goal	Performance criteria	Has performance criteria been satisfied	Corrective action required
Maintain connectivity for Koalas potentially occurring either side of the upgrade.	No change to densities, distribution, habitat use and movement patterns compared to baseline Koala population data.	**Yes.** Koala abundance in year one is consistent with the construction phase and greater than the pre-construction (baseline) phase. Koalas continue to occur both sides of the highway and regular movement beneath the highway has been recorded over a 2.9km section of carriageway in Nambucca State Forest.	No corrective action required. Continue underpass and koala population monitoring.
Minimise road kill of Koala during operation of the WC2NH Project.	All fauna fencing is installed at the minimum of locations as identified in the EPBC approval prior to the operational phase of the WC2NH Upgrade.	**Yes.** No road killed koala were recorded in year one of the operation phase. Fauna exclusion fence remains in good condition.	No corrective action required. Continue road kill monitoring.
Maintain habitat rehabilitation areas.	Self-sufficient areas of rehabilitated habitat for Koalas within all nominated areas.	**Partial.** Plantings were undertaken in areas around culverts, however, a number of areas have been impacted by ongoing defect work around culverts and drought conditions. Where construction works have been completed in other fauna connectivity areas they are being planned for planting in accordance with the plan..	Yes. Dead plants need to be replaced and remaining live plants maintained. All connectivity plantings will be included in project Landscape Maintenance Plan to ensure plantings become established in the short-term (i.e. 2-3yrs).

5. Recommendations

1. Ensure koala habitat rehabilitation sites become established in the short-term (i.e. 2-3yrs). This could be achieved by integrating management of fauna connectivity plantings into the Landscape Maintenance Plan.
2. Continue to monitor growth and establishment of fauna connectivity plantings.

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Customer feedback
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September 2019

Transport
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Warrell Creek to Nambucca Heads

Underpass Monitoring Report – year one operational phase 2018-2019

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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 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-foxes, yellow-bellied glider, giant barred frog, green-thighed frog ponds, fauna underpasses, vegetated median, roadkill, exclusion fencing, and threatened flora. Sandpiper Ecological Surveys (Sandpiper) was contracted by RMS 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). Inspection of the exclusion fence occurs annually in winter and is reported on here.

The following annual report presents methods and results of the spring/summer 2018 and winter 2019 underpass and adjacent habitat surveys conducted in year one of the operational phase. Discussion and recommendations are developed in accordance with the project brief and the potential indicators of success as outlined in the Ecological Monitoring Program (EMP). 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 sites with box culverts, three sites with pipe culverts and seven sites with 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 a dry cell. 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 the 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 consists of dual cell 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 over Upper Warrell Ck		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	

Site	Chainage	Type	Structure	Dimensions	Fauna Furniture (P/A)	Substrate	SQ	K	GBF
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.

2. Methods

2.1 Timing and weather conditions

Spring/summer underpass monitoring was conducted between 15 October and 17 December 2018. Winter underpass monitoring was conducted between 11 June and 27 August 2019. Weather conditions over the spring/summer sample period were characterised by warm humid conditions with small amounts of rain (10-30mm) occurring at regular intervals (Table 2). Weather conditions over the winter sample period were characterised by mild temperature and low rainfall (Table 2). Rain events of 20-30mm during spring monitoring created moist conditions in underpasses conducive to movements by amphibians. Daily weather conditions recorded at the northern compound are presented in Tables B1 and B2, Appendix B.

Table 2: Summary of weather conditions recorded at the northern compound of the project site between 20 October and 20 December 2018 and between 1 June and 31 August 2019.

Monitoring period	Total rainfall	No. rain days	Max wind gusts	Relative Humidity	Max temp range (^{0}C)	Min temp range (^{0}C)
Spring/Summer	223mm	19	13-50kph	>70% on 90% of days	22.2-33.9	9.4-22.9
Winter	143.6mm	17	9.5-64kph	>70% on 83% of days	15.8-27	1.2-13.9

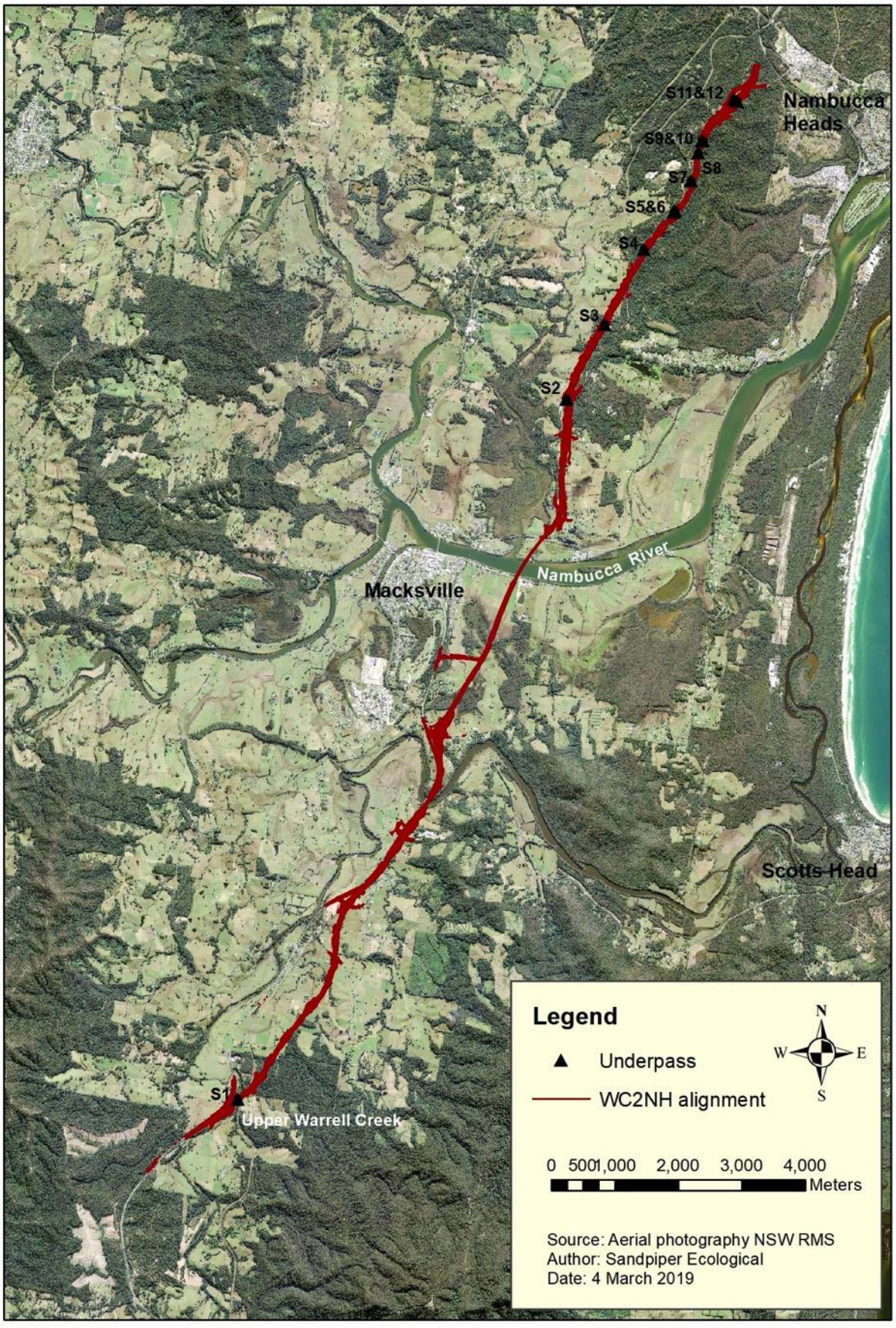

Figure 1: Location of underpass sample sites in relation to the WC2NH alignment.

2.2 Underpasses

2.2.1 Sand pads

During the spring/summer sampling period, sand pads were installed on 30 October (sites 2-12) and 14 November 2018 (site 1). During the winter sampling period, sand pads were installed on 14 June 2019. 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. 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 only covered the ledge due to standing water over the culvert floor.

Sand pads were inspected on eight consecutive days, 31 October to 7 November at sites 2-12 and 15-22 November at site 1 during the spring/summer sampling period and 14 June to 22 June 2019 during the winter sampling period. 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). Pad condition focussed on suitability of the pad for registering good quality animal tracks. 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 for scats and tracks on two occasions during each sample period. In spring/summer, sites 2-12 were sampled on 17 and 31 October and site 1 was sampled on 26 October and 8 November. During the winter sample, all sites were surveyed first on 12 and 13 June 2019 and second on 19 July 2019. 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 Cameras

Two motion activated infra-red cameras were installed centrally in each underpass except at site 1 where a single camera, fixed to a star picket, was installed on each side of Warrell Creek, and site 5 where one camera was installed centrally in each cell. In total, 24 cameras were installed. Swift Enduro cameras were used at sites 2-12 and Reconyx HC500 cameras were used at site 1. In underpasses, both cameras were installed centrally, one on the fauna furniture, and one approximately 300mm above the culvert floor. All cameras were oriented to the east except for cameras at site one that were oriented to the north on the north side of Warrell Creek and south on the south side of Warrell Creek. The floor camera at site 9 was re-orientated to the west after false triggers were recorded during spring/summer sampling. Swift cameras were set to take 10 seconds of video with no delay between activation. Cameras at site 1 were positioned at approximately 1m above ground level and oriented towards ground vegetation near the creek bank. Reconyx cameras were set on time-lapse mode to take a picture at 1-minute intervals between 8pm and 6am each day throughout the spring/summer sample period and between 5pm and 6am during the winter monitoring 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).

During the spring/summer sample period, cameras at sites 2-12 were installed on 16 and 17 October, with cameras at site 1 installed on 24 October. Cameras at sites 2-12 were checked on 21 and 22 November, and at site 1 on 14 November. Images were downloaded and batteries replaced, if capacity was below 50%. Cameras were retrieved on 17 December 2018. The total spring/summer sample period was 63 days at sites 2-12 and 54 days at site1. Three cameras were damaged and one stolen on 14 December 2018. All damaged and stolen cameras were at sites 9 and 10. SD cards in the three damaged cameras were readable and data were lost from the fauna furniture camera at site 9 only. During the winter 2019 sample period cameras were installed on 17 and 18 of June and checked on 19 July 2019. Images were downloaded and batteries replaced, if capacity was below 50%. Cameras were retrieved on 27 August 2019, a sample period of 80 days.

The total number of sample days in spring summer was 1300 across all sites, with 1636 sample days recorded in winter 2019 (Table 3). A total of 2936 sample days was recorded during year one of the operational phase (Table 3). In spring/summer 11 of the 24 cameras were active for less than the 60-day minimum sample period, although two of these cameras, both at site 5, were active for 58 days each, one camera was stolen and three were damaged. During winter 2019, three cameras were active for less than the 60-day minimum sample period, and one of these was active for 58 days. Eight cameras were active for less than 120 days across both sample periods, with three of these active for between 110 and 119 days. Camera theft (at site 10) and a high incidence of false triggers, due high pedestrian activity, contributed to the low number of sample days at some sites.

Table 3: Camera survey effort during year one operational phase monitoring**.**

Location	Cam location	Days active		
		Spr/Sum	Winter	Total
1	North	49	52	101
	South	54	68	112
2	Furniture	63	72	135
	Floor	25	72	97
3	Furniture	29	72	101
	Floor	48	72	120
4	Furniture	63	72	135
	Floor	63	72	135
5	North	58	72	130
	South	58	72	130
6	Furniture	63	72	135
	Floor	63	72	135
7	Furniture	40	72	112
	Floor	63	72	135
8	Furniture	63	72	135
	Floor	63	72	135
9	Furniture	60	72	132
	Floor	60	72	132
10	Furniture	37	72	109
	Floor	43	18	61
11	Furniture	64	72	136
	Floor	63	72	135
12	Furniture	45	72	117
	Floor	63	58	121
Totals		1300	1636	2936

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). Input from multiple ecologists was sought to identify some images.

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 underpass camera. An incomplete crossing was scored when an animal showed no directional movement (i.e. remained stationary in front of camera) or when an animal 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. If a species could not be identified or assigned to a group, it was labelled as “unidentified species”. Microbats detected were recorded as presence only due to their transient nature and not being reliant on underpasses for thoroughfare.

2.3 Adjacent habitat

2.3.1 Survey design

A total of 18 sites were sampled at the 12 underpasses as part of the adjacent habitat surveys, with one site established on each side of an underpass or underpass pair in the case of sites 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) 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), pipe traps, 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 12 and 21 November 2018 during the spring/summer sample and between 12 and 18 June 2019 during the winter sample.

Traps were set in a “X” formation with five ground and five arboreal traps (4 type B Elliott traps and 1 pipe trap in spring/summer and 5 type B Elliot traps in winter) 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. Pipe traps were replaced with type B Elliot traps in winter as no captures were recorded in pipe traps during spring/summer and to increase efficiency. 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, Elliott and pipe 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 26 October and 22 November 2018. Winter diurnal active searches were conducted between 12 and 16 June 2019. A total of 2236 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 occasions during each 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 8 and 22 November 2018 and winter surveys between 12 and 15 June 2019. A total of 2296 person minutes was 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 (S/S: 4 Type B Elliott traps and 1 pipe trap, W: 5 Type B Elliott traps)	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	2236 person minutes
Active nocturnal search	30 person minute search at UP entrance	2 samples/site	2296 person minutes

2.4 Exclusion fence

The entire length of the fauna exclusion fence was traversed on foot by one person on 15 June 2019. Any damage or holes in the fence where fauna could gain access to the highway 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 Sand pads

Seven species and 15 fauna groups were recorded during sand pad monitoring (Table 5). Two introduced species, cat (*Felis cattus*), and red fox (*Vulpes vulpes*), were confirmed and it is likely that at least some of the *Rattus* spp. tracks were from the introduced black rat (*R. rattus*). Koala (Phascolarctos cinereus) was recorded on four occasions at site 4 (Plate 3), all in spring/summer, and a possible long-nosed potoroo (*Potorous tridactylus*) was recorded from two track sequences in winter at site 8. Long-nosed potoroo is listed as vulnerable by the NSW *Biodiversity Conservation Act 2016* and the federal *Environment Protection and Biodiversity Conservation Act 1999*. Short-beaked echidna was recorded at sites 2 and 7, and brushtail possum (*Trichosurus* spp.) was recorded at sites 3, 7 and 8 (Plate 4). The highest diversity of species/groups was recorded at site 8 (12 species/groups). Cat was the most frequently recorded species with 106 track sequences, followed by red fox with 29, and lace monitor with 26 (Table 5). Small rodent spp. were recorded 51 times and Dasyuridae spp. 31 times (Table 5).

Plate 3: Koala tracks recorded on sand pads at Site 4 during spring/summer monitoring.

Plate 4: Brushtail possum tracks (L) and short-beaked echidna tracks (R) recorded during winter sand pad monitoring.

Table 5: Species and groups of fauna recorded during sand pad monitoring at 12 underpasses on the WC2NH upgrade. * possible record only, SS = Spring/Summer, W = Winter.

Species/group	1		2		3		4		5		6		7		8		9		10		11		12		Total sequences (SS)	Total sequences (W)	Total sequences year one
	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W			
Small Bird	2																								2		2
Medium Bird	1																								1		1
Waterbird	2																								2		2
Lace monitor							10						2		10						2		2		26		26
Small reptile	2								2														6		10		10
Medium reptile	1						2								2						2		3		10		10
Frog															2										2		2
Short-beaked echidna			10	4										2											10	6	16
Long-nosed potoroo*																2										2	2
Swamp wallaby		2											5												5	2	7
Wallaby spp.		1				4		2								1										8	8
Macropodidae spp.	1																								1		1
Dasyuridae spp			5						1		2	2			6		1					10			15	16	31
Peramelidae spp.			4		2				2						5									4	13		13
Koala							4																		4		4
Trichosurus spp.					2									6		9									2	15	17
Cat		2		2	16	37	4		4		1			9	6	4	1		2	2	4	4	4	4	42	64	106
Red fox			2		21		2				2				2										29		29
Rattus spp.			2						11								2								15		15
Canidae spp.					1																				1		1
Small rodent				1				4		4		16		4		2		10				6		4		51	51
Small mammal		2									1				2				1						4	2	6
Total species/group	6	4	5	3	5	2	5	2	5	1	4	2	2	4	8	5	3	1	2	1	3	3	4	3	19	9	22

3.1.2 Scat and track searches

Twelve species, five genera, and seven fauna groups were recorded during scat and track surveys of 12 underpasses (Table 6). Species recorded inside underpasses during the scat and track survey included: two bent-wing bats (*Miniopterus* spp) roosting at site 3, a minimum of six bent-wing bats at site 2, six *Nyctophilus gouldii* at site 11, and an eastern water dragon at site 5. Both little bentwing (*M. australis*) and eastern bentwing (*M. schreibersii*) are suspected to occur. Eastern water dragon was observed making a complete crossing of site 5. Possible long-nosed potoroo tracks were recorded on old sand pads at site 8 in spring/summer and winter. Koala tracks were recorded in old sand pads during the winter sample at sites 4, 9 and 10 (Table 6).

Table 6: Species and fauna groups recorded during track and scat surveys of 12 underpasses on the WC2NH upgrade. [I] = introduced species, * = Threatened species SS = Spring/Summer, W = Winter.

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				X								X				X		X		X				
Antechinus spp.				X																				
Small dasyurid												X												
Peramelidae spp.	X					X										X						X		
Koala*								X										X		X				
Trichosurus spp.								X					X	X		X								
Long-nosed potoroo *															X	X								
Eastern grey kangaroo				X																				
Swamp wallaby		X		X								X		X				X		X				
Macropodidae spp.	X	X						X					X	X										
Miniopterus spp. *				X	X																			
Nyctophilus gouldii																						X		
Microbat spp.						X			X	X												X		
Water rat										X														
House mouse										X		X						X		X				
Rodentia spp.	X			X	X				X	X							X							
Dog		X				X		X				X		X		X		X		X				
Fox [I]	X			X		X		X									X	X	X	X				
Cat [I]						X		X		X		X		X				X	X	X		X		X
Eastern water dragon	X								X															
Lace monitor		X		X						X						X								
Medium lizard		X																						
Amphibian (large)	X				X																			
Bird spp.		X			X																			
Total no. Species/groups	6	6	0	8	4	5	0	6	3	6	0	6	2	5	1	6	2	7	2	7	0	4	0	1

3.1.3 Cameras

Species richness

Twenty-one species, one genus and five fauna groups were recorded during underpass camera monitoring in spring/summer and winter (Table 7 & Table C1, Appendix C). Intermediate egret and white-throated treecreeper were the only species recorded that did not make complete crossings (Table C1, Appendix C). Koala was the only threatened species recorded, with individuals detected at sites 4, 7, 9, 11 and 12 (Table 7). Five introduced species were recorded. Cat and red fox were recorded at 11 sites, house mouse (*Mus musculus*) at six sites and black rat at five sites (Table 7). The highest fauna diversity was recorded at sites 3 and 8 with 11 species/groups each, followed by site 2 (10 species/groups), site 6 (nine species), and site 7 with eight species. The lowest diversity was recorded at site 10 where four species were recorded.

Table 7: Number of complete crossings recorded for each species and fauna group at 12 underpasses on the WC2NH upgrade in spring/summer and winter of year one operational phase. C = complete crossing; IC = incomplete crossing; * = threatened species [I] = introduced species SS = Spring/Summer; W = Winter; SB = Short-beaked; EW = Eastern water

Species/ Groups	Site and Season																								Total	S/S	W
	1		2		3		4		5		6		7		8		9		10		11		12				
	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W			
Short-beaked echidna	1		13	7												1									22	14	8
Northern brown bandicoot																1									1	0	1
Long-nosed bandicoot				1																		4		3	8	0	8
Peramelidae spp.															1	5									6	1	5
Koala							10	1					2				1				2		2		18	17	1
Short-eared brushtail possum					1								8	35	17	88									149	26	123
Common brushtail possum					1																				1	1	0
Trichosurus spp.	1				2										5	11					1				20	9	11
Eastern grey kangaroo					2	6							3												11	5	6
Red-necked wallaby			1	2			1						2			1									7	4	3
Swamp wallaby	2	3	6	8	2	24					1	1	2		5	2	1								57	19	38
Macropodidae spp.	1		2	9		25					3		1	1		2									44	7	37
Water rat										8															8	0	8
House mouse [I]				1			1			1	1	2						1						1	8	2	6
Black rat [I]			5						3	2	1						1		2						14	12	2
Rodentia spp.										3	1														4	1	3
Small mammal spp.											1														1	1	0
Red fox [I]		1	3	6	13	40	7			1	5				7	3	2	4	2			5		1	100	39	61
Cat [I]		1	2	1	68	182	8	4			10	3	4	2	8	2	6	3	3	1	11	15	12	8	354	132	222
European Hare [I]					1																				1	1	0
Lace monitor			1				21				3		1		26	3	5	2	3	2	4		4		75	68	7
Eastern water dragon					3																7		3		13	13	0
Pacific black duck									2	3															5	2	3
Pheasant coucal					1																				1	1	0
Medium frog spp.	5	3																							8	5	3
Total	10	8	33	35	94	277	48	5	5	18	26	6	23	38	69	119	16	10	10	3	25	24	21	13	936	380	556

Complete and incomplete crossings

A total of 936 (2.23/week) complete crossings were recorded in year one monitoring, including 380 (2.05/week) in spring/summer and 556 (2.38/week) in winter (Table 7). Total complete crossings were evenly split between native (49%) and introduced species (51%). This pattern was consistent in spring/summer (51% native; 49% introduced) and winter (48% native; 52% introduced). Of the introduced species, two feral predators, cat and red fox made up 95% of completed crossings. In winter, cats were responsible for 40% of all complete crossings, with 82% of these occurring at site 3. This contrasts to spring/summer when cats represented 35% of all complete crossings.

A total of 99 incomplete crossings were recorded and only two species, intermediate egret and white-throated treecreeper, that made incomplete crossings also made complete crossings (Table C1, Appendix C). Neither species is expected to utilise fauna underpasses.

The most widespread species were cat (10 sites S/S; 11 sites W), followed by lace monitor (9 sites S/S), red fox (8 sites W, 7 sites S/S), and swamp wallaby (7 sites S/S). A number of species were recorded at five sites, including koala (S/S), short-eared brushtail possum (W), house mouse (W), and black rat (S/S). Cat and red fox were recorded at all sites except site 5, and 7 respectively (Table 7).

Short-eared brushtail possum was the most common native species with 149 complete crossings (0.36/week), with 123 (0.53/week) recorded in winter, and 26 (0.14/week) in spring/summer. Lace monitor were recorded making 75 (0.18/week) complete crossings, swamp wallaby 44 (0.10/week), and short-beaked echidna 22 (0.05/week). Koala made 18 (0.04/week) complete crossings, with 10 of these recorded in spring/summer at site 4.

The number of complete crossings at the split median underpasses was consistent at sites 11 and 12 but varied between sites 9 and 10 (Table 7). Variation at sites 9 and 10 is attributed to theft of the site 9 floor camera in the second half of the spring/summer monitoring period.

Comparison of complete crossings by native and introduced species at each site highlights substantial differences in occurrence between the two groups. Native species were recorded making more complete crossings than introduced species at Sites 1, 2, 4, 5, 7 and 8. Introduced species were recorded making more complete crossings than native species at Sites 3, 6, 9, 10, 11 and 12 (Table 7). The 304 complete crossings at site 3, were due to a single (easily distinguished) cat that made crossings on most days (Figure 2, Plate 5). Macropods including swamp wallabies were detected at Sites 1, 2, 3, 6, 7, 8 and 9 (Plate 7). Medium frog was recorded crossing the camera monitoring zone at Site 1 on eight occasions.

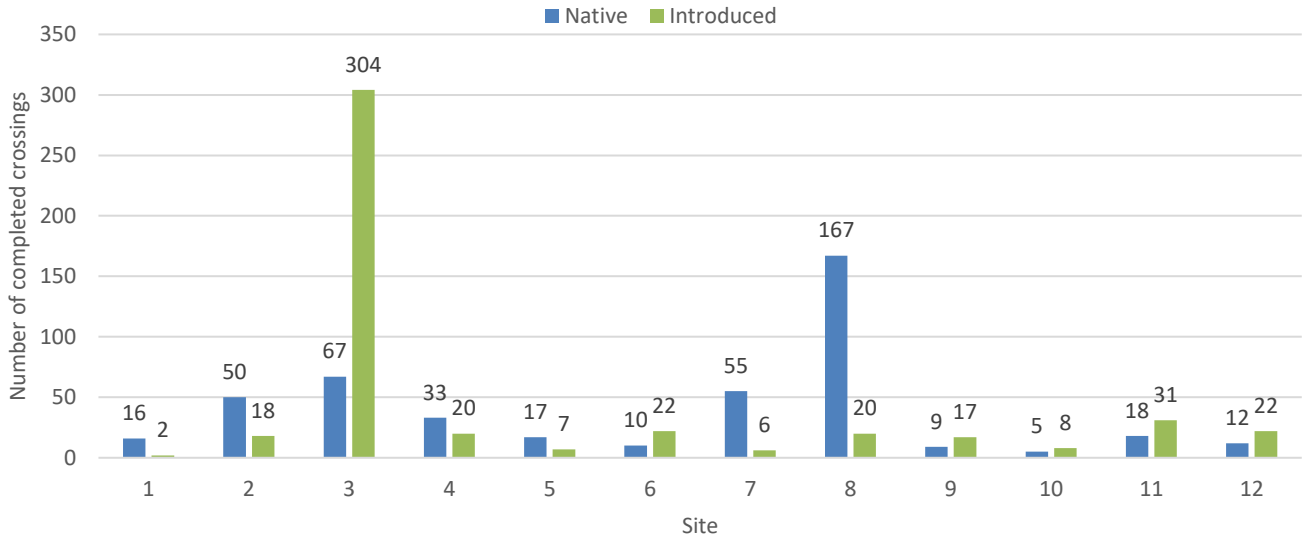

Figure 2: Number of complete crossings by native and introduced species at each underpass during year one monitoring.

Plate 5: Single cat responsible for the majority of complete crossings at Site 3.

The average number of completed crossings per underpass was 2.19/week (SD 2.24, n = 12) in spring/summer, and 2.32 (SD 3.83, n = 12) in winter. Average crossings/week were greater in spring/summer than winter at sites 1, 2, 4, 6, 9, 10, and 12 (Figure 3). The reverse occurred at sites 3, 7, and 8. The higher average number of crossings/week in winter is attributed to increased activity of cats (site 3), and small-eared brushtail possum (site 7 & 8).

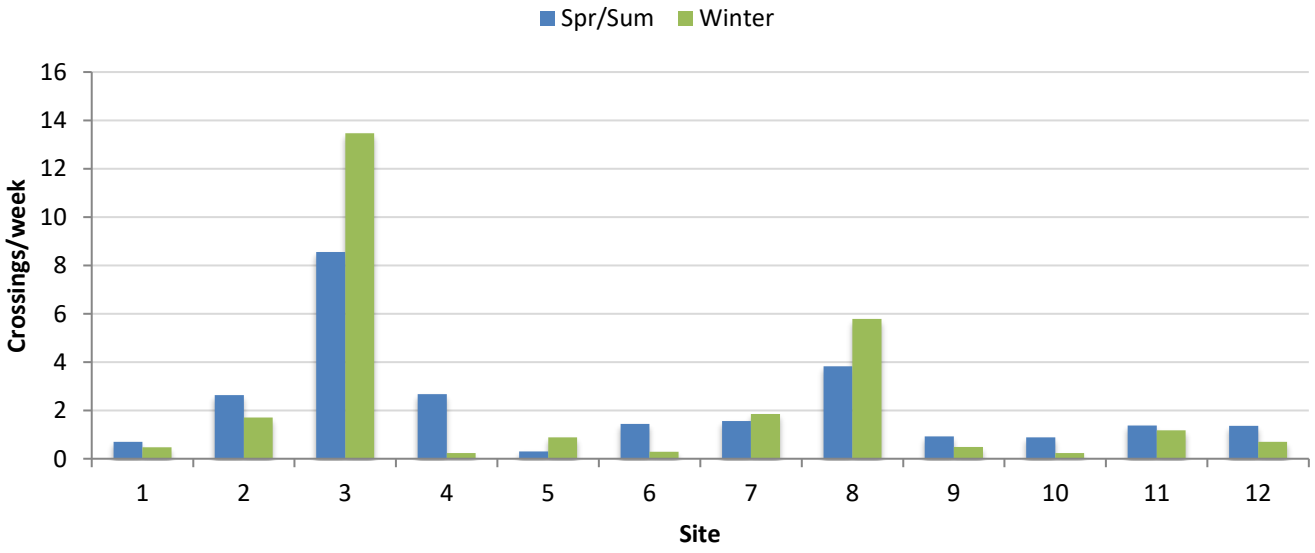

Figure 3: Average number of complete crossings/week recorded in spring/summer and winter at each site. n = 12 for each site.

Use of floor and fauna furniture

Fauna were recorded using both the underpass floor and fauna furniture. In total, 802 complete crossings (3.83/week) were recorded on the underpass floor and 134 complete crossings (0.75/week) were recorded on fauna furniture (Table 8). No fauna were recorded using fauna furniture at sites 9 and 10, and sites 1 and 5 did not contain furniture. Use of the underpass floor was substantially greater than use of furniture across all sites except sites 7 and 8 (Figure 3). Use of furniture exceeded use of the floor at site 7 and use was similar between the two features at site 8. The result at both sites was due to preferential use of furniture by short-eared brushtail possum. Brushtail possums were recorded using the floor at sites 3, 8 and 11. Other species to utilise the floor and furniture were water dragon, cat, and black rat (Table 8).

As expected, several terrestrial species were recorded using the floor only. Microbats were recorded roosting (temporarily) in the joins of the fauna furniture at Sites 2, 8 and 10. Koalas were recorded using the floor only (Plate 6).

Plate 6: Short-eared brushtail possum crossings using fauna furniture at site 7 (L).

Plate 7: Koala recorded at Site 12, moving east on 22 October (L) and west of 23 October (R).

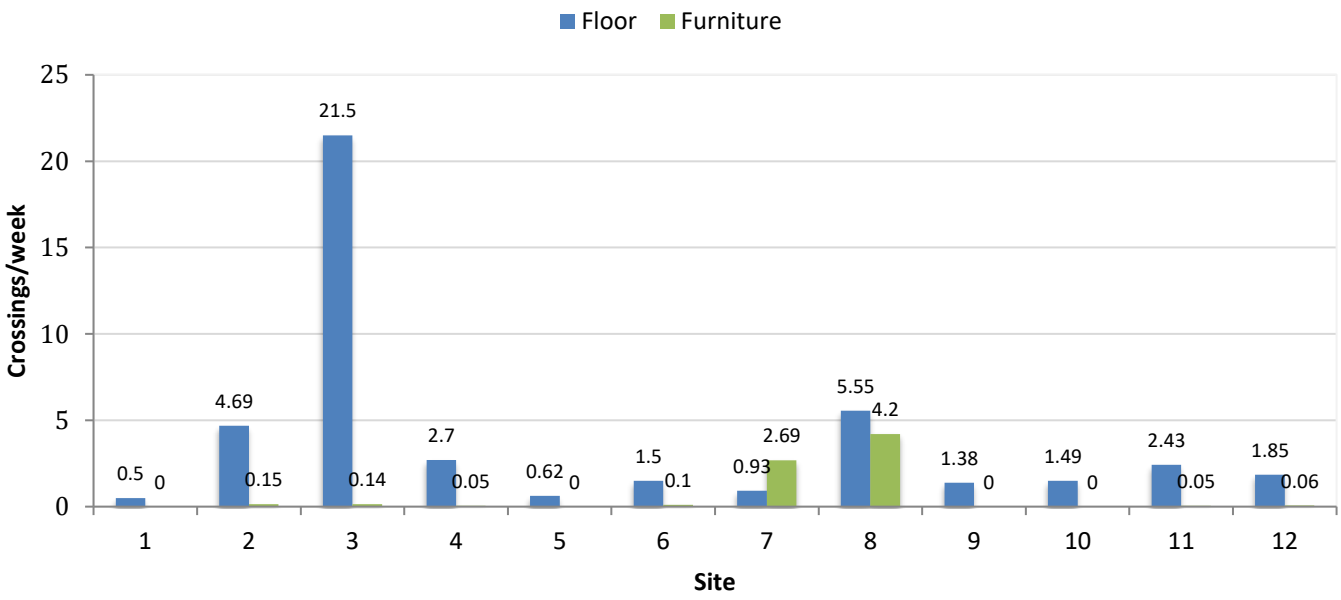

Figure 4: Complete crossings/week in spring/summer and winter by all species on underpass floor and fauna furniture during year one operational phase monitoring. Sites 1 and 5 do not have fauna furniture installed.

Table 8: Number of complete crossings made by each species/group at each of 12 underpasses monitored on the WC2NH upgrade. Sites 1 and 5 did not contain fauna furniture. [I] = introduced species, Fl = Floor, Fu = furniture, SS = Spring/Summer, W = Winter.

Species/group	Site and number of complete crossings																					
	1	2		3		4		5	6		7		8		9		10		11		12	
	Fl	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu
Short-beaked echidna	0.03	1.44	0	0	0	0	0	0	0	0.05	0	0	0.05	0	0	0	0	0	0	0	0	0
Long-nosed bandicoot	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.17	0
Northern brown bandicoot	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0
Peramelidae spp.	0	0	0	0	0	0	0	0	0	0	0	0	0.31	0	0	0	0	0	0	0	0	0
Koala	0	0	0	0	0	0.57	0	0	0	0	0.1	0	0	0	0.5	0	0	0	0.1	0	0.11	0
Short-eared brushtail possum	0	0	0	0.06	0	0	0	0	0	0	0	2.69	1.61	3.84	0	0	0	0	0	0	0	0
Common brushtail possum	0	0	0	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trichosurus spp.	0.03	0	0	0.12	0	0	0	0	0	0	0	0	0.47	0.36	0	0	0	0	0.05	0	0	0
Swamp wallaby	0.14	1.01	0	1.4	0	0	0	0	0.1	0	0.1	0	0.36	0	0.05	0	0	0	0	0	0	0
Red-necked wallaby	0	0.22	0	0.12	0	0.05	0	0	0	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0
Eastern grey kangaroo	0	0	0	0.41	0	0	0	0	0	0	0.16	0	0	0	0	0	0	0	0	0	0	0
Macropodidae spp.	0.03	0.79	0	1.46	0	0	0	0	0.16	0	0.1	0	0.1	0	0	0	0	0	0	0	0	0
House mouse [I]	0	0.07	0	0	0	0.05	0	0.03	0.06	0	0	0	0	0	0.05	0	0	0	0	0	0.06	0
Black rat [I]	0	0.14	0.15	0	0	0	0	0.14	0	0.05	0	0	0	0	0.05	0	0.23	0	0	0	0	0
Water rat	0	0	0	0	0	0	0	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia spp.	0	0	0	0	0	0	0	0.08	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0
Cat [I]	0.03	0.22	0	14.47	0.14	0.57	0.05	0	0.62	0	0.31	0	0.52	0	0.48	0	0.46	0	1.32	0	1.06	0.06
Red fox [I]	0.03	0.65	0	3.09	0	0.36	0	0.03	0.26	0	0	0	0.52	0	0.32	0	0.23	0	0.25	0	0.06	0
European Hare [I]	0	0	0	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lace monitor	0	0.07	0	0	0	1.09	0	0	0.16	0	0.05	0	1.5	0	0.37	0	0.57	0	0.2	0	0.22	0
Eastern water dragon	0	0	0	0.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.05	0.17	0
Pacific black duck	0	0	0	0	0	0	0	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pheasant coucal	0	0	0	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium frog spp.	0.22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0.5	4.69	0.15	21.53	0.14	2.7	0.05	0.62	1.5	0.1	0.93	2.69	5.55	4.2	1.38	0	1.49	0	2.44	0.05	1.85	0.06

3.2 Adjacent habitat

Fifty species were recorded in habitat adjoining underpasses (Table 9). A further nine species were identified to genus level only. Most of these are likely to belong to one of the identified species. For example, *Petaurus* spp. was most likely a sugar glider and *Antechinus* spp. is most likely brown antechinus. Some records during active search and spotlighting were assigned to three families, Macropodidae (wallaby/kangaroo), Peramelidae (bandicoots), and Chelidae (freshwater turtles). Three threatened species were recorded in adjacent habitat. Yellow-bellied glider (*Petaurus australis*) was recorded on the west side of the alignment at site 8, giant barred frog (*Mixophyes iteratus*) was recorded on the west side of the alignment at site 1, little eagle (*Hieraaetus morphnoides*) and a pair of eastern osprey (*Pandion cristatus*) were recorded flying above the alignment at sites 11 and 12.

The majority of species/groups (48 in total) were detected by diurnal and nocturnal active searches (Table 9). Short-eared brushtail possum, sugar glider, and brown antechinus were captured in arboreal Elliott traps (Plates 8 & 9). No fauna was captured in pipe traps. Six species, four reptiles and two frogs, were captured in pitfall traps and five species were captured in ground Elliott traps. A total of eight species and two genera were detected via hair funnels. A total of 54 individuals were captured in all trap types in spring/summer and 62 in winter (Table 13). During spring/summer trapping 12 individuals were captured in cage traps, 15 in ground Elliott traps, 26 in pitfall traps and one in an arboreal Elliott trap (Plate 8). During winter 14 individuals were captured in cage traps, 43 in ground Elliott traps, one in pitfall traps and three in arboreal Elliott traps.

During spring/summer trapping, introduced black rat was the most commonly captured species (14 individuals), followed by garden skink (*Lampropholis delicata*; 9 individuals); *Calyptotis ruficauda* (7 individuals), fawn-footed melomys (*Melomys cervinipes*; 5 individuals), grass skink (*L. guichenoti*; 4 individuals), and brown antechinus (*Antechinus stuartii*; 3 individuals, Plate 8).

During winter trapping, brown antechinus were the most commonly captured species (22 individuals), followed by fawn-footed melomys (10 individuals), black rat and house mouse (7 individuals each) and bush rat (six individuals). As to be expected, significantly fewer reptiles were recorded during the winter sampling period. Interestingly, three species of bird; green catbird (*Ailuroedus crassirostris*), eastern yellow robin (*Eopsaltria australis*), and eastern whipbird (*Psophodes olivaceus*) were captured in a cage trap at site 1 (Plate 9). Also in winter one feral cat was captured in a cage trap at site 7. Single cats were also captured in cage traps installed in underpasses at sites 3 and 7. All introduced mammals captured were euthanased.

Table 9: Species of vertebrate recorded during surveys of habitat adjoining each side of all underpasses. ^ denotes threatened species; [I] = Introduced species, SS = Spring/Summer, W = Winter.

Species	Active Search		Spotlight		Ground Elliott trap		Arboreal Elliott trap		Pitfall trap		Pipe trap		Cage trap		Hair funnel	
	SS	W	SS	W	SS	W	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)	*	*														
Yellow-bellied glider ^			*	*												

Species	Active Search		Spotlight		Ground Elliott trap		Arboreal Elliott trap		Pitfall trap		Pipe trap		Cage trap		Hair funnel	
	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W
Sugar glider			*	*				*								
Petaurus spp.			*													
Common ringtail possum															*	
Feathertail glider				*												
Short-eared brushtail possum			*	*			*						*	*		
Trichosurus spp.															*	*
Swamp wallaby		*	*	*												
Macropodidae spp.	*	*	*	*												
Grey-headed flying fox ^				*												
Pteropus spp.				*												
Fawn-footed melomys				*	*	*								*		*
Melomys spp.					*	*										
Bush rat					*	*							*	*	*	
House mouse [I]						*										*
Black rat [I]					*	*							*	*	*	
Rattus spp.															*	*
Red fox [I]	*															
Cat [I]														*		
Reptiles																
Burton's legless lizard	*															
Lace monitor	*															
Eastern water dragon	*		*													
Agamid spp.		*														
Calyptotis ruficauda	*	*							*							
Egernia mcpheii	*															
Eastern water-skink	*															
Lampropholis delicata	*	*							*							
Lampropholis guichenoti									*							
Lampropholis spp.	*	*														
Saiphos equalis		*														
Blackish blind snake									*							
Coastal carpet python	*															
Yellow-faced whipsnake	*															
Black-bellied swamp snake	*															
Red-bellied black snake	*															
Small snake spp.		*														
Chelidae spp. (Freshwater turtle)	*															
Birds																
Little eagle^	*															
Tawny frogmouth			*	*												
Owlet-nightjar			*													
Glossy black cockatoo^		*														
Eastern whipbird														*		
Green catbird														*		
Eastern yellow robin														*		
Eastern osprey^		*														
Frogs																
Litoria chloris			*													
Litoria fallax	*		*													

Species	Active Search		Spotlight		Ground Elliott trap		Arboreal Elliott trap		Pitfall trap		Pipe trap		Cage trap		Hair funnel	
	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W
Litoria peronii (tadpoles)	*															
Litoria tyleri			*													
Litoria tyleri (tadpoles)	*															
Adelotus brevis	*		*													
Limnodynastes peronii			*						*	*						
Mixophyes fasciolatus			*													
Mixophyes iteratus ^			*													
Crinia signifera			*	*												
Pseudophryne coriacea			*						*							
Uperolia fusca			*													
Uperolia spp.			*													
Total Nº. Species/groups	**22**	**10**	**20**	**11**	**5**	**7**	**1**	**0**	**6**	**1**	**0**	**0**	**4**	**7**	**6**	**8**

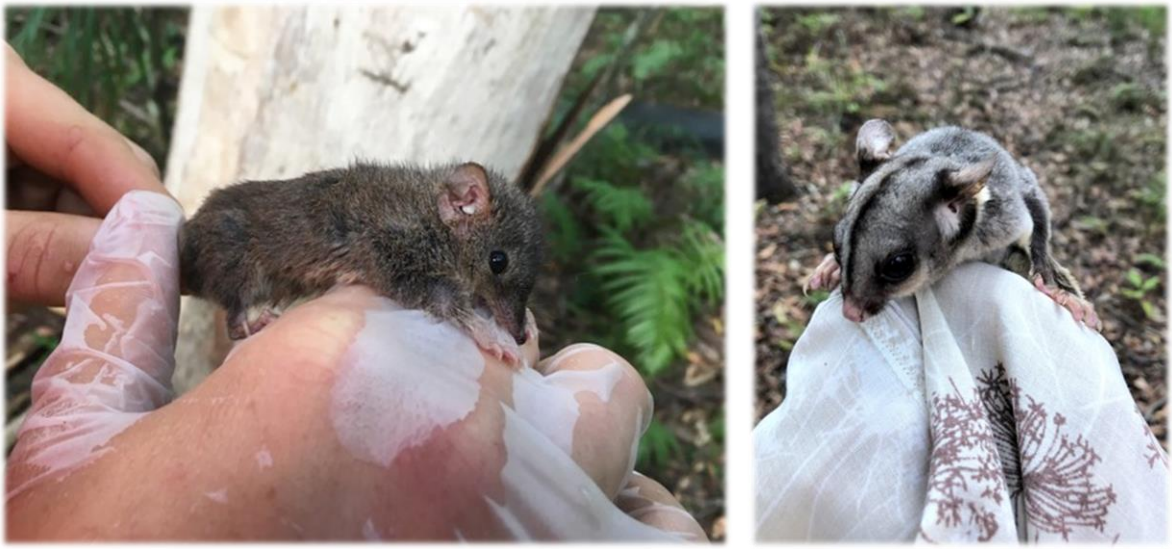

Plate 8: Brown antechinus (L) captured in adjacent habitat during spring trapping and a sugar glider captured during winter trapping.

Plate 9: A green catbird captured in a cage trap during winter trapping (L). A short-eared brushtail possum captured in a cage trap during winter trapping (R).

3.3 Species recorded in underpasses and adjacent habitat

A total of 46 species/groups were recorded in spring/summer and 34 species/groups in winter monitoring of underpasses and adjacent habitat (Table 10). Most of the individuals attributed to Genera, Families and Groups would be species that were confirmed during surveys. For example, *Trichosurus* spp. would be either short-eared or common brushtail possum, *Rattus* spp. would most likely be bush rat or black rat, Antechinus spp would be brown antechinus and small mammal and Dasyuridae spp. would most likely be one of the *Rattus* species or brown antechinus.

The use of various sample methods each with different degrees of accuracy in identifying fauna to species level has contributed to the large number of Families and groups recorded. Methods like sand pads only allow identification to the group level for some fauna and contribute substantially to the inclusion of broad groups such as small or medium reptile. The inclusion of broad groups makes it difficult to be definitive in determining how many species from adjacent habitat have used underpasses. In addition, infra-red cameras often miss small reptiles and frogs meaning these groups are under-represented in underpass monitoring results. It is likely that several of the fauna groups recorded in underpasses (particularly during sand pad surveys) include species that were recorded in adjacent habitat.

Excluding gliders, bats and birds, 32% of species/groups recorded in adjacent habitat were recorded in underpasses. For the reasons noted above this represents a substantial underestimate of the actual proportion of species present that are likely to be using underpasses. Notwithstanding, some species were recorded using the underpasses but not detected in adjacent habitat. These species include red-necked wallaby (*Macropus rufogriseus*), eastern grey kangaroo (*M. giganteus*), common brushtail possum (*T. vulpecula*), water rat (*Hydromys chrysogaster*), European Hare (*Lepus europaeus*) and possibly, long-nosed potoroo. Giant barred frogs were detected in adjacent habitat at site 1 but not recorded on underpass cameras.

Table 10: Species and fauna groups recorded using underpasses by all methods and those recorded in adjacent habitat. Shading denotes a species or group not confirmed in both areas that is likely to be represented in another species/group that was recorded in both areas, for example northern brown bandicoot is likely represented by Peramelidae spp. ^ denotes threatened species.

Species	Recorded in underpass		Recorded in adjacent habitat	
	SS	W	SS	W
Mammals				
Short-beaked echidna	*	*	*	
Brown antechinus			*	*
Antechinus spp.				*
Dasyuridae spp.	*	*		
Northern brown bandicoot		*	*	
Long-nosed bandicoot		*		*
Peramelidae spp.	*		*	*
Koala^	*	*	*	
Yellow-bellied glider^			*	*
Sugar glider			*	*
Petaurus spp.			*	
Common ringtail possum			*	
Feather tail glider				*
Short-eared brushtail possum	*	*	*	*
Common brushtail possum	*			
Long-nosed potoroo^	*			
Trichosurus spp.	*	*	*	*
Eastern grey kangaroo	*	*		
Red-necked wallaby	*	*		
Swamp wallaby	*	*	*	*
Macropodidae spp.	*	*	*	*
Grey-headed flying fox^				*
Flying fox spp.				*

Species	Recorded in underpass		Recorded in adjacent habitat	
	SS	W	SS	W
Miniopterus spp.^	*	*		*
Water rat		*		
Fawn-footed melomys			*	*
Melomys spp.			*	*
Bush rat			*	*
Rodentia spp.	*	*	*	*
Small mammal spp.	*			
Reptiles				
Burton's legless lizard			*	
Lace monitor	*	*	*	
Eastern water dragon	*		*	
Agamid spp.				*
Calyptotis ruficauda			*	*
Egernia mcpheii			*	
Eastern water skink			*	
Lampropholis delicata			*	*
Lampropholis guichenoti			*	
Lampropholis spp.			*	*
Saiphos equalis				*
Scincidae spp.			*	
Blackish blind snake			*	
Coastal carpet python			*	
Yellow-faced whipsnake			*	
Black-bellied swamp snake			*	
Red-bellied black snake			*	
Chelidae spp.			*	
Small snake spp.				*
Medium reptile spp.	*			
Small reptile spp.	*			
Birds				
Pacific black duck	*	*		
Intermediate egret	*			
Tawny frogmouth				*
Glossy black cockatoo^				*
Pheasant coucal	*			
White-throated treecreeper		*		
Green catbird				*
Eastern yellow robin				*
Eastern whipbird				*
Eastern osprey^				*
Little eagle^				*
Water bird spp.	*			
Medium bird spp.	*			
Small bird spp.	*			
Frogs				
Litoria chloris			*	
Litoria fallax			*	
Litoria tyleri			*	
Adelotus brevis			*	
Limnodynastes peronii			*	*
Mixophyes fasciolatus			*	
Mixophyes iteratus^			*	
Crinia signifera			*	*
Pseudophryne coriacea			*	
Uperolia fusca			*	
Uperolia spp.			*	
Medium frog spp.	*	*		
Frog spp.	*			
Introduced				

Species	Recorded in underpass		Recorded in adjacent habitat	
	SS	W	SS	W
Cat	*	*		*
Red fox	*	*	*	
Black rat	*	*	*	*
European Hare	*			
House mouse	*	*		*

3.4 Exclusion fence

A total of three exclusion fence defects were recorded during the fence traverse (Table 14). Gaps where drains intersect the fence can be difficult to exclude fauna and installed flaps can become cluttered with debris after rain. Vegetation growing up fences may aid fauna ability to scale the fence. Unlocked/open gates have been implicated 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, although an audit by RMS identified several additional defects, which have been rectified.

Table 11: Exclusion fence breaches with location description, GPS coordinates.

Date	Fence Issue	Location	Easting	Northing	Status at time of reporting
15/06/2019	Unlocked fence gate	480m north of Old Coast Rd Bridge, SB.	497550	6610720	Gate is locked
15/06/2019	15cm gap under drain fence where there is no extension wire.	100m south of Old Coast Rd. SB.	497340	6610161	Gap has been repaired.
15/06/2019	Shrubs hang over fence for entire stretch of road.	850m north of Mattick Rd Bridge.	494585	6605590	The vegetation has been sprayed as part of routine maintenance.

4. Discussion

Results from year one of operational phase monitoring are discussed with reference to the indicators of success specified in the Ecological Monitoring Program (RMS 2018).

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

Five introduced species were detected during underpass monitoring and of these, two (red fox and cat) are considered feral predators. Cats (354) and foxes (100) made a combined total of 454 complete crossings, and were responsible for 48.5% of all complete crossings during year one monitoring. Compared to NH2U where year one monitoring recorded 12% use by feral predators (including dog *Canis lupus familiaris*) use at WC2NH high (Sandpiper Ecological 2019a). The number of fox crossings detected during year one of monitoring at WC2NH is less than recorded at Sapphire to Woolgoolga (230 crossings) and Coopernook to Herons Creek (C2HC; ~140 crossings) and more than at Glenugie (70 crossings) over similar sample periods (Sandpiper Ecological 2015, 2017a, b).

Year one operational phase monitoring at NH2U and Glenugie recorded 13 and 34 cats respectively. AT WC2NH, most (304) of the 354 completed crossings by cats occurred at site 3, with the majority of these attributed to one (distinctive) individual. Site 3 is characterized by a disturbed and fragmented rural landscape compared to the contiguous forest adjoining sites 4-12. Records of cats, foxes and dogs from construction phase underpass monitoring at NH2U suggest feral predators habituate rapidly to underpasses (Sandpiper Ecological 2014).

During the winter sample single cats were removed from sites 7, 8 and 3. The number of completed crossings by cats declined from spring/summer to winter at sites 7 and 8 but not at site 3. This may be because the cat captured at site 3 was accidently released by the council ranger in Macksville and may have returned to the site. Site 7 recorded four cat crossings in spring/summer and two in winter. Site 8 recorded eight cat crossings in spring/summer and two in winter. Whilst based on a small sample size the results suggest that removal of cats reduces crossings in the short term. Given the high use by one easily distinguished individual it is likely that targeted trapping could reduce cat crossings. Roads and Maritime Services conducted fox baiting at sites 8 and 9/10 in August 2019 but no evidence of bait take was recorded.

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

A total of 21 species and five fauna groups were detected on underpass cameras. Twenty species, including 16 native species, made complete crossings and all five fauna groups made complete crossings. Of the five groups, three were native species, i.e. *Trichosurus* spp. and two could be either native or introduced. The number of native species making complete crossings is slightly higher than other comparable projects. For example, 14 native species made complete crossings in year one at NH2U, 12 native species in year one at W2B (sections 1&2) and five native species at S2W in the first year of monitoring (Sandpiper 2017, 2019a, b).

Year one operational phase results show that a higher diversity of vertebrates are using underpasses at WC2NH than at similar sites in northern NSW.

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 using underpasses during year one monitoring. This is consistent with baseline monitoring where no spotted-tailed quolls were detected after three weeks of camera trapping at the locality (GeoLink 2014). The closest record to the project was a road killed individual recorded in 2014 near the southern end of the project (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 2018). Year one underpass monitoring recorded 18 complete crossings by koalas at four sites, with 10 crossings recorded at site 4. Year one population surveys indicate that the number of koalas occurring near the alignment has remained stable since the construction phase. There is no substantive baseline data to confirm if changes in habitat use and movement patterns have occurred. Operational phase results show that koalas are using underpasses to cross the highway alignment and are using habitat on both sides of the alignment (Sandpiper Ecological 2019c). Whilst it is unknown if changes in habitat use have occurred the year one results 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. Monitoring has identified a substantial decline in population between 2013/14 (pre-construction baseline) and year one of the operational phase (Lewis 2014; Sandpiper Ecological 2019d). The population decline was initially noted during year one of the construction phase (Geolink 2015). Improved habitat connectivity beneath the Warrell Creek bridge in conjunction with significant rainfall events and reduced human

disturbance may allow the giant barred frog population to recover. Further monitoring is required to confirm if the species can rebound to previous population levels.

4.4 Evidence of use by dispersing individuals and different age cohorts

Underpass monitoring at WC2NH has demonstrated use by fauna of different age cohorts. Immature short-eared brushtail possums were regularly recorded making complete crossings following adults, particularly at sites 7 and 8. Analysing black and white videos in low resolution can prove difficult to determine age classes of fauna meaning some juveniles or dispersing immature individuals may have been recorded as adults.

4.5 Use by cover-dependent species with low mobility

Use of underpasses by cover-dependent species with low mobility is a subjective criterion. Small dasyurids (namely *Antechinus* spp.), and small to medium reptiles are considered cover dependent species with low mobility. Dasyurids and small to medium reptiles have been detected in sand pad monitoring but not by cameras. Whilst this result is not surprising cameras have detected house mouse at WC2NH, and *Antechinus* spp. at W2B, and NH2U (Sandpiper Ecological 2019a, b). Use of underpasses by cover dependent species is likely to improve as vegetation grows and matures, and finishing work ends. At present, revegetation near underpass entrances is in a relatively poor condition owing to ongoing finishing works and drought.

Underpass use by cover-dependent species with low mobility has been recorded during year one operational phase monitoring. With increased revegetation of underpass aprons it can be expected that use will increase.

4.6 No breaches in fauna exclusion fencing

Fauna exclusion fence was generally in good condition, although a small number of gaps were detected. Roadkill monitoring has identified minimal fauna mortality between Mattick Road and the northern extent where type 1 and 3 fence is continuous on both sides of the carriageway. Numerous gaps under the fence were detected on the Gumma floodplain, however, RMS has advised that this fence is targeted at exclusion of macropods only. To date there have been no recorded breaches of the fauna exclusion fence by any target species.

4.7 Low incidences of fauna road strike mortality

Road-killed fauna within fence excluded areas is considered low. Summer, autumn and winter 2019 roadkill monitoring recorded 3, 4 and 8 road-killed individuals respectively in areas where the exclusion fence should have prevented access to the highway. It should be acknowledged that road-killed fauna recorded within 100m of fence was included within this count and access to the highway could be attributed to entry via a fence end. Areas where exclusion fencing does not occur have exhibited substantially higher rates of medium to large mammal kills (i.e. around Bald Hill Road and Albert Drive) where 22 red-necked wallaby and macropod kills have been recorded during three seasonal samples in 2019 (Sandpiper 2018b; 2019e, f, g). Roadkill monitoring data show frogs, reptiles and small mammals, species that can move through exclusion fence continue to be killed on the highway but are also using underpasses to cross the highway. Without exclusion fence the incidence of road mortality would be substantially higher in the section between Mattick Road and the northern project extent.

4.8 Underpass survey effort

Underpass survey effort (i.e. number of days sampled) during spring/summer was compromised by initial technical difficulties at site 1, theft/destruction of equipment at sites 9 and 10, and higher than expected number of false triggers due to ongoing construction work and ecological survey work at all sites. Spring/summer 2018 was the first major deployment of the Swift 3C and Swift Enduro cameras by the survey team, and the first time that data were conducted using video rather than still images. The combination of video and high pedestrian activity caused SD cards to reach capacity prior to the scheduled one month inspection period. These issues were resolved prior to commencement of the winter sample period. Indeed, the need to sample fauna in the spring/summer period and the pre-christmas cut-off in sampling to reduce the risk of theft during the Christmas holidays compressed the year one sample period. In future spring/summer surveys the sample period will be extended further into spring.

5. Recommendations

1. Inclusion of infrared cameras as part of adjacent habitat monitoring should be considered.
2. Management to control feral predator use of underpasses should be evaluated. Feral cat management may reduce the incidence of feral predator species using underpasses. Targeted trapping with cage traps may be an effective means of reducing cat numbers.
3. Actively manage revegetation of underpass aprons, mulch around plants to retain moisture, replace dead plants and exclude people and machinery where possible.
4. Using time-lapse photography in underpasses should be considered to confirm use by small reptiles, frogs and small mammals.

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Appendix A – Species list

Table A1: Common and scientific names for all species recorded during year one 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*
	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 fox^	*Pteropus poliocephalus*
Flying fox spp.	*Pteropus spp.*
Bent-wing spp.	*Miniopterus spp.*
Small mammal spp.	
	Dasyuridae spp.
McPhee's skink	*Egernia mcpheii*
Rainbow skink	*Lampropholis delicata*
Common garden 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*
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*
Little eagle^	*Hieraaetus morphnoides*

Common Name	Scientific Name
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*
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 fox	*Vulpes vulpes*
Black rat	*Rattus rattus*
European hare	*Lepus europaeus*
House mouse	*Mus musculus*

Appendix B – Field Data

Table B1: Weather during the spring/summer monitoring period.

Date	MAXIMUM Wind Speed km/h	AVERAGE Wind Direction DESCRIPTION	AVERAGE Relative Humidity %	MAXIMUM Air Temperature DegC	MINIMUM Air Temperature DegC	TOTAL Rain Gauge mm
20/10/18	32.4	ESE	82.9	25.4	14.5	0.2
21/10/18	36	ESE	85.6	25.9	17.6	8.4
22/10/18	13.4	SW	90.1	24.9	17	0.2
23/10/18	18.5	SSW	87.9	25.8	14.9	0.2
24/10/18	25.3	S	85.7	26.1	16.1	0
25/10/18	16.9	SSW	80.7	27.5	17.4	0
26/10/18	13.6	S	82.2	24.2	15.1	0
27/10/18	20.5	SSW	80.5	28.2	16.6	0
28/10/18	19.9	SSE	81.6	25.4	14.4	0
29/10/18	16.4	SW	79.9	22.2	15.6	0
30/10/18	12.8	SSW	77.7	22.2	15.3	0
31/10/18	28.5	SSE	83.2	24.7	13.7	0
1/11/18	18.5	S	80.5	30.5	14.1	0
2/11/18	23	SSE	80.1	27.5	12.4	0
3/11/18	33.4	ESE	72.5	29.7	18.8	0
4/11/18	22.8	SSE	73.4	33.6	19.6	0
5/11/18	14.4	S	82.6	30	17.3	0
6/11/18	16.6	SSE	88.2	28.6	19.1	0
7/11/18	20.9	ESE	84.9	30.4	22.9	0.2
8/11/18	24	SSE	89.8	30.2	14.9	21
9/11/18	20.4	SW	76.8	23	10.7	0
10/11/18	17.4	S	74.2	22.9	13.5	0
11/11/18	32.1	S	79.3	25.4	12.8	0
12/11/18	20.5	SW	81	25.7	12.8	0
13/11/18	18.5	SSW	79.8	25	12.5	0
14/11/18	25	SE	81.5	25.1	13.3	0
15/11/18	25.9	SSE	82.8	27.1	18.5	0
16/11/18	21.2	SSE	83	28.4	19.1	0
17/11/18	15.4	SSW	83.6	26.1	18.1	0
18/11/18	24	SSW	87.8	26.3	16.6	14.2
19/11/18	16	SW	93	23	15.7	15
20/11/18	17.4	SSW	78.3	23.7	14.6	0.2
21/11/18	30.2	ESE	77.9	27	17.6	0
22/11/18	16	SSE	89.9	30.3	19.5	6
23/11/18	33.1	SW	58.9	31.7	9.4	0
24/11/18	31.1	WSW	44.6	28.1	10.3	0
25/11/18	20.5	SW	68	28.8	10.9	0
26/11/18	21.9	SSW	66.2	30.4	13.9	0
27/11/18	18.7	SSW	73	26.2	14.3	0
28/11/18	28.5	SE	83.3	27.1	17.8	0
29/11/18	33.5	SSW	69.2	28.7	18.3	9.6
30/11/18	17	SW	69.4	28.6	13.4	0
1/12/18	20.2	S	80.6	27.1	14.1	0
2/12/18	20.2	SSW	77.8	31.8	12.5	0
3/12/18	24.1	SSE	70.8	33.9	17.8	0
4/12/18	19.9	SSE	78.1	27.9	14.4	0
5/12/18	19.5	S	76.3	28.8	18.3	9.6
6/12/18	17.7	SSW	82	25.9	17	1.2
7/12/18	22.4	S	74.9	25.8	15.4	0.2
8/12/18	24	SSE	75.6	25.8	14.9	0
9/12/18	33.7	ESE	78.1	26.9	13.5	0
10/12/18	30.1	SE	80.9	27.4	14.7	0
11/12/18	26.2	SE	84.4	29.3	17.7	0
12/12/18	13.7	SSW	92.1	28.2	19.2	6.8
13/12/18	13	SE	89.9	26.2	18.1	0.8
14/12/18	29.3	ENE	88.4	28.5	19.8	14.8
15/12/18	38.2	NE	86.3	29	22.2	0
16/12/18	50	NE	88	28.8	22.2	0
17/12/18	27.1	ESE	97.2	25	17.5	101.6
18/12/18	40.5	ESE	89.8	27.7	18.1	0
19/12/18	28.2	ESE	72.8	28.7	21	0
20/12/18	23.1	SE	79.2	29.6	20.1	12.8

Table B2: Weather during the winter monitoring period.

Date	MAXIMUM Wind Speed km/h	AVERAGE Wind Direction DESCRIPTION	AVERAGE Relative Humidity %	MAXIMUM Air Temperature DegC	MINIMUM Air Temperature DegC	TOTAL Rain Gauge mm
1/06/2019	10.7	70.2	20.4	13	5.3	0
2/06/2019	15.4	84.4	20.7	17.8	11.3	1.6
3/06/2019	15.2	88.6	21.4	15.4	10.2	2
4/06/2019	14.2	62.5	23	35.5	8.3	0.4
5/06/2019	14.3	63.3	18.6	37.9	10.9	0
6/06/2019	11.8	78.2	20.4	23.7	5.9	0
7/06/2019	14.1	71.6	22.2	17.8	8.1	0
8/06/2019	15.4	85.2	22.3	23.7	12.4	2.2
9/06/2019	14.4	96.7	15.8	13	12.6	8.2
10/06/2019	14.2	88.3	23.4	11.8	8.5	1.8
11/06/2019	14.9	85	23.3	14.2	8.9	0
12/06/2019	15.4	82.3	27	17.8	8.2	0
13/06/2019	15.2	85.6	22.8	27.2	8.9	0
14/06/2019	17.3	83	26.1	13	11.2	0
15/06/2019	16.8	76.4	22.9	15.4	13.2	0
16/06/2019	16.1	79	20.6	13	13.9	0
17/06/2019	14.8	84.4	21.8	13	8.5	0
18/06/2019	14.2	75	22.5	22.5	8.7	0
19/06/2019	15.7	85.1	22.8	14.2	9.5	4.6
20/06/2019	11.8	73	20.9	17.8	6.3	0
21/06/2019	12.1	81.8	21	21.3	6	0
22/06/2019	10.6	67	20.1	22.5	2.7	0
23/06/2019	10.6	75.3	20.3	21.3	4.5	0
24/06/2019	13	74.6	20	18.9	9.9	0
25/06/2019	12.7	93.9	17.1	18.9	10.7	0
26/06/2019	13.3	95.1	17.8	17.8	10.8	0
27/06/2019	13.9	96.4	16.1	18.9	13	1.8
28/06/2019	14.9	86.2	20.5	17.8	11.5	60.6
29/06/2019	14.1	89.5	20.6	14.2	9.7	13.2
30/06/2019	14.4	90.5	20.9	11.8	8.9	0
1/07/2019	16.6	78.1	22.4	15.4	12.8	0
2/07/2019	13.8	84.8	21.7	15.4	8.3	0
3/07/2019	13.5	88.1	22.1	14.2	7.9	0
4/07/2019	16.2	83.4	22.5	20.1	12.2	0.2
5/07/2019	15.7	88.8	21.2	18.9	13.4	24.8
6/07/2019	14.4	89.9	19.5	23.7	11.3	12.2
7/07/2019	15.1	90.2	20.9	20.1	12.4	0
8/07/2019	12.9	91.2	19.2	13	8	0
9/07/2019	12.8	93.1	17.7	9.5	8	4.8
10/07/2019	12.3	81.7	21.9	16.6	5.4	3.4
11/07/2019	11	78.5	21.5	21.3	3.4	0
12/07/2019	13.4	67.8	23.9	24.9	5.6	0
13/07/2019	13.1	75	23.2	24.9	7	0
14/07/2019	12.8	53.3	21.9	45	5.3	0
15/07/2019	12.2	52.3	18.5	35.5	5.7	0
16/07/2019	9.7	72.4	19.7	39	1.9	0
17/07/2019	10.6	74.7	22.7	14.2	3	0
18/07/2019	12.6	68.4	20	29.6	5.8	0
19/07/2019	11.2	71.4	21.4	31.9	2.6	0
20/07/2019	10.7	73.9	21.9	16.6	3.9	0
21/07/2019	11.3	82.4	21.4	18.9	3.8	0
22/07/2019	12.1	82	22.3	17.8	4.7	0
23/07/2019	13.6	78.8	24.7	18.9	6.2	0
24/07/2019	13	74.7	25.9	20.1	3.6	0
25/07/2019	13.3	73.4	25.2	23.7	6.4	0
26/07/2019	14	83.4	21.1	18.9	7.2	0
27/07/2019	15	84.3	22.7	16.6	9.7	0
28/07/2019	14.4	79.3	23.7	21.3	7.9	0
29/07/2019	13.8	82.1	22.4	20.1	7.3	0
30/07/2019	13.8	83.2	22.6	17.8	9.2	0
31/07/2019	14.4	77	22.9	23.7	8.8	0
1/08/2019	13.2	86	18.7	18.9	8.6	1
2/08/2019	13.6	83.3	22.5	20.1	9	0
3/08/2019	13	86	21	20.1	6.7	0
4/08/2019	12.6	82.5	22.2	21.3	5.4	0
5/08/2019	13.4	80.7	22.8	16.6	7.3	0
6/08/2019	13.2	82.2	22	22.5	6.2	0
7/08/2019	13	75.3	25.2	23.7	4.7	0
8/08/2019	14.1	74.6	25.1	16.6	7.8	0
9/08/2019	16.6	47.7	25.8	60.3	4	0
10/08/2019	17.8	36.8	23.2	60.3	9.1	0

Date	MAXIMUM Wind Speed km/h	AVERAGE Wind Direction DESCRIPTION	AVERAGE Relative Humidity %	MAXIMUM Air Temperature DegC	MINIMUM Air Temperature DegC	TOTAL Rain Gauge mm
11/08/2019	14.5	35.7	20.1	63.9	11.2	0
12/08/2019	12	49	18.2	43.8	6.5	0
13/08/2019	11.7	72.4	21.3	30.8	4.2	0
14/08/2019	12.9	76.8	20.9	20.1	7.4	0
15/08/2019	13.6	84.6	19.5	21.3	7.4	0
16/08/2019	13.2	81.4	22.5	22.5	5.7	0
17/08/2019	13.2	70	23.7	24.9	4.8	0
18/08/2019	14.8	70	27	36.7	7.2	0
19/08/2019	15.8	79.3	21.3	31.9	9.8	0
20/08/2019	13.1	51.1	24.9	39	1.2	0
21/08/2019	11.1	65.5	21.2	22.5	4.4	0
22/08/2019	15.8	56.9	25.5	36.7	8.7	0
23/08/2019	15.8	54.2	25.3	53.3	8.9	0
24/08/2019	12	73.3	21.9	23.7	4.7	0
25/08/2019	13.6	79.6	22.4	31.9	5.6	0
26/08/2019	17.3	72.4	25.2	24.9	11.1	0
27/08/2019	16.7	82.9	24.9	22.5	10.8	0
28/08/2019	16.8	87.1	21.6	23.7	12.3	0
29/08/2019	16	86.6	22.3	26	9.8	0
30/08/2019	13.9	82.8	21.8	27.2	6.9	0.8

Table B3: Underpass camera survey effort for spring/summer monitoring.

Location	Cam Location	Easting	Northing	Date installed	Date checked	Pics	Last pic date	Days Active	Date removed	Pics	Days Active	Total Days Active
12	Furniture	497115	6610068	17/10/18	22/11/18	383	1/11/18	16	17/12/18	38	29	45
	Ground	497115	6610068	16/10/18	22/11/18	326	22/11/18	38	17/12/18	73	29	67
11	Furniture	497168	6610040	17/10/18	22/11/18	286	22/11/18	37	17/12/18	300	27	64
	Ground	497168	6610040	17/10/18	22/11/18	397	22/11/18	37	17/12/18	47	29	66
10	Furniture	496622	6609409	17/10/18	22/11/18	317	22/11/18	37	17/12/18	Stolen		37
	Ground	496622	6609409	17/10/18	22/11/18	543	5/11/18	20	17/12/18	75	23	43
9	Furniture	496622	6609409	17/10/18	22/11/18	169	22/11/18	37	17/12/18	37	23	60
	Ground	496622	6609409	17/10/18	22/11/18	412	22/11/18	37	17/12/18	47	23	60
8	Furniture	496506	6609219	17/10/18	22/11/18	110	22/11/18	37	17/12/18	19	26	63
	Ground	496506	6609219	17/10/18	22/11/18	202	22/11/18	37	17/12/18	85	26	63
7	Furniture	496438	6608780	17/10/18	22/11/18	154	30/10/18	14	17/12/18	14	26	40
	Ground	496438	6608780	17/10/18	22/11/18	158	22/11/18	37	17/12/18	30	26	63
6	Furniture	496188	6608319	17/10/18	21/11/18	10	21/11/18	36	17/12/18	13	27	63
	Ground	496188	6608319	17/10/18	21/11/18	138	21/11/18	36	17/12/18	50	27	63
5	North	496171	6608286	22/10/18	21/11/18	184	21/11/18	31	17/12/18	64	27	58
	South	496168	6608282	22/10/18	21/11/18	128	21/11/18	31	17/12/18	75	27	58
4	Furniture	495702	6607693	17/10/18	22/11/18	60	22/11/18	37	17/12/18	18	26	63
	Ground	495702	6607693	17/10/18	22/11/18	175	22/11/18	37	17/12/18	106	26	63
3	Furniture	495082	6606515	17/10/18	21/11/18	186	2/11/18	17	17/12/18	317	12	29
	Ground	495082	6606515	17/10/18	21/11/18	258	21/11/18	36	17/12/18	60	12	48
2	Furniture	494477	6605329	18/10/18	21/11/18	718	21/11/18	35	17/12/18	676	31	66
	Ground	494477	6605329	18/10/18	21/11/18	185	5/11/18	19	17/12/18	66	6	25
1	North	489300	6594286	30/10/18	22/11/18	13799	22/11/18	24	17/12/18	15000	39	63
	South	489262	6594252	24/10/18	22/11/18	17400	22/11/18	30	17/12/18	15000	39	69

Table B4: Underpass camera survey effort for winter monitoring.

Location	Cam Location	Easting	Northing	Date installed	Date checked	Battery	Pics	Days active	Date removed	Days Active	Pics	Total Days Active
12 median west	Furniture	497115	6610068	17/6/19	19/07/2019	100	93	33	27/08/2019	39	65	72
	Ground	497115	6610068	17/6/19	19/07/2019	Flat	51	17	27/08/2019	20	41	37
11 median east	Furniture	497168	6610040	17/6/19	19/07/2019	100	261	33	27/08/2019	39	181	72
	Ground	497168	6610040	17/6/19	19/07/2019	100	264	33	27/08/2019	39	151	72
10 median west	Furniture	496622	6609409	17/6/19	19/07/2019	100	72	33	27/08/2019	39	114	72
	Ground	496622	6609409	17/6/19	19/07/2019	100	1067	3	27/08/2019	15	286	18
9 median east	Furniture	496622	6609409	17/6/19	19/07/2019	100	29	33	27/08/2019	39	61	72
	Ground	496622	6609409	17/6/19	19/07/2019	80	57	33	27/08/2019	39	96	72
8 full length	Furniture	496506	6609219	17/6/19	19/07/2019	100	90	33	27/08/2019	39	71	72
	Ground	496506	6609219	17/6/19	19/07/2019	100	80	33	27/08/2019	39	101	72
7 full length	Furniture	496438	6608780	17/6/19	19/07/2019	100	78	33	27/08/2019	39	98	72
	Ground	496438	6608780	17/6/19	19/07/2019	100	57	33	27/08/2019	39	81	72
6 full length	Furniture	496188	6608319	17/6/19	19/07/2019	100	14	33	27/08/2019	39	6	72
	Ground	496188	6608319	17/6/19	19/07/2019	100	66	33	27/08/2019	39	43	72
5	North	496171	6608286	17/6/19	19/07/2019	100	25	33	27/08/2019	39	31	72
	South	496168	6608282	17/6/19	19/07/2019	100	30	33	27/08/2019	39	84	72
4	Furniture	495702	6607693	17/6/19	19/07/2019	100	34	33	27/08/2019	39	52	72
	Ground	495702	6607693	17/6/19	19/07/2019	100	61	33	27/08/2019	39	1	72
3	Furniture	495082	6606515	17/6/19	19/07/2019	75	309	33	27/08/2019	39	510	72
	Ground	495082	6606515	17/6/19	19/07/2019	100	45	33	27/08/2019	39	278	72
2	Furniture	494477	6605329	17/6/19	19/07/2019	100	486	33	27/08/2019	39	755	72
	Ground	494477	6605329	17/6/19	19/07/2019	100	503	33	27/08/2019	39	440	72
1	North	489300	6594286	18/6/19	19/07/2019	Reinstalled	12240	18	27/08/2019	14	9558	52
	South	489262	6594252	18/6/19	19/07/2019	Flat	19998	26	27/08/2019	13	9360	67

Table B5: All species detected in fauna underpasses by infrared camera during spring/summer monitoring. ^ = Threatened species, D = Definite, Pr = Probable, Po = Possible, NDM = no directional movement, EXM = exploratory movement, E then W = east then west.

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
12	**Furniture**	13/12/18	2213	Cat	D	E	36	Complete	
	Ground	17/10/2018	0105	Cat	D	W	38-40	Complete	
		17/10/2018	2332	Cat	D	W	50	Complete	
		22/10/2018	0147	Koala^	D	E	54	Complete	
		23/10/2018	0337	Koala^	D	W	77	Complete	
		28/10/2018	0020	Cat	D	W	145	Complete	
		31/10/2018	2237	Cat	D	E	199	Complete	
		5/11/2018	0840	Lace monitor	D	East	14	Complete	
		5/11/2018	1124	Water dragon	D	West	15	Complete	
		5/11/2018	2305	Cat	D	East	16	Complete	
		8/11/2018	1359	Water dragon	D	East	46	Complete	
		9/11/2018	2305	Cat	D	East	53	Complete	
		13/11/2018	1138	Water dragon	D	East	82	Complete	
		17/11/2018	1431	Lace monitor	D	East	102	Complete	
		19/11/2018	2307	Cat	D	West	103	Complete	
		20/11/2018	1855	Cat	D	West	104	Complete	
		1/12/2018	2005	SEBtP	D	NDM	33-42	Incomplete	Back and forth then climbs railing (prob)
		2/12/2018	1944	Cat	D	E	43	Complete	
		3/12/2018	1110	Lace Monitor	D	E	44	Complete	
		7/12/2018	1954	Cat	D	E	51	Complete	
		11/12/2018	1056	Lace Monitor	D	W	52, 53	Complete	
		13/12/2018	1955	Cat	D	W	54	Complete	
11	**Furniture**	3/11/2018	1400	Water dragon	D	East	172	Complete	
	Ground	22/10/2018	146	Koala^	D	East	26-34,36-42	Complete	
		23/10/2018	332	Koala^	D	West	49	Complete	
		28/10/2018	0015	Cat	D	W	214	Complete	
		31/10/2018	2243	Cat	D	E	259	Complete	
		3/11/2018	1042	Water dragon	Pr	East	215	Complete	
		5/11/2018	0121	Cat	D	West	219	Complete	
		5/11/2018	0832	Lace Monitor	D	East	225	Complete	
		5/11/2018	1459	Water dragon	D	West	226	Complete	
		5/11/2018	1518	Water dragon	D	East	227	Complete	
		8/11/2018	0804	Intermediate Egret	D	EXM	248-259	Incomplete	
		9/11/2018	2305	Cat	D	East	264	Complete	
		17/11/2018	1421	Lace Monitor	D	East	302	Complete	
		17/11/2018	2153	Cat	D	West	303	Complete	
		18/11/2018	2051	Cat	D	West	304	Complete	
		19/11/2018	2312	Cat	D	W-E	305-306	Incomplete	
		20/11/2018	1904	Cat	D	West	307	Complete	
		21/11/2018	0851	Water dragon	D	West	308	Complete	
		27/11/2018	2337	BtPoss spp.	D	E	227	Complete	
		2/12/2018	0232	Cat	D	W	229	Complete	
		2/12/2018	1949	Cat	D	E	230	Complete	
		3/12/2018	1109	Lace Monitor	D	E	231	Complete	
		7/12/2018	1951	Cat	D	E	236	Complete	
		10/12/2018	1417	EW Dragon	D	W	237	Complete	
		11/12/2018	1103	Lace Monitor	D	W	238, 239	Complete	
		13/12/2018	1008	EW Dragon	D	E	240	Complete	
		17/12/2018	0054	Cat	D	W	243	Complete	
10	**Furniture**	27/11/2018	1945	Microbat spp.	D	NDM	8	Incomplete	Roosting in FF joins. Not recorded hereafter.

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		19/10/2018	0259	Cat	D	E	11	Complete	
			0150	Fox	D	W	12	Complete	
		28/11/2018	0858	Lace Monitor	D	E	9	Complete	
	Ground	28/11/2018	2132	Black Rat	D	E	10	Complete	
		2/12/2018	2004	Black Rat	D	W	11, 12, 13	Complete	
		2/12/2018	2119	Cat	D	W	14	Complete	
		3/12/2018	1153	Lace Monitor	D	W	15	Complete	
		3/12/2018	1926	Black Rat	D	E then W	16, 17	Incomplete	
		4/12/2018	0241	Cat	D	W	18	Complete	
		7/12/2018	0006	Fox	D	E	30	Complete	
		13/12/2018	1311	Lace Monitor	D	E	34	Complete	
				Human x 2 tagging					
9	**Furniture**	5/11/2018	0034	Small mammal	Pr	NDM	111	Incomplete	Only eyeshine visible
				Cam stolen					
		19/10/2018	0303	Cat	D	E	39	Complete	
		21/10/2018	0030	Cat	D	E	40	Complete	
		21/10/2018	0152	Fox	D	W	41-42	Complete	
		7/11/2018	0247	Cat	D	W	309	Complete	
		20/11/2018	1248	Lace monitor	D	W	403	Complete	
		21/11/2018	0259	Koala^	D	W	404	Complete	
		22/11/2018	0258	Cat	D	W	409	Complete	
		26/11/2018	0356	Swamp Wallaby	D	W	236, 237	Complete	
	Ground	28/11/2018	2142	Black Rat	D	E	238	Complete	
		2/12/2018	0923	Lace Monitor	D	E	239	Complete	
		2/12/2018	2118	Cat	D	W	241	Complete	
		3/12/2018	1152	Lace Monitor	D	W	243	Complete	
		4/12/2018	0242	Cat	D	W	244	Complete	
		7/12/2018	0009	Fox	D	E	250	Complete	
		13/12/2018	1318	Lace Monitor	D	E	252	Complete	
		14/12/2018	1404	Lace Monitor	D	E	253	Complete	
				Human x 2 tagging					
8		31/10/2018	2250	SEBtP	D	E	34	Complete	
		7/10/2018	0233	SEBtP	D	E	65	Complete	
		10/11/2018	2339	SEBtP	D	E	72	Complete	
		12/11/2018	2138	SEBtP	D	E	88	Complete	
	Furniture	29/11/2018	0026	BtPoss spp.	D	E	7	Complete	
		2/12/2018	0222	BtPoss spp.	D	E	9	Complete	
		9/12/2018	2109	Microbat spp.	D	NDM	13	Incomplete	Roosting in FF joins?
		17/10/2018	2303	Fox	D	E	12	Complete	
		19/10/2018	2135	SEBtP	D	E	13	Complete	
		21/10/2018	0140	Fox	D	E	14	Complete	
		22/10/2018	1418	Lace monitor	D	W	17	Complete	
		26/10/2018	1058	Lace monitor	D	W	22	Complete	
		27/10/2018	1119	Lace monitor	D	E	23	Complete	
		29/10/2018	2137	Cat	D	E	27	Complete	
	Ground	30/10/2018	2328	Bandicoot spp	Pr	E	50	Complete	
		31/10/2018	2004	Echidna	D	E	63-65	Incomplete	
		1/11/2018	1922	Cat	D	E	83	Complete	
		2/11/2018	1826	Cat	D	E	94	Complete	
		6/11/2018	2343	Cat	D	W	131	Complete	
		7/11/2018	0238	Cat	D	E	132	Complete	
		10/11/2018	0012	Swamp wallaby	Pr	E	149	Complete	
		10/11/2018	0944	Lace Monitor	D	W	150	Complete	
		11/11/2018	0847	Swamp wallaby	D	W	151-152	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		11/11/2018	1645	Swamp wallaby	Pr	E	153	Complete	
		12/11/2018	0921	Lace Monitor	D	W	155	Complete	
		17/11/2018	0007	Fox	D	E	187-189	Complete	
		18/11/2018	2328	Fox	D	E	190	Complete	
		20/11/2018	0824	Lace Monitor	D	W	192	Complete	
		20/11/2018	2036	SEBtP x 2	D	W	193	Complete	Mother with back young
		20/11/2018	2107	SEBtP x 2	D	E-W	194-195	Incomplete	
		20/11/2018	2137	SEBtP x 2	D	E	196	Complete	
		23/11/2018	2202	SEBtPx2	Pr	W	14	Complete	
		23/11/2018	2339	SEBtPx2	D	E	15	Complete	
		24/11/2018	2112	BtPoss spp.	Pr	W	20	Complete	
		26/11/2018	1216	Lace Monitor	D	W	21	Complete	
		26/11/2018	1602	Lace Monitor	D	E	22	Complete	
		28/11/2018	2142	SEBtPx2	D	E	24	Complete	
		29/11/2018	0751	Lace Monitor	D	W	26	Complete	
		30/11/2018	0829	Lace Monitor	D	W	27	Complete	
		30/11/2018	2136	Cat	D	W	28	Complete	
		1/12/2018	0226	Fox	D	E	29	Complete	
		2/12/2018	1031	Lace Monitor	D	E	31	Complete	
		2/12/2018	1455	Lace Monitor	D	E	32	Complete	
		2/12/2018	2129	BtPoss spp.x2	D	W	33	Complete	
		2/12/2018	2314	Cat	D	E	34	Complete	
		2/12/2018	2339	SEBtPx2	D	E	35	Complete	
		4/12/2018	1326	Lace Monitor	D	W	36	Complete	
		6/12/2018	0021	Fox	D	W	37	Complete	
		7/12/2018	1131	Lace Monitor	D	W	39	Complete	
		7/12/2018	1345	Lace Monitor	D	E	40	Complete	
		8/12/2018	2352	Cat	D	W	41	Complete	
		9/12/2018	1129	Lace Monitor	D	W	42	Complete	
		9/12/2018	1438	Lace Monitor	D	W	43	Complete	
		9/12/2018	1949	Swamp Wallaby	Pr	E	44	Complete	
		9/12/2018	1954	Swamp Wallaby	D	NDM	46/47	Incomplete	
		9/12/2018	1958	SEBtP	D	W	49	Complete	
		9/12/2018	2023	Swamp Wallaby	Pr	E	50	Complete	
		10/12/2018	1017	Lace Monitor	D	W	52	Complete	
		10/12/2018	1411	Lace Monitor	D	E	53	Complete	
		13/12/2018	0853	Lace Monitor	D	W	54	Complete	
		13/12/2018	1359	Lace Monitor	D	E	55	Complete	
		14/12/2018	1347	Lace Monitor	D	W	56	Complete	
		15/12/2018	0033	Fox	D	E	57	Complete	
		15/12/2018	1046	Lace Monitor	D	W	58	Complete	
		15/12/2018	1128	Lace Monitor	D	W	59	Complete	
		15/12/2018	1312	Lace Monitor	D	W	60	Complete	
		15/12/2018	1616	Lace Monitor	D	E	61	Complete	
7	**Furniture**	20/10/2018	0142	SEBtP	D	E	14	Complete	
		25/10/2018	2114	SEBtP x 2	D	W	15	Complete	
		5/12/2018	1955	SEBtP x 2	D	E	10	Complete	
		5/12/2018	2116	SEBtP x 2	D	W	11	Complete	
		6/12/2018	1937	SEBtP	Pr	E	12	Complete	Urinates on FF
	Ground	26/10/2018	1723	EG Kangaroo x 3	Pr	E	30-32	Complete	
		26/10/2018	2242	Red-necked wallaby	Pr	W	34-35	Complete	
		3/11/2018	0103	Swamp Wallaby	D	W	77	Complete	
		3/11/2018	1821	Cat	D	W	81	Complete	
		7/11/2018	0539	Macropod spp	D	E	95	Complete	
		8/11/2018	0011	Red-necked wallaby	Pr	W	98-99	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		11/11/2018	0351	Cat	D	E	107	Complete	
		11/11/2018	1846	Cat	D	W	109	Complete	
		20/11/2018	0013	Koala^	D	E	152	Complete	
		23/11/2018	1440	Lace Monitor	D	E	14	Complete	
		1/12/2018	1848	Swamp Wallaby	Pr	E	15	Complete	
		5/12/2018	2127	Cat	D	W	16	Complete	
		8/12/2018	2255	Koala^	D	W	19	Complete	
6	**Furniture**	3/12/2018	0013	Black Rat	Pr	W	6	Complete	
	Ground	18/10/2018	2321	Cat	D	W	16	Complete	
		20/10/2018	1935	Cat	D	W	17	Complete	
		21/10/2018	0144	Fox	D	W	18	Complete	
		21/10/2018	0312	Cat	D	W	19	Complete	
		1/11/2018	0257	Cat	D	E	51	Complete	
		2/11/2018	0130	Fox	D	W	58	Complete	
		2/11/2018	1919	Cat	D	W	61	Complete	
		3/11/2018	0434	Cat	D	E	62	Complete	
		7/11/2018	1311	Lace Monitor	D	E	86	Complete	
		8/11/2018	0057	Rodent spp	Pr	E	87	Complete	
		11/11/2018	0029	Fox	D	W	91	Complete	
		20/11/2018	0215	House mouse	Pr	E	136	Complete	
		24/11/2018	2033	Cat	D	E	15	Complete	
		25/11/2018	2341	Wallaby spp.	D	W	16	Complete	
		26/11/2018	0902	Lace Monitor	D	W	19	Complete	
		27/11/2018	2055	Small mammal spp.	D	W	20	Complete	
		30/11/2018	0434	Wallaby spp.	D	E	28	Complete	
		3/12/2018	0237	Fox	D	W	31	Complete	
		5/12/2018	1925	Cat	D	W	32	Complete	
		5/12/2018	2017	Cat	D	E	33	Complete	
		8/12/2018	2020	Fox	D	E	34	Complete	
		9/12/2018	0032	Cat	D	E	35	Complete	
		9/12/2018	2008	Swamp Wallaby	Pr	W	36	Complete	
		10/12/2018	2311	Wallaby spp.	D	E	37	Complete	
		14/12/2018	1142	Lace Monitor	D	E	38	Complete	
5	**North**	30/10/2018	1527	Microbat spp.	D	EXM	46-49	Incomplete	
		1/11/2018	0331	Microbat spp	D	NDM	62	Incomplete	
		7/11/2018	0109	Black rat	Pr	W	134	Complete	
		8/11/2018	0358	Microbat spp	D	EXM	142	Incomplete	
		10/11/2018	0005	Black rat	D	W	150-153	Complete	
		14/12/2018	2320	Black Rat	Pr	E	49	Complete	
	South	26/10/2018	0140	Microbat spp	D	EXM	42,51-53	Incomplete	
		27/10/2018	2251	Microbat spp	D	EXM	58-60	Incomplete	
		1/11/2018	0409	Microbat spp	D	EXM	76	Incomplete	
		3/11/2018	0407	Microbat spp	D	EXM	80,82-83	Incomplete	
		6/11/2018	1843	Microbat spp	D	EXM	88	Incomplete	
		9/11/2018	0355	Microbat spp	D	E	104	Complete	
		11/11/2018	0354	Microbat spp	D	EXM	105	Incomplete	
		14/11/2018	0401	Microbat spp	D	EXM	112	Incomplete	
		19/11/2018	1904	Microbat spp	D	EXM	117,120	Incomplete	
		2/12/2018	0413	Microbat spp.	D	W	29	Complete	
		7/12/2018	1656	PB Duck x 2	D	E	34, 35	Complete	
4	**Furniture**			Nil					
	Ground	17/10/2018	2006	Cat	D	W	55	Complete	
		20/10/2018	0108	Koala^	D	E	56	Complete	
		22/10/2018	1250	Cat	D	E	57-58	Complete	
		26/10/2018	1042	Lace monitor	D	E	68	Complete	
		30/10/2018	1020	Lace monitor	D	W	71	Complete	
		30/10/2018	1140	Lace monitor	D	E	72	Complete	
		30/10/2018	2030	Koala^	D	E	93	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		31/10/2018	1044	Lace monitor	D	E	98	Complete	
		31/10/2018	2131	House mouse	D	E	99	Complete	
		2/11/2018	0054	Fox	D	E	108	Complete	
		2/11/2018	0220	Cat	D	E	109	Complete	
		2/11/2018	0411	Cat	D	W	110	Complete	
		2/11/2018	0837	Lace monitor	D	W	51	Complete	
		2/11/2018	1201	Lace monitor	D	W	52	Complete	
		3/11/2018	1341	Lace monitor	D	E	55	Complete	
		4/11/2018	0132	Koala^	D	W	56	Complete	
		6/11/2018	1036	Lace monitor	D	W	70	Complete	
		7/11/2018	2015	Koala^	D	E	80	Complete	
		10/11/2018	1302	Lace monitor	D	W	81	Complete	
		10/11/2018	1840	Cat	D	W	82	Complete	
		10/11/2018	2254	Koala^	D	W	83	Complete	
		10/11/2018	2358	Fox	D	E	84	Complete	
		11/11/2018	1348	Lace monitor	D	E	85	Complete	
		12/11/2018	2305	Koala^	D	E	86	Complete	
		13/11/2018	0059	Koala^	D	W	87	Complete	
		15/11/2018	0937	Lace monitor	D	E	102	Complete	
		16/11/2018	2257	Fox	D	E	121	Complete	
		17/11/2018	0155	Cat	D	W	122	Complete	
		19/11/2018	2252	Koala^	D	E	136	Complete	
		20/11/2018	1228	Lace monitor	D	W	139	Complete	
		20/11/2018	2038	Cat	D	W	144	Complete	
		23/11/2018	1126	Lace monitor	D	E	69, 70	Complete	
		24/11/2018	1222	Lace Monitor	D	E	72	Complete	
		29/11/2018	0858	Lace monitor	D	E	77	Complete	
		29/11/2018	1734	RN Wallaby	Pr	W	80	Complete	
		1/12/2018	0432	Koala^	D	W	81	Complete	
		2/12/2018	0858	Lace Monitor	D	E	82	Complete	
		3/12/2018	0155	Fox	D	E	83	Complete	
		5/12/2018	1314	Lace Monitor	D	W	84	Complete	
		5/12/2018	2314	Fox	D	E	85	Complete	
		7/12/2018	0310	Cat	D	W	86	Complete	
		8/12/2018	0944	Lace monitor	D	E	87	Complete	
		8/12/2018	1045	Lace monitor	D	E	88	Complete	
		8/12/2018	2051	Fox	D	E	91-92	Complete	
		9/12/2018	1201	Lace Monitor	D	W	93	Complete	
		14/12/2018	2313	Koala^	D	E	96	Complete	
		15/12/2018	0249	Fox	D	W	97	Complete	
		15/12/2018	1245	Lace monitor	D	W	98	Complete	
3	**Furniture**	18/10/2018	0830	Welcome swallow x 2	D	NDM	7-81	Incomplete	Not recorded hereafter.
		30/10/2019	1009	Water dragon	D	E-W	82-97	Incomplete	
		23/11/2018	0101	Microbat spp.	D	W	38, 39, 40	Complete	Not recorded hereafter.
	Ground	18/10/2018	0002	Cat	D	E	5	Complete	
		19/10/2018	0841	Fox	D	E	7	Complete	
		20/10/2018	0831	Welcome swallow x 2	D	NDM	8	Incomplete	Not recorded hereafter
		20/10/2018	1522	Water dragon	D	E	12	Complete	
		20/10/2018	1606	Water dragon	D	W	13	Complete	
		22/10/2018	0109	Cat	D	W	15	Complete	
		22/10/2018	0549	Fox	D	East	16	Complete	
		23/10/2018	0945	Cat	D	West	17	Complete	
		24/10/2018	0319	Cat	D	West	18-19	Complete	
		24/10/2018	0452	Cat	D	East	20	Complete	
		24/10/2018	0517	Cat	D	East	22-31	Complete	
		24/10/2018	2339	Cat	D	West	32	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		25/10/2018	0104	Cat	D	East	33-34	Complete	
		25/10/2018	0342	Brushtail Possum spp	D	East	35	Complete	
		26/10/2018	0255	Cat	D	West	36-37	Complete	
		26/10/2018	0518	Cat	D	East	38	Complete	
		27/10/2018	0908	Water dragon	D	East	39	Complete	
		27/10/2018	1942	Cat	D	West	42	Complete	
		27/10/2018	2207	Fox	D	West	43	Complete	
		27/10/2018	2209	Cat	D	West	44	Complete	
		27/10/2018	2331	Cat	D	East	45-69	Complete	
		28/10/2018	2004	Cat	D	West	71	Complete	
		29/10/2018	0307	Cat	D	East	72-73	Complete	
		29/10/2018	1854	Cat	D	West	74	Complete	
		29/10/2018	2009	Cat w prey	D	East	75	Complete	
		30/10/2018	1345	Pheasant coucal	D	West	76	Complete	
		30/10/2018	2006	Cat	D	West	105	Complete	
		30/10/2018	2031	Cat	D	East	106	Complete	
		30/10/2018	2200	Cat	D	West	107	Complete	
		31/10/2018	0220	Cat	D	East	108	Complete	
		31/10/2018	0450	Cat	D	East	109	Complete	
		31/10/2018	1817	Cat	D	West	117	Complete	
		31/10/2018	2013	Cat	D	East	118	Complete	
		1/11/2018	0107	Cat	D	West	119	Complete	
		1/11/2018	0249	Cat	D	East	120	Complete	
		1/11/2018	2330	Cat	D	West	131	Complete	
		2/11/2018	0232	Cat	D	East	132	Complete	
		2/11/2018	2017	Cat	D	West	142	Complete	
		2/11/2018	2346	Cat	D	East	143	Complete	
		3/11/2018	0037	Cat	D	West	144	Complete	
		3/11/2018	0401	Cat	D	East	145	Complete	
		3/11/2018	2124	Cat	D	West	152	Complete	
		4/11/2018	0607	Fox	D	East	154	Complete	
		4/11/2018	1859	Cat	D	W-E	157-158	Incomplete	
		5/11/2018	0319	Cat	D	East	159	Complete	
		6/11/2018	0106	Cat	D	West	167	Complete	
		6/11/2018	0334	Cat	D	East	168	Complete	
		7/11/2018	0312	Cat	D	East	178	Complete	
		7/11/2018	1938	Cat	D	West	182	Complete	
		7/11/2018	2218	Cat	D	East	183	Complete	
		7/11/2018	2227	Fox	D	West	184	Complete	
		8/11/2018	2207	Cat	D	West	185	Complete	
		9/11/2018	0224	Brushtail Possum spp	D	East	186	Complete	
		9/11/2018	0253	Cat	D	East	187	Complete	
		9/11/2018	0352	Swamp Wallaby	D	East	188	Complete	
		9/11/2018	1951	Cat	D	West	191	Complete	
		9/11/2018	2114	Fox	D	West	192	Complete	
		10/11/2018	0030	Cat	D	East	193-194	Complete	
		11/11/2018	0117	Cat	D	West	196	Complete	
		11/11/2018	0304	Cat	D	East	197	Complete	
		11/11/2018	0346	Swamp Wallaby	D	East	198-199	Complete	
		11/11/2018	2132	Swamp Wallaby	D	W-E	200	Incomplete	
		11/11/2018	2209	Cat	D	East	201	Complete	
		12/11/2018	0050	Cat	D	West	203	Complete	
		12/11/2018	0207	Fox w prey	D	East	204	Complete	
		12/11/2018	0350	Cat	D	East	205	Complete	
		13/11/2018	0154	Cat	D	East	206	Complete	
		15/11/2018	0319	Cat	D	West	215	Complete	
		15/11/2018	0538	Cat	D	East	216	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		17/11/2018	0109	Fox	D	West	236	Complete	
		18/11/2018	0239	Cat	D	East	239	Complete	
		19/11/2018	0312	Common Brushtail possum	D	East	249	Complete	
		19/11/2018	2124	Cat	D	East	250	Complete	
		20/11/2018	0424	Cat	D	West	251	Complete	
		20/11/2018	0526	Cat	D	East	252	Complete	
		21/11/2018	0059	Cat	D	West	255	Complete	
		21/11/2018	0358	Cat	D	East	256	Complete	
		21/11/2018	2100	Fox	D	W	25	Complete	
		21/11/2018	2107	Cat	D	E	26	Complete	
		21/11/2018	0221	Fox	D	E	27	Complete	
		21/11/2018	0236	Fox	D	W	28	Complete	
		23/11/2018	0225	Cat	D	W	32	Complete	
		23/11/2018	0406	Cat	D	E	33	Complete	
		24/11/2018	0311	Cat	D	E	35	Complete	
		24/11/2018	0440	EG Kangaroo	Pr	E	36	Complete	
		25/11/2018	0229	Fox	D	E	38	Complete	
		25/11/2018	2048	Cat	D	W	39	Complete	
		25/11/2018	2306	Cat	D	E	40	Complete	
		26/11/2018	0242	Hare	Po	E	41	Complete	
		26/11/2018	0314	Cat	D	E	42	Complete	
		27/11/2018	0110	Fox	Pr	W	43	Complete	
		27/11/2018	0323	Cat	D	E	44	Complete	
		27/11/2018	2316	SEBtP	D	W	45	Complete	
		28/11/2018	2129	Cat	D	W	46	Complete	
		28/11/2018	2319	Cat	D	E	47	Complete	
		29/11/2018	0501	EG Kangaroo	Pr	E	48	Complete	
		29/11/2018	2009	Cat	D	W	51	Complete	
2	**Furniture**	27/10/2018	2057	Black rat	D	W-E	41-46	Incomplete	
		28/10/2018	2049	Black rat	D	W-E	49-52	Incomplete	
		31/10/2018	2003	Black rat	D	W-E	91-94	Incomplete	
		2/11/2018	2124	Black rat	D	W	203	Complete	
		2/11/2018	2144	Black rat	D	E	205-208	Complete	
		7/11/2018	0045	Black rat	D	W-E	341-348	Incomplete	
		8/11/2018	0040	Black rat	Pr	W	381	Complete	
		17/11/2018	0213	Black rat	D	W-E	637-644	Incomplete	
	Ground	19/11/2018	0321	Echidna	D	East	11	Complete	
		20/11/2018	0502	Cat	D	East	12	Complete	
		20/11/2018	1925	Echidna	D	West	13	Complete	
		20/11/2018	2144	Echidna	D	West	14	Complete	
		21/11/2018	2340	Fox	D	East	15	Complete	
		23/10/2018	0122	Echidna	D	East	16-17	Complete	
		23/10/2018	2022	Echidna	D	East	18	Complete	
		24/10/2018	0329	Echidna	D	East	19	Complete	
		26/10/2018	1923	Swamp Wallaby	Pr	West	24	Complete	
		27/10/2018	0209	Swamp Wallaby	D	East	25	Complete	
		27/10/2018	2014	Swamp Wallaby	D	EXM	26-36	Incomplete	
		28/10/2018	2338	Swamp Wallaby	D	East	38	Complete	
		29/10/2018	0045	Fox	D	East	39	Complete	
		29/10/2018	0243	Swamp Wallaby	D	East	40	Complete	
		29/10/2018	0410	Swamp Wallaby	D	East	41	Complete	
		30/10/2018	1834	Swamp Wallaby	D	West	42	Complete	
		31/10/2018	2353	Echidna	D	East	72	Complete	
		1/11/2018	0102	Echidna	D	East	73	Complete	
		2/11/2018	0218	Echidna	D	West	113	Complete	
		3/11/2018	2249	Echidna	D	East	153	Complete	
		23/11/2018	1223	Lace monitor	D	E	29	Complete	
		23/11/2018	1854	RN Wallaby	Pr	E	35	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		23/11/2018	2146	Black rat	Pr	E	36	Complete	
		24/11/2018	1934	Black rat	Pr	E	48	Complete	
		24/11/2018	2313	Fox	D	E	49	Complete	
		24/11/2018	2346	Cat	D	W	50	Complete	
		26/11/2018	0049	Echidna	D	E	59, 60	Complete	
		26/11/2018	0121	Wallaby spp.	D	E	61	Complete	
		26/11/2018	0237	Echidna	D	E	62	Complete	
		13/12/2018	2311	Med frog	D	NDM	2853	Incomplete	
		25/11/2018	2045	Echidna	D	W	1906	Complete	
		10/12/2018	0017	Macropod spp.	D	W	519	Complete	
1		31/10/2018	1205	BtPoss spp	D	W	306	Complete	
		2/11/2018	2127	Swamp Wallaby	Pr	NDM	1948	Incomplete	
		3/11/2018	0222	Swamp Wallaby	D	W	2243,2246	Complete	
		3/11/2018	2329	Swamp Wallaby	Pr	E	2670	Complete	
		6/11/2018	0147	Medium frog spp	D	E	4008-4017	Complete	
	North	6/11/2018	1112	Medium frog spp	D	E	4453-4461	Complete	
		7/11/2018	1920	Medium frog spp	D	W	4821-4825	Complete	
		21/11/2018	2246	Medium frog spp	D	NDM	91-96	Complete	
		22/11/2018	0112	Medium frog spp	D	E	237-240	Complete	
		13/12/2018	2311	Medium frog spp	D	NDM	2853	Incomplete	
		25/11/2018	2045	Echidna	D	W	1906	Complete	
	South	10/12/2018	0017	Macropod spp.	D	W	519	Complete	

Table B6: All fauna detections in underpasses during winter monitoring. ^ denotes threatened species.

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
12	**Furniture**			Nil full period					
		18/06/2019	0054	Cat	D	E	11	Complete	tabby
		20/06/2019	0320	Cat	D	E	26	Complete	tabby
		21/06/2019	1924	Cat	D	E	37	Complete	black cat
		22/06/2019	0446	Cat	D	E	38	Complete	tabby
		22/06/2019	0527	Cat	D	E	39	Complete	tabby
		24/06/2019	1933	house mouse	Pr	W	42	Complete	
		24/06/2019	2210	cat	D	W	43	Complete	tabby
	Ground	27/06/2019	0406	cat	D	E	44	Complete	brown cat
		30/06/2019	0304	Long-nosed bandicoot	D	E	49	Complete	
		3/07/2019	0144	Long-nosed bandicoot	D	E	51	Complete	
		23/07/2019	2354	Cat	D	E	6	Complete	tabby
		25/07/2019	1953	Fox	D	W	12	Complete	
		1/08/2019	0006	LN Bandicoot	D	E	17	Complete	
11	**Furniture**	nil							
		18/06/2019	0057	cat	D	E	7	Complete	tabby
		20/06/2019	322	cat	D	E	50	Complete	tabby
		21/06/2019	1929	cat	D	E	116	Complete	black cat
		22/06/2019	0453	cat	D	E	117	Complete	tabby
		22/06/2019	0530	cat	D	E	118	Complete	tabby
		22/06/2019	2118	cat	D	W	126	Complete	brown cat
	Ground	24/06/2019	2159	cat	D	W	127	Complete	tabby
		27/06/2019	0410	cat	D	E	131	Complete	brown cat
		30/06/2019	0038	Long-nosed bandicoot	D	W	136	Complete	
		30/06/2019	0306	Long-nosed bandicoot	Pr	E	137	Complete	
		3/07/2019	0146	Long-nosed bandicoot	Pr	E	141	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		6/07/2019	0529	fox	D	E	143	Complete	
		10/07/2019	2348	cat	D	E	145	Complete	tabby
		12/07/2019	1820	fox	D	E	146	Complete	
		23/07/2019	2358	Cat	D	E	34	Complete	tabby
		1/08/2019	0009	LN Bandicoot	Pr	E	79	Complete	
		9/08/2019	0056	Fox	Pr	E	100	Complete	
		12/08/2019	0312	Fox	D	E	110	Complete	
		12/08/2019	0513	Cat	D	E	111	Complete	
		18/08/2019	0433	Fox	D	E	122	Complete	
		19/08/2019	0239	Cat	D	W	123	Complete	
		19/08/2019	1903	Cat	D	E	125	Complete	
		26/08/2019	0326	Cat	D	E	137	Complete	
		27/08/2019	0318	Cat	D	W	144	Complete	
10	**Furniture**			microbat spp	present				
	Ground	18/06/2019	0150	cat	D	W	346	Complete	tabby
		19/08/2019	1200	Lace Monitor	D	W	10	Complete	
		27/08/2019	1210	Lace Monitor	D	E	20	Complete	
9	**Furniture**			nil					
		11/08/2019	0931	WT Treecreeper	Pr	E	11-12	Incomplete	
	Ground	22/06/2019	1803	cat	D	E	27	Complete	tabby
		23/06/2019	0218	fox	D	W-E	28-29	Incomplete	
		27/06/2019	2010	house mouse	D	E	30	Complete	
		5/07/2019	0122	cat	D	E	32	Complete	tabby
		10/07/2019	2358	fox	D	W	34	Complete	
		11/07/2019	0032	cat	D	E	35	Complete	
		16/07/2019	0052	fox	D	W	36	Complete	
		18/07/2019	2013	fox	D	W	38-41	Complete	
		26/07/2019	0315	Fox	D	E	4	Complete	
		19/08/2019	1154	Lace Monitor	D	W	62	Complete	
		27/08/2019	1209	Lace Monitor	D	E	93	Complete	
8	**Furniture**	17/06/2019	1930	SEBtP	D	W	2	Complete	
		19/06/2019	0217	SEBtP	D	E	18	Complete	
		20/06/2019	0253	SEBtP	D	E	21	Complete	
		21/06/2019	0210	SEBtP	D	E	25	Complete	
		23/06/2019	0351	SEBtP	D	E	31	Complete	
		24/06/2019	0201	SEBtP	D	E	32	Complete	
		24/06/2019	1830	SEBtP	D	W	33	Complete	
		25/06/2019	0205	SEBtP	D	E	34	Complete	
		25/06/2019	0327	SEBtP	D	E	35	Complete	
		27/06/2019	0322	SEBtP	D	E	40-41	Complete	
		27/06/2019	1904	SEBtP	D	W	42	Complete	
		28/06/2019	0511	SEBtP	D	E	43	Complete	
		28/06/2019	1920	SEBtP	D	W	44	Complete	
		29/06/2019	0113	SEBtP	D	E	45	Complete	
		29/06/2019	0217	SEBtP	D	E	46	Complete	
		30/06/2019	2054	SEBtP	D	W	48	Complete	
		3/07/2019	0019	SEBtP	D	E	51	Complete	2 x individuals
		4/07/2019	0140	SEBtP	D	E	53	Complete	
		5/07/2019	0319	SEBtP	D	E	56	Complete	
		5/07/2019	0431	SEBtP	D	E	57	Complete	
		5/07/2019	1835	SEBtP	D	W	58	Complete	
		6/07/2019	0202	SEBtP	D	E	59	Complete	
		6/07/2019	0339	SEBtP	D	E	60	Complete	
		6/07/2019	2007	SEBtP	D	W	61	Complete	
		7/07/2019	0254	SEBtP	D	E	63	Complete	
		7/07/2019	0406	SEBtP	D	E	64	Complete	
		7/07/2019	1821	SEBtP	D	W	65	Complete	
		8/07/2019	0226	SEBtP	D	E	66	Complete	2 x individuals
		9/07/2019	0220	SEBtP	D	E	67	Complete	
		10/07/2019	0247	SEBtP	D	E	72	Complete	2 x individuals
		12/07/2019	2254	SEBtP	D	W	75	Complete	
		13/07/2019	0342	SEBtP	D	E	76	Complete	2 x individuals

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		13/07/2019	2258	SEBtP	D	W	77	Complete	
		15/07/2019	0348	SEBtP	D	E	78	Complete	
		15/07/2019	2136	SEBtP	D	W	79	Complete	
		16/07/2019	0415	SEBtP	D	E	80	Complete	
		16/07/2019	0437	SEBtP	D	E	81	Complete	
		19/07/2019	0400	SEBtP	D	E	85	Complete	2 x individuals
		19/07/2019	1818	SEBtP	Pr	W	5-6	Complete	
		21/07/2019	0251	SEBtPx2	D	E	10	Complete	
		23/07/2019	0042	BtPoss spp.	D	E	12	Complete	
		23/07/2019	1922	BtPoss spp.	D	W	13	Complete	
		24/07/2019	0306	SEBtP	Pr	W	14, 15	Complete	
		24/07/2019	1834	SEBtP	D	W	16	Complete	
		27/07/2019	0201	BtPoss spp.	D	E	20	Complete	
		30/07/2019	1829	SEBtP	D	W	21	Complete	
		1/08/2019	0146	BtPoss spp.	D	E	26	Complete	
		2/08/2019	0408	SEBtP	Pr	E	27	Complete	
		4/08/2019	0242	SEBtP	Pr	E	29	Complete	
		5/08/2019	0314	SEBtP	Pr	E	32	Complete	
		6/08/2019	0227	SEBtP x 2	Pr	E	35	Complete	
		8/08/2019	0251	SEBtP	Pr	E	38	Complete	
		10/08/2019	0250	SEBtP x 2	Pr	E	40	Complete	
		12/08/2019	0348	SEBtP x 2	Pr	E	46	Complete	
		13/08/2019	0400	SEBtP	Pr	E	49	Complete	
		14/08/2019	0408	SEBtP	Pr	E	51	Complete	
		16/08/2019	0233	SEBtP	Pr	E	53	Complete	
		18/08/2019	0319	SEBtP x 2	Pr	E	57	Complete	
		20/08/2019	0241	SEBtP	Pr	E	59	Complete	
		20/08/2019	2103	BtPoss spp	D	W	62	Complete	
		22/08/2019	0115	SEBtP	Pr	W	64	Complete	
		23/08/2019	0215	SEBtP	Pr	E	66	Complete	
		25/08/2019	0049	SEBtP	Pr	E	67	Complete	
		25/08/2019	0157	SEBtP	Pr	E	68	Complete	
		27/08/2019	0031	SEBtP	Pr	E	69	Complete	
				microbat spp	present				
	Ground	17/06/2019	2117	SEBtP	D	W	3	Complete	
		18/06/2019	0528	Swamp wallaby	Pr	E	4	Complete	
		19/06/2019	2343	SEBtP	D	E	24	Complete	
		21/06/2019	2145	echidna	D	E	31	Complete	
		22/06/2019	1851	cat	D	W	38	Complete	tabby
		23/06/2019	0715	Swamp wallaby	Pr	E	39	Complete	
		29/06/2019	1908	SEBtP	D	E	41	Complete	
		29/06/2019	2351	BtPoss spp	D	W	42	Complete	can only see end of animal
		30/06/2019	2312	SEBtP	D	W	43	Complete	
		2/07/2019	1920	SEBtP	D	E	44	Complete	
		3/07/2019	0259	BtPoss spp	D	W	45	Complete	can only see end of animal
		6/07/2019	0052	SEBtP	D	E	47	Complete	
		6/07/2019	1925	SEBtP	D	E	48-50	Complete	
		7/07/2019	0152	fox	D	W	52	Complete	
		7/07/2019	0215	fox	D	E	53	Complete	
		8/07/2019	2056	Northern brown bandicoot	Pr	E	59	Complete	
		11/07/2019	0250	SEBtP	D	E	60	Complete	
		11/07/2019	0323	SEBtP	D	E	62	Complete	
		12/07/2019	0137	SEBtP	Pr	W	63	Complete	
		17/07/2019	1931	SEBtP	D	E	64	Complete	
		17/07/2019	2032	fox	D	W	65	Complete	
		20/07/2019	0054	SEBtP	Pr	E	7	Complete	
		20/7/190	2151	Bandicoot spp.	D	E	9	Complete	
		21/07/2019	1853	BtPoss x 2	D	E	11	Complete	
		21/07/2019	2005	BtPoss	D	E	13	Complete	
		24/07/2019	2000	SEBtP	D	E	15	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		27/07/2019	2101	Cat	D	E	17	Complete	
		27/07/2019	2205	Bandicoot spp.	Pr	E	18	Complete	
		30/07/2019	0314	SEBtP	Pr	E	20	Complete	
		1/08/2019	0148	SEBtP	D	E	31	Complete	
		12/08/2019	0143	BTPoss spp.	D	W	44	Complete	
		16/08/2019	1156	Lace Monitor	D	E	49	Complete	
		16/08/2019	2135	SEBtP	D	E	53	Complete	
		16/08/2019	2333	Bandicoot spp.	D	E	54	Complete	
		17/08/2019	2317	SEBtP	D	E	55	Complete	
		20/08/2019	0144	Large macropod	D	E	56	Complete	
		21/08/2019	1957	SEBtP	D	E	68	Complete	
		22/08/2019	1433	Lace Monitor	D	E	71	Complete	
		23/08/2019	0115	RN Wallaby	Pr	W	72, 73	Complete	
		24/08/2019	0340	Large macropod	D	E	80	Complete	
		24/08/2019	1311	Lace Monitor	D	W	81	Complete	
		25/08/2019	2036	Bandicoot spp.	Pr	E	85	Complete	
		26/08/2019	2203	Bandicoot spp.	Pr	E	93	Complete	
7		20/06/2019	2012	SEBtP	D	W	18	Complete	
		20/06/2019	2103	SEBtP	D	E	19-23	Complete	
		20/06/2019	2320	SEBtP	D	W	24	Complete	
		24/06/2019	2136	SEBtP	D	W	35	Complete	
		27/06/2019	0252	SEBtP	D	E	36-38	Complete	2 x individuals
		30/06/2019	1937	SEBtP	D	W	40	Complete	
		30/06/2019	2249	SEBtP	D	E	41	Complete	
		1/07/2019	0151	SEBtP	D	W	42	Complete	
		2/07/2019	1951	SEBtP	D	W	44	Complete	
		8/07/2019	2000	SEBtP	D	W	47	Complete	
		9/07/2019	1908	SEBtP	D	W	48	Complete	
		11/07/2019	2129	SEBtP	D	W	49	Complete	
		12/07/2019	0136	SEBtP	D	E	50-52	Complete	
		13/07/2019	0400	SEBtP	D	E	53-55	Complete	
		14/07/2019	2234	SEBtP	D	W	56-57	Complete	
		15/07/2019	2112	SEBtP	D	W	59	Complete	
		15/07/2019	2227	SEBtP	D	E	60	Complete	
	Furniture	16/07/2019	0251	SEBtP	D	W	61	Complete	
		17/07/2019	2027	SEBtP	D	W	67	Complete	
		19/07/2019	0022	SEBtP	D	E	71-73	Complete	2 x individuals
		19/07/2019	0221	SEBtP	D	E	74	Complete	
		22/07/2019	2110	SEBtP x 2	D	W	11	Complete	
		27/07/2019	0300	SEBtP	Pr	E	19, 20	Incomplete	
		28/07/2019	2057	SEBtP	D	W	21	Complete	
		29/07/2019	0223	SEBtP	D	E	22	Complete	
		30/07/2019	0032	SEBtP	D	E	23	Complete	marks FF
		3/08/2019	2131	SEBtP	D	W	26	Complete	marks FF
		5/08/2019	0008	SEBtP	D	NDM	28	Incomplete	
		6/08/2019	2009	SEBtP	D	W	32	Complete	
		11/08/2019	2010	SEBtP	D	W	42 - 45	Incomplete	
		13/08/2019	2053	SEBtP	D	W	48	Complete	
		13/08/2019	2150	SEBtP	D	W	49	Complete	
		20/08/2019	2007	SEBtP	D	W	74	Complete	
		24/08/2019	2349	SEBtP	D	W	94	Complete	
		26/08/2019	2201	SEBtP	D	W	95	Complete	
		11/07/2019	1349	Cat	D	W	32	Complete	
	Ground	29/07/2019	0709	Cat	D	E	21	Complete	
		4/08/2019	1605	Med macropod	D	E	27	Complete	
6	**Furniture**			nil					
		21/06/2019	1738	house mouse	Pr	E	24	Complete	
		28/06/2019	1837	house mouse	Pr	E	27	Complete	
		5/07/2019	2156	cat	D	W	34	Complete	
	Ground	11/07/2019	2035	cat	D	E	47	Complete	tabby
		17/07/2019	0453	Swamp wallaby	D	E	48	Complete	
		23/07/2019	0136	Cat	D	W	6	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		24/08/2019	1419	Echidna	D	NDM	38	Incomplete	
5	North	23/06/2019	0157	Fox	D	E	2	Complete	
		27/06/2019	0446	house mouse	Pr	E	6	Complete	
		16/07/2019	2157	house mouse	Pr	EXM	19	Incomplete	
		26/07/2019	0010	Black Rat	Pr	EXM	2106-2110	Incomplete	
		27/08/2019	0006	Rodent spp.	Pr	E	2128	Complete	
	South	19/06/2019	0431	Rodent spp	D	W	14	Complete	
		26/06/2019	0338	Water rat	D	W	16	Complete	
		26/06/2019	2130	Rodent spp	D	E	17	Complete	Swimming in water
		2/07/2019	0158	Water rat	D	W	19	Complete	
		2/07/2019	2036	Water rat	Pr	W	20	Complete	
		3/07/2019	2139	Water rat	D	W	21	Complete	
		20/07/2019	1850	Water rat	D	E	3	Complete	
		22/07/2019	2015	Water rat	D	W	4	Complete	
		23/07/2019	2115	Black rat	D	NDM	5	Incomplete	
		27/07/2019	2331	Black rat	D	NDM	8	Incomplete	
		29/07/2019	1820	Water rat	D	E	10	Complete	
		29/07/2019	2331	Water rat	D	E	12	Complete	
		4/08/2019	1524	P Black Duck	D	E	25-27	Complete	
		4/08/2019	1622	P Black Duck x 2	D	W then E	28 - 29	Complete	
		24/08/2019	2331	Black Rat	D	E	78-80	Complete	
		27/08/2019	0052	Black Rat	D	W	82	Complete	
4	Furniture	5/07/2019	2218	cat	D	W	25	Complete	tabby
	Ground	25/06/2019	0253	cat	D	W	81	Complete	tabby
		4/07/2019	0447	Koala^	D	E	84	Complete	
		11/07/2019	2111	cat	D	E	87	Complete	
		17/07/2019	1154	cat	D	W	88	Complete	
3	Furniture	7/07/2019	0411	cat	D	E	204	Complete	black, white paws
		16/07/2019	0510	cat	D	E	210	Complete	black, white paws
	Ground	17/06/2019	1909	cat	D	E	9	Complete	black, white paws
		17/06/2019	2017	cat	D	W	10	Complete	black, white paws
		17/06/2019	2311	cat	D	NDM	11-51,81-138	Incomplete	in trap
		18/06/2019	0237	cat	D	EXM	52-80	Incomplete	black, white paws hanging around other cat in trap
		18/06/2019	1949	cat	D	W	147-148	Complete	black, white paws
		19/06/2019	0050	cat	D	W	150	Complete	tabby and fat
		19/06/2019	0237	cat	D	E	151-152	Complete	black, white paws
		19/06/2019	0253	EG kangaroo	Pr	E	153	Complete	
		19/06/2019	0459	cat	D	E	154	Complete	tabby and poss pregnant
		19/06/2019	1929	cat	D	W	160	Complete	black, white paws
		19/06/2019	2327	cat	D	E	163	Complete	black, white paws
		20/06/2019	0246	cat	D	E	164	Complete	black, white paws
		20/06/2019	1654	cat	D	E	170	Complete	black, white paws
		20/06/2019	2025	cat	D	W	171-172	Complete	black, white paws
		20/06/2019	2211	cat	D	E	173	Complete	black, white paws
		21/06/2019	0455	cat	D	W	174	Complete	black, white paws
		21/06/2019	0516	cat	D	E-W	175	Incomplete	black, white paws
		21/06/2019	1518	cat	D	W	181	Complete	black, white paws
		21/06/2019	1608	cat	D	E	182	Complete	black, white paws
		21/06/2019	2332	cat	D	E	183	Complete	black, white paws
		22/06/2019	1856	cat	D	W	186	Complete	black, white paws
		23/06/2019	0836	Swamp wallaby	D	E	187	Complete	
		23/06/2019	1240	Swamp wallaby	D	W	188	Complete	
		23/06/2019	1955	cat	D	W	191	Complete	black, white paws
		23/06/2019	2310	cat	D	E	192	Complete	black, white paws
		24/06/2019	1926	cat	D	W	193	Complete	black, white paws
		24/06/2019	2059	cat	D	E	195	Complete	black, white paws
		26/06/2019	0309	cat	D	W	197	Complete	black, white paws
		26/06/2019	0549	cat	D	E	199	Complete	black, white paws
		27/06/2019	0014	cat	D	W	200	Complete	black, white paws

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		27/06/2019	0234	cat	D	E	201	Complete	black, white paws
		27/06/2019	0400	cat	D	W	202	Complete	black, white paws
		27/06/2019	0538	cat	D	E	203	Complete	black, white paws
		27/06/2019	1848	cat	D	W	204	Complete	black, white paws
		28/06/2019	0530	cat	D	E	205	Complete	black, white paws
		28/06/2019	1806	cat	D	W	206	Complete	black, white paws
		28/06/2019	2036	cat	D	E	208	Complete	black, white paws
		29/06/2019	0012	cat	D	W	209	Complete	black, white paws
		29/06/2019	0200	cat	D	W	210	Complete	black, white paws
		29/06/2019	0241	cat	D	E	211	Complete	black, white paws
		29/06/2019	0749	cat	D	E	212	Complete	black, white paws
		29/06/2019	1810	cat	D	W	213	Complete	black, white paws
		29/06/2019	2320	cat	D	E	214	Complete	black, white paws
		30/06/2019	0803	EG kangaroo	D	E	215	Complete	
		30/06/2019	0940	Swamp wallaby	D	W	218	Complete	
		1/07/2019	0037	cat	D	W	219-220	Complete	black, white paws
		1/07/2019	0524	cat	D	E	221-222	Complete	black, white paws
		1/07/2019	0729	EG kangaroo	D	E	223	Complete	
		1/07/2019	1843	EG kangaroo	D	W	225	Complete	
		1/07/2019	1946	cat	D	W	226	Complete	tabby and poss pregnant
		1/07/2019	2317	cat	D	E	227	Complete	tabby and poss pregnant
		2/07/2019	0152	cat	D	E	228	Complete	black, white paws
		2/07/2019	0441	cat	D	E	229	Complete	black, white paws
		2/07/2019	1852	cat	D	W	231	Complete	black, white paws
		2/07/2019	2233	cat	D	W	232	Complete	black, white paws
		3/07/2019	0042	cat	D	E	233	Complete	black, white paws
		3/07/2019	1944	cat	D	W	235	Complete	tabby and poss pregnant
		3/07/2019	2343	cat	D	W	236-237	Complete	black, white paws
		4/07/2019	0111	cat	D	E	238	Complete	tabby and poss pregnant
		4/07/2019	0322	cat	D	E	239	Complete	black, white paws
		4/07/2019	2101	cat	D	W	240	Complete	black, white paws
		5/07/2019	0448	cat	D	E	241	Complete	black, white paws
		6/07/2019	2029	cat	D	W	242	Complete	black, white paws
		6/07/2019	2338	cat	D	W	243	Complete	black, white paws
		7/07/2019	0345	cat	D	E	244	Complete	black, white paws
		7/07/2019	2124	cat	D	E	245	Complete	tabby and poss pregnant
		8/07/2019	0346	cat	D	E	246	Complete	black, white paws
		9/07/2019	0418	Swamp wallaby	D	E	247	Complete	
		9/07/2019	0439	cat	D	E	248	Complete	black, white paws
		9/07/2019	1211	cat	D	W	249	Complete	black, white paws
		9/07/2019	1536	cat	D	E	250	Complete	black, white paws
		9/07/2019	1837	cat	D	W	252	Complete	black, white paws
		10/07/2019	0425	cat	D	E	253	Complete	black, white paws
		10/07/2019	1807	cat	D	W	254	Complete	black, white paws
		10/07/2019	2036	cat	D	W	255	Complete	tabby and poss pregnant
		11/07/2019	0048	cat	D	E	256	Complete	black, white paws
		11/07/2019	0125	cat	D	W	257-258	Complete	black, white paws
		11/07/2019	0432	cat	D	E	259	Complete	black, white paws
		11/07/2019	1959	cat	D	W	260	Complete	black, white paws
		12/07/2019	0416	cat	D	E	261	Complete	black, white paws
		13/07/2019	0730	EG kangaroo	Pr	E	266	Complete	
		13/07/2019	2204	cat	D	W	268	Complete	black, white paws
		14/07/2019	0246	cat	D	E	269	Complete	black, white paws
		14/07/2019	0413	Swamp wallaby	D	E	270	Complete	
		14/07/2019	0433	cat	D	E	271-274	Incomplete	tabby and poss pregnant
		15/07/2019	0053	cat	D	E	276	Complete	black, white paws

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		15/07/2019	1416	cat	D	W	277	Complete	black, white paws
		15/07/2019	1631	cat	D	E	278	Complete	black, white paws with prey in mouth
		15/07/2019	1812	Swamp wallaby	Pr	W	279	Complete	
		15/07/2019	2105	cat	D	W	280	Complete	black, white paws
		16/07/2019	0020	cat	D	E	281	Complete	black, white paws
		16/07/2019	0328	cat	D	W	282	Complete	black, white paws
		16/07/2019	1903	cat	D	W	285	Complete	tabby and poss pregnant
		17/07/2019	0145	cat	D	E	287	Complete	black, white paws
		17/07/2019	0850	cat	D	E	289	Complete	black, white paws
		17/07/2019	1221	cat	D	W	290	Complete	black, white paws
		17/07/2019	1431	cat	D	E	291	Complete	black, white paws
		17/07/2019	2133	cat	D	E	293	Complete	black, white paws
		17/07/2019	2247	fox	D	E	294	Complete	
		17/07/2019	2315	cat	D	E	295	Complete	tabby and poss pregnant
		18/07/2019	0306	Swamp wallaby	Pr	E	296		
		18/07/2019	0645	cat	D	W	297	Complete	black, white paws
		18/07/2019	1431	cat	D	W-E	298-299	Incomplete	black, white paws
		18/07/2019	1645	cat	D	E	301	Complete	black, white paws
		18/07/2019	1843	cat	D	W	302	Complete	black, white paws
		18/07/2019	2340	cat	D	E	303	Complete	black, white paws
		19/07/2019	1411	Cat	D	W	6	Complete	
		19/07/2019	1547	Cat with prey	D	E	7	Complete	
		20/07/2019	0504	Cat	D	E	9	Complete	
		20/07/2019	1829	Cat	D	W	10	Complete	
		20/07/2019	2352	Cat	D	E	11	Complete	
		21/07/2019	0428	Cat	D	W	12	Complete	
		21/07/2019	0527	Cat	D	W	13	Complete	
		21/07/2019	1105	Cat	D	W	14	Complete	
		21/07/2019	1252	Cat	D	E	15	Complete	
		21/07/2019	1411	Cat	D	W	16	Complete	
		21/07/2019	1528	Cat	D	E	17	Complete	
		21/07/2019	1750	Cat	D	W	18	Complete	
		21/07/2019	1818	Cat	D	E	19	Complete	
		21/07/2019	1918	Cat	D	W	20	Complete	
		22/07/2019	0022	Wallaby spp.	D	E	21	Complete	
		22/07/2019	0433	Cat	D	E	22	Complete	
		22/07/2019	1421	Cat	D	W	32	Complete	
		22/07/2019	1552	Cat	D	E	33	Complete	
		22/07/2019	1758	Cat	D	W	35	Complete	
		22/07/2019	2328	Cat	D	E	36	Complete	
		23/07/2019	1517	Cat	D	E	37	Complete	
		23/07/2019	2155	Fox	D	E	38	Complete	
		24/07/2019	2240	Cat	D	E	39	Complete	
		25/07/2019	0343	Cat with prey	D	E	43	Complete	
		25/07/2019	2024	Cat	D	W	44	Complete	
		26/07/2019	0045	Cat	D	E	45	Complete	
		26/07/2019	0405	Wallaby spp.	D	E	46	Complete	
		26/07/2019	1943	Cat	D	W	47	Complete	
		26/07/2019	1946	Cat with prey	D	E	48	Complete	
		27/07/2019	0327	Fox	D	E	49	Complete	
		27/07/2019	0519	Large macropod	D	E	50	Complete	
		27/07/2019	1803	Swamp Wallaby	D	W	51	Complete	
		27/07/2019	2035	Cat	D	W	52	Complete	
		28/07/2019	0441	Swamp wallaby	D	E	53, 54	Complete	
		28/07/2019	0557	Wallaby spp.	D	E	55	Complete	
		28/07/2019	1752	Wallaby spp.	D	W	57	Complete	
		28/07/2019	2037	Cat	D	W	58	Complete	
		28/07/2019	2153	Wallaby spp.	D	E	59	Complete	
		29/07/2019	0227	Cat with prey	D	E	61	Complete	
		29/07/2019	2328	Cat	D	E	66	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		30/07/2019	0445	Fox	D	E	67	Complete	
		30/07/2019	0555	Wallaby spp.	D	E	68	Complete	
		31/07/2019	0426	Cat	D	E	72	Complete	
		1/08/2019	0355	Cat	D	E	77	Complete	
		1/08/2019	0534	Fox	D	E	78	Complete	
		1/08/2019	2012	Cat	D	W	79	Complete	
		1/08/2019	2155	Cat with prey	D	E	80	Complete	
		2/08/2019	0243	Cat	D	E	81	Complete	
		2/08/2019	2106	Cat	D	W	84	Complete	
		2/08/2019	2346	Fox	D	E	85	Complete	
		3/08/2019	0141	Cat	D	E	86	Complete	
		3/08/2019	0508	Wallaby spp.	D	E	87	Complete	
		4/08/2019	0216	Fox	D	W	88	Complete	
		4/08/2019	0310	Wallaby spp.	Pr	NDM	89	Incomplete	
		4/08/2019	0600	Fox	D	E	90	Complete	
		4/08/2019	1646	Swamp Wallaby	Pr	W	91	Complete	
		4/08/2019	1818	Large macropod	D	E	94	Complete	
		4/08/2019	2007	Cat	D	W	95	Complete	
		4/08/2019	2111	Fox	D	E	96	Complete	
		4/08/2019	2117	Cat	D	E	97	Complete	
		4/08/2019	2156	Cat	D	E	98	Complete	
		5/08/2019	0027	Fox	D	E	99	Complete	
		5/08/2019	0431	Wallaby spp.	D	E	100	Complete	
		5/08/2019	1828	Swamp wallaby	Pr	W	101-102	Complete	
		6/08/2019	0514	Wallaby spp.	D	E	103	Complete	
		6/08/2019	1321	Cat	D	W	104	Complete	
		6/08/2019	1341	Cat	D	E	105	Complete	
		6/08/2019	1857	Fox	D	W	106	Complete	
		6/08/2019	1907	Cat	D	W	107-108	Complete	Marks culvert wall
		6/08/2019	1917	Cat	D	E	110	Complete	
		6/08/2019	2047	Cat	D	W	111	Complete	
		6/08/2019	2137	Cat	D	W	112	Complete	
		6/08/2019	2145	Cat	D	E	113	Complete	
		7/08/2019	2023	Cat	D	W	114	Complete	
		7/08/2019	2110	Cat	D	E	115	Complete	
		8/08/2019	0507	Wallaby spp.	D	E	116	Complete	
		8/08/2019	1423	Cat	D	W	118	Complete	
		8/08/2019	1554	Cat	D	E	119	Complete	
		8/08/2019	1815	Cat	D	W	120	Complete	
		8/08/2019	2143	Swamp Wallaby	Pr	W	121-122	Complete	
		9/08/2019	0527	Swamp Wallaby	Pr	E	125-126	Complete	
		9/08/2019	0559	Large macropod	D	E	127	Complete	
		9/08/2019	2022	Cat	D	E	129	Complete	
		9/08/2019	2217	Swamp Wallaby	Pr	W	131	Complete	
		9/08/2019	2309	Cat	D	W	132	Complete	
		10/08/2019	0334	Cat	D	E	133	Complete	
		10/08/2019	0456	Wallaby spp.	D	E	134	Complete	
		10/08/2019	0509	Swamp Wallaby	D	E	135-136	Complete	
		10/08/2019	0521	Fox	D	E	137	Complete	
		10/08/2019	2337	Cat	D	W	141	Complete	
		11/08/2019	0400	Cat	D	E	143	Complete	
		11/08/2019	0425	Swamp wallaby x 2	Pr	E	144	Complete	
		11/08/2019	1828	Fox	Pr	E	145	Complete	
		12/08/2019	0135	Cat	D	W	147	Complete	
		12/08/2019	0619	Wallaby spp.	D	E	148	Complete	
		12/08/2019	0634	Wallaby spp.	D	E	149	Complete	
		12/08/2019	1436	Cat	D	W	153	Complete	
		12/08/2019	1531	Cat	D	E	154	Complete	
		12/08/2019	1927	Swamp Wallaby	D	W	155	Complete	
		12/08/2019	2125	Fox	D	E	156	Complete	
		13/08/2019	0331	Fox	D	E	157	Complete	
		13/08/2019	0527	Cat	D	W	161-162	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		13/08/2019	0658	Fox	D	E	163	Complete	
		13/08/2019	1930	Cat	D	E	164	Complete	May be pregnant
		13/08/2019	2105	Swamp Wallaby	Pr	W then stops	165	Incomplete	
		13/08/2019	2245	Cat	D	E	167	Complete	
		13/08/2019	2254	Cat	D	E	168	Complete	
		14/08/2019	0113	Cat	D	W	169	Complete	
		14/08/2019	1826	Fox	D	W	170	Complete	
		15/08/2019	0337	Swamp wallaby	Pr	E then W	171-172	Incomplete	
		15/08/2019	1834	Fox	D	W	173	Complete	
		16/08/2019	0349	Cat	D	E	179	Complete	
		16/08/2019	1816	Fox	D	W	181	Complete	
		17/08/2019	0703	Fox	Pr	E	182	Complete	
		17/08/2019	1748	Swamp wallaby	Pr	W	183	Complete	
		17/08/2019	1819	Fox	D	W	184	Complete	
		17/08/2019	2007	Wallaby spp.	D	E	185	Complete	
		17/08/2019	2218	Cat	D	E	186	Complete	
		18/08/2019	0147	Cat	D	W	187	Complete	
		18/08/2019	2034	Cat	D	W	188	Complete	
		18/08/2019	2231	Cat	D	E	189	Complete	
		19/08/2019	0533	Cat	D	W	190	Complete	
		19/08/2019	0548	Cat	D	E	191	Complete	
		19/08/2019	1621	Wallaby spp.	D	E	192	Complete	
		19/08/2019	1939	Cat with prey	D	E	193	Complete	
		19/08/2019	2238	Fox	D	E	194	Complete	
		20/08/2019	0336	Fox	D	W	199	Complete	
		20/08/2019	0547	Cat	D	E	200	Complete	
		20/08/2019	1352	Cat	D	W	207	Complete	
		20/08/2019	1738	Cat	D	E	209	Complete	
		20/08/2019	1833	Cat	D	W	210	Complete	
		20/08/2019	2057	Cat	D	W	211	Complete	
		20/08/2019	2304	Fox	Pr	E	213	Complete	
		20/08/2019	2327	Swamp Wallaby	Pr	W	215	Complete	
		21/08/2019	0015	Cat	D	W	216	Complete	
		21/08/2019	0323	Fox	D	W	217	Complete	
		21/08/2019	0413	Cat	D	W	218	Complete	
		21/08/2019	0438	Fox	Pr	E	219	Complete	
		21/08/2019	0530	Fox	D	W	220	Complete	
		21/08/2019	0710	Swamp wallaby	D	E	221	Complete	
		21/08/2019	1605	Wallaby spp.	D	W	226	Complete	
		21/08/2019	1903	Cat	D	W	227	Complete	
		22/08/2019	0204	Cat	D	E	228	Complete	
		22/08/2019	0249	Fox	Pr	E	229	Complete	
		22/08/2019	0712	Cat	Pr	E	230	Complete	
		22/08/2019	1834	Swamp wallaby	Pr	W	233-235	Complete	
		22/08/2019	1949	Fox	D	W	237	Complete	
		22/08/2019	1949	Fox	D	W	238	Complete	
		23/08/2019	0328	Wallaby spp.	D	E	239	Complete	
		23/08/2019	0434	Cat	D	E	240	Complete	
		23/08/2019	0733	Large macropod	D	E	242	Complete	
		23/08/2019	1750	Fox	D	W	243	Complete	
		23/08/2019	2137	Cat	D	W	246	Complete	
		24/08/2019	0130	Large macropod	D	E	247	Complete	
		24/08/2019	0244	Cat	D	W	248	Complete	
		24/08/2019	0318	Fox	D	W	250	Complete	
		24/08/2019	0735	Fox	D	E	251-252	Complete	
		24/08/2019	1541	Swamp Wallaby	D	W	253	Complete	Slips over
		24/08/2019	1814	Fox x 2	D	W	254	Complete	
		24/08/2019	2103	Cat	D	W	255	Complete	
		24/08/2019	2356	Cat	D	E	256	Complete	
		25/08/2019	0314	Cat	D	E	257	Complete	
		25/08/2019	0337	Cat	D	E then W	258	Incomplete	
		25/08/2019	0622	Fox	D	E	260	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		25/08/2019	0641	Fox	Pr	E	261	Complete	
		25/08/2019	1839	Fox	D	W	262	Complete	
		25/08/2019	2029	Cat	D	W	263	Complete	
		26/08/2019	0549	Wallaby spp.	Po	E	264	Complete	
		26/08/2019	0640	Fox	Pr	E	265	Complete	
		26/08/2019	1937	Cat	D	W	266	Complete	
		26/08/2019	2039	Swamp Wallaby	Pr	W	267	Complete	
		26/08/2019	2109	Cat	D	E	269	Complete	
		27/08/2019	0257	Fox	D	E	272	Complete	
		27/08/2019	0549	EG kangaroo	Pr	E	273	Complete	
		27/08/2019	0657	Wallaby spp.	D	E	274	Complete	
		27/08/2019	0706	Wallaby spp.	Po	E	275	Complete	
2	**Furniture**			microbat spp	present				
		23/06/2019	0555	fox	D	E	78	Complete	
		24/06/2019	0130	Swamp wallaby	D	E	82	Complete	
		24/06/2019	0353	fox	D	E	83	Complete	
		10/07/2019	0516	echidna	D	E	250	Complete	
		15/07/2019	2030	echidna	D	E	386	Complete	
		18/07/2019	2357	echidna	D	W	475	Complete	
		19/07/2019	0255	Swamp wallaby	D	E	476	Complete	
		22/07/2019	0351	echidna	D	E	26	Complete	
		22/07/2019	2349	echidna	D	E	45	Complete	
		27/07/2019	2308	bandicoot spp	D	E	99	Complete	
		29/07/2019	1800	Swamp wallaby	D	W	126	Complete	
		29/07/2019	1959	Bandicoot spp	D	E	128	Complete	
		30/07/2019	0445	echidna	D	E	130	Complete	
		30/07/2019	0521	Wallaby spp	D	E	131	Complete	
		2/08/2019	0150	Cat	D	W	153	Complete	Black, white tips
		2/08/2019	2108	Bandicoot spp	D	E	162	Complete	
		3/08/2019	1757	Swamp wallaby	Pr	W	166	Complete	
		3/08/2019	1837	Swamp wallaby	Pr	E-W	167-168	Incomplete	
		8/08/2019	1806	Swamp wallaby	Pr	E-W	211-212	Incomplete	
		10/08/2019	0305	Swamp wallaby	Pr	E	245	Complete	
	Ground	11/08/2019	2336	Wallaby spp	D	E	253	Complete	
		12/08/2019	1806	Swamp wallaby	Pr	W	267	Complete	
		12/08/2019	1923	Swamp wallaby	Pr	W	269	Complete	
		13/08/2019	0112	Wallaby spp	D	W	270	Complete	
		13/08/2019	0541	Wallaby spp	D	E	271	Complete	2 x individuals
		18/08/2019	1923	house mouse	Pr	E	321	Complete	
		20/08/2019	2157	Echidna	D	E	358	Complete	
		21/08/2019	0258	Red-necked wallaby	Pr	E	359-361	Complete	2 x individuals
		21/08/2019	0521	Fox	D	E	362	Complete	
		22/08/2019	0259	Wallaby spp	D	E	384	Complete	
		22/08/2019	1951	Wallaby spp	D	W	390	Complete	
		22/08/2019	2303	Bandicoot spp	D	E	391	Complete	
		23/08/2019	0444	Wallaby spp	Pr	E	392	Complete	
		23/08/2019	2141	Bandicoot spp	D	E	397	Complete	
		23/08/2019	2220	Bandicoot spp	D	E	398	Complete	
		24/08/2019	0031	Long-nosed bandicoot	D	W	399	Complete	
		24/08/2019	2139	Swamp wallaby	Pr	W	404	Complete	
		25/08/2019	0544	Wallaby spp	D	E	406	Complete	
		25/08/2019	1824	Fox	D	W	408	Complete	
		26/08/2019	1803	Fox	D	W	418	Complete	
		26/08/2019	1842	Fox	D	W	419-420	Complete	
1		23/06/2019	210	swamp wallaby	D	NDM	3431	Incomplete	
		30/06/2019	1230	Medium frog	Po	W	8371-8390	Complete	
	North	30/06/2019	1803	Medium frog	Pr	E	8704-8918	Complete	
		3/07/2019	2020	Medium frog	Pr	E	1002-1005	Complete	
		22/07/2019	0255	Swamp wallaby	D	NDM	2181-2184	Incomplete	
		23/07/2019	0517	Swamp wallaby	D	W	3109-3114	Complete	
	South	30/07/2019	0558	Swamp wallaby	D	W	8631-8647	Complete	

Site	Side	Date	Time	Species	Accuracy	Movement	Pic/vid No.	Complete or incomplete	Comments
		4/08/2019	0234	Swamp wallaby	D	NDM	2361-2372	Incomplete	
		30/07/2019	1741	Swamp wallaby	D	W	8697-8704	Complete	
		17/08/2019	0257	Medium macropod	Po	NDM	1397-1403	Incomplete	
		21/06/2019	1949	swamp wallaby	D	NDM	2510	Incomplete	
		12/08/2019	1709	Fox	D	W	8731	Complete	
		12/08/2019	1823	cat	D	E	8805	Complete	

Table B7: Results from spring/summer diurnal active searches. OBS = Observed, prob = probable.

Site	Date	Side	Day/Night (survey no.)	Obs	Start Time	Finish Time	Wind	Rain	Visibility	Air Temp	RH	Species (no. of individuals / behaviour)	Signs (scats/tracks)
11 & 12	26/10/2018	W	D1	NP	938	1010	RL	Nil	Good	22.5	76	Lampropholis spp.	OBS
												Wallaby spp.	Scats
	26/10/2018	E	D1	NP	1015	1045	RL	Nil	Good	22.5	76	Lace Monitor	OBS
												Yellow-faced whip snake	OBS
												Bandicoot spp.	Diggings
												Macropod spp.	Scat
												Lampropholis spp.	OBS
												Adelotis brevis	HC
												Little Eagle soaring above	
	14/11/2018	W	D2	DR	940	1010	Nil	Nil	Good	25	77	Lampropholis delicata x2	OBS
	14/11/2018	E	D2	DR	1015	1050	Nil	Nil	Good	25	77	Egernia mcpheei	OBS
												Lampropholis delicata	OBS
												Lampropholis spp.	OBS
	22/11/2018											Swamp Snake	Incidental obs
9 & 10	26/10/2018	W	D1	NP	1110	1140	Msb	Nil	Good	23	73	Nil	
	26/10/2018	E	D1	NP	1145	1215	Msb	Nil	Good	23	73	Wallaby spp.	Tracks
												Bandicoot spp.	Diggings
												Echidna	Diggings
	14/11/2018	E	D2	DR	1100	1135	Nil	Nil	Good	25	75	Lampropholis spp.	OBS
	14/11/2018	W	D2	DR	1137	1210	Nil	Nil	Good	25	75	Lampropholis spp.	OBS
												Litoria fallax	Heard
8	1/11/2018	E	D1	NM/OT	1217	1232	Msb	Nil	Good	23.9	75	Lampropholis spp.	OBS
												Wallaby spp.	Scat
	1/11/2018	W	D1	NM/OT	1233	1248	Msb	Nil	Good	23.9	75	Bandicoot spp.	Diggings
												Wallaby spp.	Scat
	14/11/2018	W	D2	DR	1300	1330	Nil	Nil	Good	28	75	Lampropholis delicata	OBS
												Lampropholis spp.	OBS
	14/11/2018	E	D2	DR	1335	1410	Nil	Nil	Good	30	72	Nil	
7	1/11/2018	W	D1	NM/OT	1259	1314	MsB	Nil	Good	25.4	73	Wallaby spp.	Scat
	1/11/2018	E	D1	NM/OT	1315	1330	Msb	Nil	Good	24.7	69	Wallaby spp.	Scat
												Bandicoot spp.	Diggings
	16/11/2018	W	D2	LA	1400	1430	Nil	Light shower	Good	26	70	Wallaby spp.	Scat
												Small Scincidae spp.	OBS

Site	Date	Side	Day/Night (survey no.)	Obs	Start Time	Finish Time	Wind	Rain	Visibility	Air Temp	RH	Species (no. of individuals / behaviour)	Signs (scats/tracks)
	16/11/2018	E	D2	NP	1400	1430	Nil	Light shower	Good	26	70	Nil	
5 & 6	6/11/2018	W	D1	NP	1047	1120	Nil	Nil	Good	26.9	75	Lampropholis delicata	OBS
	6/11/2018	E	D1	NP	1120	1150	Nil	Nil	Good	26.9	75	Carpet Python	OBS
												Lampropholis delicata	OBS
												Swamp Wallaby	Scat
												Tadpoles (prob Lit. tyleri, Lit peronii)	OBS
												Freshwater Turtle spp.	OBS
	16/11/18	W	D2	NP/LA	1145	1200	Nil	Nil	Good	22.6	74	Swamp snake	OBS
												Wallaby spp.	Tracks
												Lampropholis spp.	OBS
												Bandicoot spp.	Diggings
	16/11/18	E	D2	NP/LA	1200	1215	Nil	Nil	Good	22.6	74	Wallaby spp.	Scat, tracks
												Large snake spp.	Skin
												Lampropholis spp.	Obs
												Lampropholis delicata	OBS
												Fox	Tracks
												Tadpoles (prob Lit. tyleri, Lit. peronii)	OBS
4	11/06/2018	W	D1	NP	1200	1230	Nil	Nil	Good	26	76	Lampropholis delicata	OBS
												Swamp Wallaby	OBS
	11/06/2018	E	D1	NP	1230	1300	Nil	Nil	Good	26	76	Lampropholis spp.	OBS
												Swamp Wallaby	Scat
	16/11/2018	W	D2	LA	1320	1350	Nil	Nil	Good	23.7	75	Swamp Wallaby (prob)	Heard
												Lampropholis spp.	OBS
	6/11/2018	E	D2	NP	1320	1350	Nil	Nil	Good	23.7	75	Lampropholis spp.	OBS
												Burton's Legless Lizard (prob)	OBS
												Bandicoot spp.	Diggings
3	9/11/2018	E	D1	NP	1130	1200	Nil	Nil	Good	22	55	Lampropholis spp.	OBS
												Wallaby spp.	Scat
												Bandicoot spp.	Diggings
	14/11/2018	W	D1	NP	920	950	Nil	Nil	Good	24	53	Bandicoot spp.	Diggings
												Lampropholis spp.	OBS
												EW Dragon	Scat
	16/11/2018	W	D2	NP/LA	1200	1245	Nil	Nil	Good	24.3	74	Calyptotis ruficauda	OBS

Site	Date	Side	Day/Night (survey no.)	Obs	Start Time	Finish Time	Wind	Rain	Visibility	Air Temp	RH	Species (no. of individuals / behaviour)	Signs (scats/tracks)
												(prob)	
												EW Dragon	Scat
	16/11/2018	E	D2	NP/LA	1245	1300	Nil	Nil	Good	24.3	74	Bandicoot spp.	Diggings
2	9/11/2018	E	D1	NP	1020	1050	Nil	Nil	Good	21.3	53	Lampropholis spp.	OBS
												Wallaby spp.	Scats
												Echidna	Diggings
												Bandicoot spp.	Diggings
	11/09/2018	W	D1	NP	1050	1120	Nil	Nil	Good	21.3	53	Wallaby spp.	Scats
												Lampropholis spp.	OBS
	14/11/2018	W	D2	NP	1330	1400	MLB	Nil	Good	26	62	Bandicoot spp.	Diggings
												Wallaby spp.	Scat
												Lampropholis spp.	Obs
	14/11/2018	E	D2	NP	1400	1430	MLB	Nil	Good	26	62	Echidna	Tracks and diggings
												Bandicoot	Diggings
												Lampropholis spp.	OBS
1	8/11/2018	E	D1	NP	1230	1300	Msb	Nil	Good	20.2	60	Wallaby spp.	Scat
	8/11/2018	W	D1	NP	1300	1330	Msb	Nil	Good	20.2	60	Eastern Water Dragon	OBS
												Wallaby spp.	Scat
	14/11/2018	E	D2	NP	1100	1130	RL	Nil	Good	25.6	54	EW Dragon	OBS
												Wallaby spp.	Scats
												Water Skink	OBS
	14/11/2018	W	D2	NP	1130	1200	RL	Nil	Good	25.6	54	Red-bellied Black Snake	OBS
												EW Dragon	OBS
												Wallaby spp.	Scat

Table B8: Diurnal survey data for winter monitoring period.

Site	Date	Side	Day/Night (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	12/6/19	W	1	DR/LA	915	930						Lampropholis spp.	Obs	
	12/6/19	E	1	DR/LA	932	947						Swamp Wallaby	Scats	Osprey x 2 overhead
	15/6/19	W	2	NP	11:00	11:30	Nil	Nil	Good	18.4	74	Nil		
	15/6/19	E	2	NP/LA	11:30	12:00	Nil	Nil	Good	18.4	74	Calyptotis ruficauda		
9&10	12/6/19	W	1	NP	13:00	13:30	Msb	Nil	Good	23.1	61	Bandicoot spp.	Diggings	
	12/6/19	E	1	NP	1340	1410	Msb	Nil	Good	23.1	61	Nil		
	15/6/19	W	2	LA	12:00	12:30	Nil	Nil	Good	18.2	74	Nil		
	15/6/19	E	2	NP	12:00	12:30	Nil	Nil	Good	18.2	74	Nil		
8	12/6/19	E	1	NP	1430	1500	Msb	Nil	Good	23.4	46	Bandicoot spp.	Diggings	
	14/6/19	W	1	NP	1535	1605	Nil	Nil	Good	20.9	74	Nil		
	15/6/19	E	2	NP	12:30	13:00	Nil	Nil	Good	18.2	74	Nil		
	15/6/19	W	2	LA	12:30	13:00	Nil	Nil	Good	18.2	74	Nil		
7	13/6/19	W	1	DR	1015	1045						Swamp Wallaby		
												Lampropholis delicata		
	13/6/19	E	1	DR	1055	1127						Calyptotis ruficauda		
												Glossy Black Cockatoo	Feeding sign	
	15/6/19	E	2	NP	1305	1335	Nil	Nil	Good	18.5	71	Nil		
	15/6/19	W	2	LA	1305	1335	Nil	Nil	Good	18.5	71	Nil		
5&6	12/6/19	E	1	DR	1200	1230						Nil		
	12/6/19	W	1	DR	1235	1305						Nil		
	16/6/19	W	2	NP	1215	1245	Nil	Nil	Good	20	86	Nil		
	16/6/19	E	2	NP	1245	1315	Nil	Nil	Good	20	86	Nil		
4	13/6/19	E	1	NP	12:00	12:30	Nil	Nil	Good	22	54	Small snake spp.	OBS	
												Bandicoot spp.	Diggings	
												Wallaby spp.	Scat	
	13/6/19	W	1	NP	12:30	13:00	Nil	Nil	Good	22	54	Nil		
	16/6/19	E	2	DR	11:30	12:00						Nil		
	16/6/19	W	2	DR	12:00	12:30						Nil		

Site	Date	Side	Day/Night (survey no.)	Observers	Start Time	Finish Time	Wind	Rain	Visibility	Air Temp	Humidity	Species (no. of individuals / behaviour)	Signs (scats/tracks etc)	Comments
3	12/6/19	W	1	DR/LA	11:00	1115						Bandicoot spp.	diggings	
	12/6/19	E	1	DR/LA	1120	1150						Nil		
	16/6/19	E	2	NP	11:10	11:40	Nil	Nil	Good	19	96	Saiphos equalis		
	16/6/19	W	2	NP	11:40	12:10	Nil	Nil	Good	19	96	Nil		
2	12/6/19	W	1	DR/LA	1010	1025						Lampropholis spp.		
	12/6/19	E	1	DR/LA	1030	1045						Agamid spp.		
												Bandicoot spp		
												Lampropholis spp.		
												Swamp Wallaby		
	16/6/19	W	2	DR	1000	1030						Lampropholis spp.		
												Swamp Wallaby		
	16/6/19	E	2	DR	1032	1105						Lampropholis spp.		
												Swamp Wallaby		
1	6/12/19	W	1	NP	10:00	10:30	Nil	Nil	Good	18.5	60	Bandicoot	Diggings	
	6/12/19	E	1	NP	10:30	11:00	Nil	Nil	Good	18.5	60	Nil		
	16/6/19	E	2	NP	9:30	10:00	Nil	Nil	Good	19.1	95	Nil		
	16/6/19	W	2	NP	10:00	10:30	Nil	Nil	Good	19.1	95	Nil		

Weather key	**Wind**	**Visibility**		**Behaviour Key**		F=forage
	Nil	Very dark (no moon/heavy cloud				C=call
	Rustles leaves	Dark (quarter moon/some cloud				R=rest/roost
	Moves small branches	Detail seen (qrt moon no cloud)				T=transit/moving
	Moves	Bright (half+				

Site	Date	Side	Day/Night (survey no.)	Observers	Start Time	Finish Time	Wind	Rain	Visibility	Air Temp	Humidity	Species (no. of individuals / behaviour)	Signs (scats/tracks etc)	Comments
	large branches	moon no cloud												
	Moves canopy													

Table B9: Results from nocturnal active searches for spring/summer. Upe = Uperolia spp., P. coriacea = Pseudophryne coriacea, ONj = Owlet-nightjar, A. = Adelotus, M. = Mixophyes, Lim. = Limnodynastes, Lit = Litoria, YBG = Yellow-bellied glider.

Location	Side	Date	Obs. No.	Observers	Start	Finish	Species	Wind	Rain	Visibility	Air Temp	RH	Comment
11&12	E	08/11/2018	1	DR	2215	2245	P. coriacea, A. brevis, Upe. spp., Wallaby spp.	Nil	Nil	Good	15.6	65	
	W	08/11/2018	1	NP	2215	2245	Nil	Nil	Nil	Good	15.6	65	
	E	21/11/18	2	NP/NM	2230	2255	P. coriacea, A. brevis	Nil	Nil	Moderate	23	90	
	W	21/11/2018	2	DR, LA	2255	2315	Nil	Nil	Nil	Moderate	23	90	
9&10	E	08/11/2018	1	DR	2140	2210	ONj, P. coriacea	Nil	Nil	Good	16	64	
	W	08/11/2018	1	NP	2140	2210	A. brevis, P. coriacea	Nil	Nil	Good	16	64	
	E	21/11/2018	2	DR, LA	2235	2250	M. fasciolatus, A. brevis	Nil	Nil	Moderate	23	90	
	W	21/11/2018	2	DR, LA	2215	2230	P. coriacea	Nil	Nil	Moderate	23	90	
8	E	08/11/2018	1	DR	2107	2137	P. coriacea, A. brevis	RL	Nil	Good	16.1	65	
	W	08/11/2018	1	NP	2107	2137	A. brevis, Lit. fallax	RL	Nil	Good	16.1	65	
	E	21/11/2018	2	DR, LA	2145	2205	Sugar glider, Lim. peronii, A. brevis	Nil	light	Moderate	23	88	
	W	21/11/2018	2	DR, LA	2120	2140	Sugar glider, Lit. fallax, A. brevis; **YBG** (496489; 6609135)	Nil	light	Moderate	23	88	YBG heard calling from east side of H'way, clear call heard by both obs.
7	E	08/11/2018	1	DR	2030	2100	P. coriacea	Nil	Nil	Good	16.1	67	
	W	08/11/2018	1	NP	2030	2100	P. coriacea, A. brevis	Nil	Nil	Good	16.1	67	
	E	21/11/2018	2	DR, LA	2050	2110	A. brevis	Nil	light	Moderate	23	88	
	W	21/11/2018	2	DR, LA	2025	2040	Petaurus spp. (prob breviceps), A. brevis, P. coriacea	Nil	light	Moderate	23	88	
5&6	E	08/11/2018	1	DR	1950	2025	TF, Lit. peronii, Lit. fallax	Msb	Nil	Good	18.4	63	
	W	08/11/2018	1	NP	1950	2025	P. coriacea, Lit. tyleri, Long-finned eel	Msb	Nil	Good	18.4	63	Eel heading west in fish passage
	E	19/11/18	2	DR, LA	2320	2335	L. fallax, L. peroni, L. tyleri	Nil	Nil	Good	17.5	81	
	W	19/11/18	2	DR, LA	2300	2315	Ps. coriacea	Nil	Nil	Good	17.5	81	
4	E	16/11/2018	1	NP	1945	2015	Nil	Nil	Showers	Poor	20.6	83	
	W	16/11/18	1	NP	2015	2045	Nil	Msb	Rain	Poor	20	88	

Location	Side	Date	Obs. No.	Observers	Start	Finish	Species	Wind	Rain	Visibility	Air Temp	RH	Comment
	E	19/11/18	2	DR, LA	2125	2145	Ps. coriacea, Lim. peroni	Nil	Nil	Good	16.5	81	
	W	19/11/18	2	DR, LA	2105	2120	Ps. coriacea	Nil	Nil	Good	16.5	81	
3 (E only)	E	21/11/18	1	NP/NM	1955	2022	Ps. coriacea, Upe. fusca, C. signifera	Nil	Moderate	Moderate	22.4	90	
	E	22/11/18	2	NP/NM	1955	2015	SEBtP, Wallaby spp., Ps. coriacea	RL	Nil	Moderate	25.6	27	Dust storm
2	E	19/11/18	1	DR, LA	2230	2245	Ps. coriacea	Nil	Nil	Good	16.8	64	
	W	19/11/18	1	DR, LA	2205	2220	Nil	Nil	Nil	Good	16.8	64	
	E	21/11/18	2	NP/NM	2047	2104	A. brevis, C. signifera	Nil	Light	Moderate	21	97	
	W	21/11/18	2	NP/NM	2030	2045	Wallaby spp.	Nil	Light	Moderate	21	97	
1	E	19/11/18	1	DR, LA	2000	2015	Microbat spp.	Nil	Nil	Good	18	69.7	
	W	19/11/18	1	DR, LA	2020	2040	L. fallax, L. chloris, A. Brevis, **M. iteratus** (M, at trib), SEBtP x 2, swamp wallaby	Nil	Nil	Good	18	69.7	
	E	21/11/18	2	NP/NM	2200	2220	EW Dragon	Nil	Nil	Good	20	90	
	W	21/11/18	2	NP/NM	2130	2200	**M. iteratus x 2** (F1: 489368, 6594460, M: 5m SW of previous location), A. brevis, L. fallax, EW Dragon	Nil	Nil	Good	20	90	

Table B10: Results from nocturnal active searches in winter. GHFF – Grey-headed flying-fox, FF = Flying-fox, SuG = Sugar glider, YBG = Yellow-bellied glider, C. = Crinia, FF Melomys = Fawn-footed Melomys, TF = Tawny Frogmouth, FtG = Feathertail glider, SEBtP = Short-eared brushtail possum, MLB = Moves large branches, MSB = moves small branches.

Location	Side	Date	Obs. No.	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	Humidity	Comment
11&12	E	12/6/19	1	NP	1745	1815	GHFF	MLB	Nil	Good	19.3	74	
	W	12/6/19	1	DR	1745	1815	Nil	MLB	Nil	Good	19.3	74	
	E	15/6/19	2	DR/LA	1750	1805	GHFF						
	W	15/6/19	2	DR/LA	1805	1820	FF spp.						
9&10	E	12/6/19	1	NP	1820	1850	Nil	MLB	Nil	Good	19.3	74	
	W	12/6/19	1	DR	1820	1850	Nil	MLB	Nil	Good	19.3	74	
	E	15/6/19	2	NP	1730	1800	SuG	Nil	Nil	Good	17.1	78	
	W	15/6/19	2	NP	1800	1830	SuG	Nil	Nil	Good	17.1	78	
8	E	12/6/19	1	NP	1900	1930	Nil	Msb	Nil	Good	18.6	77	YBG heard from east
	W	12/6/19	1	DR	1900	1930	**YbG**, Swamp Wallaby	Msb	Nil	Good	18.6	77	
	E	15/6/19	2	DR/LA	1825	1840	C. signifera, Swamp wallaby						
	W	15/6/19	2	DR/LA	1840	1855	Sugar Glider, **YBG**						
7	E	13/6/19	1	NP	1740	1810	GHFF	Nil	Some drops	Good	20.2	72	
	W	13/6/19	1	DR	1740	1810	**YBG** (similar location to last night)	Nil	Some drops	Good	20.2	72	
	E	15/6/19	2	NP	1900	1930	Nil	Nil	Nil	Good	16.7	81	
	W	15/6/19	2	NP	1830	1900	**YBG.HC@496438.6608922**, SuG	Nil	Nil	Good	16.7	81	
5&6	E	12/6/19	1	NP	1935	2005	GHFF	Msb	Nil	Good	18.6	77	
	W	12/6/19	1	DR	1935	2005	Swamp Wallaby	Msb	Nil	Good	18.6	77	
	E	15/6/19	2	DR/LA	1910	1925	GHFF						
	W	15/6/19	2	DR/LA	1925	1940	FF Melomys						
4	E	13/6/19	1	NP	1815	1845	TF	Nil	Some drops	Good	20.2	72	
	W	13/6/19	1	DR	1815	1845	SuG	Nil	Some drops	Good	20.2	72	
	E	15/6/19	2	NP	1945	2015	Nil	Nil	Nil	Good	16.8	80	
	W	15/6/19	2	NP	2015	2045	GHFF	Nil	Nil	Good	16.8	80	
3 (E only)	E	13/6/19	1	NP/DR	1855	1910	C. signifera	Nil	Nil	Good	19	87	
	E	15/6/19	2	NP	2050	2120	C. signifera, macropod spp.	Nil	Nil	Good	16.9	81	
2	E	13/6/19	1	NP	1915	1945	GHFF	Nil	Nil	Good	19	87	

Location	Side	Date	Obs. No.	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	Humidity	Comment
	W	13/6/19	1	DR	1915	1945	FtG, GHFF	Nil	Nil	Good	19	87	
	E	15/6/19	2	DR/LA	1950	2005	GHFF						
	W	15/6/19	2	DR/LA	2005	2020	FtG, GHFF						
1	E	13/6/19	1	NP	2005	2035	Nil	Nil	Nil	Good	19.1	89	
	W	13/6/19	1	DR	2005	2035	SEBtP, GHFF	Nil	Nil	Good	19.1	89	
	E	15/6/19	2	DR/LA	2045	2100	Nil						
	W	15/6/19	2	DR/LA	2100	2115	SEBtP, Swamp Wallaby, GHFF						

Table B11: Adjacent habitat trapping data for winter**.** NR = Not recorded.

Site	Date	Trap type	Species	Sex	Weight	Comments
3 west	12/6/19	Small Elliot	Black Rat			Euthanised
3 east	12/6/19	Small Elliot	House mouse			Euthanised
5/6 west	12/6/19	Large Elliot (on ground)	Brown Antechinus	M	32g	
5/6 west	12/6/19	Small Elliot	Brown Antechinus	F	18g	
5/6 west	12/6/19	Small Elliot	Brown Antechinus	M	35g	
8 west	12/6/19	Small Elliot	Brown Antechinus	M	27g	
11/12 west	12/6/19	Small elliot	House mouse	M	12g	Euthanised
11/12 east	12/6/19	Small elliot	FF Melomys	M	NR	
9/10 west	12/6/19	Small elliots	Brown antechinus	M	25g	
3 west	13/6/19	Small Elliot	Black Rat			Euthanised
5/6 west	13/6/19	Small Elliot	Brown Antechinus	F	17g	
5/6 west	13/6/19	Small Elliot	Brown Antechinus	M	35g	
5/6 east	13/6/19	Small Elliot	Brown Antechinus	M	53g	
11/12 west	13/6/19	Small Elliot	House mouse	F	12g	Euthanised
11/12/ east	13/6/19	Small Elliot	Brown Antechinus	M	33g	
11/12 east	13/6/19	Cage	FF Melomys	F	NR	
8 east	13/6/19	Small elliot	FF Melomys	F	52g	
5/6 west	14/6/19	Small Elliot	Black Rat			Escaped
5/6 west	14/6/19	Small Elliot	Brown Antechinus	F	UK	Not well, euthanised after observation.
5/6 west	14/6/19	Cage	Black Rat			Euthanised
5/6 west	14/6/19	Small Elliot	House Mouse			Euthanised
5/6 east	14/6/19	Small Elliot	Brown Antechinus	F	18g	
8 west	14/6/19	Small Elliot	Brown Antechinus	F	28g	
8 west	14/6/19	Small Elliot	Brown Antechinus	M	39g	
8 west	14/6/19	Small Elliot	Melomys spp.	M	22g?	Weight probably incorrect
11/12 west	14/6/19	Small elliot	House mouse	F	9g	Euthanised
11/12 east	14/6/19	Small elliot	Brown Antechinus	M	32g	
11/12 east	14/6/19	Cage	FF Melomys	F	NR	
9/10 West	14/6/19	Small elliot	FF Melomys	F	63g	
9/10 west	14/6/19	small elliot	Brown antechinus	F	20g	
9/10 west	14/6/19	Small elliot	FF Melomys	M	70g	
9/10 west	14/6/19	small elliot	Brown antechinus	M	40g	
1 west	15/6/19	Cage	Green catbird			
2 west	15/6/19	Cage	Black Rat			Euthanised
2 east	15/6/19	Small Elliot	Brown Antechinus	M	33g	

Site	Date	Trap type	Species	Sex	Weight	Comments
2 east	15/6/19	Small Elliot	Bush Rat	M	100g +	Scales maxed out
7 west	15/6/19	Small elliot	Bush Rat	M	125g	
4 west	15/6/19	Small elliot	FF Melomys	M	97g	
4 west	15/6/19	Cage	Cat	M	NR	Euthanised
2 east	16/6/19	Small Elliot	Bush Rat	M	100g +	Probably same individual as yesterday
1 east	16/6/19	Cage	Black Rat			Euthanised
1 east	16/6/18	Cage	SEBtP	M		
1 west	16/6/19	Pitfall	Striped marsh frog			
7 west	16/6/19	Small elliot	FF Melomys	F	75g	
7 west	16/6/19	Small elliot	FF Melomys	F	75g	
4 west	16/6/19	Small elliot	Brown Antechinus	M	39g	
4 west	16/6/19	Small elliot	FF Melomys	M	85	
1 west	16/6/18	Cage	Eastern whipbird			
2 west	17/6/19	Small Elliot	House mouse			Euthanised
2 west	17/6/19	Cage	Black Rat			Euthanised
2 east	17/6/19	Large Elliot	Sugar Glider	F		Parous
2 east	17/6/19	Large Elliot	Brown Antechinus	M	35g	Both animals in same trap
2 east	17/6/19	Large Elliot	Brown Antechinus	M		Both animals in same trap. Escaped before weight taken.
2 east	17/6/19	Small Elliot	Bush Rat	M		Prob same individual as previous two morn
4 west	17/6/19	Small Elliot	House mouse	M	10g	
4 west	17/6/19	Small elliot	Brown Antechinus	M	NR	
4 west	17/6/19	Cage	Bush Rat	M	NR	
7 east	17/6/19	Small elliot	Brown antechinus	M	40g	
7 west	17/6/19	Small elliot	Bush Rat	F	105g	
7 culvert	17/6/19	Cage	Cat	M	NR	Euthanised
3 culvert	18/6/19	Cage	Cat	UK	NR	Taken to pound

Table B12: Adjacent habitat trapping data for spring/summer.

Site	Date	Trap type	Species	Sex	Weight	Comments
1 east	19/11/2018	Small cage	Black rat	F	NR	
1 east	19/11/2018	Large cage	Black rat	F	NR	
1 east	21/11/2018	Small elliott	Black rat	M	130	
1 west	19/11/2018	Small cage	Black rat	F	130g	Euthanised
1 west	21/11/2018	Small elliott	Black rat	F	130	Euthanised
1 west	21/11/2018	Large elliott	SEBtP	M	NR	
2 east	19/11/2018	Small elliott	Melomys spp.	M	87g	
2 east	19/11/2018	Small elliott	Melomys spp.	F	82g	Lactating
2 east	20/11/2018	Small elliott	Fawn-footed melomys	M	92g	
2 east	20/11/2018	Pitfall	Lampropholis delicata	Uk	NA	
2 east	21/11/2018	Small elliot	Black rat	F	150	
2 east	21/11/2018	Small elliott	Bush rat	M	120	
2 west	20/11/2018	Large cage	Black rat	M	NR	
2 west	20/11/2018	Pitfall	Lampropholis guichenoti	Uk	NA	
2 west	21/11/2018	Small elliott	Black rat	UK	NA	
3 east	15/11/2018	Pitfall	Lampropholis delicata x 2	UK	NA	
3 east	18/11/2018	Pitfall	Calyptotis ruficauda	Uk	NA	
3 east	18/11/2018	Pitfall	Lampropholis delicata	F		
3 west	16/11/2018	Pitfall	Calyptotis ruficauda	UK	NA	
3 west	16/11/2018	Pitfall	Calyptotis ruficauda	UK	NA	
3 west	17/11/2018	Pitfall	Lampropholis delicata	UK	NA	RN Wallaby in veg patch .
3 west	18/11/2018	Pitfall	Calyptotis ruficauda	UK	NA	
3 west	18/11/2018	Pitfall	Lampropholis guichenoti	UK	NA	
3 west	20/11/2018	Pit fall	Lampropholis guichenoti	UK	NA	
4 east	17/11/2018	Pitfall	Pseudophryne coriacea	UK	NA	
4 west	15/11/2018	Pitfall	Blackish blind snake	UK	NA	
4 west	18/11/2018	Small elliott	Black rat	M	183g	Euthanised
5&6 east	14/11/2018	Pitfall	Lampropholis delicata x 2	UK	NA	All animals in same trap.
5&6 west	14/11/2018	Pitfall	Lampropholis delicata	UK	NA	
5&6 west	15/11/2018	Small cage	Bush rat	M	120g	
5&6 west	15/11/2018	Small elliot	Bush rat	M	155g	
5&6 west	16/11/2018	Large cage	Northern brown bandicoot	UK	NA	
5&6east	15/11/2018	Pitfall	Calyptotis ruficauda	UK	NA	
7 east	16/11/2018	Pitfall	Lampropholis guitchinoti	UK	NA	
7 west	14/11/2018	Pitfall	Lampropholis delicata	UK	NA	
7 west	14/11/2018	Small cage	SEBtP	UK	NA	Released immediately
7 west	15/11/2018	Pitfall	Calyptotis ruficauda	UK	NA	
8 west	13/11/2018	Small elliot	Fawn-footed melomys	F	80g	Lactating teats

Site	Date	Trap type	Species	Sex	Weight	Comments
8 west	13/11/2018	Small elliot	Brown antechinus	F	30g	Evidence of recent pouch young
8 west	15/11/2018	Small elliott	Brown antechinus	F	37g	Evidence of recent pouch young
8west	14/11/2018	Small elliott	Fawn-footed melomys	Male	87g	
8west	14/11/2018	Pitfall	Red-backed toadlet	UK	NA	
9&10 east	14/11/2018	Pitfall	Lampropholis delicata	UK	NA	
9&10 east	15/11/2018	Large cage	SEBtP	UK	NA	
9&10 west	13/11/2018	Large cage	Black rat	F	NA	Euthanised
9&10 west	14/11/2018	Small cage	Black rat	M	NA	Euthanised
9&10 west	15/11/2018	Small cage	Black rat	UK	NA	Escaped
9&10 west	15/11/2018	Small elliot	Brown antechinus	UK	24g	
11&12 east	13/11/18	Pitfall	Calyptotis ruficauda	UK	NA	
11&12 west	14/11/2018	Pitfall	Striped marsh frog	Uk	NA	
11&12 west	14/11/2018	Small cage	Black rat	Male	100g	Euthanised
11&12 west	14/11/2018	Pitfall	Lampropholis delicata	UK	NA	

Table B13: Results from hair funnel sampling in adjacent habitat in spring/summer. BtPoss = Brushtail possum species, CRtP = Common ringtail possum.

Site	Side	Spring 2018		
		Install Date	Collect date	Fauna
1	E-1	12-16/11/18	30/11/2018	BtPoss spp.
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	BtPoss spp.
	W-2	12-16/11/18	30/11/2018	Rattus spp.
2	E-1	12-16/11/18	30/11/2018	
	E-2	12-16/11/18	30/11/2018	Bush rat
	W-1	12-16/11/18	30/11/2018	Black rat
	W-2	12-16/11/18	30/11/2018	
3	E-1	12-16/11/18	30/11/2018	
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	Northern brown bandicoot
	W-2	12-16/11/18	30/11/2018	
4	E-1	12-16/11/18	30/11/2018	
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	
	W-2	12-16/11/18	30/11/2018	
5 & 6	E-1	12-16/11/18	30/11/2018	
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	Rattus spp.
	W-2	12-16/11/18	30/11/2018	
7	E-1	12-16/11/18	30/11/2018	BtPoss spp.
	E-2	12-16/11/18	30/11/2018	Bush rat
	W-1	12-16/11/18	30/11/2018	
	W-2	12-16/11/18	30/11/2018	
8	E-1	12-16/11/18	30/11/2018	CRtP
	E-2	12-16/11/18	30/11/2018	BtPoss spp.
	W-1	12-16/11/18	30/11/2018	BtPoss spp.
	W-2	12-16/11/18	30/11/2018	
9 & 10	E-1	12-16/11/18	30/11/2018	BtPoss spp.
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	
	W-2	12-16/11/18	30/11/2018	
11 & 12	E-1	12-16/11/18	30/11/2018	Carnivora spp.
	E-2	12-16/11/18	30/11/2018	
	W-1	12-16/11/18	30/11/2018	
	W-2	12-16/11/18	30/11/2018	

Table B14: Results from hair funnel sampling in adjacent habitat in winter. FF Melomys = Fawn-footed melomys.

Site	Side	Winter 2019		
		Install Date	Collect date	Fauna
1	E-1	13/06/2019	24/06/2019	Trichosurus spp.
	E-2	13/06/2019	24/06/2019	Trichosurus spp.
	W-1	13/06/2019	24/06/2019	House mouse
	W-2	13/06/2019	24/06/2019	
2	E-1	13/06/2019	24/06/2019	Antechinus spp.
	E-2	13/06/2019	24/06/2019	Antechinus spp.
	W-1	13/06/2019	24/06/2019	Rodent spp.
	W-2	13/06/2019	24/06/2019	Bush rat
3	E-1	13/06/2019	24/06/2019	House mouse
	E-2	13/06/2019	24/06/2019	
	W-1	13/06/2019	24/06/2019	Long-nosed bandicoot
	W-2	13/06/2019	24/06/2019	Possum spp.
4	E-1	13/06/2019	24/06/2019	
	E-2	13/06/2019	24/06/2019	FF Melomys
	W-1	13/06/2019	24/06/2019	
	W-2	13/06/2019	24/06/2019	
5/6	E-1	11/06/2019	19/06/2019	Antechinus spp.
	E-2	11/06/2019	19/06/2019	
	W-1	11/06/2019	19/06/2019	Rattus spp., Brown antechinus
	W-2	11/06/2019	19/06/2019	
7	E-1	11/06/2019	19/06/2019	Trichosurus spp.
	E-2	11/06/2019	19/06/2019	FF Melomys
	W-1	11/06/2019	19/06/2019	
	W-2	11/06/2019	19/06/2019	Bush rat. House mouse
8	E-1	11/06/2019	19/06/2019	
	E-2	11/06/2019	19/06/2019	
	W-1	11/06/2019	19/06/2019	Antechinus spp.
	W-2	11/06/2019	19/06/2019	
9/10	E-1	11/06/2019	19/06/2019	House mouse
	E-2	11/06/2019	19/06/2019	
	W-1	11/06/2019	19/06/2019	Trichosurus spp., FF Melomys
	W-2	11/06/2019	19/06/2019	
11/12	E-1	11/06/2019	19/06/2019	Antechinus spp.
	E-2	11/06/2019	19/06/2019	
	W-1	11/06/2019	19/06/2019	
	W-2	11/06/2019	19/06/2019	

Table B15: Sand pad data for spring/summer monitoring.

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
12 median west	497115	6610068	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	nil	Good
			West	31/11/2018		Nil	Good
			East	1/11/2018	Insp2	Cat (definite, 1e)	Fair
			West	1/11/2018		Cat (definite, 1e)	Fair
			East	2/11/2018	Insp3	Nil	Fair
			West	2/11/2018		Nil	Fair
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Fair
			East	4/11/2018	Insp5	Small reptile (definite, 1e,1w), medium reptile (definite, 3 e, 1w)	Fair
			West	4/11/2018		Medium reptile (definite, 2e, 1w meandering)	Fair
			East	5/11/2018	Insp6	Small reptile (definite, 2w, 1e, 1 meandering) cat (definite 1w meandering)	Fair
			West	5/11/2018		Small reptile (definite, 1w, 1e) cat (definite 1w)	Fair
			East	6/11/2018	Insp7	Lace monitor (definite 1e), medium size reptile (definite 1e, 1w) small reptile (definite, 1e 1w)	Fair
			West	6/11/2018		Lace monitor (definite 1e), medium size reptile (definite 1e, 1w) small reptile (definite, 1e 1w)	Fair
			East	7/11/2018	Insp8	Small reptile (definite 2e2w)	Poor
			West	7/11/2018		Small reptile (definite 2e2w)	Poor
11 median east	497168	6610040	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Nil	Good
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Cat (definite, 1e)	Good
			West	1/11/2018		Cat (definite, 1e)	Fair
			East	2/11/2018	Insp3	Nil	Fair
			West	2/11/2018		Nil	Fair
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Fair
			East	4/11/2018	Insp5	Nil	Good
			West	4/11/2018		Nil	Fair
			East	5/11/2018	Insp6	Nil	Fair
			West	5/11/2018		Nil	Fair
			East	6/11/2018	Insp7	Lace monitor (definite 1e), medium reptile (definite 1e) cat (probable 1e)	Fair
			West	6/11/2018		Lace monitor (definite 1e), medium reptile (definite 1e) cat (probable 1e)	Fair
			East	7/11/2018	Insp8	Nil	Poor
			West	7/11/2018		Nil	Poor
10 median west	496622	6609409	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Small mammal (possible:1 track e/w)	Good
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Nil	Fair

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
			West	1/11/2018		Nil	Fair
			East	2/11/2018	Insp3	Nil	Fair
			West	2/11/2018		Nil	Fair
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Fair
			East	4/11/2018	Insp5	Nil	Fair
			West	4/11/2018		Nil	Fair
			East	5/11/2018	Insp6	Nil	Fair
			West	5/11/2018		Nil	Fair
			East	6/11/2018	Insp7	Nil	Fair
			West	6/11/2018		Nil	Good
			East	7/11/2018	Insp8	Cat (definite 1w)	Poor
			West	7/11/2018		Cat (definite 1w)	Poor
9 median east	496622	6609409	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10-18	Insp1	Nil	Fair
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Nil	Fair
			West	1/11/2018		Nil	Fair
			East	2/11/2018	Insp3	Nil	Fair
			West	2/11/2018		Nil	Fair
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Good
			East	4/11/2018	Insp5	Nil	Fair
			West	4/11/2018		Nil	Fair
			East	5/11/2018	Insp6	Nil	Fair
			West	5/11/2018		Nil	Fair
			East	6/11/2018	Insp7	Rat sp. (probable, 1e)	Fair
			West	6/11/2018		Rat sp. (probable, 1e)	Fair
			East	7/11/2018	Insp8	Cat (definite 1w)	Poor
			West	7/11/2018		Cat (definite 1w) small Dasyurid (probable 1e)	Poor
8 full length	496506	6609219	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Lace monitor (definite:1track e/w), Bandicoot sp. (definite 1track e/w), **LN Potoroo** (possible, 1track w/e)	Good
			West	31/10/2018		Lace monitor (definite:1track e/w), Bandicoot sp. (definite 1 track e/w), Bandicoot sp. (definite 1 track w/e).	Good
			East	1/11/2018	Insp2	Lace monitor (definite, 1 w), echidna (probable, 1 w)	Good
			West	1/11/2018		Lace monitor (definite, 1w), echidna (probable, 1 w)	Fair
			East	2/11/2018	Insp3	Cat (definite 1e)	Fair
			West	2/11/2018		Cat (definite, 1e)	Fair
			East	3/11/2018	Insp4	Definite lace monitor (1e) fox (probable, 1 e), definite medium sized reptile (1 e)	Fair
			West	3/11/2018		Definite lace monitor (1e) fox (probable, 1 e), definite medium sized reptile (1 e), Dasyurid(possible, 1e)	Fair
			East	4/11/2018	Insp5	Lace monitor (definite, 1w), Frog(definite, 1e)	Fair

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
			West	4/11/2018		Lace monitor (definite, 1w), Frog(definite, 1e)	Fair
			East	5/11/2018	Insp6	Dasyurid (possible 1w) small rodent (probable 1e)	Fair
			West	5/11/2018		Dasyurid (possible 2w 1e), probable small rodent (1e)	Fair
			East	6/11/2018	Insp7	Lace monitor (definite 1e)	Fair
			West	6/11/2018		Lace monitor (definite 1e) dasyurid (probable 1w)	Fair
			East	7/11/2018	Insp8	Cat (definite 1e1w), brushtail possum (definite 1e)	Fair
			West	7/11/2018		Cat (definite 1e1w), brush tail possum (definite 1e)	Fair
7 full length	496438	6608780	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Nil	Good
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Nil	Good
			West	1/11/2018		Nil	Good
			East	2/11/2018	Insp3	Nil	Good
			West	2/11/2018		Nil	Good
			East	3/11/2018	Insp4	Definite swamp wallaby (1e)	Good
			West	3/11/2018		Definite swamp wallaby(1e,1w)	Good
			East	4/11/2018	Insp5	Cat (definite 1w)	Good
			West	4/11/2018		Cat (definite 1w)	Good
			East	5/11/2018	Insp6	Nil	Good
			West	5/11/2018		Definite swamp wallaby(1e,1w)	Good
			East	6/11/2018	Insp7	Nil	Good
			West	6/11/2018		Nil	Good
			East	7/11/2018	Insp8	Lace monitor (definite, 1w)	Good
			West	7/11/2018		Lace monitor (definite, 1w)	Good
6 full length	496188	6608319	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Nil	Good
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Cat (definite, 1 e)	Good
			West	1/11/2018		Cat (definite, 1e)	Good
			East	2/11/2018	Insp3	Fox (probable 1 w)	Good
			West	2/11/2018		Fox (probable 1w)	Fair
			East	3/11/2018	Insp4	Probable cat (1e)	Fair
			West	3/11/2018		Probable cat (1e,1w)	Fair
			East	4/11/2018	Insp5	Possible small mammal(1e)	Fair
			West	4/11/2018		Nil	Fair
			East	5/11/2018	Insp6	Nil	Fair
			West	5/11/2018		Nil	Fair
			East	6/11/2018	Insp7	Dasyurid (possible 1e)	Fair
			West	6/11/2018		Nil	Fair
			East	7/11/2018	Insp8	Nil	Fair
			West	7/11/2018		Dasyurid (possible 1e)	Fair
5			West	30/10/2018	Install	NA	

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
			West	30/10/2018		NA	
			West	31/10/2018	Insp1	Nil	Good
			West	31/10/2018		Nil	Good
			West	1/11/2018	Insp2	Nil	Fair
			West (water)	1/11/2018		Cat (definite, 2e,2w)	Fair
			East	2/11/2018	Insp3	Nil	Fair
			West	2/11/2018		Nil	Fair
			West (water)	2/11/2018		Nil	Fair
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Fair
			West	3/11/2018		Nil	Fair
			East	4/11/2018	Insp5	Small reptile (probable, 1e)	Fair
			West	4/11/2018		Rat sp, (definite, 1e,1w, 1ew)	Fair
			West	4/11/2018		Small reptile (probable, 1e)	Fair
			East	5/11/2018	Insp6	Nil	Fair
			West	5/11/2018		Rat sp, (definite, 1e,1w)	Fair
			West	5/11/2018		Definite bandicoot (1e1w)	Fair
			East	6/11/2018	Insp7	Dasyurid (possible 1w)	Fair
			West	6/11/2018		Nil	Fair
			West	6/11/2018		Nil	Fair
			East	7/11/2018	Insp8	Rat sp (definite 1e1w)	Fair
			West	7/11/2018		Rat sp (definite 1e1w)	Fair
			West	7/11/2018		Rat sp (definite 1e1w)	Fair
4	495702	6607693	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	**Koala** (definite: 1 e)	Good
			West	31/10/2018		**Koala** (definite: 1 e)	Good
			East	1/11/2018	Insp2	Lace monitor(definite: 1e)	Good
			West	1/11/2018		Lace monitor (definite , 1e)	Good
			East	2/11/2018	Insp3	Cat (definite, 1e 1w) Fox(definite 1e)	Good
			West	2/11/2018		Cat (definite 1 e 1w) Fox (definite 1 e)	Good
			East	3/11/2018	Insp4	Lace monitor (2w)	Good
			West	3/11/2018		Lace monitor (2w)	Good
			East	4/11/2018	Insp5	**Koala** (definite 1w) medium reptile (definite 1e) lace monitor (definite 1e)	Good
			West	4/11/2018		**Koala** (definite 1w) medium reptile (definite 1e) lace monitor (definite 1e)	Good
			East	5/11/2018	Insp6	Nil	Good
			West	5/11/2018		Nil	Good
			East	6/11/2018	Insp7	Nil	Good
			West	6/11/2018		Nil	Good
			East	7/11/2018	Insp8	Lace monitor (definite, 1w)	Good
			West	7/11/2018		Lace monitor (definite, 1w)	Good
3	495082	6606515	East	30/10/2018	Install	NA	

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Cat (definite, 3e, 2w)	Good
			West	31/10/2018		Cat (definite, 1e,1 canid (probable 1 e)	Good
			East	1/11/2018	Insp2	Cat (definite, 1e, 1 w)	Fair
			West	1/11/2018		Cat (definite, 2e, 1 w)	Fair
			East	2/11/2018	Insp3	Cat (probable 1w), Fox (definite 1e)	Fair
			West	2/11/2018		Cat probable (1 w), Fox (probable e)	Fair
			East	3/11/2018	Insp4	Cat (definite, 1 e 1w) fox(probable 1w)	Fair
			West	3/11/2018		Cat (definite, 1 e) fox (probable 1e1w)	Fair
			East	4/11/2018	Insp5	Fox(definite, 1e,1w) Brushtail possum (definite, 1w)	Poor
			West	4/11/2018		Fox(definite, 1e,1w) Brushtail possum (definite, 1w)	Poor
			East	5/11/2018	Insp6	Fox(definite 2e,1w)	Poor
			West	5/11/2018		Fox(definite 2e,1w)	Poor
			East	6/11/2018	Insp7	Fox(definite 1e,1w)	Poor
			West	6/11/2018		Fox(definite 1e, 1w)	Poor
			East	7/11/2018	Insp8	Fox (probable 1e) bandicoot (definite 1w)	Poor
			West	7/11/2018		Fox (probable 1e) bandicoot (definite 1w)	Poor
2	494477	6605329	East	30/10/2018	Install	NA	
			West	30/10/2018		NA	
			East	31/10/2018	Insp1	Nil	Good
			West	31/10/2018		Nil	Good
			East	1/11/2018	Insp2	Echidna(definite, 1 w/meander)	Good
			West	1/11/2018		Echidna(definite, 1e, 1w/meander)	Good
			East	2/11/2018	Insp3	echidna (definite, 1 w) dasyurid (possible 1w)	Good
			West	2/11/2018		echidna (definite, 1 w) dasyurid (possible 1w)	Good
			East	3/11/2018	Insp4	Nil	Fair
			West	3/11/2018		Nil	Good
			East	4/11/2018	Insp5	Echidna (definite 1w)	Good
			West	4/11/2018		Echidna (definite 1w)	Good
			East	5/11/2018	Insp6	Definite bandicoot (1e1w)	Fair
			West	5/11/2018		Definite bandicoot (1e1w)	Fair
			East	6/11/2018	Insp7	Fox (definite, 1w) echidna (probable 1e) dasyurid (possible 1e)	Fair
			West	6/11/2018		Fox (definite, 1w) echidna (probable 1e)	Fair
			East	7/11/2018	Insp8	Echidna (definite 1w), dasyurid (possible 2e 1w) rat sp(definite 1e)	Fair
			West	7/11/2018		Echidna (definite 1w), dasyurid (possible 1e 1w) rat sp(definite 1e)	Fair
1	489375	6594290	North	14/11/2018	Install		
			South	14/11/2018			
			North	15/11/2018	Insp 1	Nil	Dry
			South	15/11/2018		Medium bird (prob 1e)	Dry
			North	16/11/2018	Insp 2	Nil	Dry, water added
			South	16/11/2018		Nil	Dry, water added

Location	Easting	Northing	Sand pad	Date	Action	Species (direction & no passes)	Pad condition
			North	17/11/2018	Insp 3	Wallaby sp. (1/e)	Dry, water added
			South	17/11/2018		Nil	Dry, water added
			North	18/11/2018	Insp 4	Small bird (1/e)	
			South	18/11/2018		Small bird (1/w); small lizard (1/w)	
			North	19/11/2018	Insp 5	Nil	
			South	19/11/2018		Nil	
			North	20/11/2018	Insp 6	Nil	
			South	20/11/2018		Nil	
			North	21/11/2018	Insp 7	Nil	
			South	21/11/2018		Med reptile (def 1/?), small reptile (prob 1/?)	
			North	22/11/2018	Insp 8	Water bird (def 1/w)	
			South	22/11/2018		Waterbird (def 1/meander)	

Table B16: Sand pad data for winter monitoring. D = definite.

Site	Pad	Date	Inspection	Species and Direction	Condition	Comment
1	N	15/06/2023	1	D wallaby 1 e 1w (probable swamp wallaby)	Fair	
	S			nil	Fair	
2	E			D echidna 1 e 1 w	good	
	W			D echidna 1 e 1 w	good	
3	E			D cat (2 e 3 w)	fair	
	W			D Cat (1 W)	fair	
4	E			Pr small rodent (2e, 2w)	good/firm in places	Small rodent = probable House Mouse
	W			nil	good	
5	E			nil	fair	
	SW			nil	fair	
	NW			nil	fair	
6	E			D small rodent (1e 1w)	good	
	W			D small rodent (1e 1w)	good	
7	E			D small rodent (1e 1w)	good	
	W			D small rodent (1e 1w)	good	
8	E			Nil	good	
	W			Nil	good	
9	E			NIl	fair	
	W			Nil	fair	
10	E			nil	fair	
	W			nil	Fair	
11	E			D small rodent (1w), Probable dasyurd (1E)	fair	
	W			D small rodent (1w), Probable dasyurd (1E)	fair	
12	E			Probable Dasyurid (1e)	fair	
	W			Probable Dasyurid (1e)	Fair	
1	N	16/06/2023	2	nil	Fair	Ant lions on pads
	S			nil	Fair	
2	E			D cat (1w)	good	
	W			D cat (1w)	good	
3	E			nil	fair	
	W			nil	fair	
4	E			nil	good/firm in places	
	W			nil	good	
5	E			nil	fair	
	SW			nil	fair	
	NW			D small rodent (1e)	fair	
6	E			nil	good	
	W			nil	good	
7	E			D cat (1 e 1w)	good	
	W			D cat (1 e 1w)	good	
8	E			D Brushtail Possum (1 E)	good	
	W			D Brushtail Possum (1 E)	good	
9	E			D small rodent (1e)	fair	
	W			D small rodent (1e)	fair	

Site	Pad	Date	Inspection	Species and Direction	Condition	Comment
10	E			nil	fair	
	W			nil	Fair	
11	E			Pr Dasyurid (2 e)	fair	Bounding pattern (probable antechinus sp.)
	W			Pr Dasyurid (2 e)	fair	
12	E			nil	fair	
	W			nil	Fair	
1	N	17/06/2023	3	nil	Fair	
	S			nil	Fair	
2	E			nil	good	
	W			nil	good	
3	E			nil	fair	
	W			nil	fair	
4	E			nil	good/firm in places	
	W			nil	good	
5	E			nil	fair	
	SW			nil	fair	
	NW			nil	fair	
6	E			nil	good	
	W			nil	good	
7	E			D cat (1 e), D Brushtail (1 e)	good	
	W			D cat (1 e), D Brushtail (1 e)	good	
8	E			Pr small rodent (1e)	good	
	W			Pr small rodent (1e)	good	
9	E			Pr small rodent (1e)	fair	
	W			Pr small rodent (1e)	fair	
10	E			nil	fair	
	W			nil	Fair	
11	E			Pr Small rodent (1e, 1 w), Pr dasyurid (1e,1w)	fair	
	W			Pr Small rodent (1e, 1 w), Pr dasyurid (1e,1w)	fair	
12	E			Pr Small rodent (1e, 1 w)	fair	
	W			Pr Small rodent (1e, 1 w)	Fair	
1	N	18/06/2023	4	nil	Fair	
	S			D cat 1 e	Fair	
2	E			D small rodent (1e)	good	
	W			nil	good	
3	E			Pr cat (1e,1w)	fair	
	W			Pr cat (1e,1w)	fair	
4	E			nil	good/firm in places	
	W			nil	good	
5	E			nil	fair	
	SW			D small rodent (1e)	fair	
	NW			Pr small rodent (1 e)	fair	
6	E			D small rodent (1e, 1w)	good	
	W			Pr Dasyurid (1 e 1 w)	good	
7	E			D cat (1 e,1w), D brushtail (1w)	good	Cat track meandering
	W			D cat (1e)	good	

Site	Pad	Date	Inspection	Species and Direction	Condition	Comment
8	E			Dcat (1e, 1 w)	good	
	W			Dcat (1e, 1 w)	good	
9	E			D small rodent (1e)	fair	
	W			D small rodent (1e)	fair	
10	E			nil	fair	
	W			nil	Fair	
11	E			nil	fair	
	W			nil	fair	
12	E			nil	fair	
	W			Pr Dasyurid (1e, 1 w)	Fair	Tracks bounding
1	N	19/06/2023	5	nil	Fair	
	S			nil	Fair	
2	E			nil	good	
	W			nil	good	
3	E			D cat (2e,2w)	fair	
	W			D cat (2e,2w)	fair	
4	E			nil	good/firm in places	
	W			nil	good	
5	E			nil	fair	
	SW			nil	fair	
	NW			nil	fair	
6	E			D small rodent (2 e)	good	
	W			D small rodent (4e, 2w)	good	Tracks indicate living in culvert spacing
7	E			nil	good	
	W			nil	good	
8	E			D Brushtail Possum (1 w)	good	
	W			D Brushtail (1w), D wallaby (1e)	good	
9	E			nil	fair	
	W			nil	fair	
10	E			D cat (1w)	fair	
	W			D cat (1w)	Fair	
11	E			D cat 1 e	fair	
	W			D cat 1 e	fair	
12	E			D cat 1 e	fair	
	W			D cat 1 e	Fair	
1	N	20/06/2023	6	nil	Fair	
	S			nil	Fair	
2	E			nil	good	
	W			nil	good	
3	E			D cat (2e 2w), D wallaby (1e)	fair	
	W			D cat (2e 2w), D wallaby (1e)	fair	
4	E			nil	good/firm in places	
	W			nil	good	
5	E			nil	fair	
	SW			D small rodent (1e)	fair	
	NW			D small rodent (1w)	fair	

Site	Pad	Date	Inspection	Species and Direction	Condition	Comment
6	E			nil	good	
	W			nil	good	
7	E			D echidna (1w)	good	
	W			D echidna (1w)	good	
8	E			nil	good	
	W			nil	good	
9	E			nil	fair	
	W			nil	fair	
10	E			nil	fair	
	W			nil	Fair	
11	E			nil	fair	
	W			nil	fair	
12	E			nil	fair	
	W			nil	Fair	
1	N	21/06/2023	7	D small mammal (1e, 1w)	Fair	Tracks bounding
	S			nil	Fair	
2	E			nil	good	
	W			nil	good	
3	E			D cat (1e,2w), D wallaby (1w)	fair	Probable redneck wallaby
	W			D cat (1e,2w), D wallaby (1w)	fair	
4	E			D wallaby (1w)	good/firm in places	Probable swamp wallaby
	W			D wallaby (1e)	good	
5	E			nil	fair	
	SW			D small rodent (1e, 1w)	fair	
	NW			nil	fair	
6	E			nil	good	
	W			nil	good	
7	E			nil	good	
	W			nil	good	
8	E			D brushtail (1e)	good	
	W			D brushtail (1e, 1w)	good	
9	E			D small rodent (1e,1w)	fair	
	W			D small rodent (1e,1w)	fair	
10	E			nil	fair	
	W			nil	Fair	
11	E			D cat (1e)	fair	
	W			D cat (1e)	fair	
12	E			D cat (1e)	fair	
	W			D cat (1e)	Fair	
1	N	22/06/2023	8	D wallaby (1w)	Fair	
	S			D cat (1 w)	Fair	
2	E			nil	good	
	W			nil	good	
3	E			Pr cat (3w, 2e)	fair	Prints overlapping and meandering
	W			Pr cat (2w, 2 e)	fair	Prints overlapping
4	E			nil	good/firm in places	

Site	Pad	Date	Inspection	Species and Direction	Condition	Comment
	W			nil	good	
5	E			nil	fair	
	SW			nil	fair	
	NW			nil	fair	
6	E			D small rodent (1e, 1w)	good	
	W			D small rodent (1e, 1w)	good	
7	E			D Brushtail (1e,1w)	good	Perhaps using fauna furniture
	W			D Brushtail (1w)	good	
8	E			D brushtail (1e)	good	
	W			D brushtail (1e)	good	
9	E			nil	fair	
	W			nil	fair	
10	E			nil	fair	
	W			nil	Fair	
11	E			nil	fair	
	W			nil	fair	
12	E			nil	fair	
	W			nil	Fair	

Table B17: Scat and Track search data for spring/summer.

Site	Cell	Date	Check no.	Scats/tracks	Comments
1	Bridge	26/10/2018	1	Wallaby sp. tracks, fox scats, large amphibian scat.	Scat in front of cam on south side
		8/11/2018	2	Wallaby sp. tracks, Bandicoot scats, rodent scats, Wallaby sp. scats. Dead EW Dragon stuck in fauna fence.	
2	1	17/10/2018	1	Nil	
		31/10/2018	2	Nil	
3	1	17/10/2018	1	Rat scat ground (pic), Bird scat on rail and ground	
		31/10/2018	2	Miniopterus sp. x2, Large frog scat.	
4	1	17/10/2018	1	Nil	
		31/10/2018	2	Nil	
5	2	17/10/2018	1	Nil	
		31/10/2018	2	E. Water Dragon (full crossing), microbat scat, rodent tracks.	
6	1	17/10/2018	1	Nil	
		31/10/2018	2	Nil	
7	1	17/10/2018	1	Brushtail possum scat	On FF
		31/10/2018	2	Wallaby sp. scat, Brushtail possum scat.	CBtP prob on FF (location of scat)
8	1	17/10/2018	1	Nil	
		31/10/2018	2	Nil	
9 & 10	East	17/10/2018	1	Nil	
	West	17/10/2018	1	Nil	
	East	31/10/2018	2	Cat tracks, fox tracks	
	West	17/10/2018	2	Cat tracks, Rattus sp.	
11 & 12	West	16/10/2018	1	Nil	
	East	16/10/2018	1	Nil	
	West	31/10/2018	2	Nil	
	East	31/10/2018	2	Nil	

Table B18: Scat and track data for winter monitoring period. BtPoss = Brushtail possum spp.

Site	Cell	Date	Check no.	Scats/tracks
1	NA	13/06/2019	1	Lacey Monitor, Wallaby spp. Med lizard spp. tracks, Wallaby scat
	NA	19/07/2019	2	Swamp wallaby tracks, bird tracks, canid scat
2	NA	13/06/2019	1	Swamp Wallaby, EG Kangaroo, Lace Monitor, echidna, Fox tracks, Antechinus scat on FF
	NA	19/07/2019	2	Rat, Swamp wallaby, Miniopterus spp roosting.
3	NA	13/06/2019	1	Microbat, bandicoot, Fox scat. Fox, cat tracks. Bandicoot scat
	NA	19/07/2019	2	Fox, microbat, dog
4	NA	13/06/2019	1	Cat, fox, koala, BtPoss spp., **small macropod**
	NA	19/07/2019	2	Human, dog, cat, koala
5	S	13/06/2019	1	Water rat scat and track
	N	13/06/2019	1	Water rat, lace Monitor track, microbat Scat.
	S	19/07/2019	2	House mouse
	N	19/07/2019	2	Cat, Rat
6	NA	13/06/2019	1	Echidna tracks
	NA	19/07/2019	2	Swamp wallaby, House mouse, canid, cat, small dasyurid
7	NA	13/06/2019	1	Wallaby tracks, BtPoss tracks, Cat tracks, Dog tracks
	NA	19/07/2019	2	BtPoss, cat, dog, swamp wallaby
8	NA	12/06/2019	1	Echidna, lace monitor, dog tracks. Possible Bandicoot scat
	NA	19/07/2019	2	BtPoss, canid, bandicoot, small macropod
10 & 9 median	NA	12/06/2019	1	Koala (1/e), echidna (2/e), Fox, cat tracks. Prob swamp Wallaby scat.
	E	19/07/2019	2	Cat, canid
	W	19/07/2019	2	House mouse, canid, cat, dog
Northern end median 12 & 11	E	13/06/2019	1	Microbat scat
	W	13/06/2019	1	Nil
	E	19/07/2019	2	Cat, Bandicoot, N. gouldii roosting
	W	19/07/2019	2	Cat

Table C1: Species recorded making incomplete crossings in year one operational phase.

Species/ Groups	Site and Season																								
	1		2		3		4		5		6		7		8		9		10		11		12		Tot
	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	S/S	W	
Short-beaked echidna												1			1										3
Northern brown bandicoot																									0
Long-nosed bandicoot																									0
Peramelidae spp.																									0
Koala																									0
Short-eared brushtail possum														3	4								1		16
Common brushtail possum																									0
Trichosurus spp.																									0
Eastern grey kangaroo																									0
Red-necked wallaby																									0
Swamp wallaby	1	4	1	2	1	2									1										24
Macropodidae spp.		1				1																			4
Water rat																									0
House mouse I										1															2
Black rat I			5							3									1						18
Rodentia spp.																									0
Small mammal spp.																	1								2
Red fox I																		1							2
Cat I					1	6															1				16
European Hare I																									0
Lace monitor																									0
Eastern water dragon					1				1																4
Pacific black duck																									0
Intermediate egret																					1				2
Pheasant coucal																									0
White-throated treecreeper																		1							2
Medium frog spp.	1		1																						4
	2	5	7	2	3	9	0	0	1	4	0	1	0	3	6	0	1	2	1	0	2	0	1	0	99

Table C2

Species/group	Site and number of complete crossings																																					
	SS	W	SS		W		SS		W		SS		W		SS	W	SS		W		SS		W		SS		W		SS		W		SS		W		SS		W	
	1	1	2		2		3		3		4		4		5	5	6		6		7		7		8		8		9		9		10		10		11		11		12		12	
	Fl	Fl	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fl	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu
Short-beaked echidna	1		13		7															1						1																
Long-nosed bandicoot					1																																4				3	
Northern brown bandicoot																										1																
Peramelidae spp.																									1		5															
Koala											10		1								2								1								2				2			
Short-eared brushtail possum							1															8		35	13	4	18	70														
Common brushtail possum							1																																			
Trichosurus spp.	1						2																		3	2	6	5									1						
Swamp wallaby	2	3	6		8				24								1		1		2				5		2		1													
Red-necked wallaby			1		2		2				1										2						1															
Eastern grey kangaroo							1		6												3																					
Macropodidae spp.	1		2		9				25								3				1		1				2															
House mouse [I]					1						1					1	1		2										1											1		
Black rat [I]			2	3											3	2		1											1		2										
Water rat																8																									
Rodentia spp.																3	1																								
Cat [I]		1	2		1		68		180	2	8		3	1			10		2		4		2		8		2		6		3		3		1		11		15		11	1	8	
Red fox [I]		1	3		6		13		40		7					1	5								7		3		2		5		2						5				1	
European Hare [I]							1																																			

Species/group	Site and number of complete crossings																																											
	SS	W	SS		W		SS		W		SS		W		SS	W	SS		W		SS		W		SS		W		SS		W		SS		W		SS		W		SS		W	
	1	1	2		2		3		3		4		4		5	5	6		6		7		7		8		8		9		9		10		10		11		11		12		12			
	Fl	Fl	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fl	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu	Fl	Fu
Lace monitor			1								21						3				1				26		3		5		2		3		2		4				4			
Eastern water dragon							3																														6	1			3			
Pacific black duck															2	3																												
Pheasant coucal							2																																					
Intermediate egret																																											
Medium frog spp.	5	3																																										
Total	10	8	30	3	35	0	94	0	275	2	48	0	4	1	5	18	24	1	5	1	15	8	3	35	63	6	44	75	16	0	11	0	10	0	3	0	24	1	24	0	20	1	13	0

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

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

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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 2

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18/2/2020

Contents

Executive Summary

This report presents the results of the second year of operational phase monitoring of threatened flora for the Warrell Creek to Nambucca Heads (WC2NH) section of the Pacific Highway upgrade. The monitoring program includes monitoring of threatened flora translocations, in situ threatened flora and Slender Marsdenia and Woolls' Tylophora habitat condition.

Five threatened and one nationally rare plant species impacted by the WC2NH highway upgrade are subject to the *Warrell Creek to Urunga Upgrade Threatened Flora Management Plan* (RMS 2016), which includes the monitoring of management measures:-

- 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).

Three years of construction phase monitoring and one year of operational phase monitoring have already been carried out. The second year of operational phase monitoring for the present report was conducted by Ecos Environmental in November 2019.

Two years into operational phase monitoring and five years after salvage translocation, reasonably high survival rates were recorded for all six species:- : Slender Marsdenia (70%), Woolls' Tylophora (67%), Spider Orchid (100%), Rusty Plum (86%) and Floyds Grass (substantial cover). The lower survival rate of Koala Bells (37%) was due to the annual or biennial life cycle of most individuals (i.e. growth, flowering and seeding, then dying off in 1-2 years), which appears to be common in this species.

A detailed analysis of growth patterns in translocated Slender Marsdenia was carried out to better understand the population dynamics and complex growth rhythms of this species and how its responds to translocation.

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.

The survival rate of the in-situ threatened species at the end of Year 5 (spring 2019) was 100% for Spider Orchid, Rusty Plum and Slender Marsdenis. The crown cover of Maundia was <1% compared to 40% in spring 2018. The high mortality rate of Maundia is most likely a result of the drought in 2019. For Slender Marsdenia, survival rate was 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 on in situ threatened species were observed in spring 2019.

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 on 9 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 flora impacted by the project (RMS 2016) and included a monitoring program directed 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.

Three years of construction phase monitoring (Year 1 - Ecos Environmental 2016a, Year 2 - Ecos Environmental 2017, Year 3 - Ecos Environmental 2018a) and one year of operational phase monitoring (Ecos Environmental 2018b) have already been carried out. Operational phase monitoring is being conducted yearly for four years.

In November 2019, Ecos Environmental conducted the second yearly operational phase monitoring for Sandpiper Ecological Services. 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.

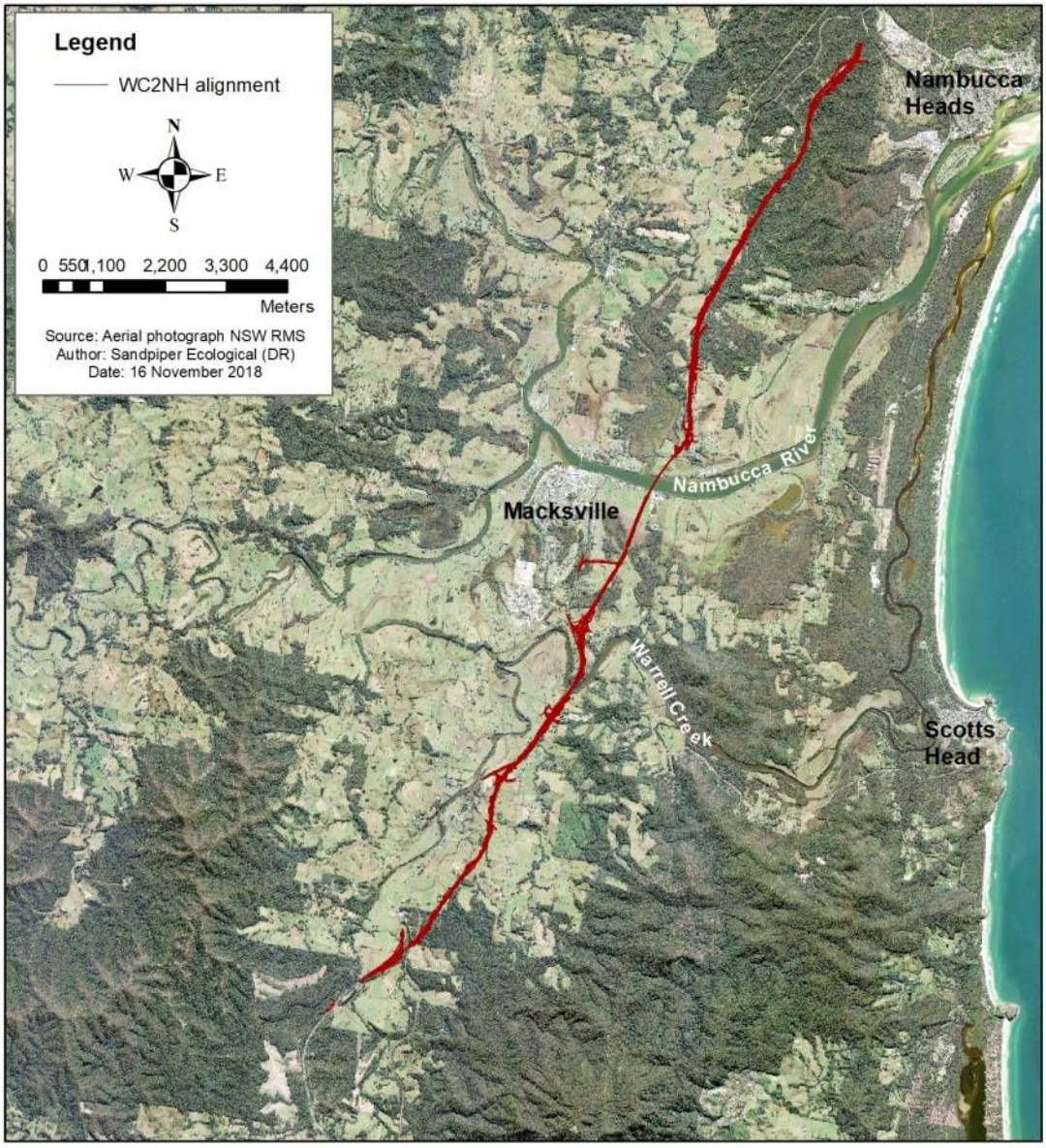

Figure 1: Location of the WC2NH alignment.

2 Threatened Flora Translocation

2.1 Aim and Species Translocated

The translocation component of the TFMP (RMS 2016) was prepared according to the Australian Network for Plant Conservation guidelines for planning threatened flora translocations (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 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).

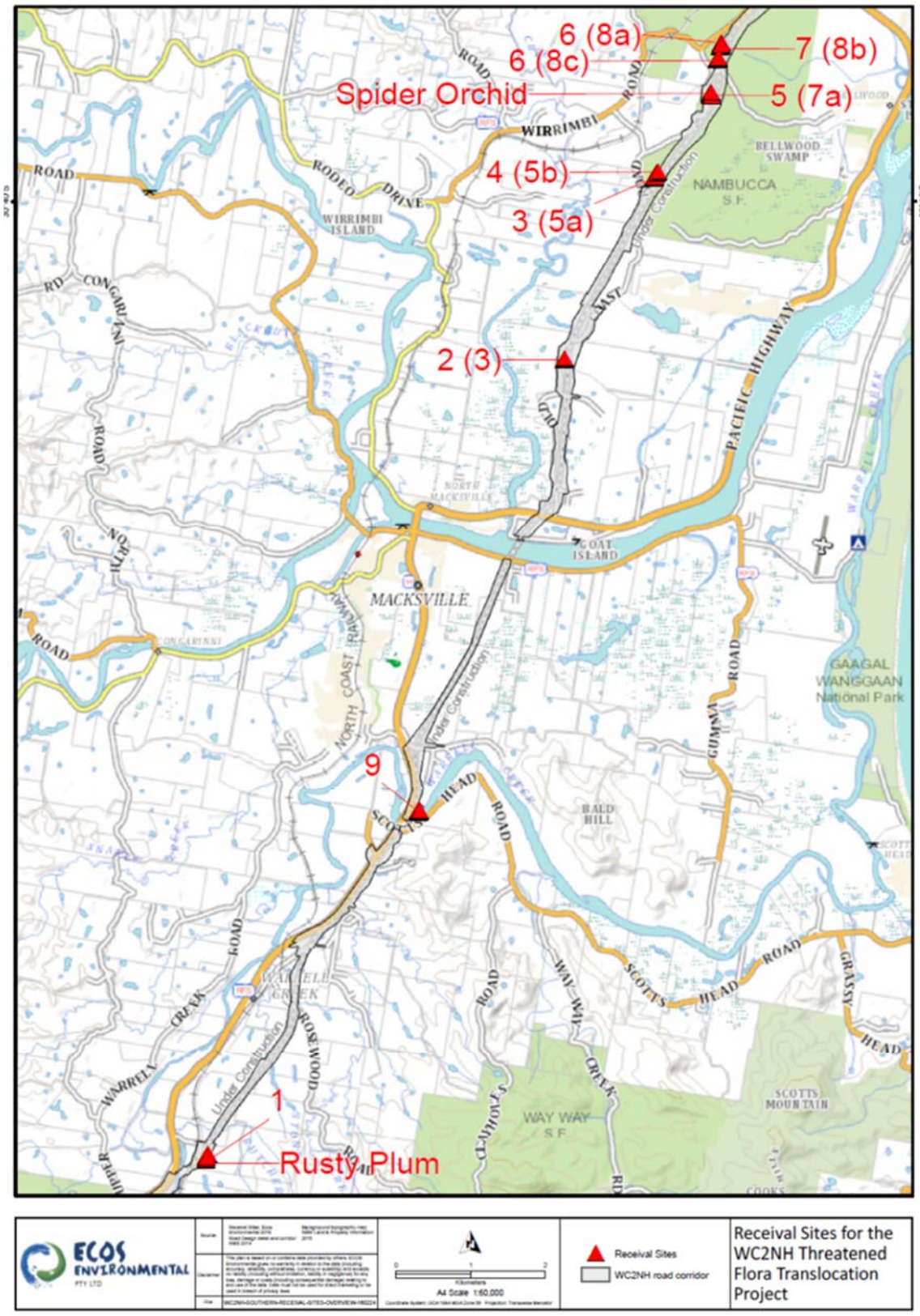

Figure 2: Location of threatened flora translocation receival sites for the WC2NH section of the Pacific Highway upgrade.

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 is placed after Woolls' Tylophora and identification not confirmed (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 excavation of plants, transport to the receival site and replanting as expeditiously as possible. Trees and saplings were dug out with an excavator and small plants with hand tools. The general approach is to move each plant with a shoot and root system reduced but intact enough so the plant is able to regenerate and regrow to reproductive maturity. Horticultural techniques were applied to improve survival such as pruning and intensive watering, which work mainly by minimising evapotranspiration stress, the main cause of mortality during transplanting.

Compared to other translocation techniques such as propagation and gradual transplanting, direct transplanting has several advantages including:

- Speed and cost-effectiveness
- Suitable for salvaging large numbers of individuals
- Suitable for implementation in rough, forested terrain
- Reduced risk of transferring disease and pests to the wild.
- Mycorrhizae and soil microflora are maintained by moving plant and soil together.

In a development situation, translocation by propagation of seed or cuttings in an ex situ environment and introduction to the field site is preferred by some workers. However, Primack (1996) has pointed out the advantages of transplanting when such plants are available: "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 are described in more detail below.

2.2.3 Slender Marsdenia

2.2.3.1 Salvage Transplanting

Slender Marsdenia plants were planted at seven receival sites (Table 6) in February 2015. Single stems were removed in a block of soil about 30 cm wide by 20 cm deep with a spade. This often involved breaking rhizomes which spread horizontally through the topsoil. Some may have two or more shoots or stem-individuals within one or a few square metres. Mapped points in the TFMP often included more than one stem-individual. All were transplanted including new unrecorded one. .

Plants and soil were kept damp during transport to the receival site. The 'stem-individuals' were planted at regular intervals (5 m) along lines, which minimised planting point bias with respect to microhabitat patterning. Additional plants were translocated in 2016 due to modification to the road design. In total, 175 plants were translocated.

They were watered thoroughly straight after planting, then once every two days for one week and once a week for four weeks. 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 was attached to each cage showing the individual's monitoring number and source code as per the TFMP. Multiple individuals from the same mapped point were indicated by an additional suffix on the source code – e.g. ML46-7.

2.2.3.2 No Fertiliser

As previous translocations of Slender Marsdenia indicated that addition of slow release fertiliser had an adverse effect on survival (although not when grown in pots), no fertilisers or mulch were applied during the WC2NH translocation of Slender Marsdenia. Experimental comparison of fertiliser and no fertiliser treatments on the NH2U project indicated that even light applications of slow release fertiliser resulted in depressed plant growth (Ecos Environmental 2016).

2.2.3.3 Propagation of Population Enhancement Plants

The results of propagation of Slender Marsdenia from rhizome pieces collected during transplanting were poor, as recorded on the NH2U project. Less than 5% of cuttings produced shoots and shoot growth was very slow. The few plants propagated were grown-on for two years and planted out in November 2017.

Slender Marsdenia produces viable seed, but the seed pods are very hard to find. About 15 large individuals of Slender Marsdenia were checked for pods adjacent to the Nambucca Heads to Urunga and Sapphire to Woolgoolga sections of the Pacific Highway, and Nambucca State Forest adjacent to WC2NH in December 2016, unsuccessfully.

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 observed. A few plants were identified as possibly this species during TFMP

surveys, based on leaf features. However, the leaves of Slender Marsdenia vary in shape and texture and some are similar to Woolls Tylophora leaves. Typically, Slender Marsdenia has a more elongated leaf, pinnate venation, cordate leaf base, paler green colouration and is glabrous (without hairs). Woolls' Tylophora has a broader leaf with purplish tinges, tends to be more 3-veined at the base and is sparsely hairy. The two species flower at different times - Woolls' Tylophora from the Bonville project flowered in late August, whereas Slender Marsdenia populations from the NSW Mid North Coast flowered in November or occasionally later.

Several Slender Marsdenia were observed flowering on the WC2NH footprint. If Woolls' Tylophora was in fact present, it was much rarer than Slender Marsdenia.

2.2.4.2 Salvage Transplanting and Population Enhancement

Individuals tentatively identified as Woolls' Tylophora were transplanted using the same method 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.

No population enhancement was carried out for Woolls Tylophora as it was not possible to positively identify this species in the absence of flowers.

2.2.5 Rusty Plum

2.2.5.1 Salvage Transplanting

Rusty Plum trees up to 12 m high were trenched around with an excavator to form a soil-root ball about 1-1.5 m wide and 0.7 m deep. Undercutting the root ball, the trees were leaned to the side and the trunk-branch system cut back by 75% or more to remove all foliage. If the root ball was small due to soil breaking up, the trunk was sometimes reduced further.

All Rusty Plums were transplanted from Cockburn's Lane at the southern end of the project into the adjacent road reserve (Receival Site 1). Several Rusty Plums outside the clearing boundary remained in-situ. The transplants received additional watering for a month. Sugar cane mulch was spread around each plant to provide a mild growth stimulant and hessian barriers erected for additional shade, as the site was exposed to the afternoon sun. No fertilisers were used.

2.2.5.1 Population Enhancement by Direct Seeding

Enhancement aimed to establish additional individuals by direct seedling. About 50 fruits, which have a single large seed, were collected in Nambucca State Forest in November 2017. Three seeds were also found beneath a Rusty Plum in the Coffs Harbour Regional Botanical Gardens. Seeds were separated from the fleshy outer layer and direct seeded into an area next to Receival Site 5 (7a) on 7 December 2017. This site is a minor gully with moist open forest and a rainforest understory. As the seeds are eaten by animals, and seedlings can also be grazed quite heavily (Ecos Environmental 2015), seed were sown into wire mesh cylinders. Fourteen cylinders were set up 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 trees (*Melaleuca styphelioides*) on the WC2NH footprint. Branch and stem sections supporting the orchids were removed so there was minimal disturbance to the orchid root system. The branch and trunk pieces with orchids were attached to small trees in a shaded gully at Receival Site 5 (7a). Apart from watering during transport, no watering was carried out.

2.2.6.2 Population Enhancement

The TFMP aimed to propagate additional Spider Orchids for population enhancement. As the number of wild plants was very low there weren't enough to sacrifice for propagation by vegetative division, so propagation by seed was proposed.

The two translocated plants flowered in spring 2015, 2016 and 2017, but no seed pods were produced. In situ plants were monitored for seed production but none were produced.

In a translocated population of 55 Spider Orchids on the NH2U project, one seed pod was formed in Spring 2016. Unfortunately, the pod opened in November between site visits so no seed was collected.

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 and watered. Site 8b was used as the receival site as this was the only site in the road reserve with swamp forest similar to Koala Bells habitat. Wire cages were installed 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 and grew rapidly, flowered in summer-autumn 2016, died back over winter then reshot in spring 2016, 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, as observed in some transplanted specimens in the field on NH2U. Twenty plants were introduced to Receival Site 9b (also part of the Floyds Grass translocation site) at Warrell Creek in January 2017. This site on alluvial soil has an open, partly bare ground layer with little competition from other plants (part of the preparation for Floyds Grass), which seems to be preferred by Koala Bells.

2.2.8 Floyds Grass

2.2.8.1 Topsoil Stripping

The receival site for Floyds Grass on the northern side of Warrell Creek consisted of two areas – 9a and 9b – about 25 m apart. It was overgrown with exotic Broad-leaved Paspalum (BLP), which was removed before translocating Floyds Grass to the site.

To create conditions with minimal weed competition for Floyds Grass, BLP and the uppermost topsoil seedbank were stripped off with an excavator. As the site was on

relatively deep alluvium, it was expected that sufficient depth of topsoil would remain for Floyds Grass to establish after the stripping operation.

Using herbicide would have still left the soil seedbank to contend with. Follow-up spraying of weed germination from the soil seedbank would have been impractical, as it is not possible to spray weed seedlings without hitting Floyds Grass, which produces runners.

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 higher clay content, but reasonable texture and drainage for young plant growth. Sed fencing was installed around the site to prevent run-off of soil material to Warrell Creek and also to act as a barrier to deter wallaby grazing.

2.2.8.2 Salvage Transplanting

Small clumps of Floyds Grass approximately 10 cm^2 were dug up with a spade and planted in Area 9a. The clumps were watered thoroughly and sugar cane mulch (weed free) spread lightly over the soil surface to reduce 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, shade-cloth fences approximately 1 m high running north-south were erected to provide additional shade.

2.2.8.3 Population Enhancement

To promote population establishment, approximately 100 additional Floyds Grass clumps were propagated at Ecos Environmental's nursery and planted in Area 9b in March 2016. They were propagated vegetatively from small pieces of runner that broke off during transplanting. As Area 9b was more exposed than Area 9a, the shade cloth fences had a roof to protect from the overhead sun. Hand weeding to remove competing exotic and native species was carried out by Pacifico workers after training by Ecos Environmental. Although most the soil seedbank had been removed, some seed germinated from deeper in the soil., notably *Phytolacca octandra* (Ink Weed), a large herbaceous shrub. Very little BLP germinated.

2.2.9 Monitoring and Data Analysis

During the construction phase, monitoring was conducted quarterly in 2015 (start of translocations project), biannually in 2016 and yearly in 2017 and 2018. Monitoring during the operation phase was carried out annually.

The following data were recorded enabling analysis of plant growth and survival:

- 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.

The data were entered into an Excel file with separate sheets for each monitoring event.

Plant condition was scored on a scale of 0 to 5, where zero is dead and 5 is fully mature and reproductive. The scale is defined slightly differently for each species, as indicated 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 monitoring events was averaged for all plants present at the start of monitoring in June 2015, therefore included plants in the total that may have had died back to ground level (i.e. height = 0; 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 after 1 year
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

Slender Marsdenia – Stem Height Growth Syndromes

Slender Marsdenia plants showed complex variation in height growth after transplanting. Some plants stayed small and showed little change in five years, while others grew vigorously the whole time. Many plants died back then reshot a year or even two years later. It was difficult to make sense of the range of different growth responses when the volume of soil with plant and rhizome was initially about the same size, or not greatly different.

To analyse stem growth patterns in Slender Marsdenia after transplanting in more detail, 12 categories of stem height growth change over a five year period were defined, as shown in Table 5. These were derived by combining the data from all monitoring events in a single sheet for each receival site then identifying the main patterns of height change. Numbers were tallied for each category and expressed as percentages of the total.

Table 5: Pattern of stem height change in stem-individuals of Slender Marsdenia over a five year period after salvage transplanting. Three primary categories or syndromes can be discerned– D, S and T, and 12 sub-categories

Code	Response syndromes of transplanted individuals
D	**Dead (or appears to be dead) – all individuals with ht = 0 in Nov/19**
D1	Never reshot
D2	Small shoot then died back, probably dead
D3	Reshot, reached small to medium height (<1.2 m) then died back to ground, some bell-shaped, some dieback-reshot-dieback
D4	Reshot, grew tall (~2 m+) then died back to ground, possibly dead
S	**Small, growing very slowly, or declining**
S1	Stayed small, most less than 10 cm high (to 40 cm), little change in height in 5 years
S2	Diedback to ground and reshot once or twice, stem continuously small (mostly <0.5 m)
S3	Declining or bell shaped (increase-decrease), to ~130cm at peak, not tiny, continuously alive
S4	Fluctuating – e.g. 'small-medium/tall-small'; or 'grew medium/tall then died back to small
T	**Thriving, plant tall, continuing to grow, or maintaining size, healthy**

T1	Thrived – tall (1.5 m+), substantial increase in height/number of leaves, or ~maintained tall height (some decreased slightly Nov 18)
T2	Thrived – moderate increase in height (0.5 – 1 m+), or constant height (1 m+)
T3	Died back to ground then reshot vigorously (>1 m)
T4	Small for 5 or 6 events then suddenly grew big (>1 m)

2.3 Translocation Results

2.3.1 Survival Summary – All Species

Survival rate five years after salvage transplanting (Table 6) was fairly high for all threatened species: Slender Marsdenia 70%, Woolls' Tylophora 67%, Spider Orchid 100%, Rusty Plum 86% and Floyds Grass (substantial cover).

The lower survival rate of Koala Bells (37%) was due to individuals exhibiting an annual or biennial life cycle (i.e. rapid growth, flowering and seeding, then dying off) after transplanting, as recorded previously with this species (e.g. NH2U).

Table 6: Percent survival of species per receival sites over 5 years (2015-2019), after salvage translocation.

Species/Receival Site	**No. plants transl.**	**Survival (%)**					
		Aug 2015 (~6 mth)	**Feb 2016 (~1 Yr)**	**Jan 2017 (~2 Yrs)**	**Nov 2017 (~3 Yrs)**	**Nov 2018 (~4 Yrs)**	**Nov 2019 (~5 Yrs)**
Slender Marsdenia(*Marsdenia longiloba*)							
Receival Site 1 - Cockburns Lane	27	93	93	75	63	59	59
Receival Site 2 (3) – Old Coast Rd	17	100	91	93	88	88	88
Receival Site 3 (5a) – Old Coast Rd	22	81	81	91	73	77	77
Receival Site 4 (5b) – Old Coast Rd	16	100	94	81	69	69	50
Receival Site 5 (7a) – Old Coast Rd	57	90	90	72	74	72	56
Receival Site 6 (8a) – Old Coast Rd	8	88	75	75	75	88	86
Receival Site 8 (8c) – Old Coast Rd	28	93	100	86	82	79	70
Total	164 (175)	92	91	80	74	74	70
Rusty Plum(*Niemeyera whitei*)							
Receival Site 1 - Cockburns Lane	7	100	100	86	86	86	86
Wooll's Tylophora (*Tylophora woollsii* – unconfirmed)							
Receival Site 6 (8a) – Old Coast Rd	6	100	100	100	83	67	67
Spider Orchid (*Dendrobium melaleucaphilum*)							

Species/Receival Site	No. plants transl.	Survival (%)					
		Aug 2015 (~6 mth)	Feb 2016 (~1 Yr)	Jan 2017 (~2 Yrs)	Nov 2017 (~3 Yrs)	Nov 2018 (~4 Yrs)	Nov 2019 (~5 Yrs)
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	100	94	Substantial cover	Substantial cover	Substantial cover	Substantial cover
Receival Site 9b – Warrell Creek	61 clumps	Not planted yet	Not planted yet	98	93	70	Reasonable cover
Koala Bells (*Artanema fimbriatum*)							
Receival Site 7 (8b) – Old Coast Rd	16	75	63	25	13	6	0
Receival Site 9 – Warrell Creek	14	Not planted yet	Not planted yet	Not yet planted	57	86	75
Total	30	75	63	25	34	43	37

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 5 years was 70%, a slight decrease from 74% the previous year (Table 6). Survivorship per site ranged from 56% to 86% after 5 years, slightly less than the previous year.

The decrease in survival rate was relatively small considering the severe drought conditions in 2019. Given the phenology of Slender Marsdenia and its tendency to die back and reshoot again, some individuals recorded as dead (ie Ht = 0) may reshoot later, so the actual survival rate (given dead stems with live rhizomes) is probably 70-80%.

When observed in November 2019 during drought conditions there was no sign of drought stress such as wilting and many plants were actively growing, with new shoots present. The tuberous rhizome in Slender Marsdenia may store water as well as food which the plant can draw on to maintain growth during spring when conditions are often dry.

2.3.2.2 Height performance

Mean plant height is a rough indicator of how well Slender Marsdenia is performing 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 height performance. Mean stem height of Slender Marsdenia per receival sites after five years ranged from 33.7 cm to 106.9 cm (Table 7).

Mean height increased at receival sites 1, 2, 5 and 8 and decreased in 3 and 6. No signs of habitat deterioration, disease or herbivory were observed, therefore, it is unlikely that declines in mean plant height were caused by these factors.

Monitoring has shown that Slender Marsdenia does not always exhibit a linear or steady increase or decrease in height but fluctuates, undergoing cycles of stem dieback and regrowth, often repeated.

Likewise, mean plant height per receival sites did not consistently increase or decrease during the monitoring program, rather it has fluctuated. For example, in Receival Site 8 mean plant height was 43.68 cm in June 2015, increased to 69.57 cm in February 2016, decreased to 50.82 cm in January 2017, decreased further to 43.96 cm in November 2017, then increased to 62.21 cm in November 2018 and 84.1 cm in November 2019.

Table 7: Table of mean height (cm) ± standard error of Slender Marsdenia per receival site from the first monitoring in June 2015 to November 2019 (five years after translocation) and graph of size class distribution

Receival site	n	June 2015 (6 months)	Feb 2016 (~1 yr)	Jan 2017 (~2 yrs)	Nov 2017 (~3 yrs)	Nov 2018 (~4 yrs)	Nov 2019 (~5 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
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
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
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
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
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

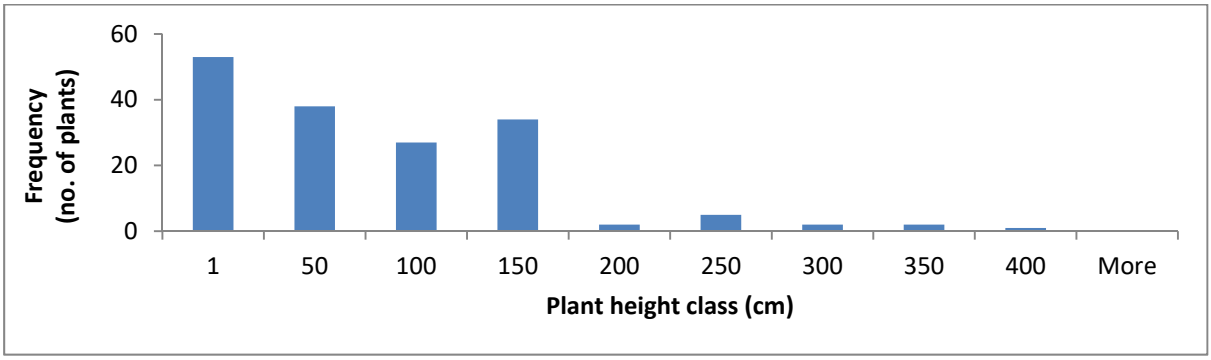

Figure 3: Size class distribution of Slender Marsdenia stem-individuals in Nov/2019

2.3.2.3 Patterns of change in stem height

Pattern of stem height change over five years in Slender Marsdenia were sorted into three primary categories (Ht = 0/ Dead or possibly Dead; Small; Thriving) and 12 sub-categories, as defined in Table 5.

Table 8 shows the breakdown of stem height change per receival site and combining the data from all six receival sites (note - site 5b omitted as most Marsdenia plants were a different species – *M. liisae*/Large-flowered Milk Vine). Results are shown graphically in Figs 3 and 4.

Overall percentages of the three primary categories of stem height growth (i.e. D, S and T) in Table 8 were as follows:-

Dead/Ht = 0 – 30.5%

Small – 27.4%

Thriving – 42%

Of the D group (Dead/Ht = 0)

- Only 3% out of 164 transplants failed to show any reshooting after transplanting (i.e. D1)
- Most in the D group reshot, grew to medium size, died back, then failed to reshoot (so far), sometimes in two cycles

Of the S group (Small)

- 10% stayed small (<10 cm high) for 5 years (i.e. S1)
- Some died back and reshot one or more times, but stayed small (i.e. S2)
- Some fluctuated from small to medium or large and then small again (i.e. S4)

Of the T group (Thriving)

- Maintained tall or medium height for 4- 5 years, often starting small probably as a result of pruning (T1 & T2)
- Some died back then reshot and grew tall again (T3)
- Some stayed small for several monitoring events then grew tall (T4)

Table 8: Percentage of 12 Stem Height Growth (SHG) categories in Slender Marsdenia plants after salvage transplanting, at six receival sites. (Note –receival site 5b is not included as the majority of transplants at this site were Marsdenia liisae.)

	Stem Height Growth Syndromes of transplanted individuals		**Receival sites**					
		1 (Cb)	**2 (3)**	**3 (5a)**	**5 (7a)**	**6 (8a)**	**8 (8c)**	**All**
D	**Dead (or appears to be dead)** (all plants with ht=0 were classed as D)							
D1	Didn't reshoot	3.7	0	0	5.3	7.1	0	3.0
D2	Small shoot then died back	18.5	11.7	0	8.8	7.1	3.7	8.5
D3	Reshot, reached small to medium height (<1.2 m) then died back to ground, some bell-shaped, some died back twice.	14.8	0	13.6	26.3	0	22.2	17.7
D4	Reshot, grew tall (~2 m+) then died back to ground, sometimes twice	3.7	0	0	0	0	3.7	1.2

	Sub-total	40.7	11.8	18.2	40.4	14.3	29.6	30.4
S	**Alive but small, growing very slowly, or declining**							
S1	Stayed small, most less than 10 cm tall (to 40 cm), little change in 5 years	7.4	0	9.1	15.8	0	7.4	9.8
S2	Continuously small (mostly <0.5 m), dieback to ground and reshot once or twice, still alive	11.1	5.9	18.2	5.3	14.3	0	7.3
S3	Declining or bell shaped (increase-decrease), to ~130cm at peak, not tiny, continuously alive	0	0	0	1.8	0	3.7	3.0
S4	Fluctuating – i.e. 'small-medium/tall-small'; or 'grew medium/tall then died back to small'	7.4	0	0	7.0	7.1	14.8	7.3
	Sub-total	25.9	5.9	45.5	29.8	21.4	25.9	27.4
T	**Thriving, plant tall, continuing to grow, or maintaining size, healthy**							
T1	Thrived – tall (1.5 m+), substantial increase in height/number of leaves, or ~maintained tall height (some decreased slightly Nov 18)	3.7	5.9	0	5.3	7.1	14.8	6.1
T2	Thrived – moderate increase in height (0.5 – 1 m+), or constant height (1 m+)	7.4	64.7	27.3	21.1	50.0	25.9	27.4
T3	Died back to ground or close to ground then reshot vigorously (>1 m)	14.8	0	9.1	3.5	7.1	0	5.5
T4	Small for 5 or 6 monitoring events then suddenly grew big (>1 m)	7.4	11.8	0	0	0	3.7	3.0
	Sub-total	33.3	82.4	36.4	29.8	64.3	44.4	42.0
	% Survivorship 5 yrs	59.3	88.2	77.3	56.1	85.7	70.4	69.5
	Total individuals	27	17	22	57	14	28	164

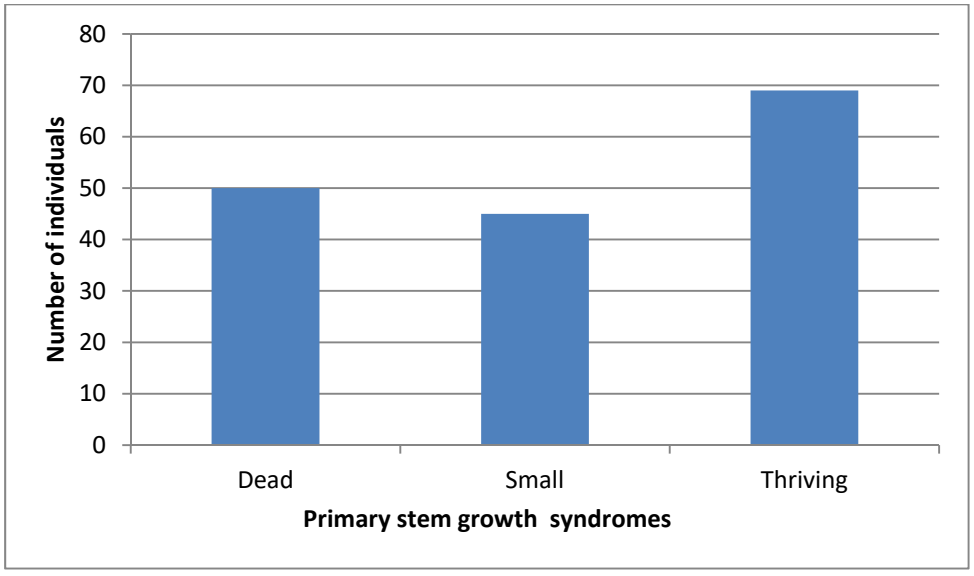

Figure 4: Stem growth pattern in translocated Slender Marsdenia over 5 years. Data pooled for 6 receival sites.

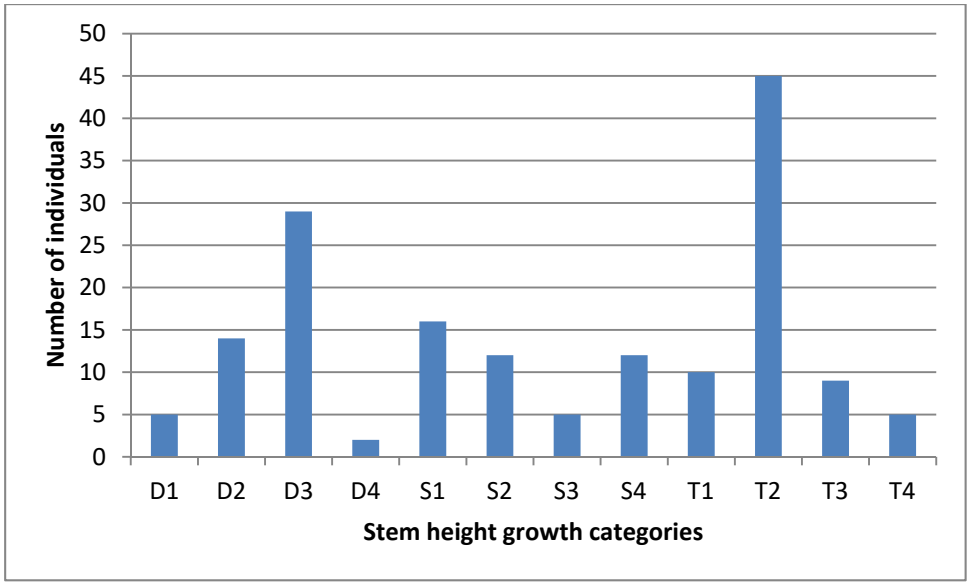

Figure 5: Stem growth pattern of 164 translocated Slender Marsdenia after five years. Data from six receival sites combined. Primary categories: D = dead, S = surviving, T = thriving. See Table 5 for definition of stem height growth sub-categories.

2.3.2.4 Effect of receival site

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

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

As there were no obvious major differences in habitat between receival sites and at least some individuals at all receival sites reached the T1 or T2 category (i.e thriving), it is more likely that the different proportions of D, S and T at receival sites (just summarised), is due to the quality or vigour of stem individuals transplanted from donor sites to the receival sites.

Donor sites for 1 and 7a included many small, possible suppressed stem-individuals, while receival sites 3 and 8a received larger, more vigorous plants.

2.3.2.5 High incidence of stem height fluctuation

Several of the categories in Table 5 (Pattern of stem height change in stem-individuals over 5 years) involve stems dying back then regenerating again, often more than once in 5 years (i.e. D3, D4, S2, S4, T3).

Stem height fluctuation was not a regular seasonal growth pattern in all plants. New shoot growth appeared to be mainly seasonal as it was concentrated in spring and early summer, but only some of these plants were regrowing after dying back (the others had maintained height and were reshooting). .

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), four primary categories can be derived with the following percentages:-

Fluctuating – 39%

Dead or probably dead – 12%

Small or resultant size small – 13%

Thriving 37%

Possible functions of stem height fluctuation in Slender Marsdenia may be:-

(i) To replenish storage in tuberous roots during the reshooting phase, while avoiding use of stored food when conditions for photosynthesis decline during the die back phase.

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

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

One individual out of 164 had flowers in November 2019 (Receival Site 2(3), plant no. 5). This plant was 2.8 m high and had 40 leaves. This is the first flowering plant recorded during the5 years of monitoring.

The same very low incidence of flowering in translocated Slender Marsdenia was recorded on the NH2U project (one individual). Flowering is also uncommon or rare in in-situ plants.

2.3.3 Rusty Plum (*Niemeyera whitei*)

Survival rate of Rusty Plums at Receival Site 1 (Cockburns Lane) remained at 86% after five years. All six increased in height and are in good condition. It may be another 5-10 years before the largest individuals reach reproductive maturity.

At Receival Site 5, Rusty Plum seeds had germinated in 8 out of 14 chicken-wire cylinders direct-seeded with Rusty Plum seeds in 2017. In November 2019, seedlings were still present in 8 plots, the tallest being 28 cm in height and most showing new shoot growth. 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), not the translocation technique.

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 liisae*)

Most Marsdenia vines salvaged and planted at Receival Site 4 (5) are *Marsdenia liisae*, not *Marsdenia longiloba*. This species was positively identified from flowers during transplanting. It can also be distinguished from *Marsdenia longiloba* by its leaves, which are larger and dark green.

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

The survival rate of *Marsdenia liisae* after five years was only about 20%, much less than *Marsdenia longiloba*. Both had received the same treatment during maintenance.

2.3.6 Spider Orchid (*Dendrobium melaleucaphilum*)

The two translocated Spider Orchid plants survived to year 5 and are in good condition. Both plants flowered in spring (August to September) each year from 2015 to 2019 but no seed pods have been produced, possibly due to lack of pollinators. Some pseudobulbs (stem units) died and new ones were produced each year demonstrating active growth.

2.3.7 Floyds Grass (*Alexfloydia repens*)

Floyds Grass has persisted at Receival Site 9 after recording high survival rates up to 2018. Merging of patches and loss of tags due to floods have made previous monitoring of individuals impractical, which has been replaced by an overall assessment of the extent of Floyds Grass and habitat condition in the two sub-areas (9a and 9b).

Area 9a

At least 10 square metres of Floyds Grass has established in Area 9a which is probably more than the area of Floyds Grass impacted by clearing.

The tall, dense growth of native Ottochloa grass recorded in the last two years, competing with Floyds Grass, had died down considerably by November 2019. A carpet of Floyds Grass was clearly visible particularly in the half of Area 9a (fenced) close to Warrell Creek.

A significant amount of exotic Broad-leaved Paspalum was regenerating in Area 9a, which poses a threat to the persistence of Floyds Grass which can be overtopped and crowded out by this aggressive exotic grass.

Area 9b

This section of the Floyds Grass translocation area is in poor condition. The work crew at Pacifico failed to carry out proper maintenance of this part of the site before leaving the project, which they were supposed to do. (Pacifico took on the responsibility of maintenance

of the translocation areas on the WC2NH project, including the Floyds Grass area. Ecos Environmental implemented and monitored the translocations and advised on maintenance by email and phone.)

The site is being overrun with Broad-leaved Paspalum which needs urgent hand weeding to prevent it displacing Floyds Grass. A good amount of Floyds Grass is still present in Area 9b (with Koala Bells) but maintenance is essential to prevent the translocation work carried out to date failing over the short to medium term.

2.3.8 Koala Bells (*Artanema fimbriatum*)

Koala Bells transplanted to Receival Site 7 have died out, but as flowering and seeding occurred for two years, dormant seed is probably present in the soil seedbank and plants may reappear in future if suitable conditions for regeneration occurs, such as a bushfire, or track maintenance. Koala Bells appears to be a short-lived perennial so this is a normal pattern of growth in this species.

Propagated Koala Bells introduced to Receival Site 9b established successfully, flowering and seeding, and recruitment from seed was recorded in spring 2017. These plants persisted in spring 2019, but there no evidence of further recruitment. This is probably because the site is growing over with Broad-leaved Paspalum which will inhibit seed germination. Koala Bells is a short-lived perennial and prefers disturbed areas where there is abundant light and minimal competition from other plant species. These conditions were created at Receival Site 9b by stripped away ground layer vegetation, enabling planted Koala Bells to recruit seedlings.

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 – survival rate between 67% and 100% in year 5 (excluding Koala Bells but this species is short-lived and persists in the soil seedbank)
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)	Most sites Yes. In the case of Floyds Grass No, particularly Receival Ste 9b where habitat condition has deteriorated significantly in the last 12 months, mainly due to inadequate maintenance being carried out by the contractor at the end of construction.

2.5 Work Plan for Year 6 (November 2019 – November 2020)

Table 10: Work plan for Threatened Translocation Areas for the period of November 2019 – November 2020.

Task	**Time**
Monitoring	
Third yearly operational phase monitoring	November 2020 (to coincide with flowering of Slender Marsdenia and Rusty Plum)
Reporting	
Third yearly operational phase monitoring report	January 2021
Maintenance	
Propose maintenance of Receival Site 9b to remove exotic species, particularly Broad-leaved Paspalum, spray out surrounding exotics, fix up shade cloth shelters, maintain planted Swamp Oak, fix monitoring tags.	Autumn 2020

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.

Andrew Benwell and Jeremy Benwell-Clarke of 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 throughout the monitoring program. In 2019, Ecos Environmental conducted the second yearly operation phase monitoring, which is described in this report.

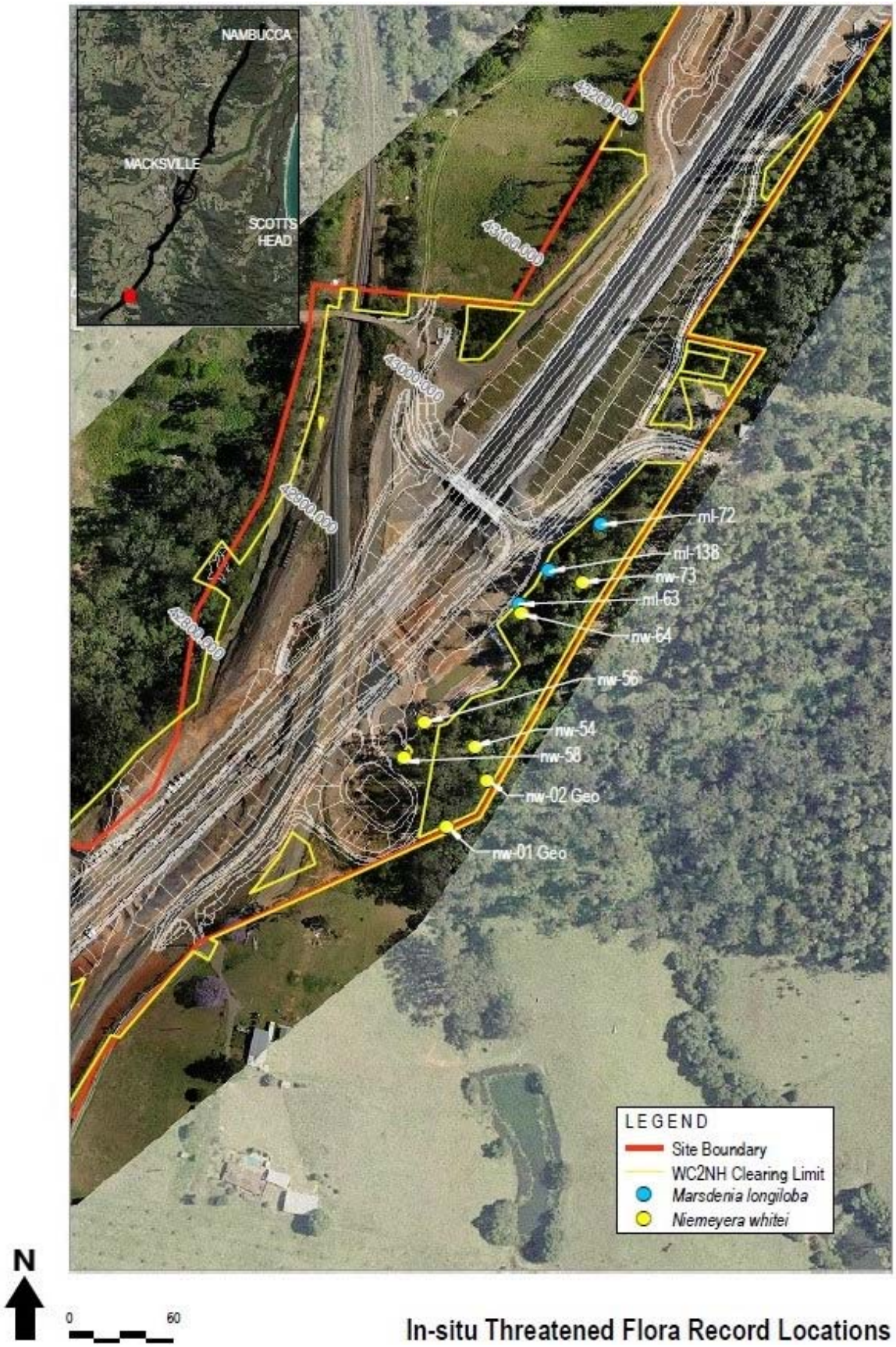

Figure 5: In-situ Slender Marsdenia and Rusty Plum at Cockburns Lane, WC2NH. Map sourced from GeoLINK (2017).

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).

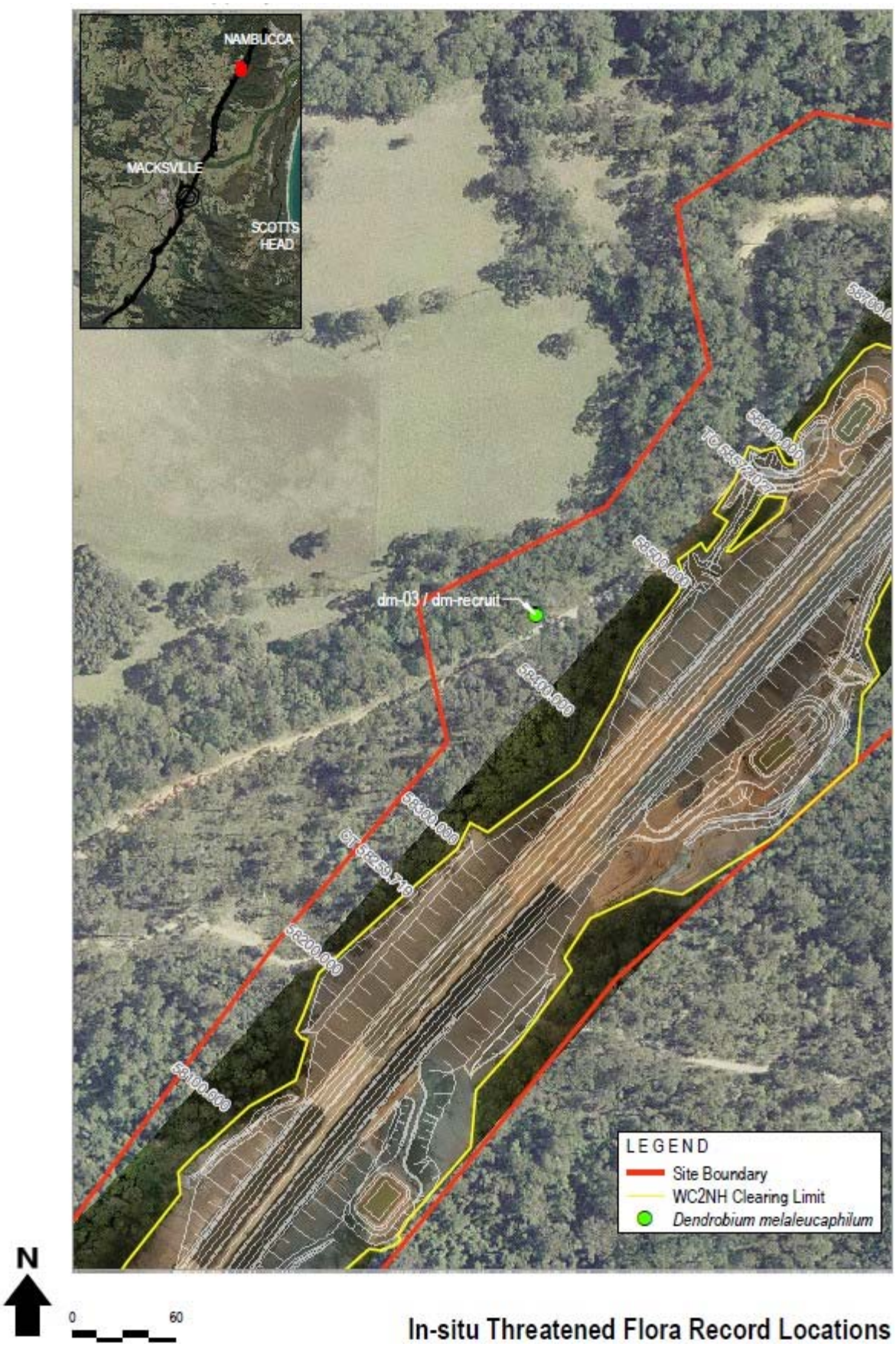

Figure 8: In-situ Spider Orchid, WC2NH. Map sourced from GeoLINK (2017).

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

3.2 Results

3.2.1 Maundia (*Maundia triglochinoides*)

In November 2018, Maundia in the monitoring plot covering 50 m x 20 m had a crown of 40% and extended beyond the plot. In November 2019, Maundia had almost completely disappeared from the plot and the site (Table 11). 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, an *Eleocharis* species, 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.

See Appendix 2 for photos of the in-situ threatened plant species in November 2019.

3.2.2 Spider Orchid (*Dendrobium melaleucaphilum*)

The Spider Orchid plants were in healthy condition in November 2019. The mature plant had flowered in spring this year (inflorescence axes still present) , but no fruit (seed pods) were observed. The number of pseudobulbs of the mature plant was about the same as spring 2018 (Table 12).

3.2.3 Rusty Plum (*Niemeyera whitei*)

All seven Rusty Plum individuals in-situ at Cockburns Lane were in healthy condition in November 2019 (Table 13). No fruiting was observed, unlike last year.

In spring 2016, nw-56 appeared to be suffering from construction-related edge effects as its leaves had turned yellow and become stunted (GeoLINK 2017). For this reason supplementary watering was carried out by Pacifico in 2016 and 2017, which appeared to have been beneficial as the health and growth of nw-56 improved. nw-56 was also in good condition in spring 2019, suggesting that it is no longer suffering from edge effects.

The habitat condition at Cockburns Lane in November 2019 was generally good. Lantana was scattered throughout the site, which did not appear to be having any negative effects on Rusty Plum or Slender Marsdenia (also occurs at site, see below), but could threaten their health and survival in the future if it were to further invade the site.

3.2.4 Slender Marsdenia (*Marsdenia longiloba*)

The monitoring program includes five in-situ Slender Marsdenia occurrences (most with more than one stem, one with 20-30 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 most likely part of Slender Marsdenia's natural life cycle rather than a response to human-related disturbances.

In November 2019, 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 to 250 cm and condition score ranged from 2 to 4 (Table 14).

In-situ location ML93 consists of a clonal patch growing between the base of a large *Eucalyptus microcorys* tree and the edge of Old Coast Road. In November 2019, this clonal patch consisted of about 20 stems within an area 15 m wide (right angles to the road) and 10 m long (parallel with the road). Most stems were small (<20 cm high), the largest stem was 120 cm high and most stems had new growth. No flowering or fruiting was recorded. Recruitment is mostly likely by asexual means (i.e. production of stems from underground tuberous roots). New tags were installed.

At ML132 shoots from last year had died back to the ground and two new small shoots were present 2 m apart. Specimens ml-72, ml-138 and ml-63 occur at Cockburns Lane (same site as in-situ Rusty Plum). The height of these plants had decreased since last year.

Table 11: In-situ threatened flora monitoring results for Maundia (*Maundia triglochinoides*). Pre-construction (PC) 2015 (data recorded by GeoLINK) and spring (Spr) 2018 and 2019 (data recorded by Ecos Environmental).

Maundia (*Maundia triglochinoides*)																
Population	Cover-Abundance and (Condition Class Score)			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions (Spr 2019)
	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	
Nambucca Floodplain	10-20% (3)	40% (5)	<1%	N	Y	N	N	Y	N	N	Y	N	N	N	M	Canopy height 10-13 m with *Melaleuca quinquenervia* dominant species; ground stratum 100% crown cover; water dried up; exotic grass spp. along fenceline but few weeds within site.

Table 12: In-situ threatened flora monitoring results for Spider Orchid (*Dendrobium melaleucaphilum*). Pre-construction (PC) 2015 (data recorded by GeoLINK) and spring (Spr) 2018 and 2019 (data recorded by Ecos Environmental). Y = yes, N = no.

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)
	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019			
3	30	35	35	2	5	5	6	50+	50)	Y	N	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 scrappy pseudobulbs
DM Recruit	-	12	12	-	3	3	-	4	4	-	N	N	-	N	N	-	N	N		This new recruit was first observed during Spring 2016.	Fairly healthy

Table 13: In-situ threatened flora monitoring results for Rusty Plum (*Niemeyera whitei*). Pre-construction (PC) 2015 (data recorded by GeoLINK) and spring (Spr) 2018 and 2019 (data recorded by Ecos Environmental). Y = yes, N = no.

Plant ID #	Height (cm)			Leaf Condition			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions (Spr 2019)
	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	
NW58	700	800	820	5	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	100	120	130	5	4	4	N	N	N	Y	Y	Y	N	N	N	N	N	N	
NW73	600	700	750	5	5	4	N	Y	N	Y	N	Y	N	N	N	N	N	N	
NW54	400	600	640	5	4	4	N	N	N	Y	N	Y	N	N	N	N	N	N	
NW64	500	800	850	5	5	4	N	Y	N	Y	N	N	N	N	N	N	N	N	
NW01-Geo	-	450	450	-	4	4	-	N	N	-	N	Y	-	N	N	-	N	N	
NW02-Geo	-	500	530	-	4	4	-	N	N	-	N	Y	-	N	N	-	N	N	

Table 14: In-situ threatened flora monitoring results for Slender Marsdenia (*Marsdenia longiloba*). PC (pre-construction) 2015 and Spr (spring) 2017 data recorded by GeoLINK, Spr 2018 data recorded by Ecos Environmental. Y = yes, N = no

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-Spr 2019)
	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019	PC 2015	Spr 2018	Spr 2019			
ML93	5	100	130	3	2	3	N	N	N	N	Y	Y	N	N	Y	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 of about 20-30 stem-individuals in an area 15m x 10 m, from the base of Eucalyptus microcorys to the edge of O)ld Coast Rd. Most plants small (<20cm high), a few >1 m high.
ML132	40	8	10	3	2	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.	Shoots tagged last year had died off. Two new small shoots this year about 1 m apart
ML72	5	40	10	2	2	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	5	90	10	2	3	3	N	N	N	N	Y	N	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 the in-situ threatened species at the end of Year 5 (spring 2019) was 100% for Spider Orchid, Rusty Plum and Slender Marsdenia. (Table15). The crown cover of Maundia was <1% compared to 40% in spring 2018. The high mortality rate of Maundia is most likely a result of the drought in 2019. For Slender Marsdenia, survival rate was 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 2019. 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 > but this is not of concern for reasons described above.

The monitoring results do not meet the performance criteria for Maundia, however above average rainfall is likely to return and when this occurs the species is expected to recover, and therefore, no corrective actions are required.

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 1 - 2015	Year 2 - 2016	Year 3 - 2017	Year 5 - 2019
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	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
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 4)	Yes - 100% in good condition (score 5)	Yes - 100% of visible plants in good condition (score 3)	No – poor condition (score 1)
Maundia (*Maundia triglochinoides*)	Yes - 100% survival No accidental damage due to clearing	Yes - 83% survival	Yes - 100%	Not applicable yet	Yes - 100% in good condition (score 4)	Yes - 100% in good condition (score 5)	Yes - 100% of visible plants in good condition (score 3)	Yes - 100% with some plants reproductive
Rusty Plum (*Niemeyera whitei*)	Yes - 100% survival No accidental damage due to clearing	Yes - 100% survival	Yes - 100%	Not applicable yet	Yes - 100% in good condition (score 4 - 5)	Yes - 80% in good condition (score 2 - 5)	Yes - 100% in good condition (score 3 - 5)	Yes - 100% with some plants reproductive
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	No - 62% (5 of 8 records) recorded scores 0 - 3	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

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 slightly different 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 second yearly operation phase monitoring in November 2019, 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% at the end of year 4.

The data also indicate that the microclimate of some plots in spring 2019 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 2018-2019 – 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.

See Appendix 3 for photos of each Slender Marsdenia and Woolls' Tylophora habitat condition plot in 2019.

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
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
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
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
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
Spring 19 (Ecos)	<5%	5

Plot	Weed Level (% crown cover)	Microclimate Class
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
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
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
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
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)	6	5

Table 18: Vegetation structure of ten Slender Marsdenia and Woolls' Tylophora habitat monitoring plots, WC2NH. Data recorded November 2019 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*	15			
Upper			20	20	30
Mid	*Lophostemon confertus*	20			

Stratum	Dominant species	Cover (% crown cover)	For the entire		
Mid	*Cissus hypoglauca*	65	Mid stratum Height to crown (m) min-mode-max		
Mid	*Acacia binervata*	15	4	5	10
Lower	*Blechnum cartilagineum*	30	Lower stratum Height to crown (m) min-mode-max		
Lower	*Dodonaea triquetra*	10			
Lower	*Cordyline stricta*	10	0.5	2	4
Plot 2					
Upper	*Syncarpia glomulifera*	40	Upper stratum Height to crown (m) min-mode-max		
Upper	*Eucalyptus microcorys*	20			
Upper	*Allocasurina torolosa*	10	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*	15	Lower stratum Height to crown (m) min-mode-max		
Lower	*Morinda jasminoides*	20			
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*	30	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*	15			
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*	25			
Mid	*Cissus hypoglauca*	20	7	10	12
Lower	*Cordyline stricta*	20			

Stratum	Dominant species	Cover (% crown cover)	For the entire		
Lower	*Gahnia aspera*	15	Lower stratum Height to crown (m) min mode max		
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*	75	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*	20			
Lower	*Morinda jasminoides*	15	2	1	0.3
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					

Stratum	Dominant species	Cover (% crown cover)	For the entire		
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.

Ecos Environmental, applying the method specified by RMS (2018), assigned different microclimate exposure scores 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 – which ranged from 0 to 10% – was below the performance threshold of 25% and vegetation structure appeared to have remained the same since year 4. 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 5 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 5 compared to year 4
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 increased from a microclimate exposure score of 4 to 5 and plots 6-9 increased from 2 to 1, but this most likely reflects observer variability rather than physical changes.

5 References

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Warrell Creek to Nambucca Heads

Grey-headed Flying Fox – Operational Habitat Monitoring

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26 April 2019
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Roads and Maritime Service
Sent via Email to: Kris.Hincks@rms.nsw.gov.au

Attention: Mr Kris Hincks

Dear Kris

WC2NH Stage 2B GHFF Habitat Monitoring – Autumn 2019

Introduction

This report presents the results of the fourth and final quarterly (autumn 2019) Grey-Headed Flying-fox (GHFF) habitat monitoring event for Stage 2B (chainage 41700 to 47700 - refer to **Appendix A**) of the Warrell Creek to Nambucca Heads Pacific Highway Upgrade (WC2NH or the Project). It duplicates as the Stage 2B annual monitoring report. Quarterly GHFF habitat monitoring is required for one year after the opening of each section of WC2NH to traffic in accordance with the *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program – Stage 2: Warrell Creek to Nambucca Heads* (Benchmark Environmental Management, 2014).

The *Warrell Creek to Nambucca Heads Flying-fox Management Plan* (Sinclair Knight Merz, 2017) recognised that the quality of vegetation adjacent to the Project area could be detrimentally affected by invasion of noxious and environmental weeds. A main goal identified for management during operation of the Project is '*no reduction of the quality of flying-fox habitats adjacent to the Project corridor due to the operation of the Project and to minimise the impact of edge effects'* (Sinclair Knight Merz, 2017).

Methodology

The WC2NH GHFF habitat monitoring includes the following components:

1. Monitoring of identified revegetation/ rehabilitation areas to ensure the establishment/ restoration of seedlings and plants.
2. Monitoring both revegetation/ rehabilitation areas and other habitat areas adjacent to the Project to manage invasion of noxious and environmental weeds.

There are no GHFF revegetation/ rehabilitation areas associated with Stage 2B, therefore the subject monitoring event exclusively related to the second component of the monitoring program (henceforth referred to as 'weed monitoring').

Weed Monitoring

The Project *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval defined GHFF habitat as the following vegetation communities:

- Swamp Forest - Swamp Mahogany/ Paperbark.
- Moist Open Forest - Flooded Gum.
- Moist Open Forest - White Mahogany/ Grey Gum/ Ironbark.
- Mixed Floodplain Forest.
- Open Forest - Blackbutt.

All instances of the above plant communities occurring along the outside of the Stage 2B Project clearing corridor were targeted during the field surveys. Within two metres of the cleared edge of these habitat areas (referred to as 'weed survey areas') the following data was recorded in relation to weeds:

- Date and time of monitoring.
- Weed locations, abundance and composition.
- Evidence of management and control of noxious and environmental weeds.

Weed abundance for individual species was measured using modified Braun-Blanquet cover classes between 1 and 5: 1 (<5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), and 5 (76-100%). Abundance scores for identified weed sites were classified based on the categories in **Table 1**. Priority weed sites for management were identified based on species present and the percentage cover, prioritising *Biosecurity Act 2015* listed species and weeds with potential to degrade flying-fox foraging habitat values. The field surveys were undertaken by GeoLINK ecologists Jessica O'Leary and Frank Makin on 10 April 2019 between 12:30pm to 4:00 pm (seven person hours in total).

Table 1 Weed Abundance Classification for Weed Sites

Noxious/ Environmental Weed Cover (%)	*Weed Abundance Classification*
0-10	NA
11-39	Low
40-69	Medium
70-100	High

Photos were taken at the fixed photo points established during the winter 2018 weed monitoring for Stage 2B. Locations of the fixed photo points are listed in **Table 2**.

Table 2 Locations of Fixed Photo Points

*Photo Point ID**	*Photo Point GPS Coordinates^*	*Notes on Photo Direction*	*Vegetation Type*	*Corresponding Weed Site*
1BE	489545, 6594390	Looking north	Moist Open Forest - Flooded Gum	2BW9
1BW	490778, 6596540	Looking south	Moist Open Forest - Flooded Gum	2BW3
2BE	488766, 6593840	Looking south-west	Mixed Floodplain Forest	2BW18
2BW	489407, 6594440	Looking north-east	Mixed Floodplain Forest	2BW8
3BE	490153, 6595330	Looking south	Moist Open Forest - Flooded Gum	Not applicable
3BW	489268, 6594420	Looking south	Mixed Floodplain Forest	2BW11

** number plus side of alignment heading north: E=east, W=west.*

^ UTM eastings, northings; Zone 56J

Results and Discussion

Noxious and/ or environmental weeds were recorded at 23 sites (identified as low, medium or high). These weed sites are shown in **Appendix A** and listed in **Table 3**. Photographs of GHFF habitat areas taken from the fixed photo points are shown in **Appendix B.**

A total of 23 noxious and environmental weed species were recorded; an increase from 21 species recorded during the summer 2019 monitoring event. Blackberry (*Rubus fruticosus*), Fireweed (*Senecio madagascariensis*) and Lantana (*Lantana camara*) were recorded and are listed as priority weed species for the North Coast of NSW under the *Biosecurity Act 2015*. The primary management duty for these is they '*must not be imported into the state or sold*'.

The autumn 2019 monitoring event has overall recorded a slight increase in weed species diversity and abundance within the weed sites. This is consistent with the warm and wet weather growth period for the end of summer/ start of autumn for the Mid-North Coast region. No new weed sites were recorded during the autumn 2019 monitoring event. Broad-leaved Paspalum (*Paspalum mandiocanum*), Setaria (*Setaria sphacelata*), Lantana and Large-leaved Privet (*Ligustrum lucidum*) were recorded within GHFF habitat areas at the highest density and were the dominant weed species in infestations with 'Medium' or 'High' weed abundance levels (refer to **Table 3**).

Table 3 Abundance and Composition of Noxious and/or Environmental Weeds at Stage 2B Weed Sites

Weed Site No.	*Chainage (side of highway)*	*Summer 2019 Weed Composition (Cover Class^)*	*GHFF Habitat Type (Plant Community)*	*Winter 2018 Weed Abundance^^*	*Spring 2018 Weed Abundance^^*	*Summer 2019 Weed Abundance^^*	*Autumn 2019 Weed Abundance^^*	*Comments*	*Evidence of Management and Control*	*Weed Management Priority*
2BW1	46180 – 46190 (east)	Setaria (2), Camphor Laurel (1), Lantana* (1), Tobacco Bush (1), Broad-leaved Paspalum (2)	Open Forest - Blackbutt	High	Medium	Medium	Medium	No change since the previous monitoring event (summer 2019).	No evidence of weed control	Medium
2BW2	45440 – 45450 (east)	Broad-leaved Paspalum (2), Camphor Laurel (1), Setaria (3)	Moist Open Forest - Flooded Gum	Low	Low	Low	Low	Small creek and riparian zone within survey area. No change since the previous monitoring event (summer 2019)	No evidence of weed control.	Low
2BW3	45170 – 45280 (west)	Broad-leaved Paspalum (2), Camphor Laurel (2), Setaria (2), Blackberry* (1), Small-leaved Privet (1), Lantana* (1), Fleabane (1), Balloon Cotton Bush (1), **Paddy's Lucerne (1)**	Moist Open Forest - Flooded Gum	Medium	Medium	Medium	Medium	**Additional weed species recorded since previous monitoring event (summer 2019)**	No evidence of weed control	Low
2BW4a	44230 – 44280 (west)	Camphor Laurel (1), Lantana* (1), Setaria (1) **Broad-leaved Paspalum (1)**	Open Forest - Blackbutt	Not recorded	Not recorded	Low	Low	**Additional weed species recorded since previous monitoring event (summer 2019)**	No evidence of weed control	**Low**
2BW4b	44100 – 44200 (east)	Broad-leaved Paspalum (3), Purple Top (1), Rhodes	Open Forest - Blackbutt	Medium	Low	Low	Low	**Increase in abundance of Camphor Laurel**	No evidence of weed control	Low

Weed Site No.	Chainage (side of highway)	Summer 2019 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Summer 2019 Weed Abundance^^	Autumn 2019 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
		Grass (1), **Camphor Laurel (2)**, Whiskey Grass (1), Setaria (1)						**since summer 2019**		
2BW5	43960 – 44030 (east)	Broad-leaved Paspalum (3), Balloon Cotton Bush (1), Crofton Weed (1), Fireweed* (1), Setaria (1)	Moist Open Forest - Flooded Gum	Medium	Medium	Medium	Medium	No GHFF habitat vegetation exists immediately adjacent to the weed survey area. The weeds recorded within 2BW5 pose low risk of encroachment into the retained Moist Open Flooded Gum Forest which is 15 m from the weed infestation area. No change since the previous monitoring event (summer 2019).	No evidence of weed control	Low
2BW6	43050 – 43090 (east)	Lantana* (1), Broad-leaved Paspalum (1) **Rhodes Grass (1)**	Moist Open Forest - Flooded Gum	Low	Low	Low	Low	**Additional weed species recorded since previous monitoring event (summer 2019)**	No evidence of weed control	Low
2BW7	42980 – 42990 (west)	Lantana* (2), Large-leaved Privet (1), Broad-leaved Paspalum (1)	Mixed Floodplain Forest	Low	Low	Low	Low	No change since the previous monitoring event (summer 2019)	No evidence of weed control	Low

Weed Site No.	Chainage (side of highway)	Summer 2019 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Summer 2019 Weed Abundance^^	Autumn 2019 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
2BW7a	42800 - 42900	Lantana* (1)	Moist Open Forest - Flooded Gum	Not recorded	Low	Low	Low	No change since the previous monitoring event (summer 2019)	No evidence of weed control	Low
2BW8	42700 – 42880 (west)	Lantana* (3), Large-leaved Privet (3), Camphor Laurel (1), Winter Senna (1), Tobacco Bush (1), Broad-leaved Paspalum (1), Setaria (1), Rhodes Grass (1), Annual Ragweed (1), Fleabane (1), Setaria (1), Spear Thistle (1), Paddy's Lucerne (1)	Mixed Floodplain Forest	Medium	Medium	Medium	Medium	During spring 2BW8 was split into two sections (see 2BW8a below) to identify area of high weed activity. No change since the previous monitoring event (summer 2019)	No evidence of weed control	Medium
2BW8a	42650 - 42700	Large-leaved Privet (4), Lantana* (3), Tobacco Bush (2), Broad-leaved Paspalum (2), Setaria (1)	Mixed Floodplain Forest	Medium	High	High	High	No change since the previous monitoring event (summer 2019)	No evidence of weed control	High
2BW9	42770 – 42800 (east)	Broad-leaved Paspalum (2), Lantana* (1), Blue Billygoat Weed (1), **Setaria (1)**	Moist Open Forest - Flooded Gum	Low	Low	Low	Low	**Additional weed species recorded since previous monitoring event (summer 2019)**	No evidence of weed control	Low
2BW10	42620-42630 (east)	Setaria (3), Farmers Friends (1), Tobacco Bush (1), **Lantana* (3),** Annual Ragweed	Mixed Floodplain Forest	Medium	Medium	Medium	Medium	**Additional weed species recorded since previous**	Evidence of weed control.	Low

Weed Site No.	Chainage (side of highway)	Summer 2019 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Summer 2019 Weed Abundance^^	Autumn 2019 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
		(1), **Purple top (1), Large-leaved Privet (1), Paddy's Lucerne (1)**						**monitoring event (summer 2019). Increase in abundance of Lantana.**		
2BW11	42500 – 42600 (west)	Broad-leaved Paspalum (3), Lantana* (1), Tobacco Bush (1), Annual Ragweed (1), Setaria (1), Paddy's Lucerne (1)**, Blackberry* (2), Winter Senna (1)**	Mixed Floodplain Forest	Medium	Medium	Medium	Medium	**Additional weed species recorded since previous monitoring event (summer 2019).**	No evidence of weed control	Low
2BW12	42600 – 42610 (west)	Lantana* (3), Broad-leaved Paspalum **(3)**, Tobacco Bush (1), Setaria (2) Purple Top.	Mixed Floodplain Forest	Low	Low	Low	Low	**Increase in abundance of Broad-Leaved Paspalum.**	No evidence of weed control	Low
2BW13	42500 – 42510 (west)	Large-leaved Privet (2), Lantana* (3), Small-leaved Privet (2), **Blackberry* (2), Winter Senna (1)**	Mixed Floodplain Forest	Low	Low	Medium	Medium	**Additional weed species recorded since previous monitoring event (summer 2019). Increase in weed management priority since summer 2019.**	No evidence of weed control	**High**
2BW14	42570 – 42600 (east)	Large-leaved Privet (2), Broad-leaved Paspalum (1)	Mixed Floodplain Forest	Low	Low	Low	Low	No change since the previous monitoring event (summer 2019).	No evidence of weed control	Low

Weed Site No.	Chainage (side of highway)	Summer 2019 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Summer 2019 Weed Abundance^^	Autumn 2019 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
2BW15	42530 – 42600 (east)	Lantana* (2), Large-leaved Privet (2), Small-leaved Privet (2), Broad-leaved Paspalum (1), Camphor Laurel (saplings) (1)	Mixed Floodplain Forest	Low	Low	Low	Low	No change since the previous monitoring event (summer 2019).	No evidence of weed control	Low
2BW16	42090 – 42220, 42290, 42390 (east)	Broad-leaved Paspalum (4), Setaria (3), Lantana* **(2)**, Camphor Laurel (1), Tobacco Bush **(2)**, Blue Billy Goat (1), Purple Top (1), Crofton Weed (1), Fleabane (1), Farmers Friends (1)**.**	Mixed Floodplain Forest	High	High	High	High	**Increase in abundance of Tobacco Bush and Lantana.**	No evidence of weed control	Medium
2BW17	41900 – 41920 (east)	Small-leaved Privet (2), Setaria (2), Lantana* (1), Paddy's Lucerne (1), Tobacco Plant (1), **Purple Top (1), Fireweed* (1), Annual Ragweed (2), Broad-leaved Paspalum (2)**	Mixed Floodplain Forest	Not recorded	Low	Low	Low	**Additional weed species recorded since previous monitoring event (summer 2019).**	No evidence of weed control	Low
2BW18	41830 – 41880 (east)	Lantana* (2), Camphor Laurel (2), Paddy's Lucerne **(2)**, White Passionflower (1), **Broad-leaved Paspalum (1), Purple Top (1)**	Mixed Floodplain Forest	Not recorded	Low	Low	Low	Weeds recorded at this survey area pose minimal risk of encroachment into the adjacent Mixed Floodplain Forest which is >5	No evidence of weed control	Low

Weed Site No.	Chainage (side of highway)	Summer 2019 Weed Composition (Cover Class^)	GHFF Habitat Type (Plant Community)	Winter 2018 Weed Abundance^^	Spring 2018 Weed Abundance^^	Summer 2019 Weed Abundance^^	Autumn 2019 Weed Abundance^^	Comments	Evidence of Management and Control	Weed Management Priority
								m from the weed infestation area. **Additional weed species recorded since previous monitoring event (summer 2019)**		
2BW19	41560 – 41620 (east)	Blackberry* **(1)**, Lantana* **(1)**, Broad-leaved Paspalum **(3)**, Paddy's Lucerne (2), Annual Ragweed (1), Tobacco Bush (1) **White Passion Flower (1), Farmers Friends (1), Fireweed* (1)**	Mixed Floodplain Forest	Not recorded	Low	Low	Low	Grass species currently being grazed. **Decrease in abundance of Blackberry and Lantana. Increase in abundance of Broad-leaved Paspalum.**	No evidence of weed control	Low
2BW20	41765-41960 (west)	Setaria (1), Lantana* **(2)**, Tobacco Bush (1)	Moist Open Forest - Flooded Gum	Not recorded	Not recorded	Low	Low	**Increase in abundance of Lantana**	No evidence of weed control	Low

^ *Modified Braun-Blanquet cover classes of 1=<5%, 2=6-25%, 3=26-50%, 4=51-75%, and 5=76-100%.*

^^ Refer to Table 2.

* Denotes *Biosecurity Act 2015* listed priority weed species. Lantana, Blackberry and Fireweed are listed as Weeds of National Significance and as priority weed species for the North Coast of NSW. They must not be imported into the State or sold.

Bold text denotes change from summer 2019 monitoring event.

Two weed sites were nominated as 'High' priority weed management areas and three weed sites were nominated as 'Medium' weed management priority areas. Weed management priority areas are listed below and shown in **Appendix C**:

- 2BW8a - High weed management priority
- 2BW13 - High weed management priority
- 2BW1 - Medium weed management priority
- 2BW8 - Medium weed management priority
- 2BW16 - Medium weed management priority.

These five sites should be targeted during weed management works. To date, no management of weed infestation areas has be recorded during field surveys.

No significant change to the structure or composition of GHFF habitat has been recorded during fixed photo point monitoring. No exotic vines with the potential to inhibit native regeneration and smother the canopy of intact GHFF habitat were observed.

Comparison with previous results

Table 4 shows the combined area of weed site per weed abundance class; and the total number of weed species (i.e. diversity or composition) recorded during each Stage 2B monitoring event. In general, the weed site area and abundance within the Stage 2B survey areas have remained fairly consistent, with only minor changes (refer to **Table 4**) to areas recorded with high and medium weed abundance. Areas classified as having low weed abundance have steadily increased over the monitoring period as areas with low abundance levels have been added to the survey areas. The total number of weed species has increased over the monitoring period which is attributed to small scale weed growth post construction.

Table 4 Comparison of Weed Abundance and Composition

Weed Abundance (m2)	***Winter 2018***	***Spring 2018***	***Summer 2019***	***Autumn 2019***
High	397	433	433	433
Medium	1329	1137	1204	1204
Low	567	969	1618	1618
Total	**2294**	**2540**	**3256**	**3256**
Total number of weed species	12	19	21	23

Recommendations

Weed sites 2BW8a, 2BW13, 2BW1, 2BW8 and 2BW16 are target weed management areas to mitigate degradation to GHFF habitat. At these sites, there is the potential for Lantana, Large and small-leaf Privet and Blackberry to alter community structure and inhibit regeneration.

Management of the weeds at these sites would be consistent with the key objectives of the WC2NH *Weed and Pathogen Management Plan* (GeoLINK 2015) which is to '*ensure the Project avoids, suppresses and controls the spread of all weeds, plant pathogens and invasive species to ensure that impacts to the environment are minimised.*'

Conclusion (Project Success)

In relation to weed monitoring, the *Warrell Creek to Nambucca Heads Flying-fox Management Plan* (Sinclair Knight Merz, 2017) identifies the main goal for management during the duration of the Project as '*no reduction of the quality of flying-fox habitats adjacent to the Project corridor due to the operation of the Project and to minimise the impact of edge effects'*. The performance threshold by which this is measured is '*Deterioration in the quality of adjacent habitat vegetation as a result of the Project (as determined by qualified ecologist*)' (Sinclair Knight Merz, 2017). Potential indicators of success as listed in the *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program – Stage 2: Warrell Creek to Nambucca Heads* (Benchmark Environmental Management, 2014) include '*No deterioration in the quality of adjacent habitat vegetation as a result of the Project'*.

The following limitations must be considered when interpreting the data:

- Limited dataset (short survey period of four survey events contained within one year) making it challenging to observe weed impacts over time.
- Natural seasonal variations in species growth/ dieback.

Based on the results to date '*deterioration in the quality of adjacent habitat vegetation as a result of the Project'* has not been detected and the main goal of '*no reduction of the quality of flying-fox habitats adjacent to the Project corridor due to the operation of the Project and to minimise the impact of edge effects'* has been observed.

Please contact the undersigned if require any further information.

Yours sincerely
GeoLINK

Jessica O'Leary
Ecologist

References

Benchmark Environmental Management (2014). *Warrell Creek to Urunga Pacific Highway Upgrade Ecological Monitoring Program. Stage 2: Warrell Creek to Nambucca Heads*. Report to Roads and Maritime Services.

GeoLINK (2015). *Weed and Pathogen Management Plan: Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway.* Unpublished report to Acciona and Ferrovial Joint Venture/ Roads and Maritime Services. GeoLINK Consulting, Coffs Harbour.

Sinclair Knight Merz (2017). *Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway; Flying-fox Management Plan.* Report to Roads and Maritime Services.

Issue Log

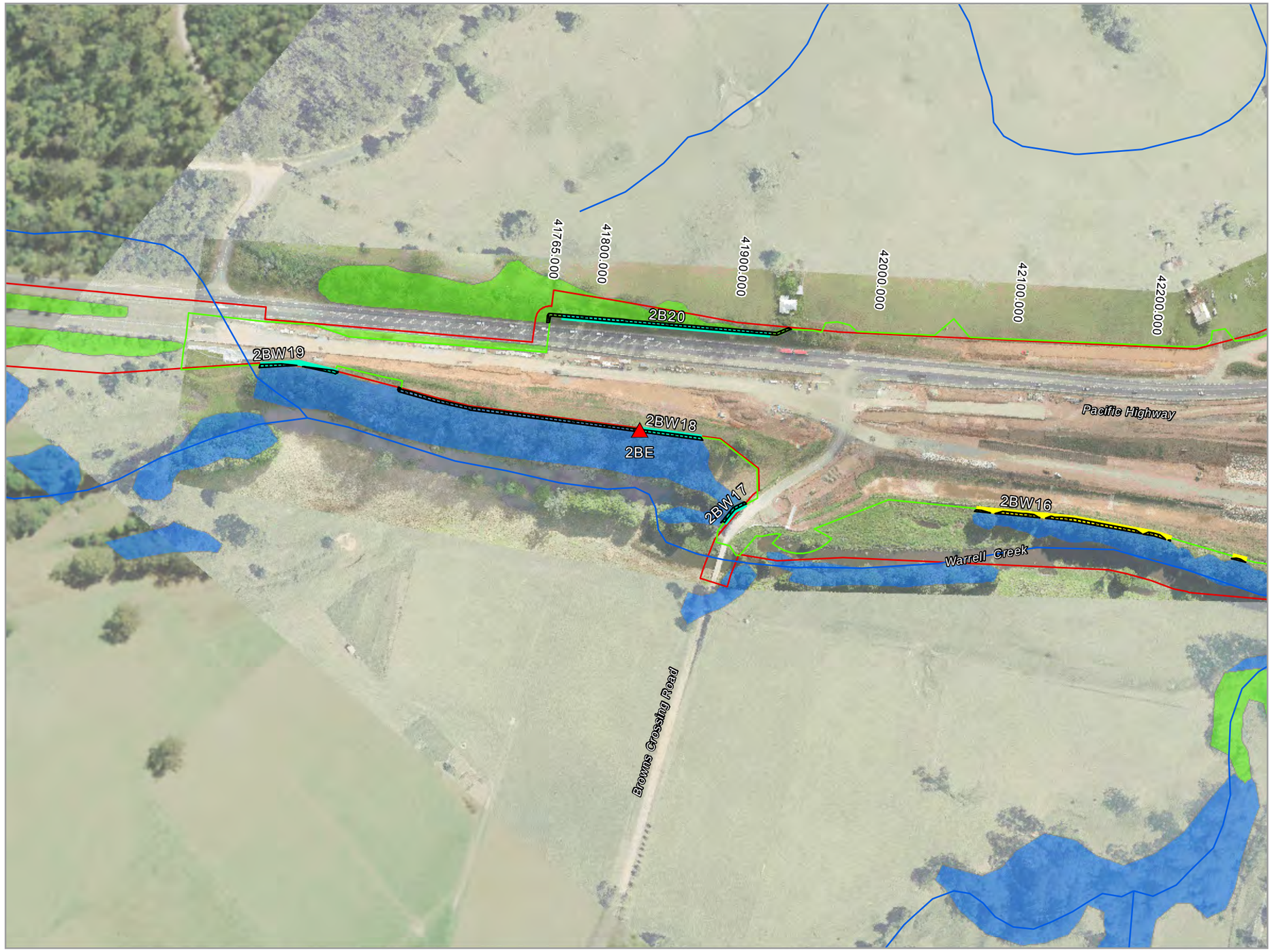
UPR	***Description***	***Date issued***	***Issued By***
2692-1165	First issue	26/04/2019	Jessica O'Leary

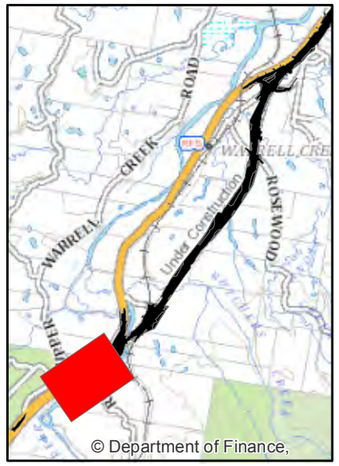
Appendix A

GHFF Weed Survey Areas and Weed Infestation Levels (Autumn 2019)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 24/04/2019
Source of base data: ESRI and AFJV





LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

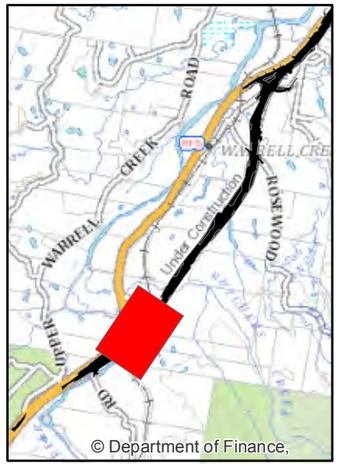
- High
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 24/04/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

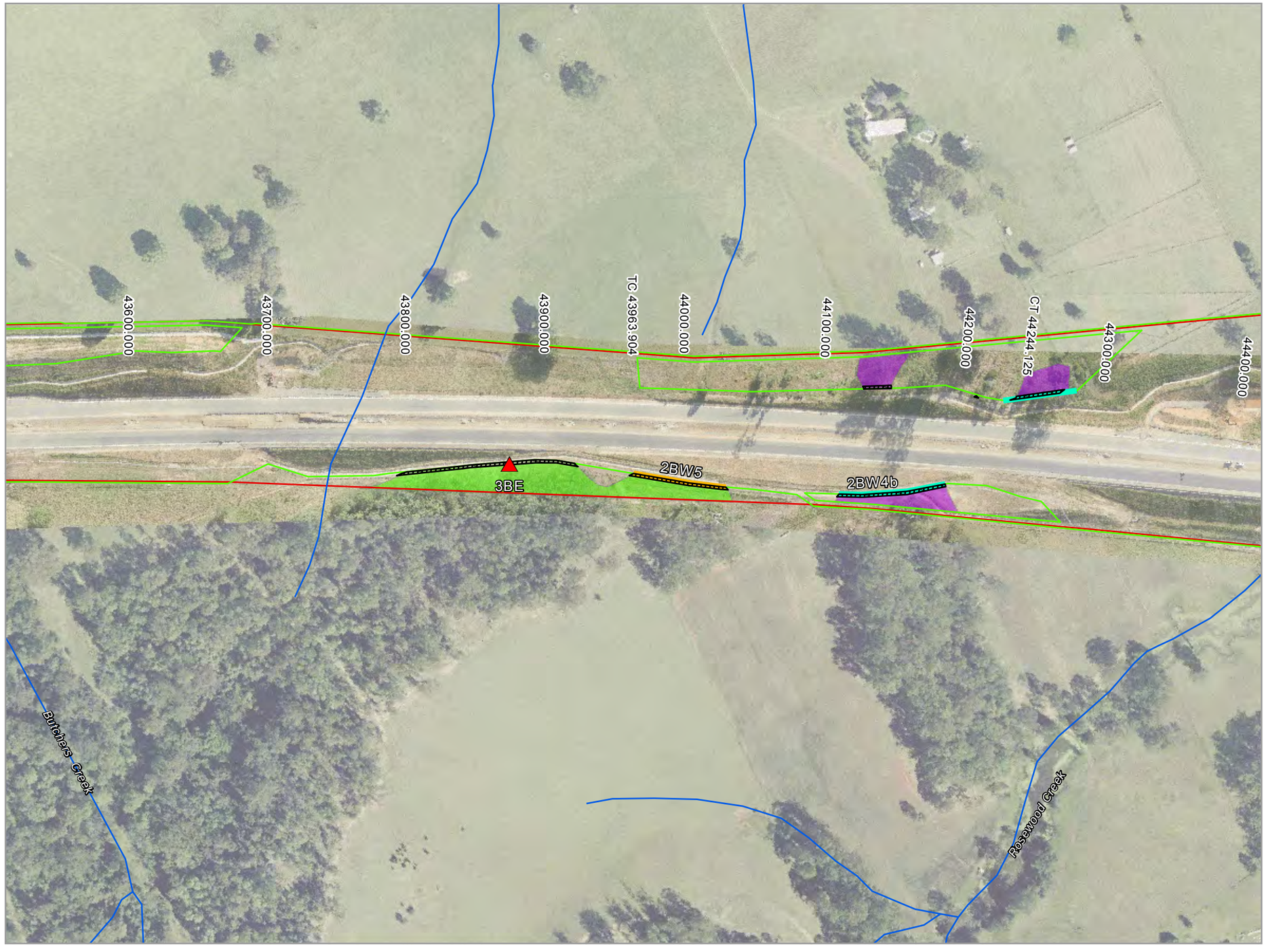
- High
- Medium
- Low

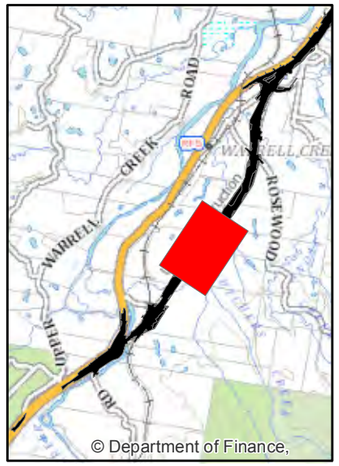
0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 24/04/2019
Source of base data: ESRI and AFJV





LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

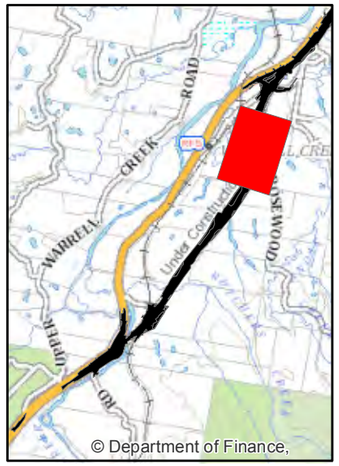
- Medium
- Low

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 24/04/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Moist Open Forest - Flooded Gum

Weed Site (Abundance)

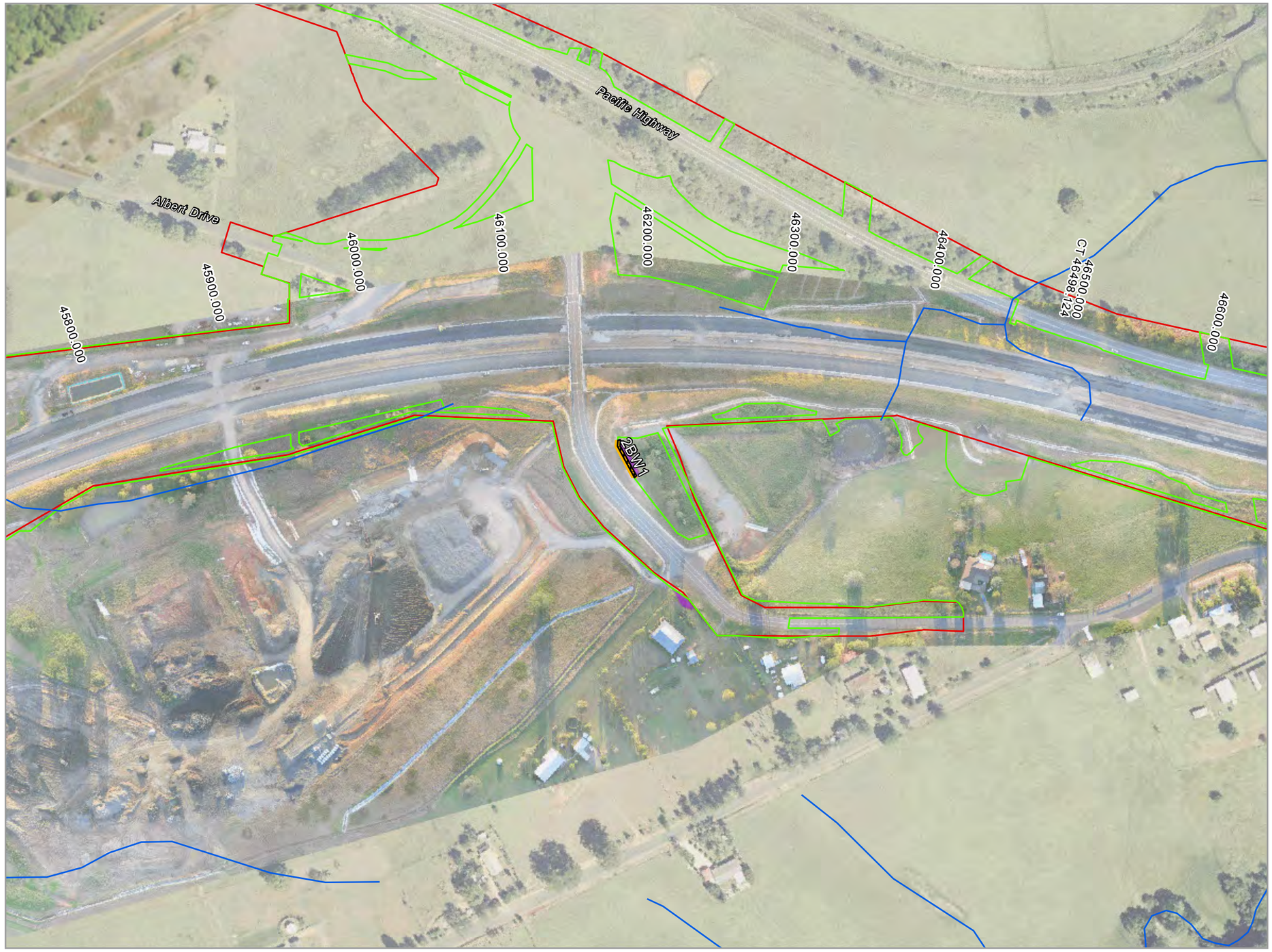
- Medium
- Low

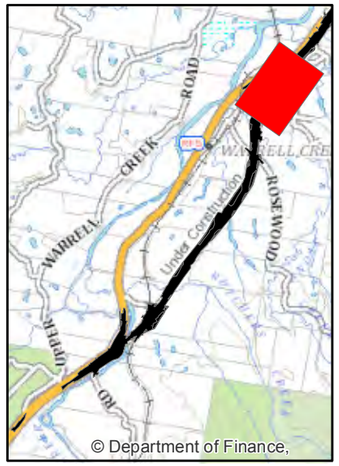
0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 24/04/2019
Source of base data: ESRI and AFJV





LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Vegetation

- Blackbutt Open Forest

Weed Site (Abundance)

- Medium

0 60

GHFF Weed Survey Areas and Weed Infestation Levels (Stage 2B)

Appendix B

Fixed Photo Point Results

Table B1 Weed Monitoring Fixed Photo Points (Stage 2B)

*Photo Point ID **	*Photo Point GPS Coordinates^*	*July 2018 photograph*	*October 2018 photograph*	*January 2019 photograph*	*April 2019 Photograph*
1BE	489545, 6594390				
1BW	490778, 6596540				
2BE	488766, 6593840				

*Photo Point ID **	*Photo Point GPS Coordinates^*	*July 2018 photograph*	*October 2018 photograph*	*January 2019 photograph*	*April 2019 Photograph*
2BW	489407, 6594440				
3BE	490153, 6595330				
3BW	489268, 6594420				

Appendix C

Weed Management Priority Areas

Information shown is for illustrative purposes only

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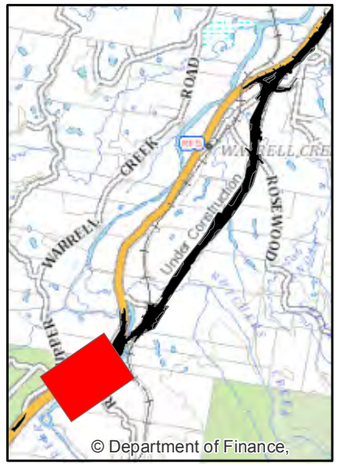
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Management Priority

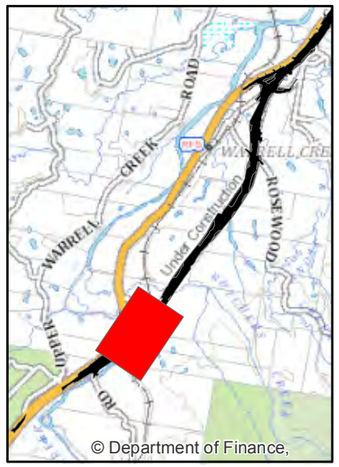
- Medium
- Low

0 60

Weed Management Priority Areas (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 24/04/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Mixed Floodplain Forest (EEC)
- Moist Open Forest - Flooded Gum

Weed Management Priority

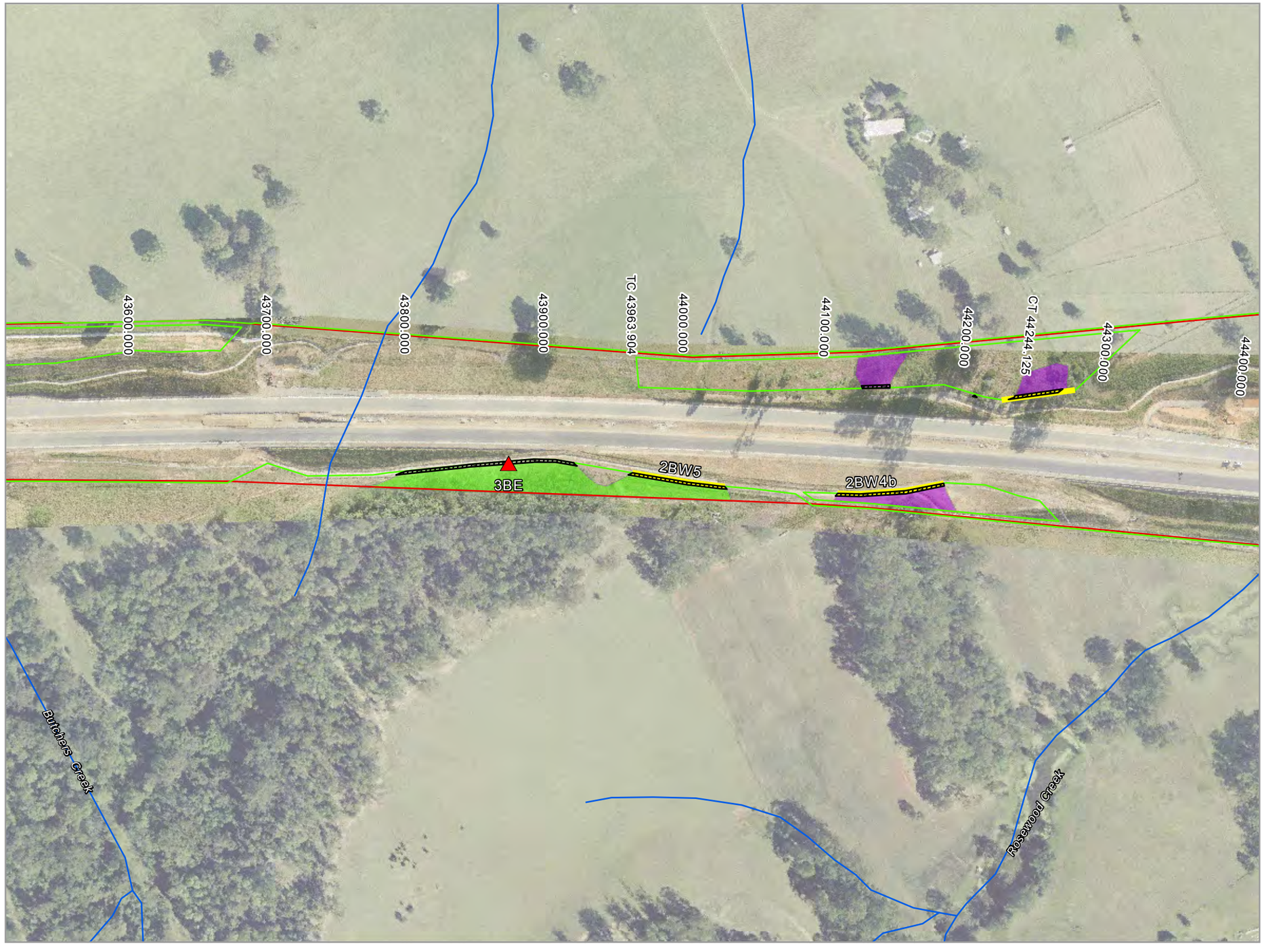
- High
- Medium
- Low

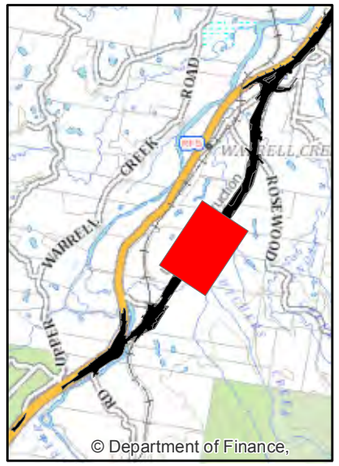
0 60

Weed Management Priority Areas (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 24/04/2019
Source of base data: ESRI and AFJV





LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Blackbutt Open Forest
- Moist Open Forest - Flooded Gum

Weed Management Priority

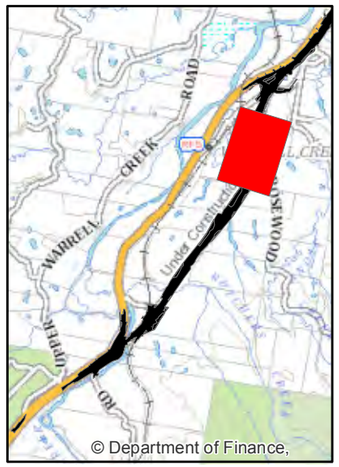
- Low

0 60

Weed Management Priority Areas (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 24/04/2019
Source of base data: ESRI and AFJV



LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area
- Fixed photo point

Vegetation

- Moist Open Forest - Flooded Gum

Weed Management Priority

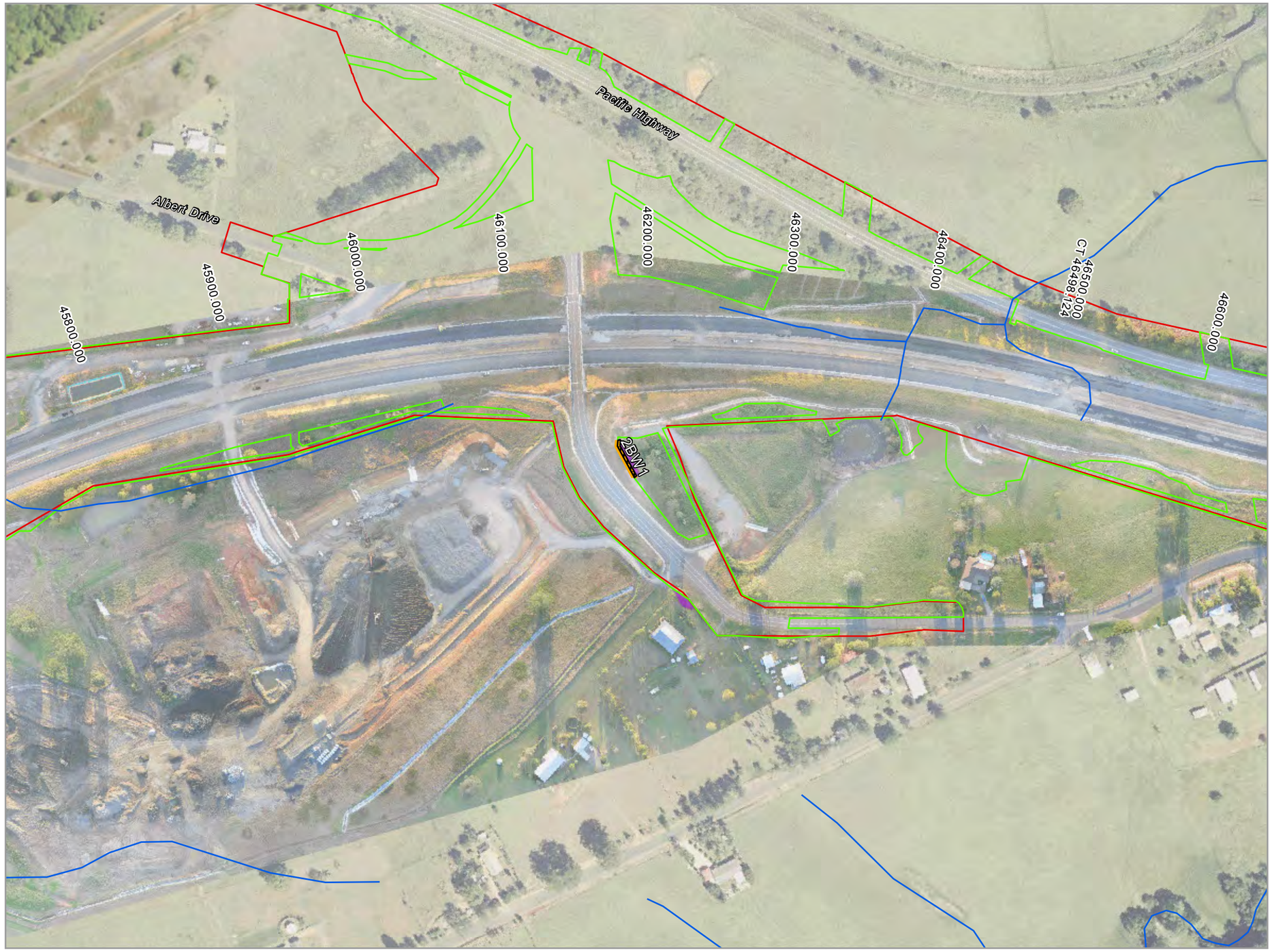
- Low

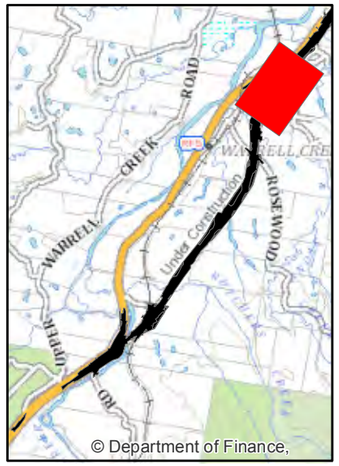
0 60

Weed Management Priority Areas (Stage 2B)

Information shown is for illustrative purposes only

Drawn by: AB Checked by: RE Reviewed by: JOL Date: 24/04/2019
Source of base data: ESRI and AFJV





LEGEND

- Project boundary
- Clearing limit
- Watercourse
- Stage 2B GHFF weed survey area

Vegetation

- Blackbutt Open Forest

Weed Management Priority

- Medium

0 60

Weed Management Priority Areas (Stage 2B)

NSW GOVERNMENT | Transport Roads & Maritime Services

Warrell Creek to Nambucca Heads

Giant Barred Frog Monitoring Report
Annual Report, Year One - Operational Phase

Roads and Maritime Services | June 2019

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Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
7/6/2019	A	Draft	D. Rohweder	SES	MSW	N. Priest
12/6/2019	B	Draft	D. Rohweder	SES	MSW	N. Priest
12/6/2019	1	Draft	S. Hardiman	RMS	MSW	D. Rohweder

Document Distribution

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
19/6/2019	2	Final	S. Hardiman	RMS	MSW	D. Rohweder

Project team:

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

Report prepared for:

Roads and Maritime Services NSW

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Cover Photo: A gravid female giant barred frog (*Mixophyes iteratus*) recorded at Upper Warrell Creek during summer year one operational phase monitoring.

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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, roadkill, 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 year one 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.

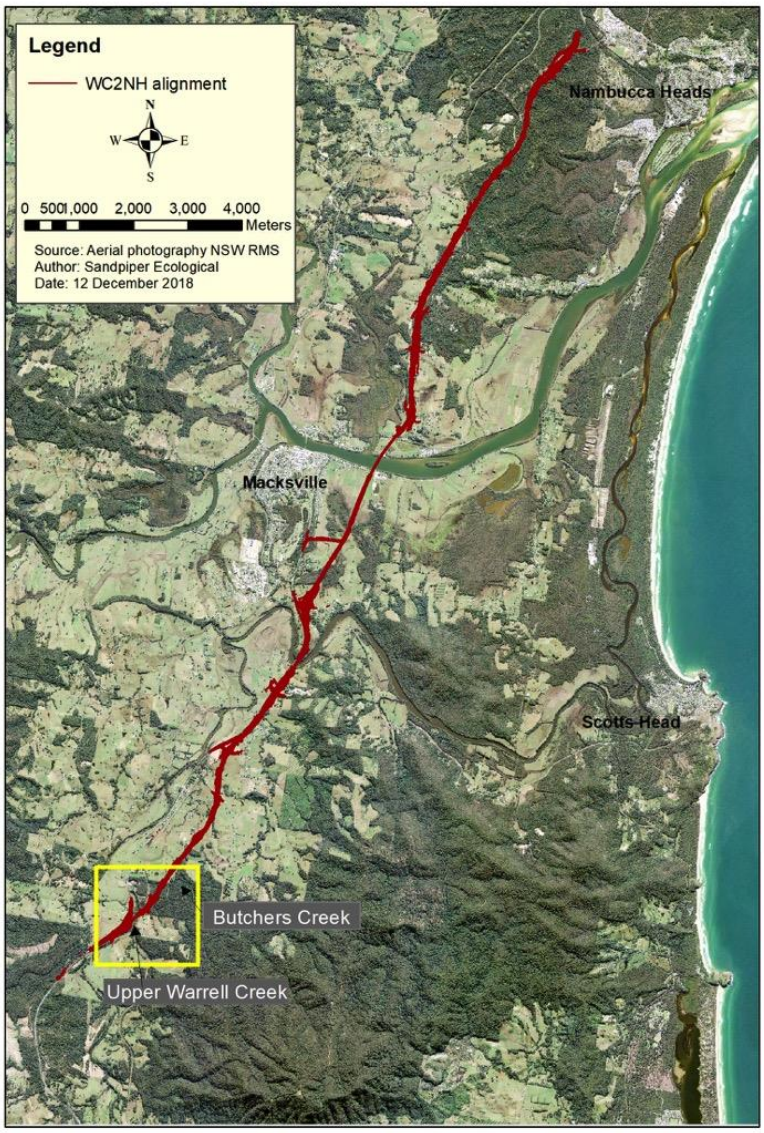

Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment.

2. Methodology

2.1 Timing and weather conditions

Three monitoring events were conducted during year one operational phase giant barred frog monitoring; spring, summer and autumn. A rainfall trigger of 10mm, recorded at the southern or northern project compounds, was used to determine seasonal survey commencement. Spring surveys were conducted on 17 October 2018 after the rainfall trigger was recorded on 16 October 2018. Summer surveys were conducted on 25 and 26 February 2019 after the rainfall trigger occurred on 22 February 2019. Autumn surveys were conducted on 19 and 20 March 2019 after the rainfall trigger was recorded on 18 March 2019. Surveys were conducted between dusk and 1am.

Weather variables including rainfall (preceding and throughout surveys), relative humidity, temperature, dew point and wind speed were recorded at the start and finish of each survey at each site. Weather conditions for each survey were recorded at each site using a hand-held kestrel weather meter.

2.2 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 based 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.

2.3 Tadpole survey

Tadpoles were sampled in spring and autumn only. In spring, a single tadpole trap (i.e. small bait trap) was set in each zone and baited with one slice of bread. Each trap was set for a minimum of three hours. Dip-netting for tadpoles was conducted by two ecologists within each zone. Dip-netting targeted accessible vegetated banks and rocky stream beds with a sufficient detritus layer. Only dip-netting was conducted during autumn surveys as per the brief.

2.4 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).

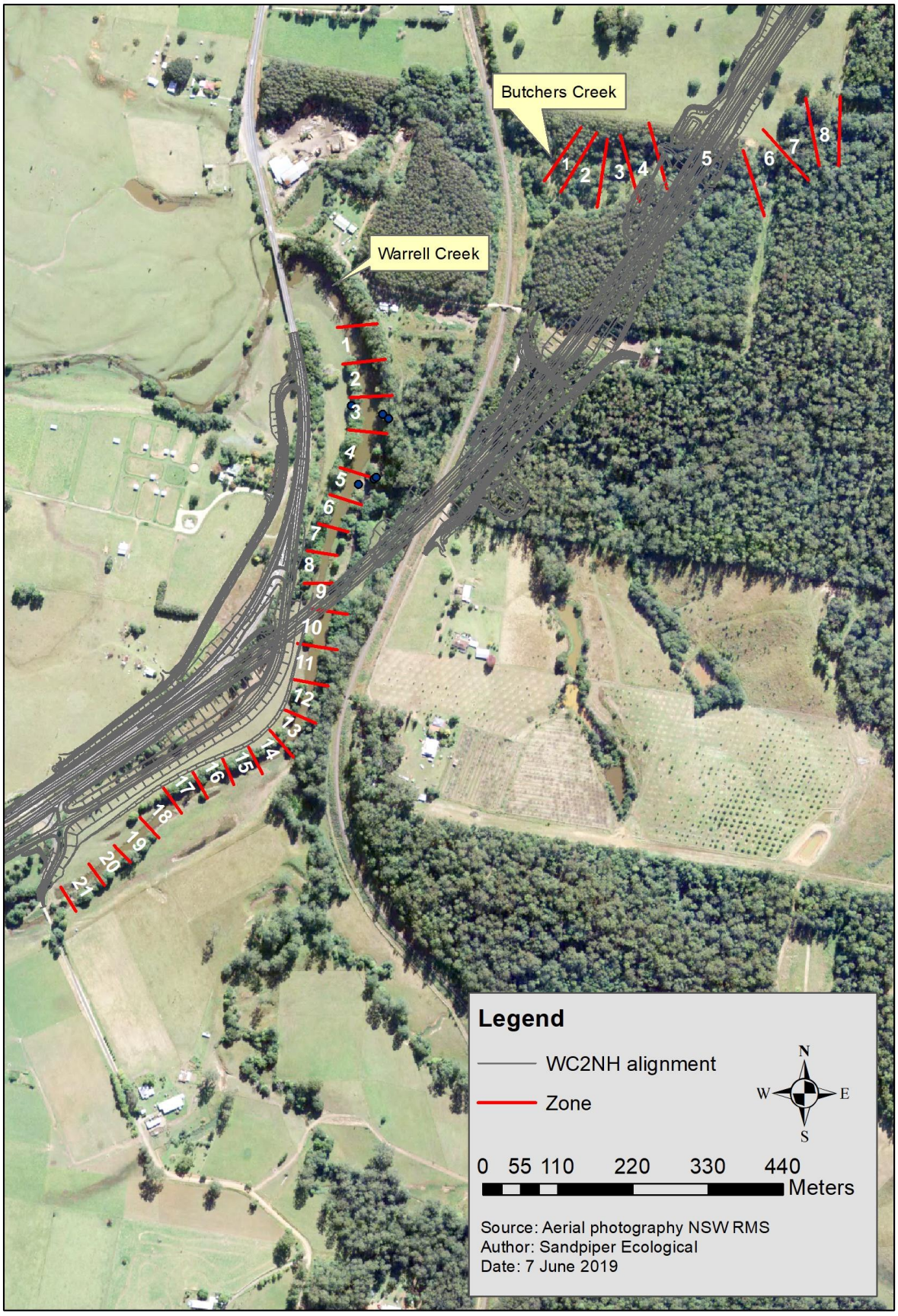

Figure 2: Survey zones within the Upper Warrell Creek and Butchers Creek sample sites.

2.5 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 physico-chemical 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.

2.6 Population estimate

The modified Petersen-Lincoln index method (that is the Petersen-Lincoln method with the Chapman estimator) was used to calculate a population estimate for year one operational phase. The method follows that applied by Lewis (2014) and Geolink (2018). Juveniles, sub-adult, and non-captured individuals were not included in the equation which is consistent with the baseline and construction phase surveys. To be consistent with the baseline sample the analysis was based on summer and autumn data, although estimates for spring/summer and spring/autumn are provided for comparison. The equation and input data, included:

$$\hat{N} = \frac{(M+1)(C+1)}{(m+1)} - 1$$

N = population size
M = total captured in sample 1
C = total captured in sample 2
m = number recaptured in sample 2

2.7 Data summary and analysis

Rainfall data used to calculate long-term averages (1915-2015) was sourced from the Bureau of Meteorology (BOM) weather station at Macksville (no. 59018). Rainfall data for 2018/19 was sourced from the project's southern compound weather station at Albert Drive Donnellyville as the Macksville Station

ceased operating in 2015. Data for calculating recent (2015-2019) yearly rainfall averages was sourced from the BOM Smokey Cape station (no. 59030).

Individual frogs were identified by comparing PIT tag numbers recorded during this survey with those reported by Geolink (2018) and Lewis (2014). The number of individuals calculated for year one construction phase might be an underestimate as it does not include individuals captured during the first autumn sample (GeoLink 2018).

2.8 Temporal comparison

Data collected during year one operational phase were compared to the construction phase and baseline surveys to provide a temporal comparison of frog abundance. The number of giant barred frogs detected (i.e. captured and heard calling but not captured), and captured in each time period is presented using histograms. Population estimates derived during each survey are also compared.

3. Results

3.1 Abiotic data

Weather conditions were suitable for frog surveys during each seasonal survey (Table 1). Temperatures were above 18^{0}C, relative humidity was above 80%, and wind was generally absent or light (Table 1). Water levels at both sites were high (flood) in spring, low in summer and very low in autumn. Butchers Creek was flowing in spring, reduced to several pools of stagnant water in summer and reduced to one pool of stagnant water in spring. This was the outcome of a summer characterised by above average temperatures and below average rainfall (Figure 3).

Table 1: Weather conditions during each survey in year one monitoring. * 0 = no wind, 1 = rustles leaves, 2 = moves small branches, 3 = moves canopy. RH = Relative Humidity.

Season	Site	Date	Start/Finish	Time	Rainfall (present)	Rainfall (prev 24hr)	Rainfall (prev 7 days)	Rainfall (prev 30 days)	RH	Temp (˚C)	Dew point	Wind*
Spring	Butchers Creek	16/10/18	Start	2023	Nil	23.8mm	112.2mm	154.4mm	94.5	19.5	18.5	0
			Finish	2210	Moderate				100	18.9	19.4	0
	Warrell Creek	17/10/18	Start	1949	Nil	16.2mm	128.4mm	170.6mm	100	20.7	21.3	2
			Finish	0049	Moderate				100	20.2	21.8	2
Summer	Butchers Creek	25/2/19	Start	2007	Nil	1.6mm	52.8mm	112mm	98.1	24.6	21.9	0
			Finish	2130	Light shower				88.6	22.2	20.0	0
	Warrell Creek	25/2/19	Start	2140	Nil				91.8	21.0	20.1	1
			Finish	2255	Moderate				100	21.4	20.4	1
	Warrell Creek	26/2/19	Start	1958	Nil	1.0mm	53.8mm	113.8mm	80.9	22.7	19.1	0
			Finish	2325	Nil				92.8	19.2	17.9	0
Autumn	Butchers Creek	19/3/19	Start	1925	Heavy showers	30mm	81.2mm	177.4mm	85.3	24.2	22.2	1
			Finish	2040	Light				99.9	24.5	25.8	1
	Warrell Creek	19/3/19	Start	2050	Nil				87.5	22.0	22.7	0
			Finish	2250	Nil				100	22.1	21.3	1
	Warrell Creek	20/3/19	Start	1930	Nil	30mm	81.2mm	177.4mm	93.8	22.8	21.2	0
			Finish	2300	Nil				96.1	20.9	21.2	0

Surveys occurred during a period of below average rainfall in eastern Australia. Monthly rainfall over the monitoring period compared to the long-term average from the nearest Bureau of Meteorology (BOM) station (59018) shows that apart from October and December 2018, monthly rainfall was lower than the long-term average (Figure 3).

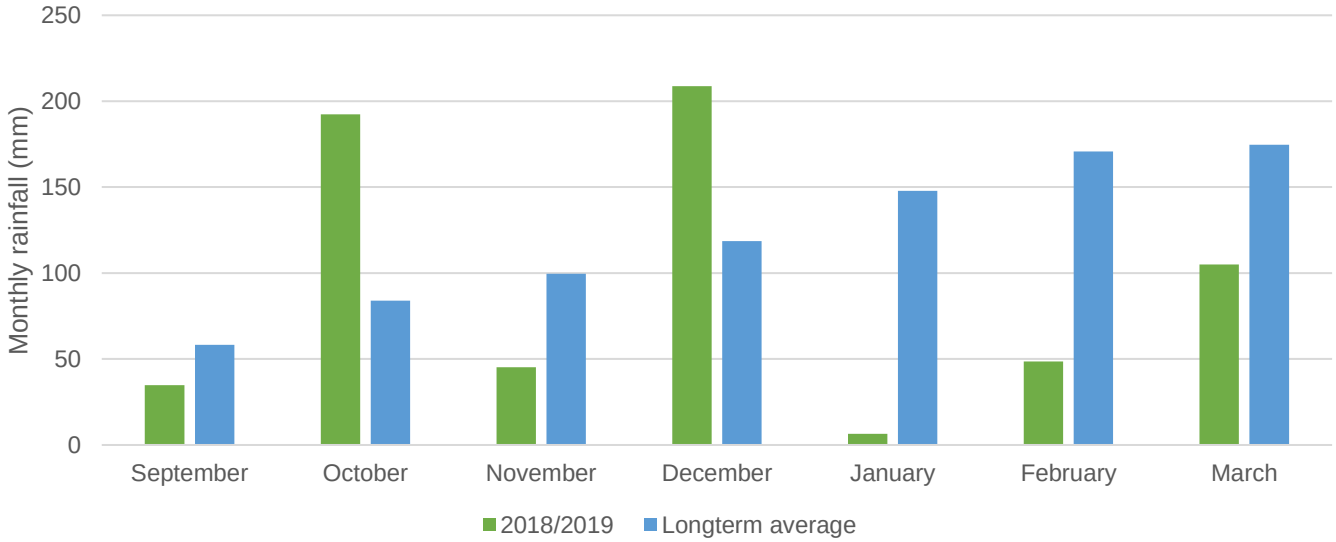

Figure 3: Monthly total rainfall recorded at the project southern compound weather station over the year one monitoring period against long term average recorded at the nearest BOM weather station – no. 59018.

3.2 Frog surveys

3.2.1 Spring survey

A total of 13.5 person hours were spent conducting nocturnal frog surveys in spring, 10 hours at Upper Warrell Creek and 3.5 hours at Butchers Creek. No giant barred frogs were recorded at Butchers Creek. Two giant barred frogs, one male and one female, were detected at Upper Warrell Creek (Table 2, Plate 1). One of these frogs was a new capture and the other a recapture. New capture Frog #1 was a female weighing 173g, a weight attributable to its gravid state (Plate 1). Re-captured Frog #2 was a male frog originally captured on 7 February 2018.

Table 2: Giant barred frogs captured at Upper Warrell Creek during spring 2018 monitoring.

Upper Warrell Creek	Record 1	Record 2
Frog no.	1	2
Date	17/10/18	17/10/18
Zone	8	6
Creek side	N	N
GPS location	489351, 6594448	489372, 6594537
Distance from stream edge (nearest 0.1m)	3.4	4.05
Position in micro-habitat*	On leaf litter	On leaf litter
Sex*	F	M
Age*	Adult	Adult
S/V length (mm)	101.5	77.1
Weight	173g	67g
Breeding condition*	Gravid	Moderate

Upper Warrell Creek	Record 1	Record 2
Microchip ID (new or re-capture)	New: 991001000620130	Recapture: 00078ABB9B
Original Date of capture		7/2/2018

*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.

Plate 1: Frog #1 weighing 173g captured during spring surveys at Upper Warrell Creek.

3.2.2 Summer survey

A total of 12 person hours were spent conducting nocturnal frog surveys in summer, 9 hours and 24 minutes at Upper Warrell Creek and 2 hours and 46 minutes at Butchers Creek. No giant barred frogs were recorded at Butchers Creek. Four adult giant barred frogs, three males and one female, were recorded at Upper Warrell Creek (Table 3; Plate 2). Three of these were recaptures and the fourth individual could not be captured. The fourth individual was heard calling from the south side of Warrell Creek but could not be relocated when ecologists sampled the south bank.

Frog #3 was originally captured on 6 November 2017, whilst frog #2 and #4 were both captured in February 2018. Frog #4 was captured at a similar location to Frog #1, which was captured during the spring 2018 survey (Sandpiper Ecological 2018). Both individuals had similar S-V length, although Frog #1 was 32 grams heavier, a result attributed to its gravid state. It is possible that frogs #1 and #4 are the same individual.

All captured frogs were situated on the north bank downstream of the alignment, and the calling male was on the south bank also downstream of the alignment (Figure 5). Distance from the waters edge ranged from 1.1 to 8.3m. Male frogs were between 1.1 and 1.3m from the waters edge. Two individuals were recorded amongst clumps of grass and one was initially observed on top of leaf litter.

Table 3: Giant barred frogs captured during the summer survey at Upper Warrell Creek. NR = not recorded

Upper Warrell Creek	Record 3	Record 4	Record 5	Record 6
Frog no.	3	4	2	5
Date	26/2/19	26/2/19	26/2/19	26/2/19
Zone	4	5	6	7
Creek side	N	N	N	S
GPS location	489322, 6594426	489354, 6594451	489364, 6594543	489318, 6594556
Distance from stream edge (nearest 0.1m)	1.1m	8.3m	1.3m	NR
Position in micro-habitat*	Amongst grass	On leaf litter	Among clumps of Grass, some leaf litter on tributary	
Sex*	M - calling	F	M- calling	M-calling
Age*	Adult	Adult	Adult	Adult
S/V length	83.8	101.5	74.8	
Weight	85g	141g	76g	
Breeding condition*	Moderate	Gravid	Moderate-dark	
Microchip ID (new or re-capture)	Recapture: 00077E8FEF	Recapture: 00078ABBF2	Recapture: 00078ABB9B	
Original date of capture	6/11/2017	5/2/2018	7/2/2018	
Recapture dates			17/10/2018	

*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.

Plate 2: Male (L) and female (R) giant barred frogs recorded at Upper Warrell Creek during the summer survey.

3.2.3 Autumn survey

A total of 12 person hours and 15 minutes were spent conducting nocturnal frog surveys in autumn, 11 hours at Upper Warrell Creek and 1 hour and 15 minutes at Butchers Creek. No giant barred frogs were detected at Butchers Creek.

Six giant barred frogs were detected at Upper Warrell Creek during autumn surveys. Of these, three were male, two female, and one (Frog #6) unknown sub-adult with a snout/vent length of 45.7mm (Plate 3). All other frogs were adult frogs. The weight of Frogs #4 and #8 suggests they were gravid at the time of capture (Table 4, Plate 3). Frog records #9 and #12 were recaptures, the remaining frogs were new individuals. Frog #4 was captured in summer 2019 and originally captured and tagged on 5 February 2018. Frog #3 was captured in summer 2019 and originally tagged and captured on 6 November 2017. Frog #6 was captured up-stream of the alignment, whilst all other individuals were captured down-stream (Figure 5). Frog #6 was not tagged due to its small size.

Table 4: Giant barred frogs detected during autumn surveys at Upper Warrell Creek.

Upper Warrell Creek	Record 7	Record 8	Record 9	Record 10	Record 11	Record 12
Frog no.	5	6	4	7	8	3
Date	19/3/19	19/3/19	20/3/19	20/3/19	20/3/19	20/3/19
Zone	3	17	5	6	5	5
Creek side	Y	Y	Y	Y	Y	Y
GPS location	489323, 6594584	489057, 6593987	489342, 6594424	489331, 6594419	489305, 6594377	489320, 6594428
Distance from stream edge (nearest 0.1m)	1.54	5.0	4.42	1.3	3.6	0.8
Position in micro-habitat*	Leaf litter, grazed paddock	Leaf litter, water gum	Leaf litter	Leaf litter, water gum overstorey	Leaf litter with water gum overstorey	In Paspalum, water gum overstorey
Sex*	M-calling	UK	F	M-calling	F	M-calling
Age*	Adult	Sub adult	Adult	Adult	Adult	Adult
S/V length (mm)	75.9	45.7	99.5	73.2	92.5	81.8
Weight	53g	11.5g	165g	57g	116g	85g
Breeding condition*	Moderate	NA	Gravid	Light-mod	Gravid	Moderate
Microchip ID (new or re-capture)	New: 991001000620121	Not tagged.	Recapture: 00078ABBF2	New: 991001000620125	New: 991001000620122	Recapture: 00077E8FEF
Original date of capture			5/2/2018			6/11/2017
Recapture dates			26/2/2019			26/2/2019

*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.

Plate 3: Adult gravid female weighing 165g (L). A sub-adult giant barred frog measuring 45.7mm S/V length (R) detected in autumn surveys at Upper Warrell Creek.

3.2.4 Year one survey summary

Eight giant barred frogs were detected (i.e. captured and heard calling) over three survey events at Upper Warrell Creek during year one operational phase monitoring (Figures 4 & 5). No giant barred frogs were recorded at Butchers Creek. All frogs, except sub-adult Frog #6, were detected down-stream of the alignment. All frogs except Frog #4 (91%) were located within 5m of the creek edge. Of the eight individuals captured, four were male and three female, with the sub-adult (Frog #6) recorded as sex unknown. Four new individuals were captured and tagged in year one operational phase surveys. The oldest recaptured frog was Frog #3 which was originally tagged on 6 November 2017. No frogs from baseline or year one construction phase surveys were captured. Gravid females were recorded during each sample. Other frog species recorded at both sites during all surveys are listed in Appendix B.

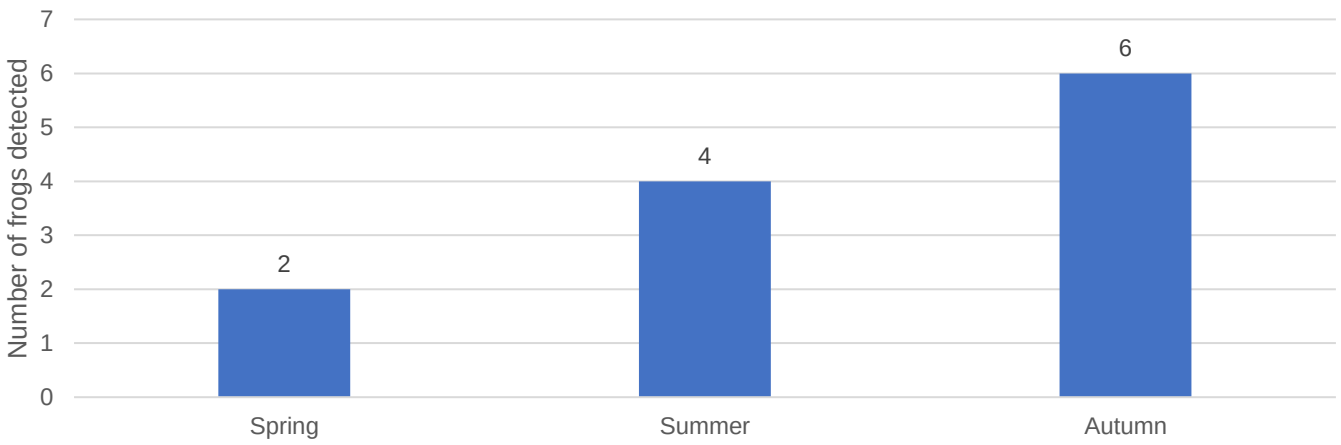

Figure 4: Giant barred frogs detected at Upper Warrell Creek over three monitoring events during year one operational phase monitoring.

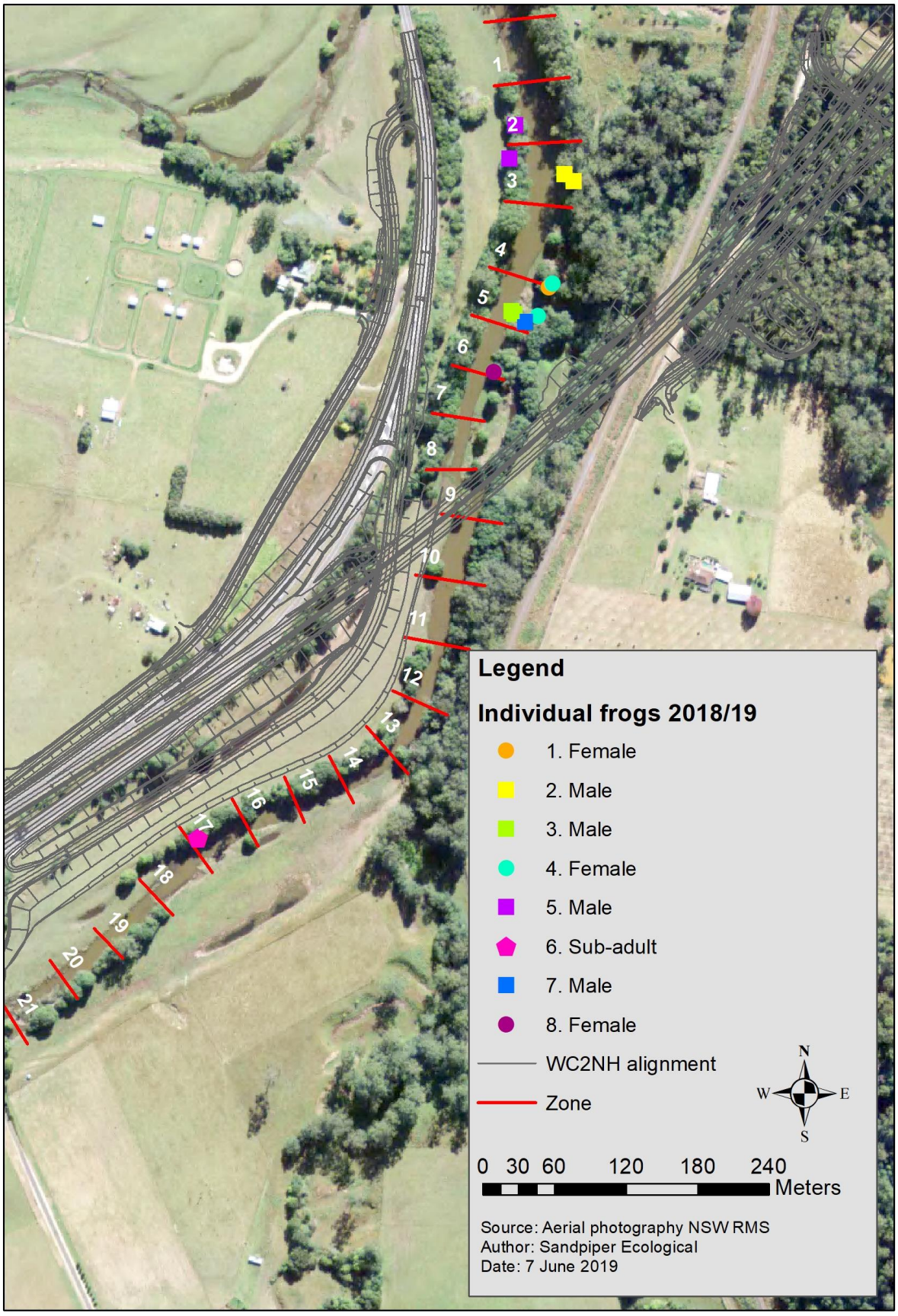

Figure 5: Location of year one operational phase giant barred frog records at Upper Warrell Creek.

3.2.5 Population estimate

The adult giant barred frog population estimate for Upper Warrell Creek in year one operational phase was seven (+/- SE 2.45) with a 95% confidence interval of 4.8 (Table 5). This suggests an adult population range of between two and 12 frogs occupying the 1km transect at Upper Warrell Creek. As seven adult frogs were recorded in year one the range for population size is more accurately presented as 7-12 individuals. No population estimate was calculated for Butchers Creek as no giant barred frogs have been recorded at that site.

Table 5: Population estimate, standard error and 95% confidence interval after the conclusion of year one operational phase giant barred frog monitoring at Upper Warrell Creek.

Population estimate	7
Standard error	2.45
95% confidence interval	4.8

3.3 Tadpole surveys

No giant barred frog tadpoles were detected at either Butchers Creek or Upper Warrell Creek during year one operational phase monitoring.

3.4 Habitat

3.4.1 Upper Warrell creek

Habitat at Upper Warrell Creek ranged from grassland/pasture to moderate quality riparian and wet sclerophyll forest with a dense litter layer (Appendix B). Parts of the Upper Warrell Creek study area contained fragmented and grazed riparian forest. Whilst some areas appear rarely used by cattle there is evidence of disturbance (i.e. clearing, weed infestation) throughout the study area. Vegetation does not extend beyond the creek bank/riparian zone. The width of riparian vegetation ranged from nil to 40m. Leaf litter cover ranged from high (>75%) in areas with an intact riparian zone to low (<10%) in cleared and grazed areas. One notable aspect of concern was growth of pigeon grass (S*etaria sphacelata*) and broad-leaved paspalum (*Paspalum mandiocanum*) on the north bank in zone 5. Whilst giant barred frogs have been recorded in broad-leaved paspalum, pigeon grass may create a barrier to movement when it occurs in dense clumps. The bank profile is characterised by a vertical face (<1m) at the waters edge and then a steep slope that ranged from 5 to 40m in length. Undercuts were recorded at the waters edge in several locations.

Weeping lilly pilly (*Waterhousia floribunda*) and flooded gum (*Eucalyptus grandis*) dominated the overstorey and mat rush (*Lomandra longifolia*) dominated the ground layer. Mat rush occurred in small clumps along the entire waters edge. Leaf litter depth, in areas of intact riparian forest, ranged from 40 to 100mm deep and total vegetation cover from 50 to 90%. Vegetation cover remained high in cleared areas due to dense grass cover.

3.4.2 Butchers Creek

Habitat at Butchers Creek varied substantially across the study area (Appendix B). During summer, the creek bed was dry except for a single pool in Zone 2. Habitat west of the alignment was highly degraded with recent (September/October) clearing to the creek bank. The dominant riparian species was camphor laurel (*Cinnamomum camphora*) with some small-leaved privet (*Ligustrum sinense*), callicoma (*Callicoma serratifolia*) and red ash (*Alphitonia excelsa*). Habitat east of the alignment was characterised by wet sclerophyll forest that extended well beyond the riparian zone. The creek bed consisted of rock and gravel with a steep bank and gravel bars. Leaf litter cover on the creek bank varied from 25 to 80% and ground vegetation cover from 10 to 60%. Despite the degree of fragmentation total vegetation cover was high, with only one of 16 sample sites receiving a cover score less than 40%. Habitat at Butchers Creek did not contain the moist microclimate that is typical of many giant barred frog habitats, which coupled with the ephemeral stream flow makes the site largely unsuitable for the target species.

3.5 Water quality

Most water quality parameters were within the ANZECC trigger values for freshwater ecosystems in south eastern Australia (Table 6). Exceptions were pH at Butchers Creek during summer and autumn surveys, and total Phosphorus at Upper Warrell Creek in spring and summer. The low dissolved oxygen levels recorded at both sites in spring and summer are attributed to a laboratory error and is not regarded as accurate. Turbidity was below the ANZECC threshold at both sites although the higher spring level is attributed to elevated stream flow during that sample. The higher nitrogen level recorded in spring is also attributed to higher stream flow. Both nitrogen and phosphorus values exceeded thresholds during the 2017/18 sample period (GeoLink 2018). Benzene, toluene, ethylbenzene and xylene levels and total recoverable hydrocarbons were within normal parameters during each sample.

Table 6: Results of water sample analysis for Upper Warrell creek and Butchers Creek. ID = insufficient data to derive a reliable trigger value (ANZECC 2000). *Laboratory error; not regarded as accurate measurement.

Parameter	Spring		Summer		Autumn		ANZECC/ARMCANZ Trigger value for freshwater (95% species level of protection)
	Warrell Creek	Butchers Creek	Warrell Creek	Butchers Creek	Warrell Creek	Butchers Creek	
Temperature (^{0}C)	19.6	18.5	No data	No data	23.4	20.8	
pH	6.7	6.9	6.59	6.12	6.63	6.39	6.5-8.0
Conductivity (us/cm)	256	110	292	179	291	159.1	125-2200
Dissolved oxygen (mg/L O_2)	8.4	9	3.5*	6.7*	No data	No data	9-10.5
Total Suspended Solids (mg/L)	9	1	3	1	3	194	
Turbidity (NTU)	18	17	3.4	1.5	4	1.2	6-50
Total Phosphorus (mg/L P)	0.04	0.02	0.03	0.01	0.02	0.02	0.025
Total Nitrogen (mg/L N)	0.49	0.19	0.29	0.10	0.24	0.15	0.35
BTEX							
Benzene (µg/L or ppb)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	950
Toluene (µg/L or ppb)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ID
Ethylbenzene (µg/L or ppb)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ID
m+p-Xylene (µg/L or ppb)	<1	<1	<1	<1	<1	<1	200
o-Xylene (µg/L or ppb)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	350
Naphthalene (µg/L or ppb)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	16
Total Recoverable Hydrocarbons (TRH)							
C6-C9 Fraction (µg/L or ppb)	<40	<40	<40	<40	<40	<40	ID
C10-C14 Fraction (µg/L or ppb)	<50	<50	<50	<50	<50	<50	ID
C15-C28 Fraction (µg/L or ppb)	<200	<200	<100	<100	<100	<100	ID
C29-C36 Fraction (µg/L or ppb)	<200	<200	<50	<50	<50	<50	ID
C10-C16 Fraction (µg/L or ppb)	<60	<60	<60	<60	<60	<60	ID
C10-C16 less Naphthalene Fraction (µg/L or ppb)	<60	<60	<60	<60	<60	<60	ID
C16-C34 Fraction (µg/L or ppb)	<500	<500	<200	<200	<200	<200	ID
C34-C40 Fraction (µg/L or ppb)	<500	<500	<100	<100	<100	<100	ID
Sum C10-C36 Fraction (µg/L or ppb)	No data	No data	<100	<100	<100	<100	ID

3.6 Temporal comparison

3.6.1 Frog surveys

The total number of giant barred frogs recorded declined substantially between baseline and year one of the construction surveys. A more gradual decline is evident from year one construction phase, where 16 detections occurred, to year one operational phase, where 12 detections occurred (Figure 6).

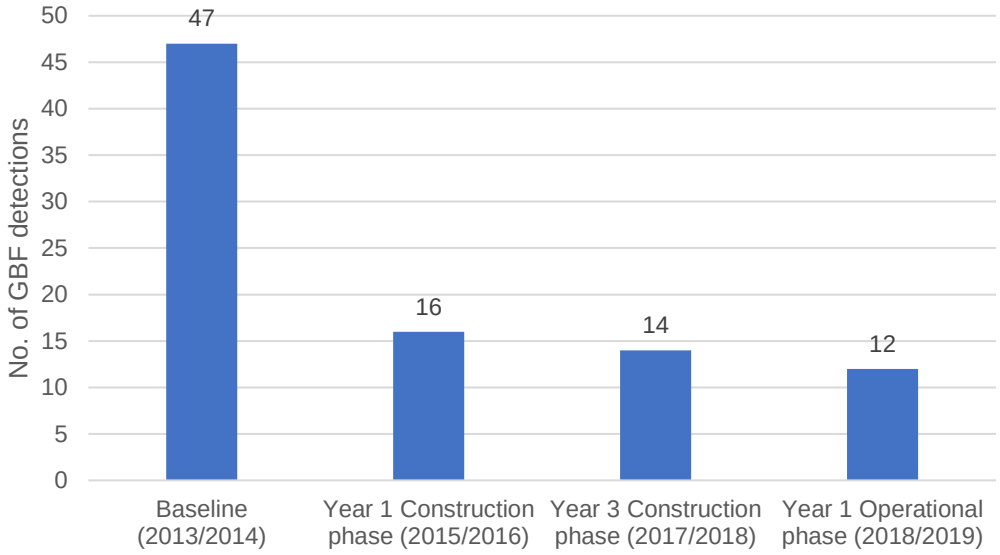

Figure 6: Total number of giant barred frog recorded in each of four sample periods at Upper Warrell Creek. Values include multiple recaptures of the same individual and calling males that were not captured.

The total number of individuals captured between baseline and year one construction phase surveys declined from 38 to eight and has remained stable over the construction and year one operational phase (Figure 7).

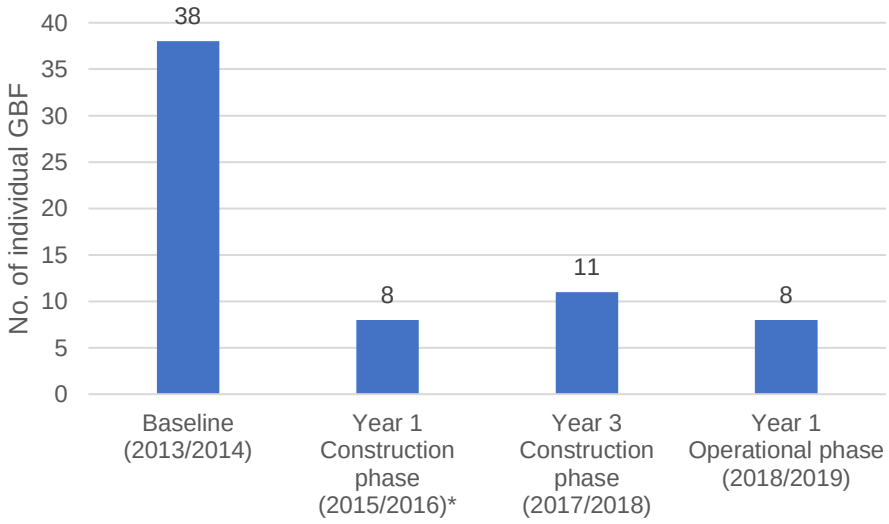

Figure 7: Number of individual giant barred frogs recorded over four sample events at Upper Warrell Creek. *Year one construction phase number may be an underestimate as it does not include frogs recorded in autumn 2015 (GeoLink 2018).

3.6.2 Population estimate

Comparison of adult population estimates across the four sample periods shows a decline at the Upper Warrell Creek site (Table 7). The population estimate of 43 adult frogs in 2013/14 declined to seven in year one of the construction phase with estimates of eight and seven recorded in year 3 construction phase and year one operation phase respectively (Table 7, Figure 8).

Table 7: Population estimates of adult giant barred frog at Upper Warrell Creek prior to construction (Lewis 2014), during construction (GeoLink 2018) and operational phase (Sandpiper 2019). GBF = giant barred frog.

Parameter	Baseline (2013/2014)	Year 1 Construction phase (2015/2016)	Year 3 Construction phase (2017/2018)	Year 1 Operational Phase (2018/2019)
GBF population estimate	43	7	8	7
Standard error	13.59	1.41	1.76	2.45
95% confidence interval	26.6	9.77	10.46	4.8

Figure 8: Adult population estimates (+ standard error) at Upper Warrell Creek during baseline (Lewis 2014), construction phase (GeoLink 2018) and year one operational phase monitoring (this study).

5. Discussion

5.1 Frog surveys

In year one operational phase monitoring no giant barred frogs were recorded at Butchers Creek, which is consistent with both pre-construction and construction phase surveys. Survey results at Upper Warrell Creek demonstrate that giant barred frogs continue to persist at that site. With a total of eight individuals recorded and an adult population estimate of 7 (± 2.45) individuals the population has remained relatively stable since year one construction phase. The substantial decline in population size from the baseline survey to the first construction phase sample suggests a stochastic event or a combination of factors negatively influenced the population.

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

The baseline population estimate may have been associated with a particularly good breeding season the preceding year. Lewis (2014) alludes to this and suggests that the adult population estimate derived from surveys in 2013/14 was an artefact of a good breeding season on 2012/13 when several flood events would have enabled frogs to breed. The high number of juveniles and sub-adults recorded (n = 16) during the baseline support the likelihood of successful breeding in 2012/13.

Year one operational phase monitoring was typified by below average rainfall with anomalies in October and December 2018 when above average rainfall was recorded. These anomalies may have contributed to the higher detection rates in the summer and autumn surveys where more calling males and a sub-adult individual were detected. Of the seven years from 2012 to 2018, six had below average rainfall, and 2015 was the only year with above average rainfall. Even with above average rainfall in 2015, the giant barred frog population at Upper Warrell Creek declined substantially from the baseline sample, which suggests other factors have affected the population. Reproductive success in giant barred frog populations may be more influenced by the timing of rain events in the breeding cycle than the average amount of rain received in a year. For example, good spring rain, with follow-up rain in summer and autumn, would provide better breeding conditions than above average rain in late autumn.

There is a paucity of basic ecological information about the factors that underlie amphibian population cycles, and such information is critical for determining whether population variations are natural, and short or long-term (Whiteman and Wissinger 2005). Giant barred frog fits the definition of an r-selected species, a species that matures rapidly, has an early age of first reproduction, has a relatively short lifespan, a large number of offspring at a time, and few reproductive events (Pianka 1970). An r-selected breeding strategy may partly explain the relatively high number of frogs recorded during baseline sampling.

This analysis considered, the causes of population decline after baseline surveys, particularly of the adult frog population, warrant further assessment. Natural attrition from predation, climate variability, and disease may have contributed to the decline, and many of the juvenile and sub-adult individuals recorded in 2013/14 may not have reached maturity. Little is known about the home range and dispersal capabilities of

giant barred frog, but it is reasonable to assume some individuals dispersed from the study area or were washed down stream during flood events.

The clearing of riparian vegetation and construction of a temporary causeway and temporary frog fencing would have reduced the habitat available to individuals in Zones 8, 9 and 10. Twenty-three giant barred frogs were recorded in these zones during baseline surveys. The zones were characterised by a flatter bank profile, narrow stream width, and a back channel and may have contained important foraging and breeding habitat (Lewis & Rohweder 2005). Indeed, the presence of 19 individuals in Zone 8 during the baseline suggests it contained high quality breeding habitat. Changes in vegetation, hydrology, and stream morphology during and post construction may have reduced habitat suitability and influenced breeding success and dispersal. Thereby contributing to a decline in frog abundance. The impact area is contrasted by the surrounding zones, which are characterised by steep banks, deep water and, in places, fragmented and narrow riparian vegetation.

Habitat fragmentation and clearing reduces habitat suitability for giant barred frogs by removing the overstorey, which provides leaf litter and cover that are critical for creating a moist ground layer with abundant organic material. Clearing also enables weeds and grasses to become established that inhibit frog movement. This is evident within the alignment at Upper Warrell Creek, and immediately to the west where pigeon grass (*Setaria* spp), broad-leaved paspalum (*Paspalum mandiocanum*), and knotweed (*Persicaria* spp.) dominate the ground layer.

5.2 Effectiveness of Mitigation Measures

5.2.1 Frog exclusion fencing

No giant barred frogs were detected as roadkill during spring, summer or autumn roadkill surveys at WC2NH (Sandpiper 2019). No incidental road killed giant barred frogs were detected on local roads in the area. The permanent frog exclusion fence is intact and functional. Movement of giant barred frogs from the creek onto the road is unlikely given the amount of scour rock and absence of vegetation cover.

5.2.2 Maintain habitat connectivity

No evidence of upstream or downstream movement by giant barred frogs was recorded during the year one surveys. The potential for movement will improve as riparian vegetation re-establishes.

6. Recommendations

- Continue giant barred frog monitoring in year three of the operational phase, as per the ecological and water quality monitoring brief.
- Dip-netting for tadpoles should target back channels and pools that contain more suitable tadpole habitat.
- Habitat remediation work involving control of pigeon grass, broad-leaved paspalum and knotweed in conjunction with additional planting of mat rush, and water gum is warranted in Zones 8, 9 and 10 to improve habitat connectivity.
- Consideration should be given to controlling pigeon grass, broad-leaved paspalum, and knotweed in Zone 4 and 5 to improve habitat connectivity.

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Appendix A – Habitat data

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

Zone	Bank	Land use (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 & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
2	N	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
3	N	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
4	N	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Rare snags & logs, knotweed & mat rush at waters edge, water lily	20-25	1-2m	No	Unknown	Water lily
5	N	Agriculture	Riparian	Snags, mat rush at waters edge, water lily, undercut bank	20	1-2m	No	Unknown	Water lily, occasional
	S	Agriculture	Riparian	Snags, mat rush at waters edge, water lily, undercut bank	20	1-2m	No	Unknown	Water lily, occasional
6	N	Road reserve	Riparian	Logs, snags, water lily, mat rush at waters edge	15	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Logs, snags, water lily, mat rush at waters edge	15	1-2m	No	Unknown	Water lily
7	N	Road reserve	Riparian	Logs, snags, water lily, mat rush at waters edge	15	1-2m	No	Unknown	Water lily
	S	Agriculture	Riparian	Logs, snags, water lily, mat rush at waters edge	15	1-2m	No	Unknown	Water lily
8	N	Road reserve	Grassland	Boulders, logs, waterlily, juncus, schoenoplectus	8	1m	Yes	Silt& gravel	Water lily, water primrose
	S	Road reserve	Grassland/ riparian	Boulders, logs, waterlily, juncus, schoenoplectus	8	1m	Yes	Silt& gravel	Water lily, water primrose
9	N	Road reserve	Riparian/cleared	Boulders, logs, waterlily, juncus, schoenoplectus	8	1m	Yes	Silt& gravel	Water lily, water primrose
	S	Road reserve	Grassland/ riparian	Boulders, logs, waterlily, juncus, schoenoplectus	8	1m	Yes	Silt& gravel	Water lily, water primrose
10	N	Agriculture	Riparian	Occasional logs & snags	15	1-2m	Yes	Unknown	Water lily, water primrose
	S	Road reserve	Grassland	Occasional logs & snags	15	1-2m	Yes	Unknown	Water lily, water primrose
11	N	Agriculture	Riparian	Snags, logs, aquatic vegetation	12	1-2m	No	Unknown	Water lily
	S	Road reserve	Grassland	Snags, logs, aquatic vegetation	12	1-2m	No	Unknown	Water lily
12	E	Agriculture	Riparian	Occasional logs, water lily, snags	15	1-2m	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, water lily, snags	15	1-2m	No	Unknown	Water lily

Zone	Bank	Land use (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
13	E	Agriculture	Riparian	Occasional logs, water lily, snags	13	1-2m	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, water lily, snags	13	1-2m	No	Unknown	Water lily
14	E	Agriculture	Grassland	Occasional logs, water lily (capensis & indica), elodea	13	1m	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, water lily (capensis & indica), elodea	13	1m	No	Unknown	Water lily
15	E	Agriculture	Grassland	Occasional logs, clumps of mat rush, water lily, knot weed	11	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, clumps of mat rush, water lily	11	Unknown	No	Unknown	Water lily
16	E	Agriculture	Grassland	Occasional logs, clumps of mat rush, water lily, knot weed	11	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, clumps of mat rush, water lily	11	Unknown	No	Unknown	Water lily
17	E	Agriculture	Grassland	Occasional logs, clumps of mat rush, water lily	11	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs, clumps of mat rush, water lily	11	Unknown	No	Unknown	Water lily
18	E	Agriculture	Riparian	Occasional logs; grass to water level	5	Unknown	No	Unknown	Water lily
	W	Road reserve	Riparian	Occasional logs; grass to water level	5	Unknown	No	Unknown	Water lily
19	E	Agriculture	Riparian	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily
	W	Road reserve	Grassland	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily
20	E	Agriculture	Riparian	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily
	W	Road reserve	Grassland	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily
21	E	Agriculture	Riparian	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily
	W	Road reserve	Grassland	Occasional logs; grass to water level	9	Unknown	No	Unknown	Water lily

Table A2: Habitat data collected in 21 zones at Upper Warrell Creek

Zone	Bank	Stream bank characteristics	Bank profile	Bank vegetation cover (%)	Groundcover composition (% of vegt, litter, rock, bare earth)	Depth of leaf litter
1	N	Intact riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, lantana,	Steep 20m	65	Mat rush, lantana, shrubs	40-50mm
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80	Mat rush, fishbone fern, vines	75-100mm
2	N	Intact riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, lantana,	Steep 20m	65	Mat rush, lantana, shrubs	40-50mm
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80	Mat rush, fishbone fern, vines	75-100mm
3	N	Intact riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, lantana,	Steep 20m	65	Mat rush, Carex, BL paspalum	40-50mm
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80	Mat rush, fishbone fern, vines	75-100mm
4	N	Immediate bank cleared - BL paspalum & igloo grass 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, occasional mat rush	50mm
	S	Intact riparian zone 12m wide, waterhousia, flooded gum, camphor laurel, mat rush at waters edge,	Undercuts, vertical 0.5m, steep 4m, moderate 5m	80	Mat rush, fishbone fern, vines	75-100mm
5	N	Riparian 40m incl side channel, waterhousia, mat rush, BL paspalum, SL privet, dense shrub & ground layer	Vertical 2m, moderate 20m	60	Mat rush, BL paspalum, lantana	40mm
	S	Intact riparian zone 15m wide from water to top of bank, waterhousia, some lantana, mat rush at waters edge	Vertical 0.5m, steep 13m	55	Mat rush, shrubs, lantana,	100mm
6	N	Riparian 40m incl side channel, waterhousia, mat rush, BL paspalum, SL privet, dense shrub & ground layer	Vertical 2m, moderate 20m	60	Mat rush, BL paspalum, lantana	40mm
	S	Established riparian zone 13m, waterhousia, good litter cover	Vertical 0.75m, steep 12m	70	Leaf litter, mat rush at waters edge, occasional vines & low shrubs	30mm
7	N	Established riparian zone 13m, waterhousia, good litter cover	Vertical 0.75m, steep 12m	70	Leaf litter, mat rush at waters edge, occasional vines & low shrubs	30mm
	S	Established riparian zone 13m, waterhousia, good litter cover	Vertical 0.75m, steep 12m	70	Leaf litter, mat rush at waters edge, occasional vines & low shrubs	30mm
8	N	Scour protection, immediate bank is flat, occasional boulders, gravel, sedges, to waters edge	Flat 20m	35	Knotweed, Schoenoplectus, juncus, cyperus spp, Carex	<10mm
	S	Scour protection, immediate bank is flat, occasional boulders, gravel, sedges, to waters edge	Flat 20m	35	Knotweed, Schoenoplectus, juncus, cyperus spp, Carex	<10mm
9	N	Scour protection, flat bank profile under bridge, 20m riparian zone, waterhousia, mat rush at waters edge,	Flat beneath bridge, moderate 20m	55	Mat rush, low shrubs	50mm
	S	Scour protection, immediate bank is flat, occasional boulders, gravel, sedges, to waters edge	Flat 20m	35	Knotweed, Schoenoplectus, juncus, cyperus spp, Carex	<10mm
10	N	Established riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80	Mat rush, BL paspalum, shrubs	40mm
	S	Scour protection (under bridge), knot weed, pigeon grass, occasional waterhousia	Vertical 1.5m, mod slope 3m	90	Knot weed, pigeon grass, BL paspalum	20mm
11	N	Established riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80	Mat rush, BL paspalum, shrubs	40mm
	S	Cleared grassland, pigeon grass, and knotweed to waters edge, sparse Schoenoplectus	Flat 3m, vertical 1m	95	Pigeon grass, knot weed	20mm

Zone	Bank	Stream bank characteristics	Bank profile	Bank vegetation cover (%)	Groundcover composition (% of vegt, litter, rock, bare earth)	Depth of leaf litter
		mucronatus.				
12	E	Established riparian zone 25m, waterhousia, flooded gum, mat rush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80	Mat rush, BL paspalum, shrubs	50mm
	W	Fragmented riparian/grassland, waterhousia, pigeon grass, knotweed & mat rush at waters edge	Vertical 1m, steep 2.5m	50	Pigeon grass, mat rush, knotweed to waters edge	50mm
13	E	Established riparian zone 35m, waterhousia, flooded gum, mat rush at waters edge, established mid storey	Vertical 1m, moderate 15m, steep 10m	80	Mat rush, BL paspalum, shrubs	50
	W	Riparian 7m wide, waterhousia, wattles, mat rush & knot weed on bank, fallen logs, woody debris	Vertical 1m, steep 2m	75	Knotweed, mat rush, basket grass, BL paspalum	75mm
14	E	Cleared grassland, knotweed to water level	Steep 0.5m	40	Knotweed	Nil
	W	Riparian 7m wide, waterhousia, wattles, mat rush & knot weed on bank, fallen logs, woody debris	Vertical 1m, steep 2m	75%	Knotweed, mat rush, basket grass, BL paspalum	75mm
15	E	Cleared grassland, knotweed to water level	Vertical 1m	55	Pasture grass, knot weed	Nil
	W	Riparian, waterhousia, camphor, mat rush at water level (clumps)	Vertical 1m, moderate 2.5m	70	Mat rush, BL paspalum	75mm
16	E	Cleared grassland, knotweed to water level	Vertical 1m	55	Pasture grass, knot weed	Nil
	W	Riparian, waterhousia, mat rush at water level	Steep 4m	75	Mat rush, BL paspalum, lantana	50
17	E	Cleared, grassland	Vertical 1m	60	Pasture grass, knot weed	Nil
	W	8m riparian zone, waterhousia	Steep 4m	65	Mat rush, low shrubs	50mm
18	E	Fragmented, grazed, half cleared, waterhousia, camphor	Moderate slope 2m	40	Knot weed, pigeon grass	10mm
	W	Fragmented riparian, waterhousia, camphor, pigeon grass & knot weed on immediate bank	Steep, with back channel	90	Knot weed, pigeon grass	20mm
19	E	Fragmented riparian vegt, waterhousia, flooded gum, grazed, cleared u/S	Sloping, moderate	70	Sparse mat rush, BL paspalum	10mm
	W	Cleared grassland, dense pigeon grass	Steep, with back channel	90	Pigeon grass	10mm
20	E	Fragmented riparian vegt, waterhousia, flooded gum, grazed, cleared u/S	Sloping, moderate	70	Sparse mat rush, BL paspalum	10mm
	W	Cleared grassland, dense pigeon grass	Steep, with back channel	90	Pigeon grass	10mm
21	E	Fragmented riparian vegt, waterhousia, grazed, cleared u/S	Sloping, moderate	70	Sparse mat rush, BL paspalum	10mm
	W	Cleared grassland, dense pigeon grass	Steep, with back channel	90	Pigeon grass	10mm

Table A3: Habitat data collected in 8 zones at Butchers Creek

Zone	Bank	Land use (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%; vegt 25%	Mat rush
	S	Agriculture	Shrubs and	Pool/riffle with rocks	3	Nil	Nil	Rock 50%; litter 25%; vegt 25%	Mat rush
2	N	Agriculture	Grassland	Pool rifle with rocks	3.5	Nil	Nil	Rock 25%; litter 40%; grass 40%	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	Nil	Nil	Rock 30%; litter 60%; silt 20%	Mat rush
	S	Agriculture	Disturbed grassland	Pool/riffle with rocks	3	Nil	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	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
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	Nil	Nil	Rock 60%; litter 40%	Nil
	S	Conservation	Wet sclerophyll	Pool/ riffle with rocks	5	Nil	Nil	Rock 60%; litter 40%	Nil
8	N	Agriculture	Wet sclerophyll	Pool/ riffle with rocks	6-7	Nil	Nil	Rock 60%; litter 40%	Nil
	S	Conservation	Wet sclerophyll	Pool/ riffle with rocks	6-7	Nil	Nil	Rock 60%; litter 40%	Nil

Table A4: Habitat data collected in 8 zones at Butchers Creek

Zone	Bank	Stream bank characteristics	Bank profile	Bank vegetation cover (%)	Groundcover composition	Depth of leaf litter
1	N	Camphor, mat rush, lantana, privet, degraded	Vertical 1.25m	60	Mat rush, carex, lantana	25mm
	S	Mat rush, Lilly pilly, privet, Brown kurrajong degraded	Steep slope 2m	60	Mat rush, BL paspalum, regrowth shrubs	<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	Mat rush, lantana, BL paspalum	20mm
3	N	3m wide, camphor, lantana, privet, highly degraded	Vertical 1.5m	60	Gahnia, mat rush, ferns, BL paspalum	50mm
	S	2m wide riparian zone, catacomb, lantana, degraded	Vertical 1.5m	40	Mat rush, gahnia, lantana, ferns	25mm
4	N	5m wide riparian zone, clumps of mat rush & gahnia, degraded	Vertical 2m	75	Gahnia, mat rush, ferns, BL paspalum	50mm
	S	2m wide riparian zone, Callicoma, lantana, degraded	Vertical 2m	10	BL paspalum	25mm
5	N	Rocky substrate, dense cover of lantana, mat rush, BL paspalum	Sloping - steep	90	Mat rush, lantana, BL paspalum	30-50mm
	S	Intact riparian zone, water vine, lantana, flooded gum, camphor laurel	Steep	80	Mat rush, lantana, BL paspalum	50-100mm
6	N	5-10m riparian, flooded gum, camphor laurel, dense midstorey	Steep	75	Occasional mat rush & ferns	30-50mm
	S	20m + riparian, various midstorey rainforest species	Moderate slope	80	Occasional mat rush & ferns	30-50mm
7	N	5-10m riparian, flooded gum, camphor laurel, dense midstorey	Steep slope	80	Very sparse, low shrubs	50-75mm
	S	20m + riparian, various midstorey rainforest species	Steep slope	80	Very sparse, low shrubs, mat rush	50-75
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, camphor laurel	Variable	80	Mat rush, lantana, BL paspalum, saw-sedge	30-50mm

Appendix B: Other frog species recorded

Table B1: Other frog species detected during year one operational phase surveys. Lit = Litoria, C = Crinia, Lim = Limnodynastes, Upe = Uperolia, Pseud = pseudophryne.

Site	Date	Frogs	Notes
Butchers Creek	16/10/18	Lit. fallax, C. signifera, Lit. gracilenta, A. brevis, Pseud. coriacea, Lim. peronii, Lit. nasuta, M. fasciolatus, Lit. barringtonensis, Lit. revelata, Lit. peronii, Lit. dentata	Lit. barringtonensis x 3, Lit. gracilenta x1 in culvert
Warrell Creek	17/10/18	Lit. dentata, Lit. fallax, Lit. gracilenta, C. signifera, Upe. sp.	
Butchers creek	25/2/19	Pseud. coriacea	
Warrell Creek	25/2/19	Lit. fallax, Lit. nasuta	
	26/2/19	Lit. fallax	
Butchers creek	19/3/19	Pseud. coriacea, Lim. peronii, C. signifera	
Warrell creek	19/3/19	Lit. gracilenta	
Warrell Creek	20/3/19	Lim. peronii, Lit. fallax	

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Customer feedback
Roads and Maritime
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June 2019

Pacific Highway Upgrade

Warrell Creek to Nambucca Heads

Operational Road Kill Monitoring Report

Transport for NSW February 2020

NSW GOVERNMENT

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Document control

Report name	Pacific Highway Upgrade Warrell Creek to Nambucca Heads Operational Road Kill Monitoring Report
Date	20 Feb 2020

Contents

Introduction

Road kill monitoring is a requirement of the approved Warrell Creek to Nambucca Heads Koala, Spotted-tailed Quoll and Grey-headed Flying-fox management plans and the Ecological Monitoring Program.

The aim of the monitoring program is to;

- report on any animal road kill on the project following the 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.

Timing of road kill surveys for the WC2NH Project is described in following table.

Project Phase	Timing of Survey	Location
Upon opening of each stage of the project to traffic (operational phase)	Weekly for 12 weeks commencing the week of opening each stage to traffic.	Entire length of opened stage.
Upon completion of the Project (operation phase)	Excluding the season/s covered by the initial 12 week monitoring period (refer above), weekly during October (spring), January (summer), April (autumn) and July (Winter) for up to 5 consecutive years post construction, or until mitigation measures have been demonstrated to be effective.	Entire length of completed Project

The approved road kill monitoring strategy is provided in Appendix 1.

Purpose of this report

The purpose of this report is to provide the road kill monitoring undertaken during the 2019 - 2020 reporting period. The reports provides the road kill data in the following reports provided in the Appendices

- Autumn (April) 2019 monitoring
- Winter (July) 2019 monitoring
- Spring (October) 2019 monitoring (Annual Report)
- Summer (January) 2020 monitoring.

Appendix 1 WC2NH Road Kill Monitoring Program

Timing of Monitoring

Timing of road kill surveys for the WC2NH Project is described in Table 1.

Table 1 – Timings and locations of road kill surveys

Project Phase	Timing of Survey	Location
During clearing operations	Daily	Portion of existing Pacific Hwy adjacent to clearing operations
One month following clearing operations	Daily	Portion of existing Pacific Hwy adjacent to clearing operations
Duration of construction	Weekly	Entire length of existing Hwy in Project area
Upon opening of each stage of the project to traffic (operational phase)	Weekly for 12 weeks commencing the week of opening each stage to traffic.	Entire length of opened stage.
Upon completion of the Project (operation phase)	Excluding the season/s covered by the initial 12 week monitoring period (refer above), weekly during October (spring), January (summer), April (autumn) and July (Winter) for up to 5 consecutive years post construction, or until mitigation measures have been demonstrated to be effective.	Entire length of completed Project

Monitoring Program Objectives

The aim of the monitoring program is to;

- report on any animal road kill on the project following the 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.

Monitoring Procedure

A two-person team vehicle being driven along the entire length of the highway in the Project area and identifying dead wildlife (road kill) seen on the road and within three metres of the road edge. The passenger will search the road and its verge for road kill. When a road kill is observed from the vehicle, a closer visual inspection of the carcass will be undertaken where safe access is available. If safe access is not possible, due to local traffic conditions, binoculars will be used to try to identify and provide as detailed information as is possible on the carcass.

Road kill fauna will be identified to species level where possible, with reference to field guides. Where there is any doubt to the identification of the carcass, photographs will be taken and forwarded to a qualified ecologist for identification /confirmation of species. Those too seriously damaged to be accurately identified will be recorded as “unknown”.

To assist with the correct identification of road kills, the following will be undertaken –

a. The provision of a qualified ecologist (shall be a recognised expert in mammal identification in coastal northern NSW) to undertake the initial phase of operational monitoring (first season) with relevant Roads and Maritime team members providing appropriate detailed training and a baseline of expert monitoring of road kills;

b. The provision of specialist training (to be provided by an expert as above in point a) in fauna identification for Contractors and Roads & Maritime staff involved in the construction phase monitoring of road kill; and

c. Where there is any doubt to the identification of the carcass, the provision of photographs of road kill to be sent to a qualified ecologist (an expert as above in point a) to confirm the identity of road kill and to maintain a permanent record of road kill for further comparisons, if needed.

Monitoring Methodology

1. The highway will be monitored using the method previously indicated (section 1.3) consisting of a two-person team traversing the Upgrade in a vehicle to locate and identify road kills;

2. The speed of travel will be the same in all cases to avoid confounding the data collection, and should be as slow as is safely possible;

3. The highway will be surveyed weekly for four weeks in Spring, Summer, Autumn and Winter (see Table 1);

4. Where possible, each survey shall be completed within two hours of sunrise in order to maximise the potential to record road kills before either carrion eating animals or traffic render any road kill unidentifiable;

5. if possible, each survey will be carried out on the same day of the week to remove the influence of varying environmental conditions and to ensure consistent temporal spacing;

6. For each road kill observed, the following attributes will be recorded

    a. Geographic Coordinates of any road kill.

    b. Whether fauna fencing was installed at/near the location.

    c. Species of road kill where possible, however, where there is any doubt as to the identification of the carcass, photographs shall be forwarded to a qualified ecologist for identification /confirmation of the species.

If the animal is identified as an EPBC Act threatened species, the carcass will be photographed and the following information will also be recorded where possible and safety considerations permit

a. Sex and age class (juvenile or adult).

b. Presence of pouch young (for marsupials).

c. Presence of flightless young (for flying-foxes or other bats).

d. Distance to a fauna connectivity structure.

e. Distance to drop down structure.

f. If fauna fencing was installed, is there any damage to the fence in the vicinity.

g. Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase.

h. If the animal is identified as a flying-fox:
    - Distance to nearest camp,

- Distance to nearest canopy vegetation,
- Presence of flowering food trees in neighbouring median or roadside vegetation; plants identified to species and referenced with diet list.

Analysis of data

The data to be collected will be analysed using a suitable nonparametric test such as a Kruskal-Wallis test. The aim will be to test both whether the fenced and unfenced locations have different mean numbers of road kills and if the amount of road kill varies through time in either or both of the two types of areas. Associations with other measured variables will be described as data allow, including sex, age class, presence of dependent young and, in the case of flying-foxes, proximity to roost sites or flowering food trees. Such information will indicate if the mitigation measures in the area are working as expected to keep road kills to acceptable levels and that none of the target species are killed.

Reporting

Quarterly reports

A report will be prepared by the ecologist following the initial 12 week monitoring period (after opening for each stage) to identify any roadkill hotspots and review the mitigation measures. The initial report and ongoing seasonal reports of the data collected will be provided to Roads and Maritime. This will include graphs of the data and any previously collected data to provide simple visual comparisons of road kill. This will also include overall road kill counts as well as separate graphs for each of the target species (if deaths have occurred).

Anecdotal road kill information collected on days that are not monitored as part of this program may be added as a note for discussion.

Annual Reports

The annual report will be prepared in consultation with a qualified ecologist and provided to DoEE and EPA within one month of completion of the fourth monitoring season. From then on it will be provided within one month of the same monitoring season in subsequent years until monitoring is completed (Table 1).

Analysis of the data itself shall be included in an annual monitoring report. This report will include a statistical analysis of all of the data collected to that time including graphical representations of the road kill that is recorded.

Annual reports will record any potential or obvious failures in road kill mitigation identified in the monitoring program and provide a date by which meetings will take place to discuss any such adverse findings. This will include at least:

- where statistically larger number numbers of road killed animals are detected on fenced sections compared to unfenced sections;
- where any of the target threatened fauna are recorded as killed;
- where there is a clear pattern of unexpected road kill at any point on the Upgrade.

Performance Measures

Lower rates of road kill in proximity to fauna fencing (ie areas of the main carriageways within areas adjacent to installed fauna fencing) than in sections of the upgrade not near fauna fencing during monitoring events up to 5 years post construction phase, or until such time as mitigation measures have been demonstrated to be effective.

Adaptive Management

Where any annual report identifies a significant difference between the road kill numbers of the fenced and unfenced areas, DoEE and EPA shall be notified, and a meeting will be set to discuss such differences with the relevant agencies & Roads and Maritime.

Such a meeting would occur within one month of completion of the annual report, which should ensure sufficient time to consider/review the response to any recorded significant differences.

Appendix 2 Autumn (April) 2019 monitoring.

Pacific Highway Upgrade Warrell Creek to Nambucca Heads

Operational phase roadkill monitoring – Autumn 2019.

Sandpiper Ecological

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Sandpipereco.com

Draft Report (Version A)
3 May 2019

Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
3/5/19	A	Draft	D. Rohweder	SES	MSW	N. Priest
3/5/19	1	Draft	S. Hardiman	SES	MSW	N. Priest

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Project team:

Dr D. Rohweder (project management, review)
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Cover Photo: Road-killed black bittern (*Ixobrychus flavicollis*) detected during April 2019 surveys. Black bittern is listed as vulnerable by the New South Wales *Biodiversity Conservation Act 2016*.

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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 roadkill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate roadkill 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*) 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 RMS to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal roadkill surveys over the entire upgrade length.

Monitoring of road-killed fauna is a requirement of the approved WC2NH koala (*Phascolarctus cinereus*), spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) management plans and the Ecological Monitoring Program (Roads and Maritime 2018a). Priority species for roadkill 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. 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. The results of monitoring in 2018 were analysed and discussed by Sandpiper Ecological (2018). The following report covers the April (autumn) monitoring event and includes the entire WC2NH alignment. Remaining seasonal monitoring events in 2019 are scheduled for July (winter) and October (spring). Previous roadkill monitoring was conducted by Geolink (2018a, b, c, d).

The aim of monitoring is to:

- report on any vertebrate roadkill 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.

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).

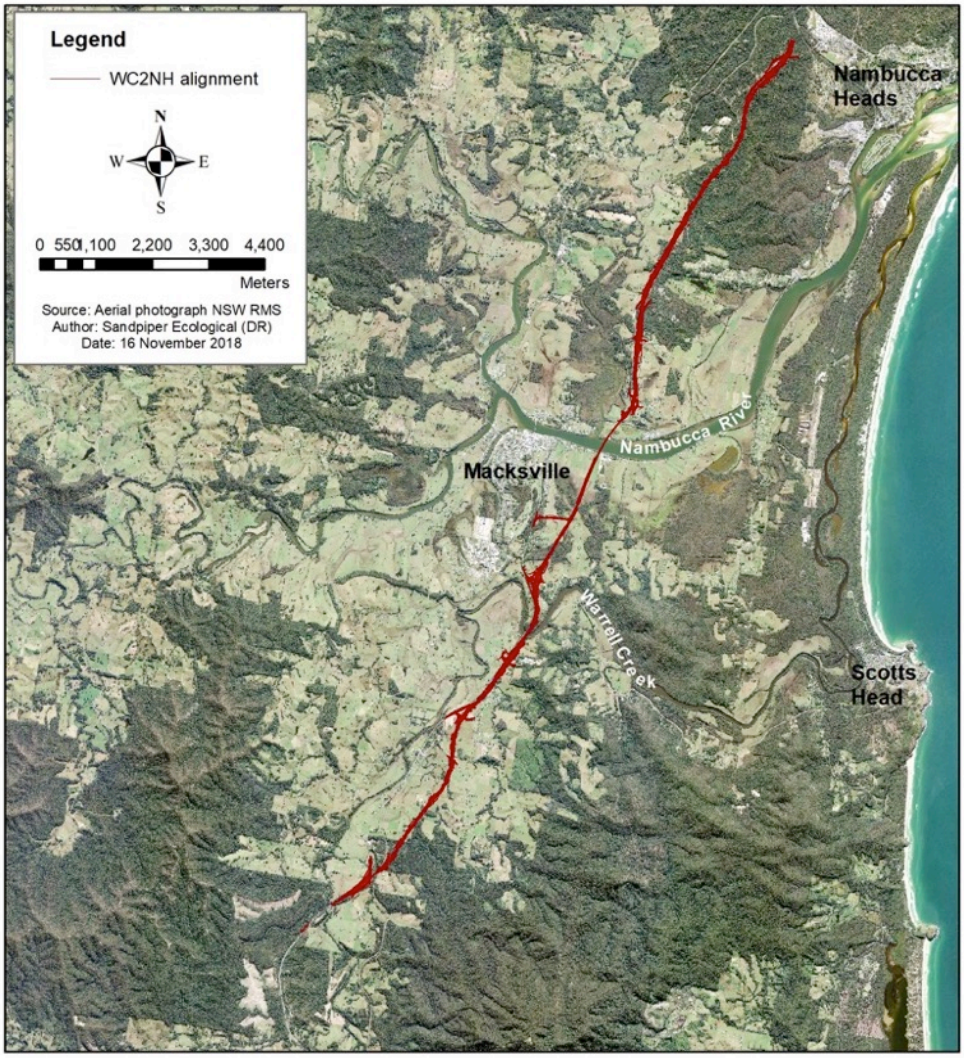

Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Roadkill surveys

Roadkill surveys were conducted by a two-person team from a vehicle driven at 70km/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. All surveys commenced within two hours of sunrise, with an interval of seven days between samples. During each survey, both the driver and ecologist 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 position behind wire rope and perpendicular to the specimen. Fauna that could not be identified immediately were photographed and images sent to colleagues. 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 roadkill included (Appendix A1):

- Geographic coordinate
- Presence/absence of fauna exclusion fence
- Species/fauna group
- Date of survey
- Roadkill location – north or southbound carriageway

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act* (EPBC) *1999* and/or the *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 (determined from GIS); distance to a drop-down structure (determined from GIS); 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 results to identify possible duplicates. Using the same team during the survey, 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 drop-down was determined via GIS. All other data were uploaded to an iPad in the field.

2.2 Data summary and analysis

Data from the April 2019 survey were uploaded to Microsoft Excel. The April data were compared with results from January to identify any duplicate records. Graphs have been produced showing the total number of road-kills in April and the number of road-kills in different fauna groups each week of the survey. The location of April road-kills has been overlaid on the WC2NH alignment to show their distribution. The April 2019 data are compared to the number of road-kills recorded in summer, autumn, winter and spring 2018, and summer 2019 (Sandpiper Ecological 2018; Sandpiper Ecological 2019; Table 2).

3. Results

3.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses (Table 1). However, rain did effect carcass identification. No rain was recorded during survey days.

Table 1: Weather conditions on the day of each sample event. Data obtained from Envirodata weather station at the southern compound.

Date	Average Relative Humidity (%)	Total Rainfall (mm)	Average Temperature (^{0}C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
3/4/19	93.4	0.4	18.5	2.9	Good	Nil
10/4/19	71.5	0.2	22.2	6.3	Good	Nil
17/4/19	88.3	0.2	17.7	3.8	Good	Nil
24/4/19	87.7	1.2	19.4	2.4	Good	Nil

3.2 Species richness and abundance

A total of 40 road-killed fauna were recorded during the April 2019 sample period. This included 14 native species, two introduced species, and six fauna groups (Table A1, Appendix A). Birds were the most diverse group represented in roadkill with eight species recorded. Six species of mammal (including 2 introduced species), and two species of reptile were recorded.

Flying foxes (*Pteropus* spp.) were the most frequently detected group of fauna with nine records (Table 2). Overnight rains and degradation of carcasses made identification to species level difficult in some cases. One of nine flying fox records could be identified to species level, a black flying fox (*Pteropus alecto*) recorded on April 3. A black bittern (*Ixobrychus flavicollis*), which is listed as vulnerable by the *Biodiversity Conservation Act* 2016, was recorded on the Gumma Floodplain on 3

April 2019. Six tawny frogmouths were detected during autumn 2019. No target species were detected during April 2019 roadkill surveys although there is a moderate likelihood one or more of the *Pteropus* spp. records was grey-headed flying-fox (*Pteropus poliocephalus*). Of the 40 roadkill records, 10 (or 25%) were individuals expected to be blocked by exclusion fence. The remaining 30 records included birds, snakes, lizards, flying foxes and small mammals that readily move through or over exclusion fence (Plate 2&3).

Plate 2: A road-killed Eastern barn owl (*Tyto javanica*) (L) and laughing kookaburra (*Dacelo novaeguineae*) (R) detected during week one of April 2019 surveys.

Plate 3: Road-killed Eastern yellow robin (*Eopsaltria australis*) (L) and black bittern (*Ixobrychus flavicollis*) (R) during week one of April 2019 surveys.

Table 2: Species of vertebrate recorded during seasonal roadkill surveys during the operational phase of the WC2NH upgrade. * denotes threatened species; ** = stage 2a only.

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Autumn 2019	Total
Birds							
Australian magpie	6	1		1			8
Grey butcherbird			1				1
Magpie-lark	2		1		1		4
Australian white ibis			1				1
Cattle egret				1			1
Little pied cormorant					1		1
Buff-banded rail					1		1
Purple swamphen	3		2	2		1	8
Crested pigeon	2						2
Galah	7				1		8
Eastern grass owl*				1			1
Southern boobook			1	1			2
Masked owl*	1				1		2
Barn owl			11	3		1	15
Tawny frogmouth	1	3	1	2		6	13
Owlet-nightjar					1		1
Laughing kookaburra	3		2	1		2	8
Forest kingfisher	1						1
Australian wood duck	20			2	2		24
Pacific black duck	2		1				3
Whistling kite				1			1
Black-shouldered kite					1	1	2
Toressian crow					1		1
Pied currawong				1			1
Dollarbird					2		1
Green catbird					1		1
Black bittern*						1	1
Eastern yellow robin						1	1
Duck spp.						1	1
Medium bird				1	2	2	5
Unidentifiable bird	5	4	1		3		13
Mammals							
Short-beaked echidna				3			3
Black flying-fox	2	1			6	1	10
Grey-headed flying-fox*					8		8
Pteropus spp.					3	8	11
Common brushtail possum			1	2			3

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Autumn 2019	Total
Common ringtail possum					1		1
Eastern grey kangaroo				3			3
Red-necked wallaby	1		6		8	2	17
Swamp wallaby	2	1		1		1	5
Wallaby spp.						2	2
Macropod spp	3		2	1	1		7
Northern brown bandicoot	1		1		1	1	4
Bandicoot spp.						1	1
Chalinolobus spp. (microbat)				1			1
Microbat spp.					1		1
Rodent spp.						2	2
Small mammal					2		2
Medium mammal				2	4	2	8
Large mammal				1	1		2
Unidentified Mammal	1			3			4
Reptiles							
Common blue-tongue skink	1			2	1		4
Carpet python	1			2	1	1	5
Common tree snake	1	2					3
Eastern long-neck turtle	1			6			7
Macleay river turtle	5	1					6
Unidentified Chelidae (turtle) spp.	6						6
Red-bellied black snake	1						1
Eastern water dragon	1			1			2
Blackish blind snake						1	1
Yellow-faced whipsnake				1			1
Frogs							
Green tree frog	2						2
Striped marsh frog	3						3
Medium frog				3			3
Large frog				1			1
Introduced species							
Cat	1						1
European fox	3	1	1	2	1	1	9
European hare	2			1			3
Rabbit	1						1
Black rat	1					1	2
House mouse					1		1
Rock pigeon			1	1			2

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Autumn 2019	Total
Domestic goose				1			1
Total	93	14	34	55	57	40	293

The number of roadkill recorded each week varied during the sample period. A trend of decreasing roadkill abundance was recorded over the first three sample weeks, with roadkill abundance increasing again in week four (Figure 2).

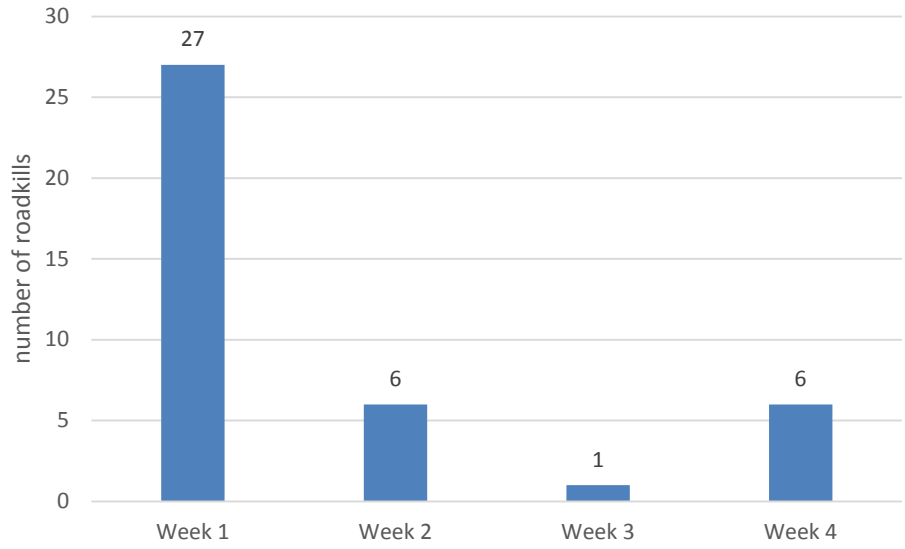

Figure 2: Number of road-kills recorded in each sample week during the April 2019 (autumn) sample period.

The abundance of road-killed fauna in the four vertebrate groups varied during the sample period (Figure 3). The number of road-killed mammals went from 18 in week one to three in week two, zero in week three and one in week four. Likewise, the number of road-killed birds decreased from nine in week one to three in week two and none in week three and back up to one in week four. Reptiles were only represented by two kills in week four. No frogs were detected during April 2019 monitoring.

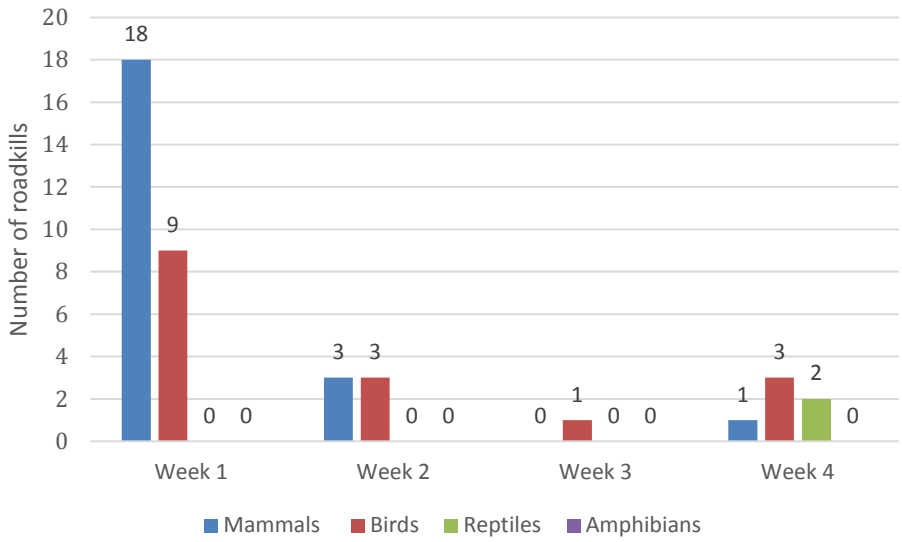

Figure 3: Number of road-killed fauna from four vertebrate classes during each sample week in April 2019.

3.1.3 Opportunistic roadkill information

No opportunistic roadkill records were detected during the period.

3.1.4 Distribution of roadkill

In April 2019, road-killed fauna was recorded over the entire WC2NH alignment (Figures 4-13), although the majority of records (80%) were situated between the Nambucca River and the southern end of the project. Within that area, 84% occurred between Albert Drive and the Nambucca River bridge (Figures 7-10) and the remaining 16% occurred between the southern end and Albert Drive (Figures 11-12). The section between the Nambucca River and the southern end of the project traverses predominantly cleared land with three drainage lines and minimal fauna exclusion fence. Eight animals (20%) were recorded in the section north of the Nambucca River bridge. Notably, this northern section is entirely fenced with floppy top exclusion fence and in places, frog exclusion fence.

In April 2019, 24 road-kills were recorded in areas with exclusion fence, and 16 were recorded in areas without exclusion fence (Figures 4-12). Four records (or 2.7%) in sections with fence were species that should have been blocked by the fence (i.e. medium and large mammals). In contrast, 31% of road-kills in sections without fence were of species that should have been blocked by an exclusion fence.

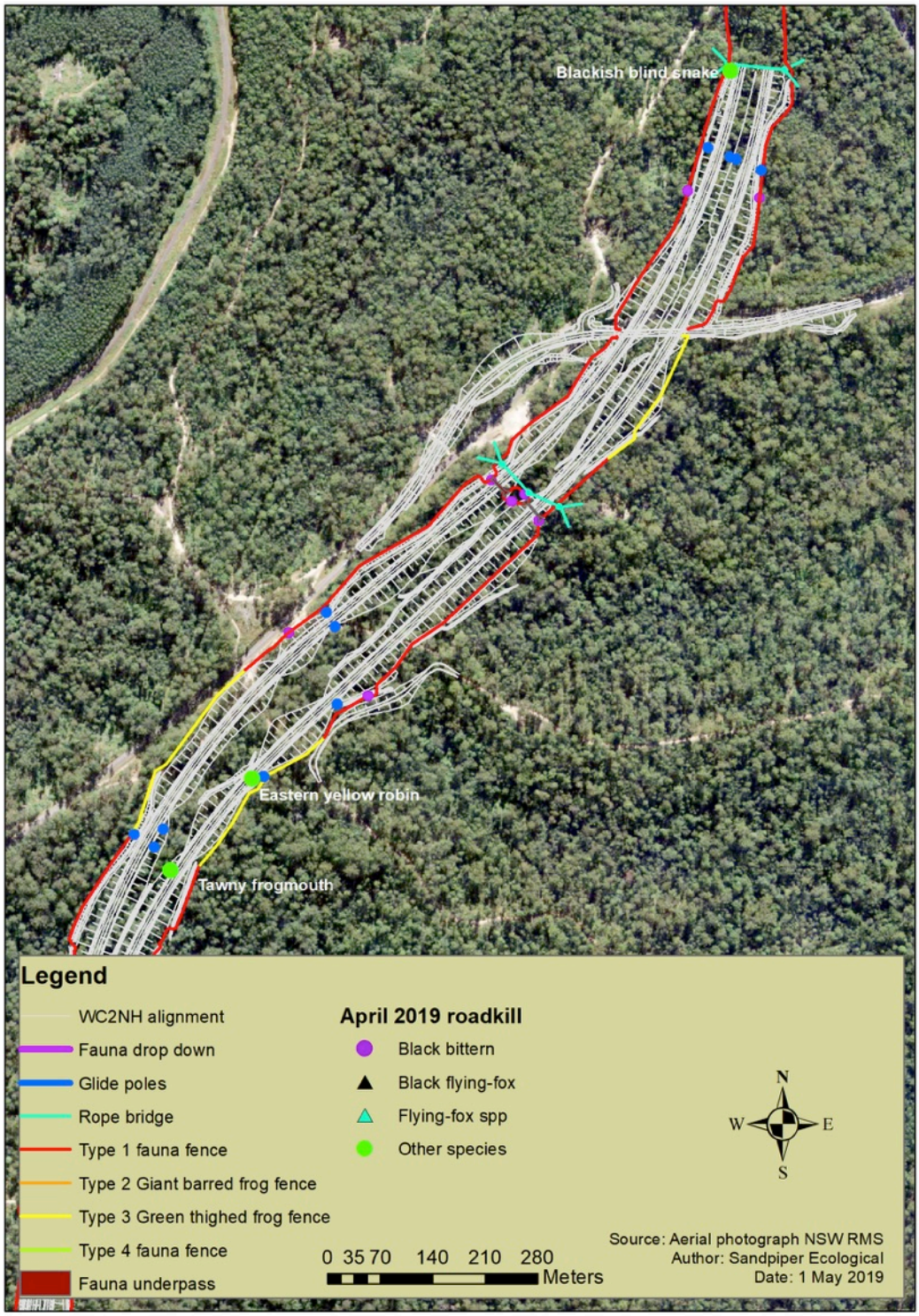

Figure 4: Location of road-killed fauna in April 2019.

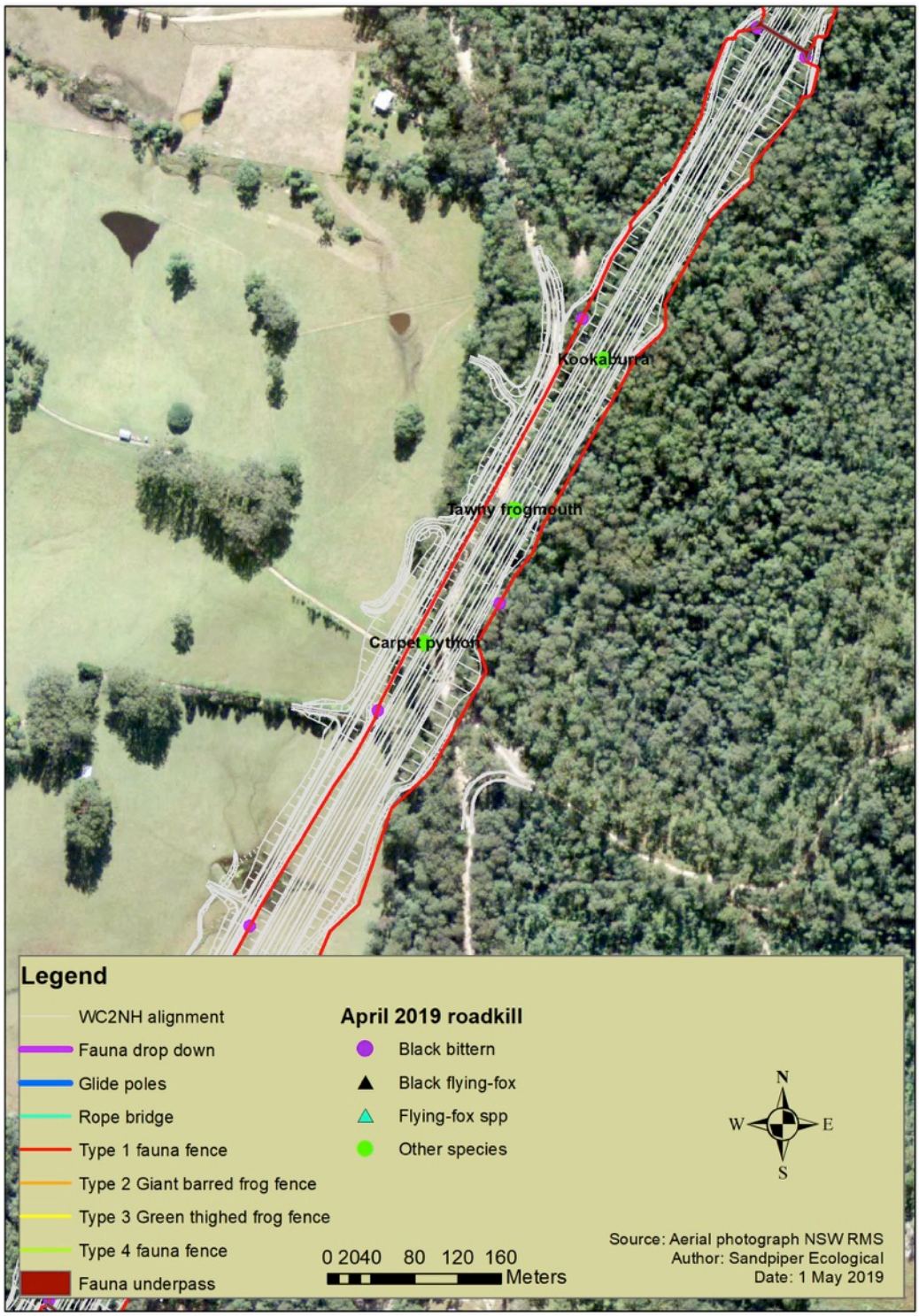

Figure 5: Location of road-killed fauna in April 2019.

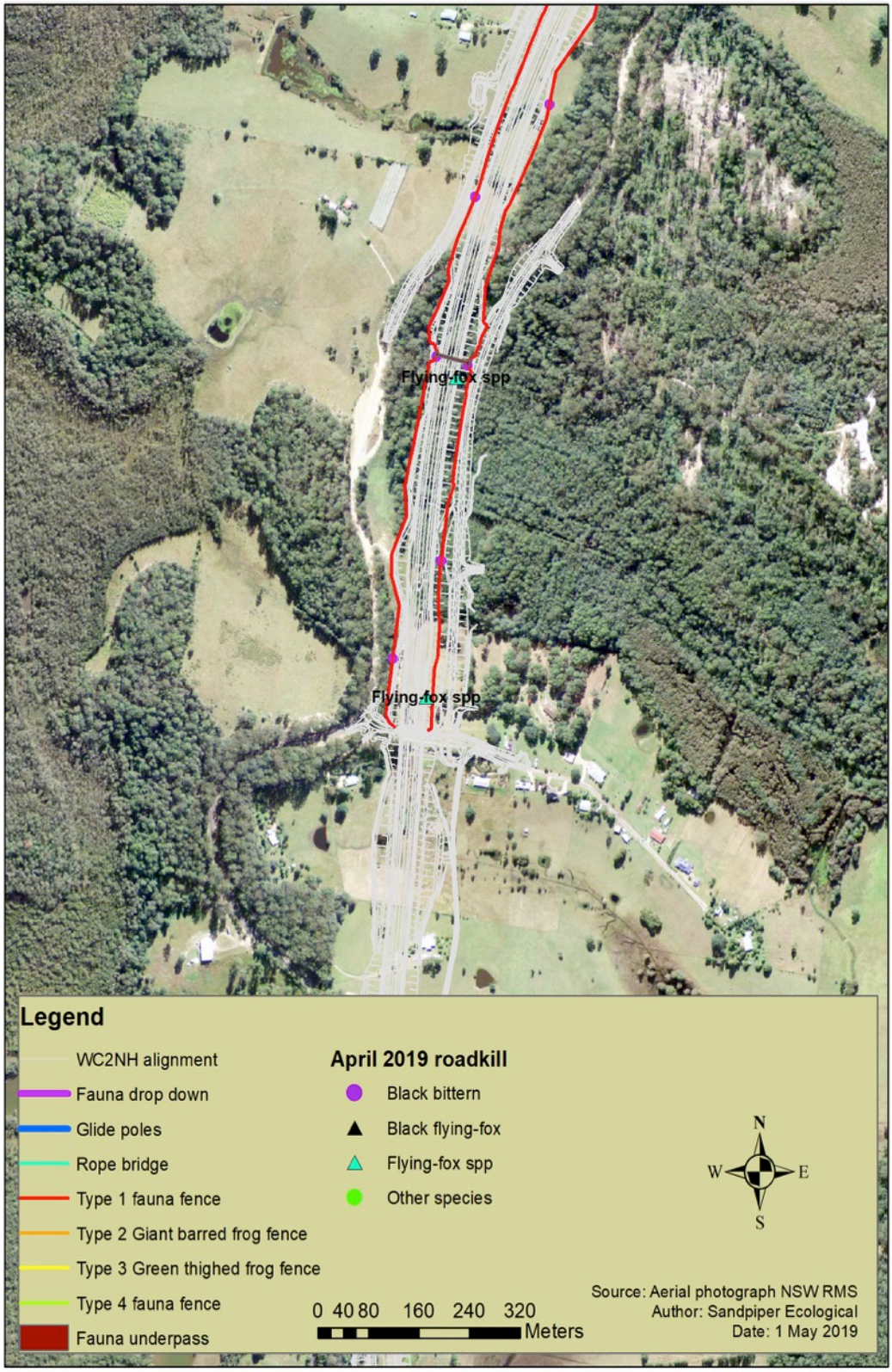

Figure 6: Location of road-killed fauna in April 2019.

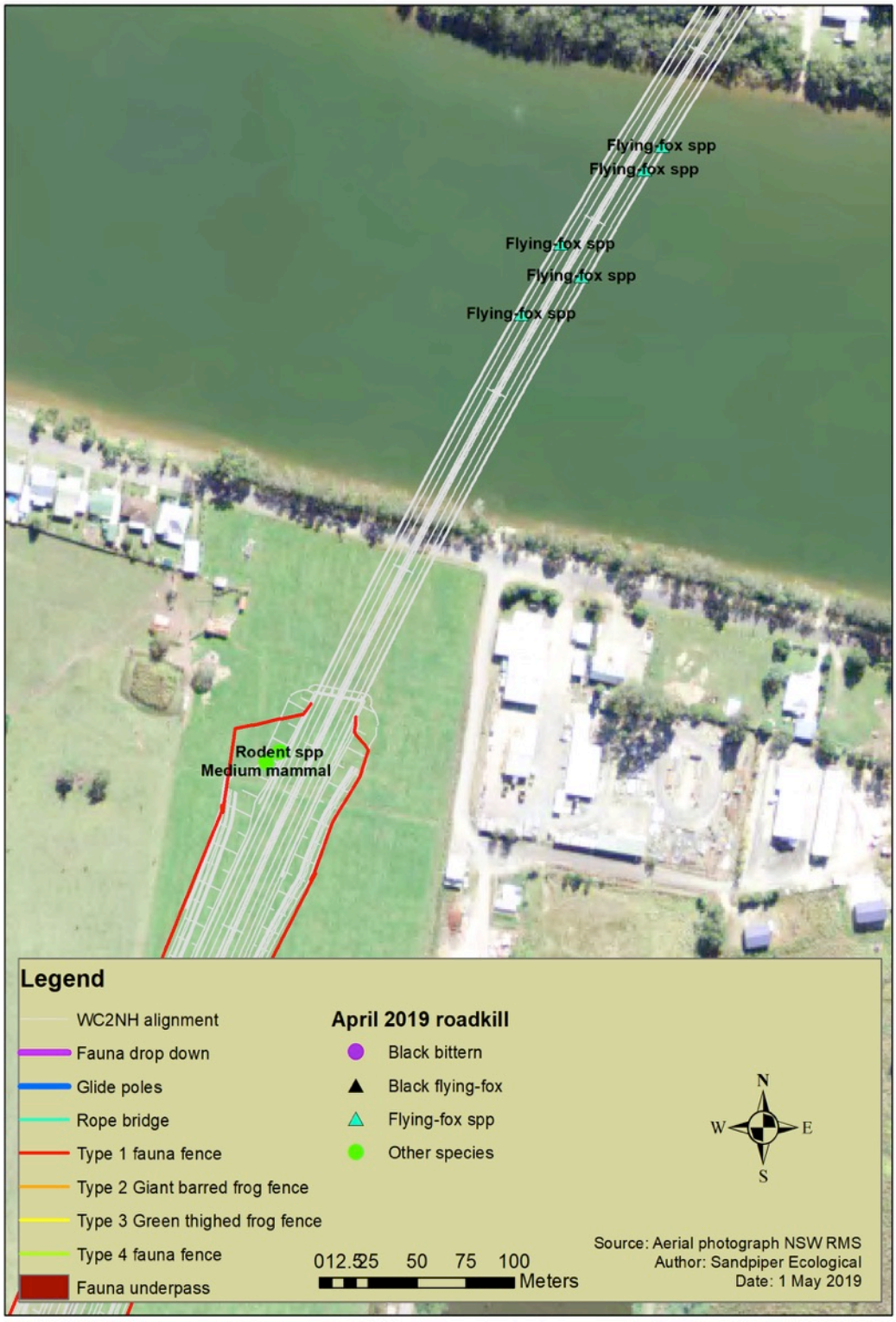

Figure 7: Location of road-killed fauna in April 2019. Flying-fox records overlap, refer to table A1.

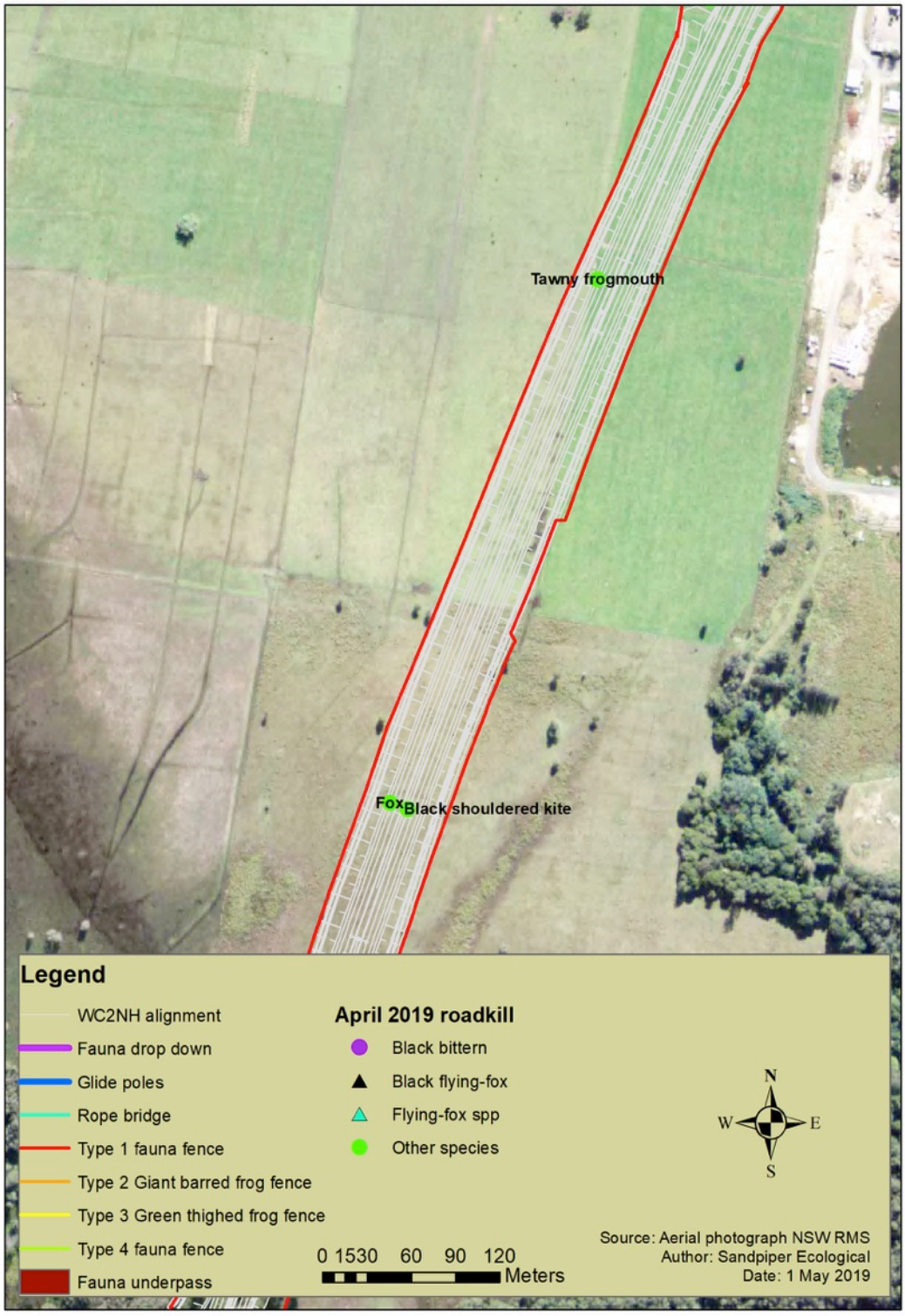

Figure 8: Location of road-killed fauna in April 2019.

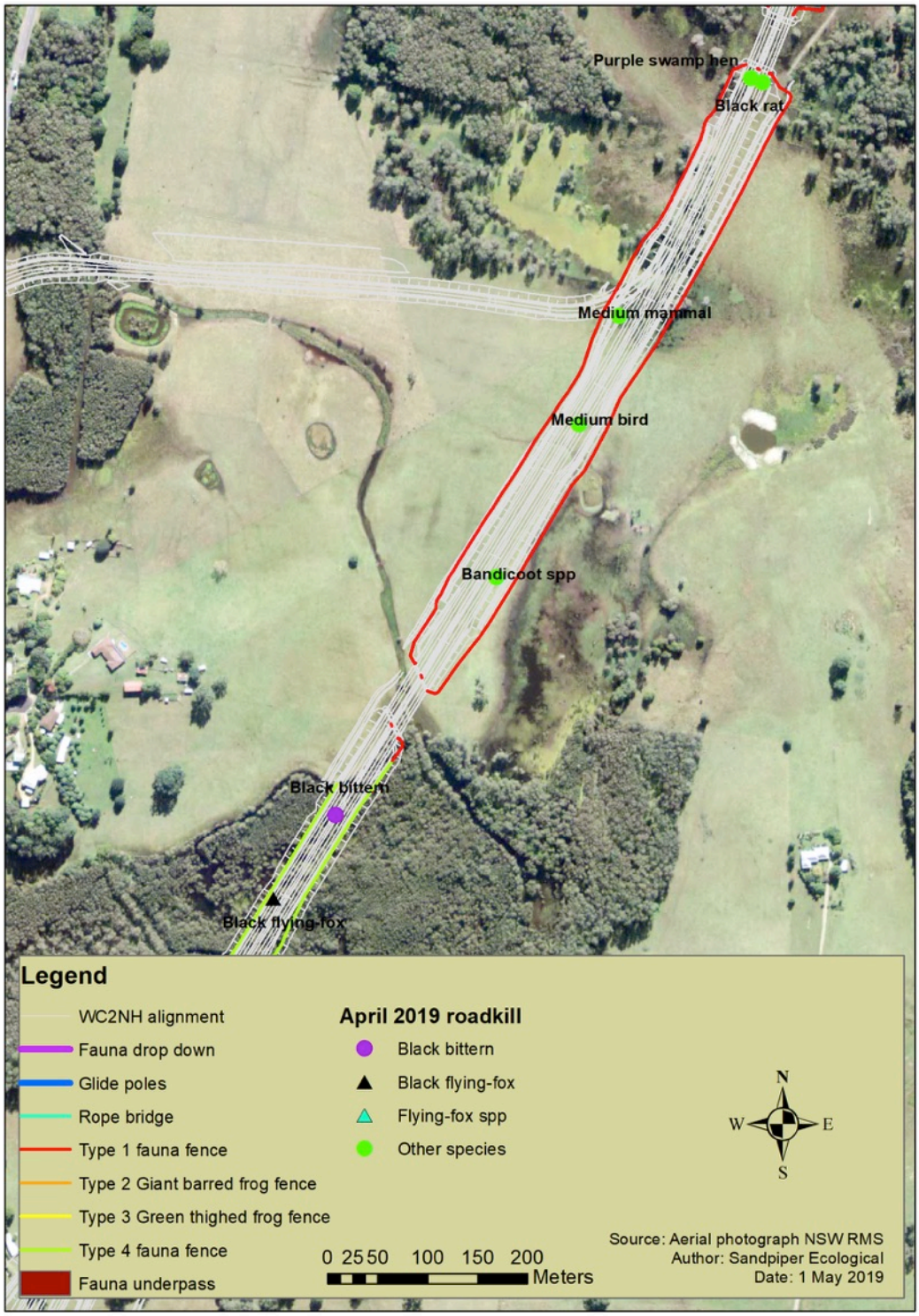

Figure 9: Location of road-killed fauna in April 2019.

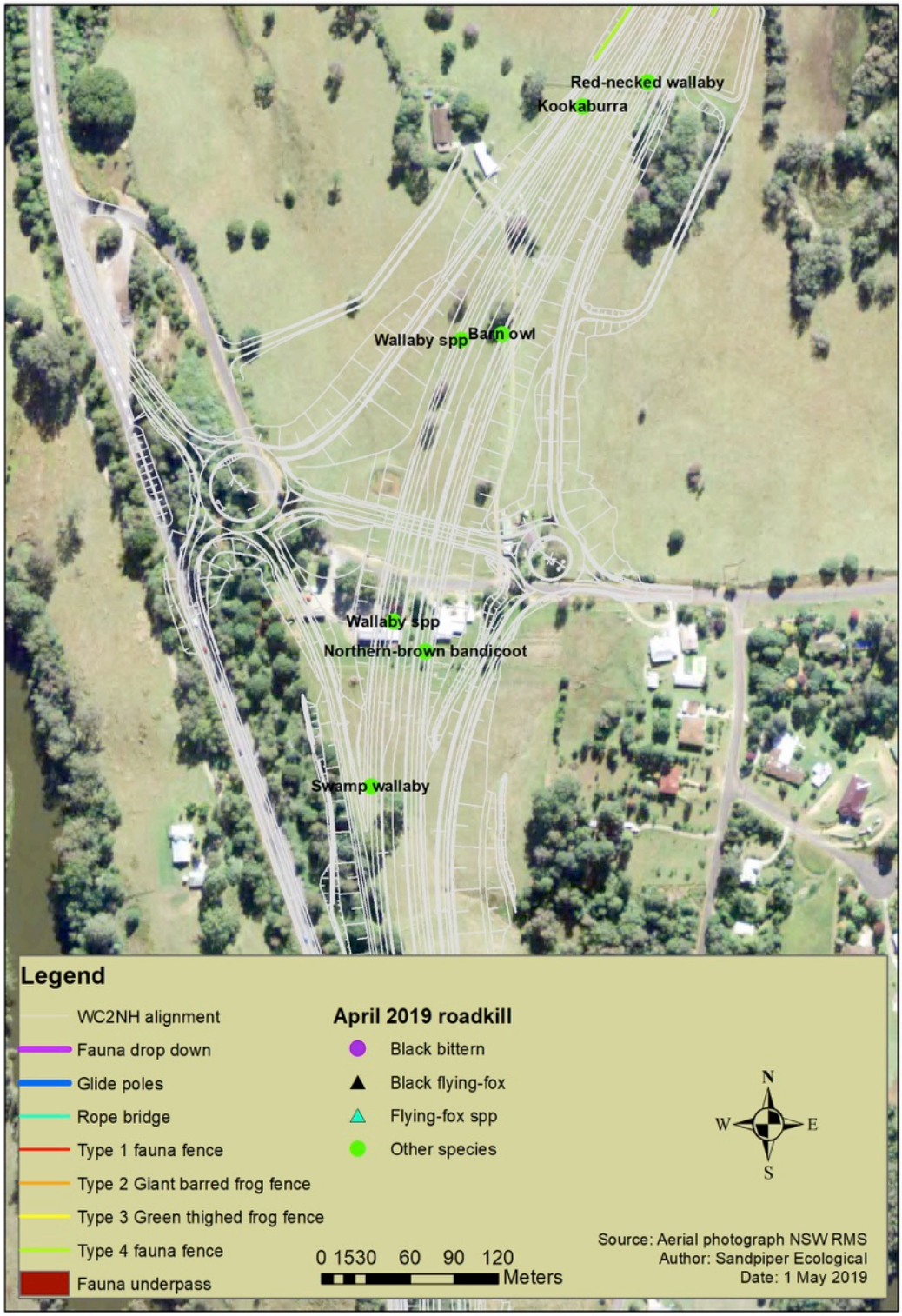

Figure 10: Location of road-killed fauna in April 2019.

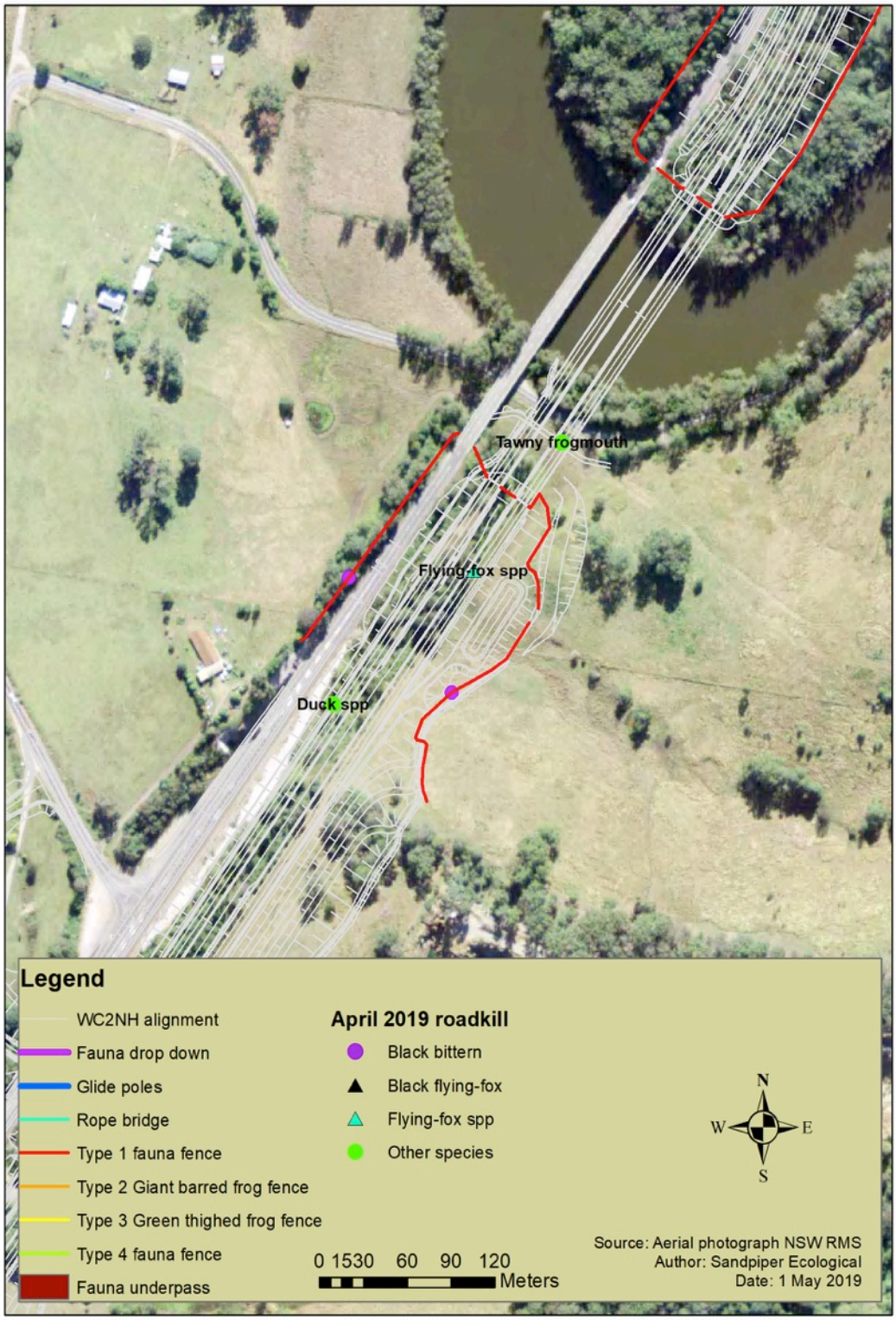

Figure 11: Location of road-killed fauna in April 2019.

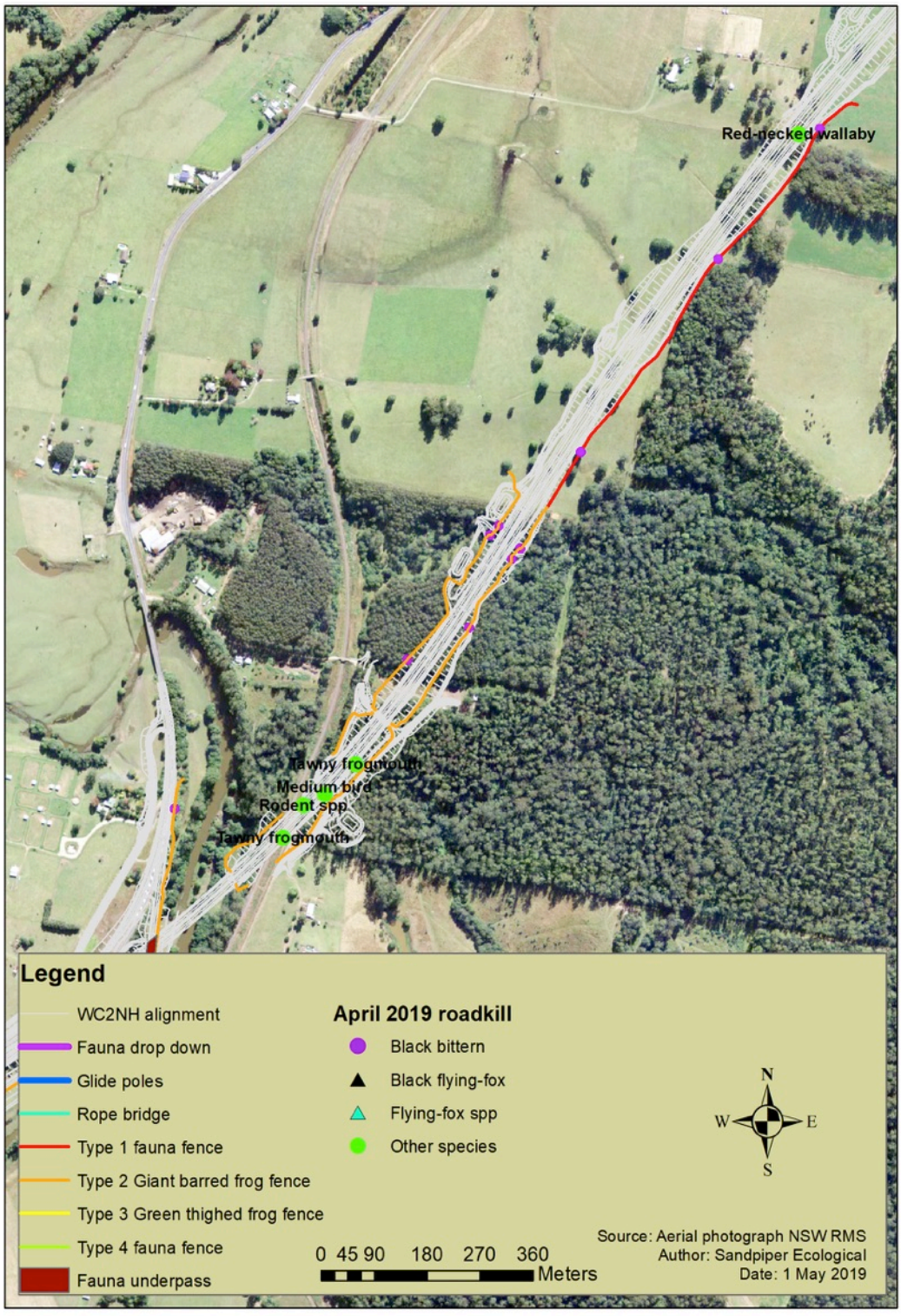

Figure 12: Location of road-killed fauna in April 2019.

4. Discussion

4.1 April 2019

Road-kill monitoring over the entire WC2NH alignment in April 2019 indicates that a substantial number of fauna continue to be killed by vehicles ten months after the entire alignment was open to traffic. However, with a total of 40 animals killed, April monitoring recorded a decrease of 17 animals when compared to January 2019. This reduction may be due to lower traffic volumes after the summer holiday period and seasonal changes in animal behaviour (see section 4.2).

The road-kills recorded in April, as in January, may be bolstered by the time between samples. The October 2018 sample was conducted immediately after the conclusion of GeoLink monitoring in September. January and April 2019 monitoring was conducted after two months (November & December 2018 and February & March 2019) of no monitoring. The higher number of road-kills recorded in the first week of both samples reflects the period over which kills could accumulate. This trend is likely to occur in all 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.

Similar diversity and species composition of roadkill was recorded between April 2019, January 2019 and October 2018 and Stage 2A monitoring, which occurred in summer/autumn 2017/18 (Geolink 2018a). Roadkill hotspots identified in April include the Gumma Floodplain (Albert Drive to Nambucca River bridge), and from the southern end to Albert Drive. This finding is consistent with findings in the annual roadkill report (Sandpiper Ecological 2018) and with previous seasonal samples. Birds and mammals comprised the majority of road-kills in both locations.

4.2 Seasonal variation and species composition

Seasonal variations in fauna abundance are linked with availability of resources and reproduction (Catling *et al* 2002). During autumn and winter months there are fewer flowering events than spring and summer months with the exception of a few species such as broad-leaved paperbark (*Melaleuca quiquinervia*) and swamp mahogany (*Eucalyptus robusta*). Many native fauna species reproduce in spring and summer, resulting in animals moving over larger distances to find potential mates. Longer movements can result in a greater likelihood of fauna interacting with linear infrastructure. This may explain the reduction in roadkill during autumn surveys.

Wallabies continue to be killed on the highway, especially within the vicinity of Bald Hill Road and Albert Drive. Results of monitoring in October 2018 and January 2019 raised concerns about the effect of roadkill on the local red-necked wallaby (*Macropus rufogriseus*) population in the Albert Drive to upper Warrell Creek area. A further two red-necked wallabies were recorded road-killed during April. Continued roadkill at present rates is likely to reduce the abundance of wallabies in habitat adjoining the road (Huijser & Bergers 2000).

April monitoring detected no road-killed frogs. Along with the difficulty in detecting frogs via a vehicle this decrease may also be explained by climatic conditions and season. Although the project received 119.6mm of rain at the southern compound weather station lower night time temperatures would have suppressed breeding activity, and frog dispersal.

Second to mammals, birds continue to be the most impacted group of fauna. This highlights the susceptibility of the group to road-kill (Loss *et al* 2014). Tawny frogmouth (*Podargus strigoides*) kills

jumped markedly in April with six kills recorded. This is significant as only seven frogmouths were recorded during all previous surveys combined. A possible explanation for the increase is a successful spring/summer breeding season and more juveniles interacting with the highway. Tawny frogmouths often hunt under lights and predate on moths and other invertebrates attracted to the light (Kaplan 2018). The species is often recorded perched on roadside guideposts.

The composition of birds in roadkill is predicted to change over time as larger species habituate to, and avoid, the highway and small birds take up residence on revegetated batters making some cover-dependant species more susceptible to road strike. Nonetheless, the results provide further evidence of the impact that roads have on bird populations (Husby 2016). Of concern is the impact on threatened species such as black bittern and masked owl (*Tyto novaehollandiae*). Black bittern is the third threatened bird species detected during roadkill surveys.

4.3 Flying-fox impacts

A total of nine flying-foxes were detected during April monitoring. This is a 50% reduction in flying fox detections from January 2019 (Sandpiper Ecological 2019). Of these nine individuals, eight were unidentified *Pteropus* spp., and one was a black flying fox (*Pteropus alecto*). It is likely that some of the eight *Pteropus* spp. were grey-headed flying fox (*Pteropus poliocephalus*) which is listed as vulnerable by the *EPBC Act* and *BC Act*. Seven of the nine individuals were recorded on the Nambucca River bridge. As it is unsafe to stop or walk on the bridge none of these individuals could be examined for young, and no young were recorded with any of the adults that could be examined. Other carcasses were severely decayed and recent rains made identification to species level difficult.

Flying-foxes often use waterways during their evening dispersal (Vardon *et al* 2001). The high incidence of flying-fox roadkill close to major river/creek crossings along the WC2NH upgrade is attributed to individuals flying low over the water and then trying to fly over the bridge but not gaining sufficient elevation. In the January 2019 report, it was noted that the direct distance to the nearest flying-fox camp, Gordon Park in Nambucca Heads, is approximately 9.8km from the Nambucca River bridge. The flying foxes killed on the Nambucca River bridge were probably dispersing from the Gordon Park camp. During February, March and April flying foxes were witnessed dispersing from a camp to the immediate west of Macksville suggesting an influx of flying foxes to the area. It is possible an ephemeral camp has been established in the area to take advantage of the annual flowering of broad-leaved paperbark (*Melaleuca quinquinervia*) (Sandpiper unpublished data 2019). This influx of flying foxes may have contributed to the road kill count in April.

5. Recommendations

1. Continue seasonal roadkill surveys during year two of the operational phase using the same methods applied in year one.
2. Continue to monitor the distribution and frequency of flying-fox road kills.
3. Explore correlations between drop-downs and the distribution of target species in the year two annual report.

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Appendix A – Field Survey Data

Table A1: April (Autumn) 2019 roadkill results. NP = Nick Priest; NM = Nirvarna Makings, SR = Sam Rohweder. NB = northbound; SB = southbound, Y = yes, N = no, prox = proximity, xing = crossing, cond. = condition; * Gordon Park, Nambucca Heads

Date	Obs	Start	End	Carriageway	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence prox.	Fence cond	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp, food
3/4/19	NP/ NM	0730	0950	SB	Eastern yellow robin	Adult	Na	North end vegetated median	496806	6609661	Yes					
				SB	Flying fox spp.	Adult	Unknown	400m north Mattick Rd	494529	6605289	No					10km. Mel quin
				SB	Flying fox spp.	Adult	Unknown	50 North Mattick Rd	494482	6604817	No					10km. Mel quin
				SB	Flying fox spp. x 3	Unknown	Unknown	On Nambucca river bridge	493895	6602853	No					10km. Mel quin
				SB	Medium mammal spp.	Unknown	Unknown	On Nambucca Bridge	493619	6602435	No	P	Good	50m	100m	
				SB	Medium bird spp.	Unknown	Na	1km north bald hill Rd, opp truck stopping bay	493079	6601116	No					
				SB	Bandicoot spp.	Unknown	Unknown	900m north bald hill Rd	492996	6600963	Yes	P	Good	120m	80m	
				SB	**Black bittern**	Adult	Na	650m north bald hill Rd, flying fox fenced area	492835	6600725	No, still on shoulder					
				SB	Prob red-necked wallaby	Adult	Unknown	200m north bald hill Rd	492621	6600345	Partially	A				
				SB	Prob northern brown bandicoot	Unknown	Unknown	65m south bald hill Rd	492470	6599965	No	A				
				SB	Tawny frogmouth	Unknown	Na	Northern edge	492182	6598920	No					

Date	Obs	Start	End	Carriageway	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence prox.	Fence cond	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp, food
								of LWC bridge								
				SB	Flying fox spp.	Prob adult	Unknown	Northern edge of LWC bridge	492174	6598804	Yes					3km. Mel quin.
				NB	Tawny frogmouth	Adult	Na	Under railway bridge	489440	6594403	No					
				NB	Rodent spp.	Unknown	Na	Under railway bridge	489475	6594457	No					
				NB	Duck spp.	Adult	Na	150m south LWC bridge	492078	6598715	No					
				NB	Swamp Wallaby	Subadult	Unknown	120m south bald hill Rd	492433	6599875	Yes	A				
				NB	Wallaby spp.	Unknown	Unknown	45m south bald hill Rd	492448	6599985	No	A				
				NB	Wallaby spp.	Subadult	Unknown	120m north bald hill Rd	492494	6600173	Yes	A				
				NB	Laughing kookaburra	Adult	Na	180M north bald hill rd	492577	6600329	Yes					
				NB	Black flying fox	Adult	No	550m. N bald hill Rd in flying fox fenced area	492773	6600641	Yes					3km. Mel quin.
				NB	Black-shouldered kite	Adult	Na	670m s nambucca river bridge	493414	6601894	Yes					
				NB	Red fox	Unknown	No	670m s nambucca river bridge	493402	6601898	No	P	Good	200m	190m	
				NB	Flying fox spp. x 2	Adult	Unknown	On Nambucca river bridge	493893	6602879	No					10km. Mel quin
				NB	Tawny frogmouth	Adult	Na	Northern end of where old coast Rd parallel to Hwy	495477	6607242	No					
10/4/19	NP/ SR	0720	0830	SB	Rodent spp.	Unknown	Na	On Nambucca River Bridge	493626	6602440	No					

Date	Obs	Start	End	Carriageway	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence prox.	Fence cond	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp, food
				SB	Red-necked wallaby	Unknown	Unknown	1km north of Cockburns lane	490318	6595581	No	A				
				SB	Tawny frogmouth	Unknown	Na	70m south of Cockburns lane	489564	6594526	Yes					
				SB	Med bird spp.	Unknown	Na	40m north of railway bridge	489511	6594476	No					
				NB	Med mammal spp.	Unknown	Unknown	1.5km south of Nambucca river bridge	493119	6601225	No	P	Good	80m	120m	
				NB	Tawny frogmouth	Unknown	Na	500m south of Nambucca river bridge	493543	6602248	Yes					
17/4/19	NP/ NM	0720	0805	NB	Purple swamp hen	Adult	Na	NR FP bridge 2	493251	6601463	No					
24/4/19	NP/ NM	0735	0830	SB	Tawny frogmouth	Adult	Na	80m N of C9	496697	6609539	Yes					
				SB	Laughing kookaburra	Adult	Na	340m S of C4	495559	6607381	Yes					
				SB	Black rat	Adult	Na	1km S of Nambucca Bridge	493263	6601459	No					
				SB	Eastern barn owl	Adult	Na	100m N Bald hill Rd	492522	6600177	Yes					
				NB	Carpet python	Adult	Na	600m S of C4	495394	6607119	No					
				NB	Blackish blind snake	Juvenile	Na	380m N of Old Coast Rd	497449	6610624	Yes					

Appendix 3 Winter (July) 2019 monitoring.

Pacific Highway Upgrade Warrell Creek to Nambucca Heads

Operational phase roadkill monitoring – Winter 2019.

Sandpiper Ecological

1/94 Main Street
Alstonville

Sandpipereco.com

Final Report
1 August 2019

Document Review

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
30/07/19	A	Draft	D. Rohweder	SES	MSW	N. Priest
1/8/2019	1	Draft	S. Hardiman	RMS	MSW	N. Priest
30/7/19	2	Draft	D. Rohweder	SES	MSW	N. Priest

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Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
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Cover Photo: A red-necked wallaby (*Macropus rufogriseus*) road-killed on north-bound lane near Bald Hill Road overpass.

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1. Introduction

1.1 Background

In 2015, Roads and Maritime Services (Roads and Maritime), 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 roadkill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate roadkill 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 Roads and Maritime to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal roadkill surveys over the entire upgrade length.

Monitoring of road-killed fauna is a requirement of the approved WC2NH koala (*Phascolarctus cinereus*), spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for roadkill 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. The results of monitoring in 2018 were analysed and discussed by Sandpiper Ecological (2018). The following report covers the July (winter) 2019 monitoring event and includes the entire WC2NH alignment. Remaining seasonal monitoring events in 2019 are scheduled for October (spring).

Annual Reports are prepared after each Spring survey and includes all data collected to date. Previous roadkill monitoring was conducted by GeoLink (2018a, b, c, d).

The aim of monitoring is to:

- report on any vertebrate roadkill 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.

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).

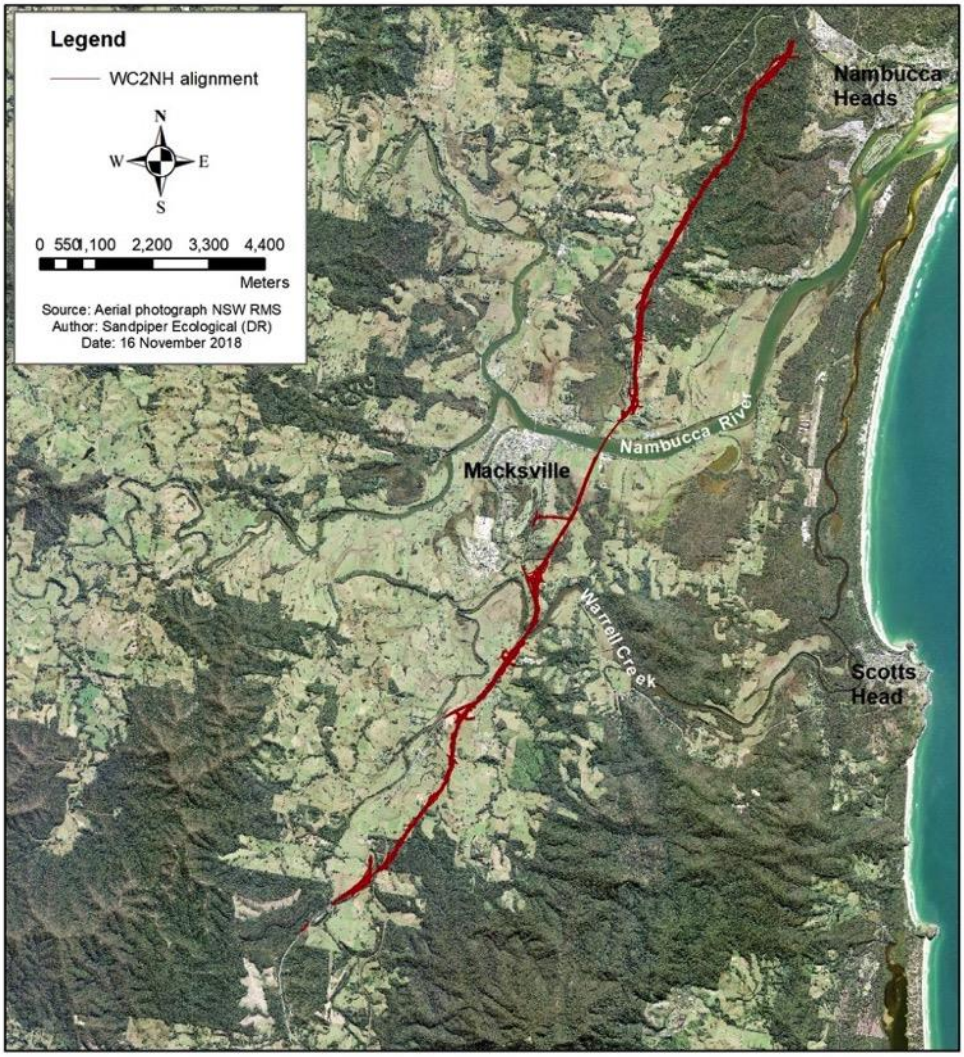

Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Roadkill surveys

Roadkill surveys were conducted by a two-person team from a vehicle driven at 80km/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. All surveys commenced within three hours of sunrise, with an interval of seven days between samples. During each survey, both the driver and ecologist 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 position behind wire rope and perpendicular to the specimen. 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.

Data collected on each roadkill included (Appendix A1):

- Geographic coordinate
- Presence/absence of fauna exclusion fence
- Species/fauna group
- Date of survey
- Roadkill location – north or southbound carriageway

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act* (EPBC) *1999* and/or the *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 (determined from GIS); distance to a drop-down structure if applicable (determined from GIS); 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 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 uploaded to an iPad in the field.

2.2 Data summary and analysis

Data from the July 2019 survey were uploaded to Microsoft Excel. The July data were compared with results from April to identify duplicate records. Graphs have been produced showing the total number of road-kills in July and the number of road-kills in different fauna groups each week of the survey. The location of April road-kills has been overlaid on the WC2NH alignment to show their distribution. The July 2019 data are compared to the number of road-kills recorded in summer, autumn, winter and spring 2018, and summer and autumn 2019 (Sandpiper Ecological 2018; Sandpiper Ecological 2019; Table 2).

3. Results

3.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses (Table 1). The survey conducted on 5 July was delayed one hour to account for rainfall. Heavy rain preceding the 5 July survey may have washed small carcasses into drains.

Table 1: Weather conditions on the day of each sample event. Data obtained from Environdata weather station at the southern compound.

Date	Average Relative Humidity (%)	Total Rainfall (mm)	Average Temperature (^{0}C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
5/7/19	89.7	10.6	15	6.8	Good	Showers
12/7/19	69.3	0.2	12.6	4.6	Good	Nil
19/7/19	71	0	9.7	3.2	Good	Nil
26/7/19	82.2	0	13.1	2.2	Good	Nil

3.2 Species richness and abundance

A total of 33 road-killed fauna were recorded during the July 2019 sample period. This included 12 native species, one introduced species, and three fauna groups (Table A1, Appendix A). Birds were the most diverse group represented with seven species and one group recorded. Six species of mammal and one group (including one introduced species), and one species of reptile were recorded.

Medium mammal was the most frequently detected group of fauna with four records (Table 2). Rain and degradation of carcasses made identification to species level difficult in some cases. A masked owl (*Tyto novaehollandiae*), which is listed as vulnerable by the *Biodiversity Conservation Act* 2016, was recorded 200m south of Old Coast Road on 19 July 2019. Eight red-necked wallabies (*Macropus rufogriseus*) were detected during winter 2019. No target species were detected although there is a small likelihood that the *Pteropus* spp. recorded near Mattick Road was a grey-headed flying-fox (*Pteropus poliocephalus*). Of the 33 roadkill records, 19 (or 57.5%) were individuals expected to be blocked by exclusion fence. The remaining 14 records included birds and flying-foxes that readily move through or over exclusion fencing (Plate 2&3).

Plate 2: A road-killed Australian boobook (*Ninox boobook*) recorded on 19 July 2019 (L). One of eight road-killed red-necked wallabies recorded during the July 2019 surveys (R).

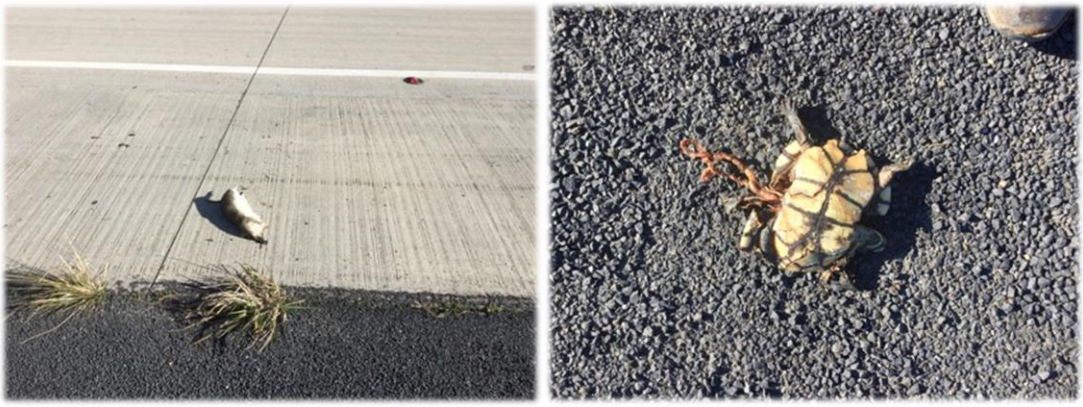

Plate 3: A road-killed northern brown bandicoot (*Isoodon macrourus*) recorded on 26 July 2019 (L). An individual Macquarie river turtle (*Emydura macquarii*) recorded on 12 July 2019 (R). Gaps under the fauna fence in this location may be facilitating movement under the fence.

Table 2: Species of vertebrate fauna recorded during seasonal roadkill surveys throughout the operational phase of the WC2NH upgrade. * denotes threatened species; ** = stage 2a only.

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Autumn 2019	Winter 2019	Total
Birds								
Australian magpie	6	1		1				8
Grey butcherbird			1					1
Magpie-lark	2		1		1		1	5
Australian white ibis			1					1
Cattle egret				1				1
Little pied cormorant					1			1
Buff-banded rail					1			1
Purple swamphen	3		2	2		1		8
Crested pigeon	2							2
Galah	7				1			8
Eastern grass owl*				1				1
Australian boobook			1	1			1	3
Masked owl*	1				1		1	3
Eastern barn owl			11	3		1	5	20
Tawny frogmouth	1	3	1	2		6		13
Australian owlet-nightjar					1			1
Laughing kookaburra	3		2	1		2		8
Forest kingfisher	1							1
Australian wood duck	20			2	2		1	25
Pacific black duck	2		1					3
Whistling kite				1				1

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Autumn 2019	Winter 2019	Total
Black-shouldered kite					1	1		2
Torresian crow					1			1
Pied currawong				1				1
Dollarbird					2			1
Green catbird					1			1
Black bittern*						1		1
Eastern yellow robin						1		1
Pheasant coucal							1	1
Masked lapwing							1	1
Duck spp.						1		1
Medium bird				1	2	2	2	7
Unidentifiable bird	5	4	1		3			13
Mammals								
Short-beaked echidna				3				3
Black flying-fox	2	1			6	1	1	11
Grey-headed flying-fox*					8			8
Pteropus spp.					3	8	1	12
Common brushtail possum			1	2				3
Common ringtail possum					1			1
Eastern grey kangaroo				3			1	4
Red-necked wallaby	1		6		8	2	8	25
Swamp wallaby	2	1		1		1	1	6
Wallaby spp.						2		2
Macropod spp.	3		2	1	1			7
Northern brown bandicoot	1		1		1	1	1	5
Bandicoot spp.						1		1
Chalinolobus spp. (microbat)				1				1
Microbat spp.					1			1
Rodent spp.						2		2
Small mammal					2			2
Medium mammal				2	4	2	4	12
Large mammal				1	1			2
Unidentified Mammal	1			3				4
Reptiles								

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Autumn 2019	Winter 2019	Total
Common blue-tongued skink	1			2	1			4
Carpet python	1			2	1	1		5
Common tree snake	1	2						3
Eastern long-neck turtle	1			6				7
Macquarie river turtle	5	1					1	7
Unidentified *Chelidae* spp.	6							6
Red-bellied black snake	1							1
Eastern water dragon	1			1				2
Blackish blind snake						1		1
Yellow-faced whipsnake				1				1
Frogs								
Green tree frog	2							2
Striped marsh frog	3							3
Medium frog				3				3
Large frog				1				1
Introduced species								
Cat	1							1
European fox	3	1	1	2	1	1	2	11
European hare	2			1				3
Rabbit	1							1
Black rat	1					1		2
House mouse					1			1
Rock pigeon			1	1				2
Domestic goose				1				1
Total	93	14	34	55	57	40	33	326

The number of roadkill recorded each week varied during the sample period. A trend of decreasing roadkill abundance was recorded over the four sample weeks (Figure 2).

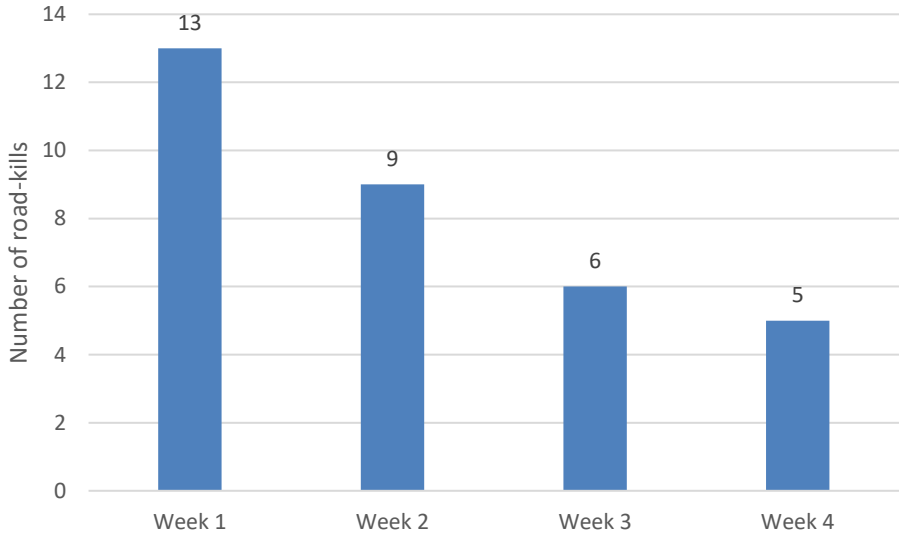

Figure 2: Number of road-kills recorded in each sample week during the July 2019 (winter) sample period.

The abundance of road-killed fauna in the four vertebrate groups also varied during the sample period (Figure 3). The number of road-killed mammals went from eight in week one to five in week two, two in week three and four in week four. Likewise, the number of road-killed birds decreased from five in week one to three in week two and then increased to four in week three and declined to one in week four. Reptiles were only represented by one kill in week two. No amphibians were detected during July 2019 monitoring.

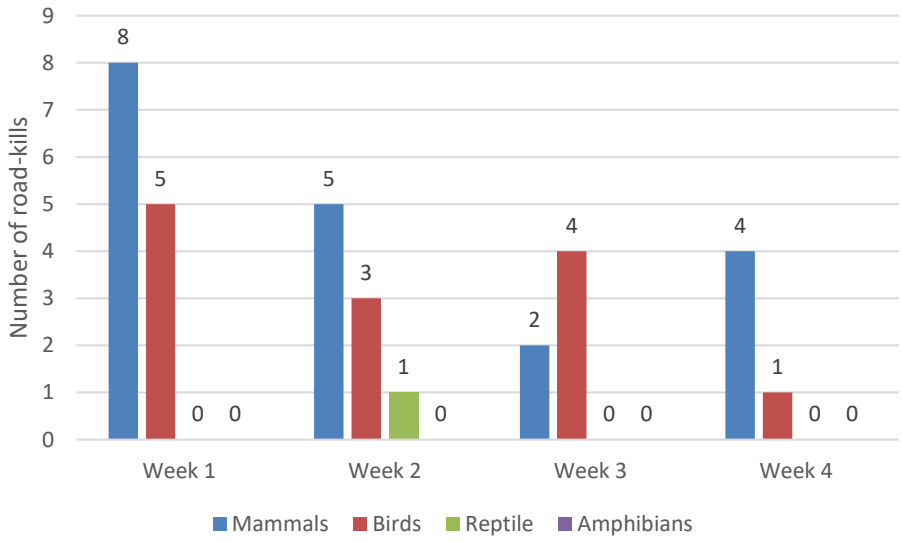

Figure 3: Number of road-killed fauna from four vertebrate classes during each sample week in July 2019.

3.1.3 Opportunistic roadkill information

No opportunistic roadkill was recorded within the sample month (July).

3.1.4 Distribution of roadkill

In July 2019, road-killed fauna was recorded over the entire WC2NH alignment (Figures 4-10), although the majority of records (79%) were situated between the Nambucca River (including the bridge) and the southern end of the project. Within that area, 65% occurred between Albert Drive and the Nambucca River bridge (Figures 4-8) and the remaining 35% occurred between the southern end and Albert Drive (Figures 9-10). The section between the Nambucca River and the southern end of the project traverses predominantly cleared land with three drainage lines and minimal fauna exclusion fence. Seven animals (21%) were recorded in the section north of the Nambucca River bridge. Notably, the section north of Mattick Road is entirely fenced with floppy top exclusion fence and in places, frog exclusion fence.

In July 2019, 14 road-kills were recorded in areas with exclusion fence, and 19 were recorded in areas without exclusion fence (Figures 4-10). Records were classified as occurring within a fenced are if fence occurred adjacent to the record regardless of whether the record was near the start/end of a fenced section. Eight records (24%) in sections with fence were species that should have been blocked by the fence (i.e. medium and large mammals). Three of these records (38%) were within 100m of a fence end. In contrast, 52% of road-kills in sections without fence were of species that should have been blocked by an exclusion fence.

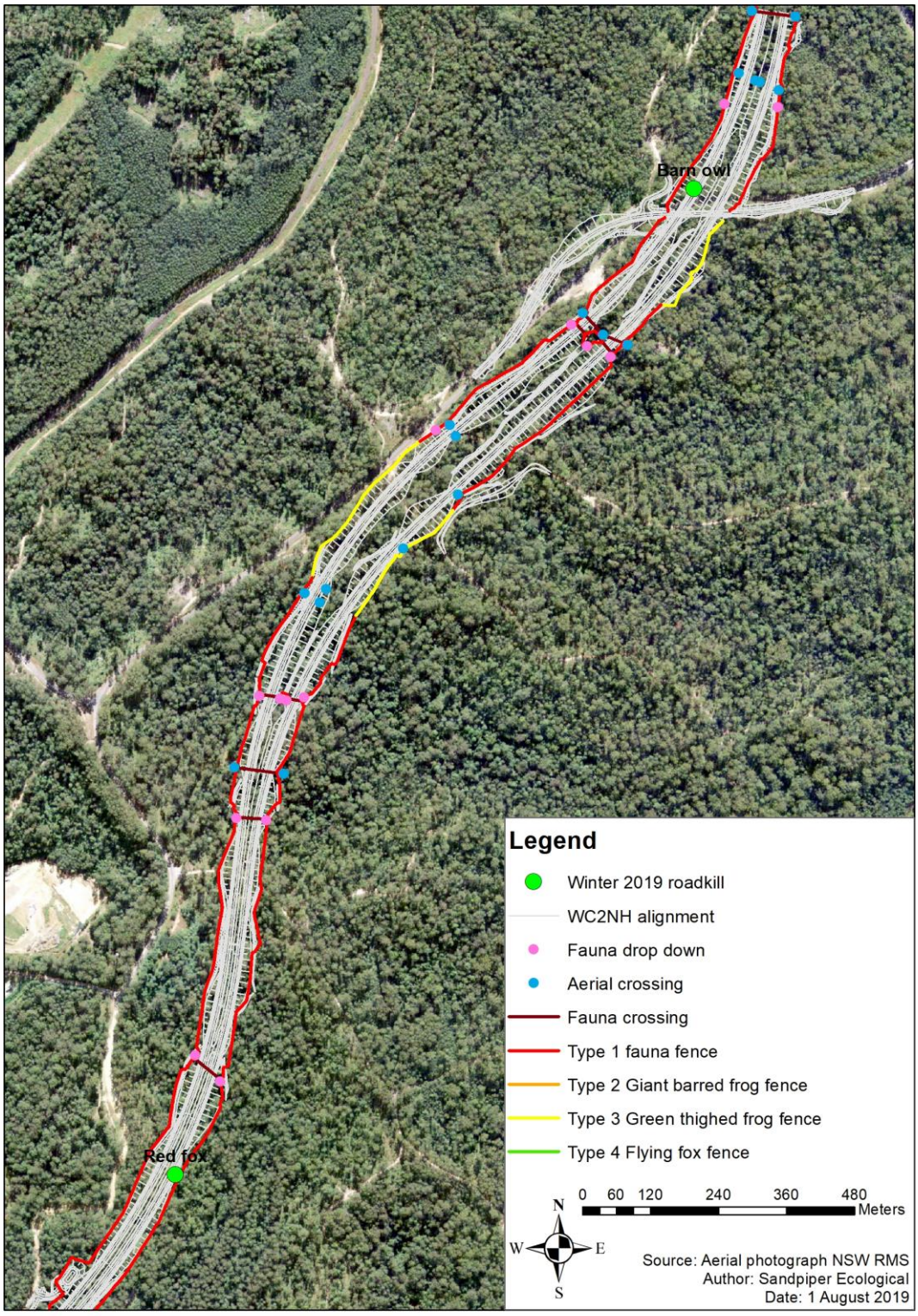

Figure 4: Location of road-killed fauna from July 2019 sample.

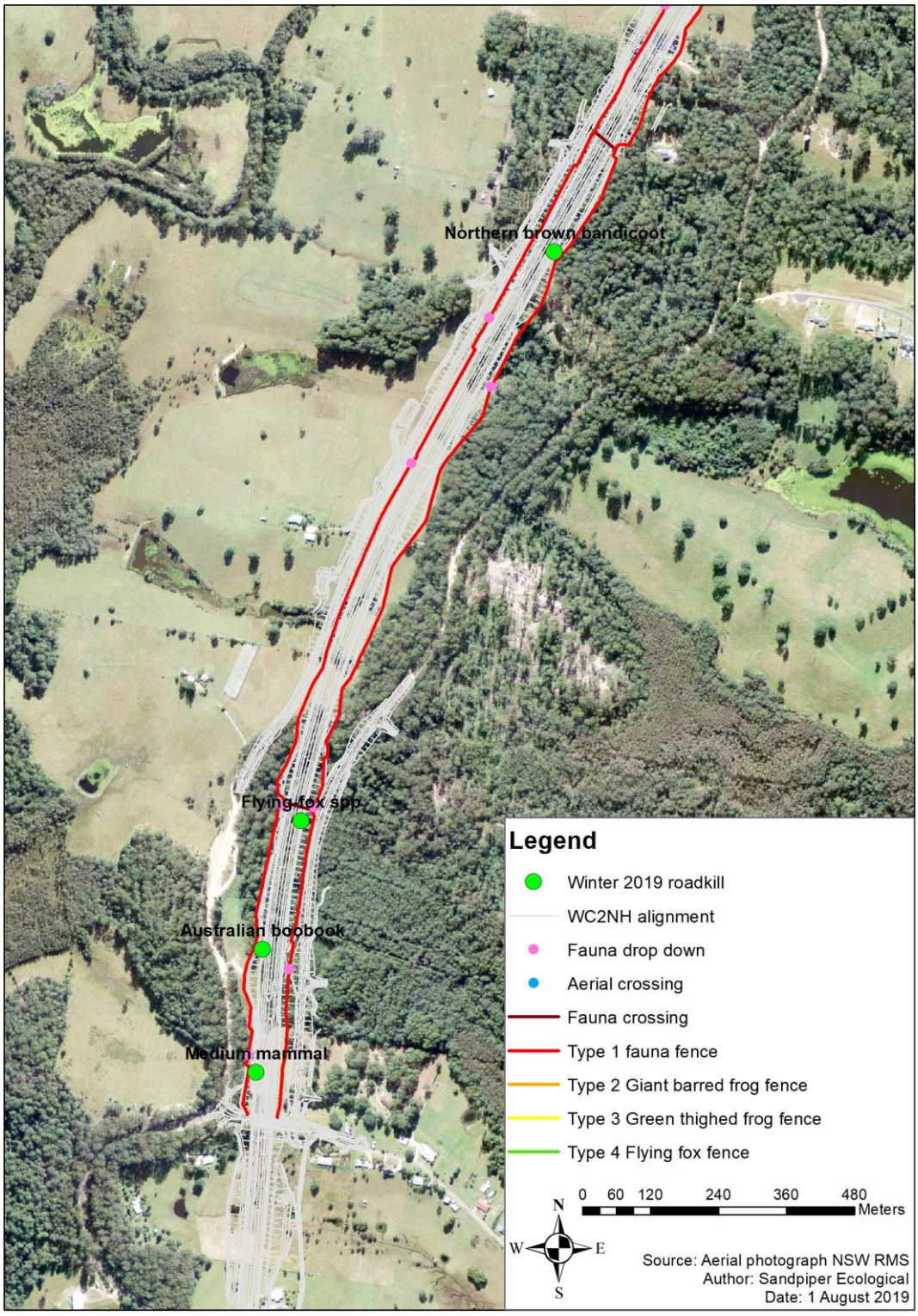

Figure 5: Location of road-killed fauna from July 2019 sample.

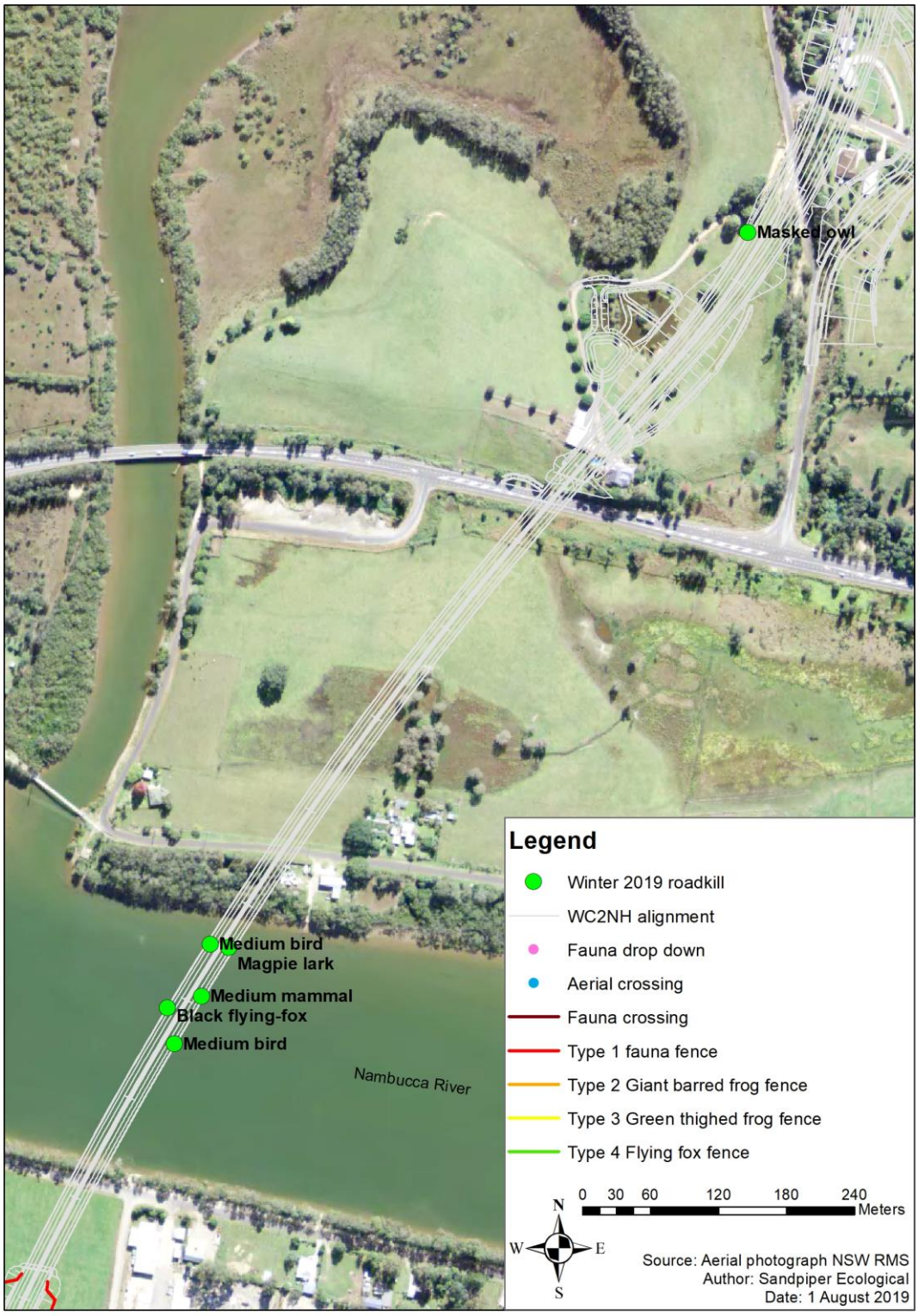

Figure 6: Location of road-killed fauna from July 2019 sample.

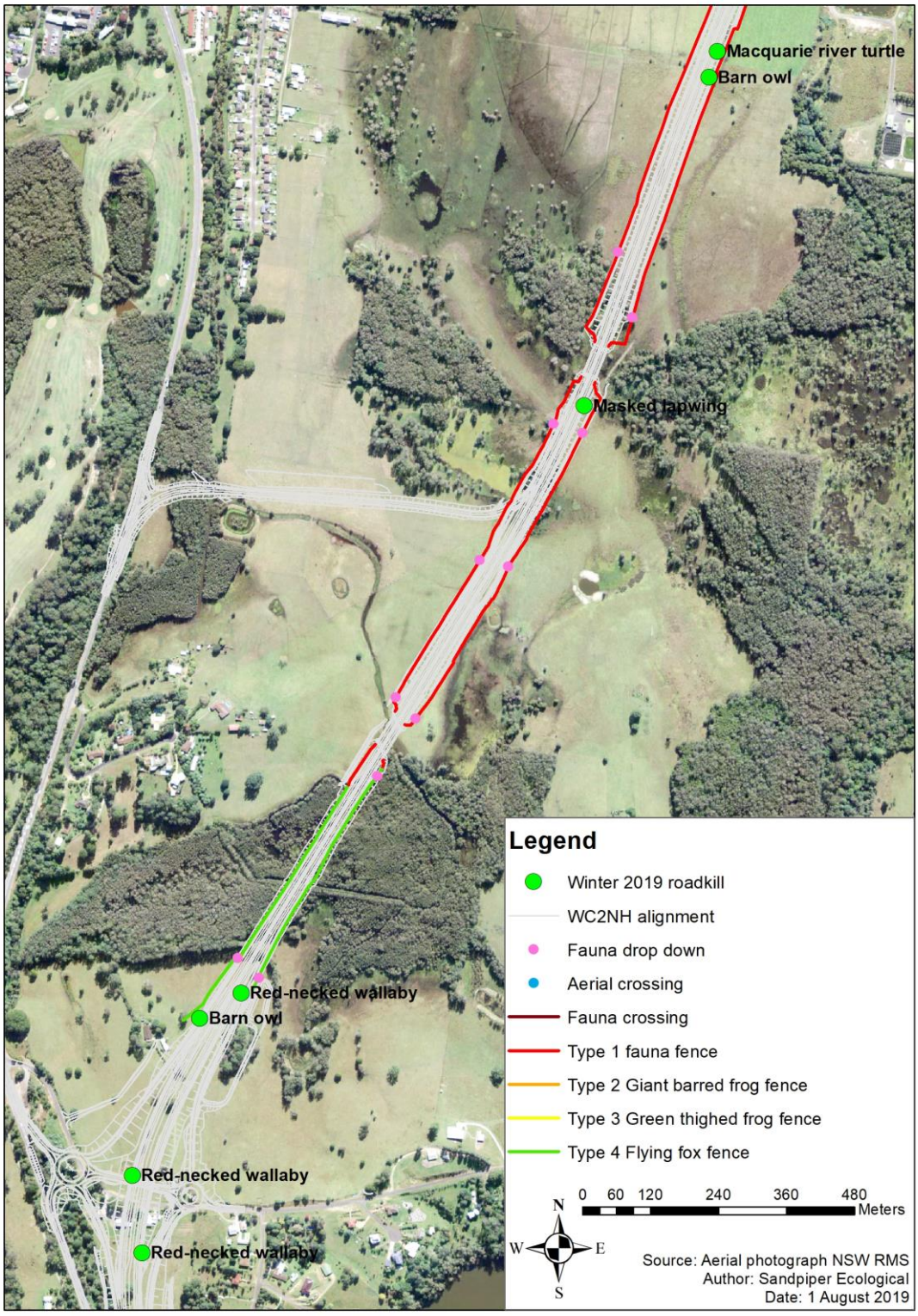

Figure 7: Location of road-killed fauna from July 2019.

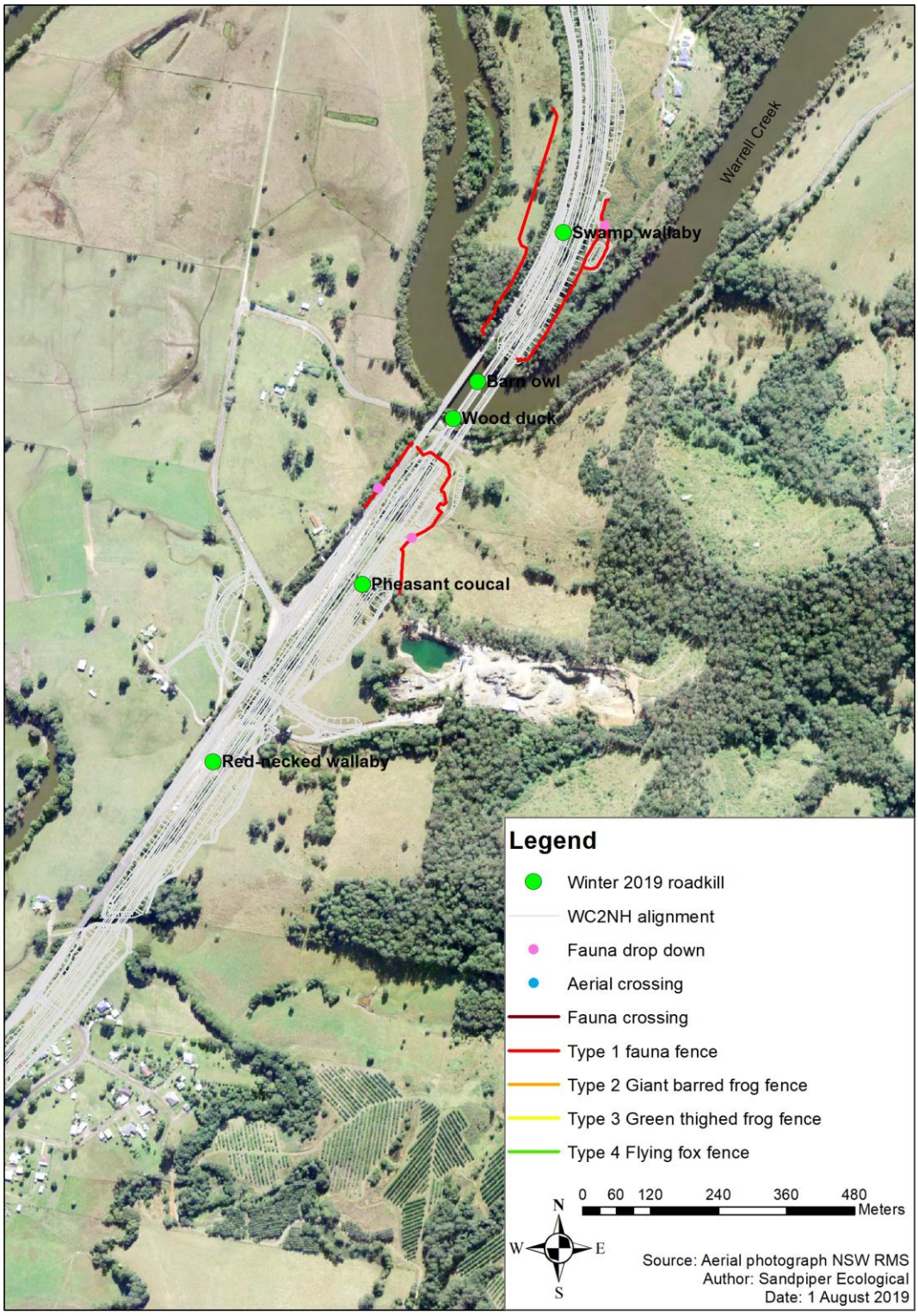

Figure 8: Location of road-killed fauna from July 2019.

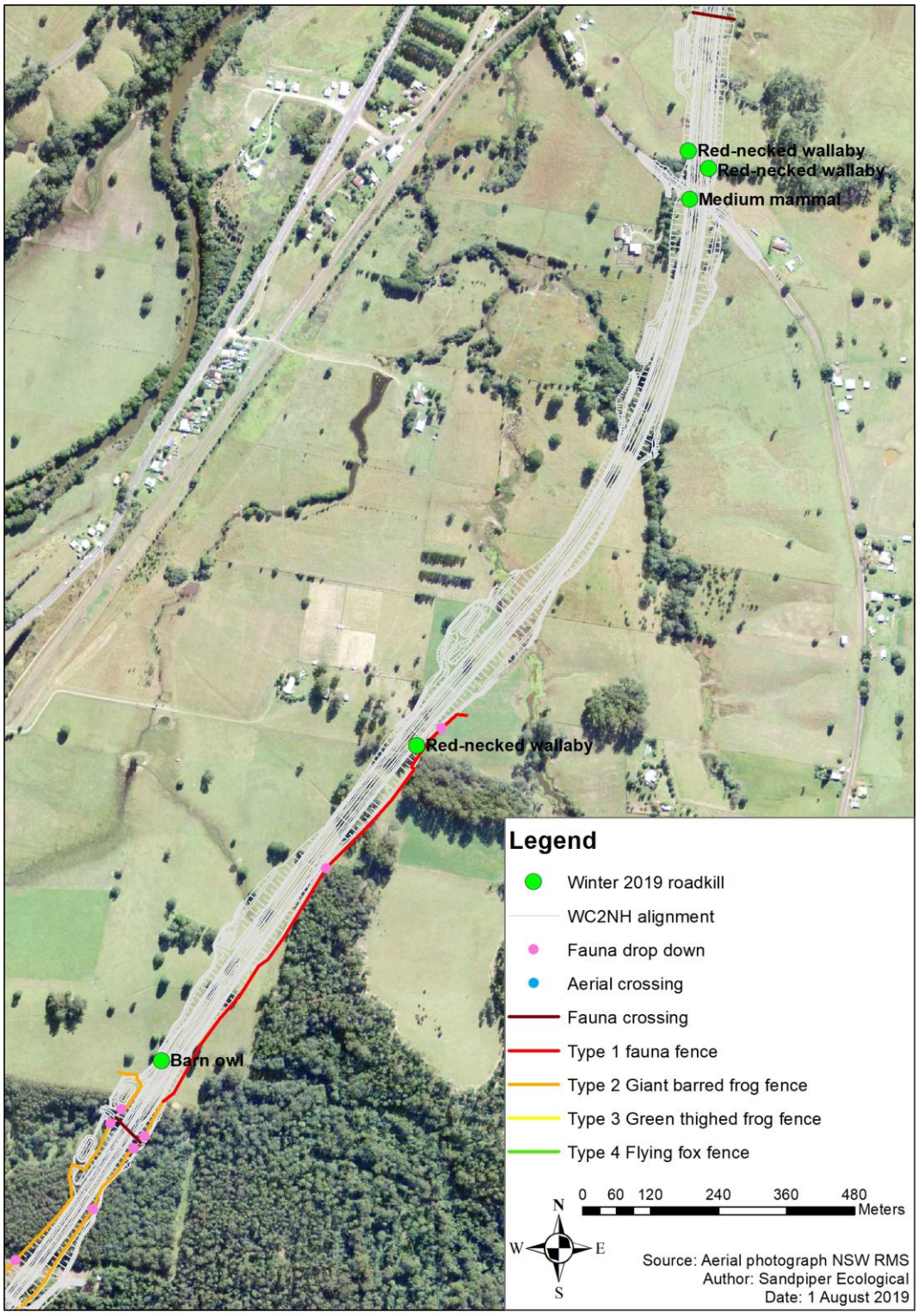

Figure 9: Location of road-killed fauna from July 2019 sample.

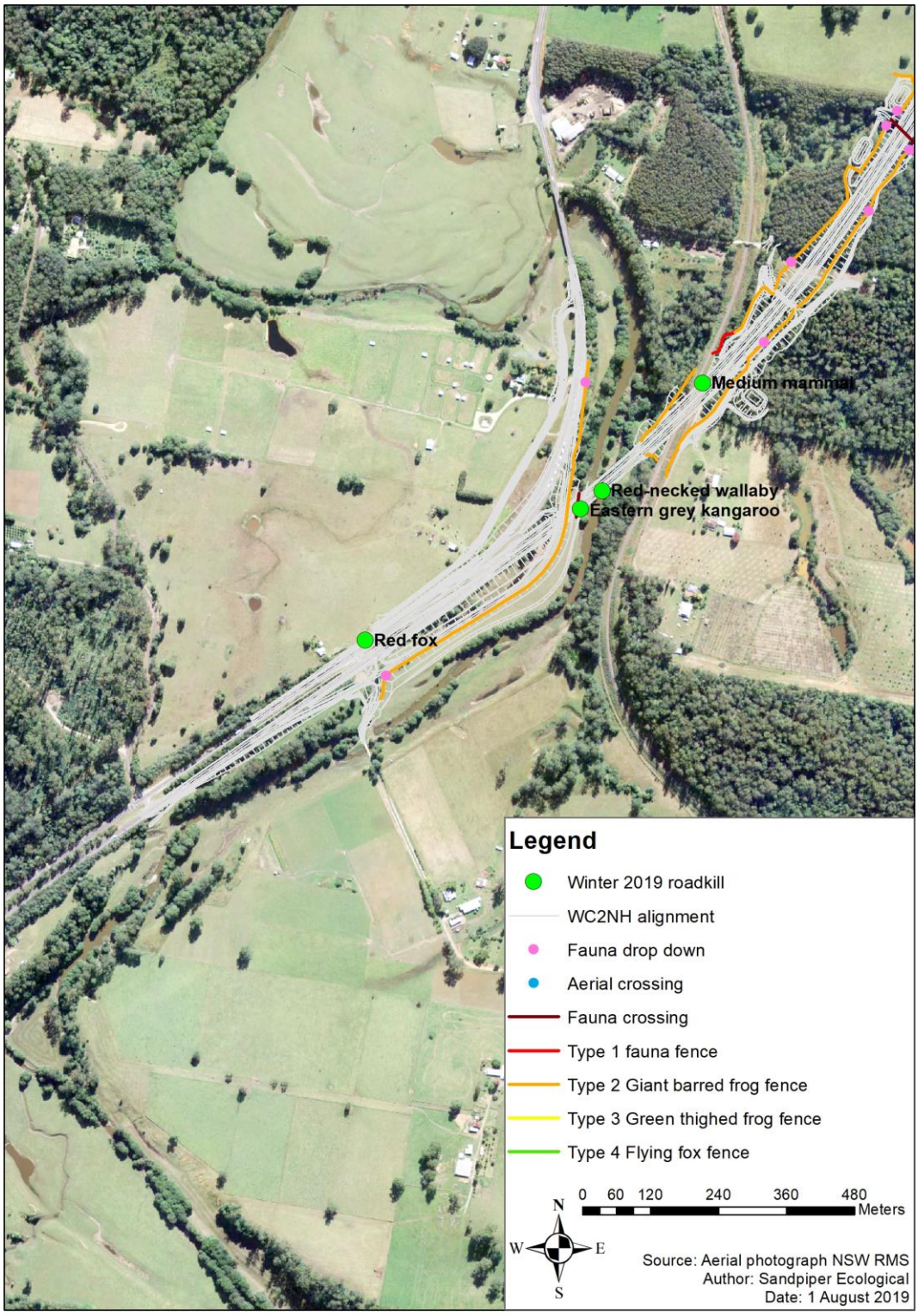

Figure 10: Location of road-killed fauna from July 2019 sample.

4. Discussion

4.1 July 2019

Road-kill monitoring over the entire WC2NH alignment in July 2019 indicates that a substantial number of fauna continue to be killed by vehicles 13 months after the entire alignment was open to traffic. However, with a total of 33 animals killed, July monitoring recorded a decrease of seven animals when compared to April 2019. A decrease of 24 vertebrate fauna was evident when compared to summer (January 2019) surveys. The decline in records may be attributed to decreased movement by many species and lower traffic volumes during winter.

The higher number of road-kills recorded in the first week of all samples reflects the period over which kills could accumulate. This trend is likely to occur in all 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.

Similar diversity and species composition of roadkill was recorded between April 2019, January 2019 and October 2018 and Stage 2A monitoring, which occurred in summer/autumn 2017/18 (GeoLink 2018a). Roadkill hotspots identified in July include the Gumma Floodplain (Albert Drive to Nambucca River bridge), and from the southern end to Albert Drive. This finding is consistent with findings in the annual roadkill report (Sandpiper Ecological 2018) and with previous seasonal samples. Birds and mammals comprised the majority of road-kills in all surveys to date.

4.2 Seasonal variation and species composition

Seasonal variations in fauna abundance are linked with availability of resources and reproduction (Catling *et al* 2002). During autumn and winter months there are fewer flowering events than spring and summer months with the exception of a few species, such as broad-leaved paperbark (*Melaleuca quiquinervia*) and swamp mahogany (*Eucalyptus robusta*). Reduced rainfall in winter can also influence the movement of grazing animals such as wallabies and kangaroos, which often move to road edges to forage and travel larger distances to find suitable food. Lengthier movements can result in a greater likelihood of fauna interacting with linear infrastructure.

Wallabies continue to be killed on the highway, specifically within the vicinity of Bald Hill Road and Albert Drive. Results of monitoring in October 2018, January 2019 and April 2019 raised concerns about the effect of roadkill on the local red-necked wallaby population in the Albert Drive to upper Warrell Creek area. A further eight red-necked wallabies were recorded road-killed in July 2019. Continued roadkill at present rates is likely to reduce the abundance of wallabies in habitat adjoining the road (Huijser & Bergers 2000).

July 2019 monitoring detected no road-killed frogs. Along with the difficulty in detecting frogs via a vehicle this decrease may also be explained by climatic conditions and season. Lower night-time temperatures and lower than average rainfall may have suppressed breeding activity, and frog dispersal.

One Macquarie river turtle was recorded on the Gumma floodplain. Freshwater turtles have been detected occupying drainage basins between the fauna fence and the highway, possibly accounting for the individual recorded. During a fauna fence audit conducted in June 2019, numerous gaps of approximately 150mm were detected (Sandpiper 2019). It is acknowledged that the fencing along the

Gumma floodplain was constructed as a measure to minimise macropod road strike. Ground mesh was not installed due to the target group. Gaps of this size are sufficient to allow turtle movement under the fence.

The number of birds recorded highlights the susceptibility of the group to roadkill (Loss *et al* 2014). Eastern barn owl (*Tyto javanica delicatula*) kills jumped markedly in July 2019 with five kills recorded. Winter 2018 surveys also detected an obvious increase in eastern barn owl road-kills suggesting seasonal movement may contribute to mortality. Irruptions of prey species may in turn cause an upsurge in numbers of eastern barn owls which inevitably leads to individuals moving further in search of prey and territory as prey irruptions dissipate (Menkhorst *et al* 2017). Additionally, drier conditions in western NSW and Queensland may encourage owls to move towards the coast in search of food. A study from North Carolina, USA argues that road mortality may be the dominant source of mortality for owl populations (Gagné *et al* 2015). Given the number of owls detected during WC2NH roadkill surveys to date (n = 27), roadkill may have a significant influence on population numbers, particularly at a local landscape level.

The composition of birds in roadkill is predicted to change over time as larger species habituate to, and avoid, the highway and small birds take up residence on revegetated batters making some cover-dependant species more susceptible to road strike. Nonetheless, the results provide further evidence of the impact that roads have on bird populations (Husby 2016). Of concern is the impact on threatened species such as black bittern (*Ixobrychus flavicollis*), eastern grass owl (*Tyto longimembris*) and masked owl (*Tyto novaehollandiae*). The masked owl individual recorded in July 2019 is the third individual recorded during road-kill surveys.

4.3 Flying-fox impacts

A reduction from nine to two flying-foxes were detected between autumn and winter 2019 monitoring events. These numbers are down from 17 flying-foxes detected during summer 2019 surveys. One of these records was a black flying-fox (*Pteropus alecto*) the other was indistinguishable but there is a possibility it may have been a grey-headed flying-fox (*Pteropus poliocephalus*). Grey-headed flying-fox are listed as vulnerable by the BC Act 2016 and the federal EPBC Act 1999. The decline in records may be attributable to dispersal of camps in autumn and winter, and the absence of juveniles.

5. Recommendations

1. Continue seasonal roadkill surveys as per the project biodiversity monitoring brief.
2. Continue to monitor the distribution and frequency of flying-fox road kills.
3. Continue to monitor the distribution and frequency of owl road kills, particularly threatened species.

6. References

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Appendix A – Field Survey Data

Table A1: July (Winter) 2019 roadkill results.

Date	Obs	Start	End	Carriageway	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence prox.	Fence cond	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp, food
5/7/19	DR& LA	1045	1245	NB	E. barn owl	Unknown		100 n butchers creek	489878	659520	N			NA	NA	
				NB	Med mammal			Rosewood road	490810	6596540	N			NA	NA	
				NB	E. barn owl	Unknown		50m nth Old Coast Road	497336	6610300	No	No		NA	NA	
				NB	Med mammal			100N Mattock road	494448	6604848	N	Adjacent		78	32	
				SB	Red fox			Nambucca state forest	496421	6608560	N	Adjacent		185	185	
				SB	Flying-fox spp.	Sub-adult	Nil	300m nth Mattock rd bridge	494528	6605292	No	Adjacent	Good	NA	NA	7km to Gordon Park camp
				SB	Magpie-lark			Nambucca bridge	493825	6602752				NA	NA	
				SB	Med mammal			Nambucca bridge	493801	6602709				NA	NA	
				SB	E. barn owl	Adult		350m Sth NR bridge - old & off shoulder- check previous records	493471	6602001	Yes	Adjacent	Gaps under fence	NA	NA	
				SB	RN Wallaby	Adult	Nil	Bald hill road	492646	6600385	N	Adjacent		NA	NA	
				SB	RN Wallaby	Adult	Nil		490329	6595576	N	Adjacent		NA	NA	
				SB	RN Wallaby		Nil	Upper Warrell creek bridge	489287	6594264						

Date	Obs	Start	End	Carriageway	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence prox.	Fence cond	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp, food
				NB	E. barn owl	Adult		100m n bald Hill road	492573	6600340	Yes	Adjacent		NA	NA	
12/7/19	DR	900	1105	SB	Macquarie river turtle	Adult		300m Sth Nambucca river	493486	6602047	Yes	Adjacent	Gaps under fence	452	364	
				SB	Masked lapwing	Adult		Floodplain bridge	493251	6601421	No	Adjacent	Good	NA	NA	
				SB	Red-necked wallaby	Adult		100m Sth Bald Hill road	492471	6599926	No	Absent	Na	NA	NA	
				SB	Red-necked wallaby	Adult		50m nth Rosewood rd	490843	6596595	No	Absent	Na	NA	NA	
				NB	Red fox	Adult		Ginagay way exit	488869	6594000	No	Absent	Na	NA	NA	
				NB	Medium mammal			Railway bridge	489464	6594454	No	Absent	Na	245	129	
				NB	Wood duck - possible	Adult		Warrell Creek bridge	492233	6598934	No	Absent	Na	NA	NA	
				NB	Black flying-fox			Nambucca River bridge	493771	6602699	No	Absent	Na	NA	NA	8km to Gordon Park camp
				NB	Medium bird			NR bridge	493809	6602755	No	Absent	Na	NA	NA	
19/07/2019	DR/SR	745	915	SB	Pheasant coucal			100m Sth Warrell creek	492073	6598641	No	Absent	Na	NA	NA	
				SB	Eastern grey kangaroo			Upper Warrell creek bridge	489249	6594232	No			NA	NA	
				NB	E. barn owl			Warrell creek bridge	492276	6598999	No	Absent	Na	20	459	
				NB	Red-necked wallaby			Bald hill overpass	492454	6600063	On shoulder	Absent	Na	NA	NA	
				NB	Masked owl			200m Sth old coast road	494283	6603383	No	Absent	Na	NA	NA	

Date	Obs	Start	End	Carriageway	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence prox.	Fence cond	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp, food
				NB	Australian Boobook			250m nth old coast road	494460	6605065	Yes	Absent	Na	NA	NA	
26/7/19	DR & TR	850	1005	SB	NB Bandicoot	Adult; male	Na	250m nth S3	494974	6606296	Yes	Present	Good	212	162	
				SB	Medium bird		Na	Nambucca River bridge	493777	6602667	No	Absent	Na	NA	NA	
				NB	Red-necked wallaby	Adult		100m nth Rosewood road	490808	6596626	On shoulder	Absent	Na	NA	NA	
				NB	Red-necked wallaby	Sub-adult		100m Sth Bald Hill Road	491809	6598328	No	Absent	Na	NA	NA	
				NB	Swamp wallaby	Adult		250m nth Warrell Creek	492427	6599262	No	Absent	Na	104	76	

Appendix 3 Spring (October) 2019 monitoring (Annual Report)

Pacific Highway Upgrade: Warrell Creek to Nambucca Heads

Operational phase roadkill monitoring – annual report 2019

Sandpiper Ecological

1/94 Main Street
Alstonville

Sandpipereco.com

Final Report
26 November 2019

Document Review

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Cover Photo: Road-killed black bittern.

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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 roadkill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate roadkill 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 contracted by RMS to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal roadkill 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 roadkill 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 roadkill monitoring was conducted by Geolink (2018a, b, c, d).

The aim of monitoring is to:

- report on any vertebrate roadkill 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 2019 and compares roadkill data from fenced verses unfenced sections of the 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).

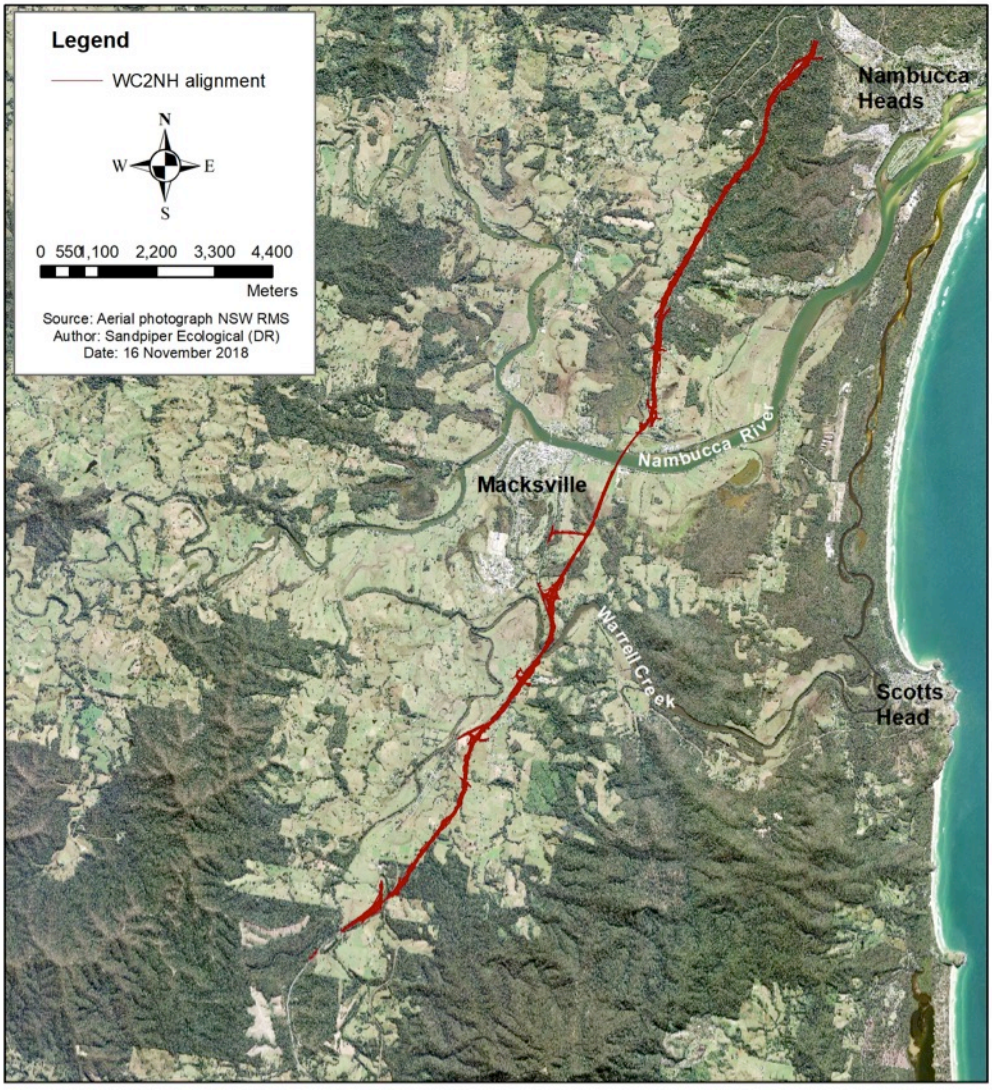

Figure 1: Location of the WC2NH alignment.

2. Methodology

2.1 Roadkill surveys

Road kill surveys were conducted over four, four-week sample periods in summer (January), autumn (April), winter (July) and spring (October). A two-person team consisting of an ecologist and driver conducted each survey from a vehicle driven at 80km/hr in the left lane. At least one team member was used consistently throughout each four-week sample period to minimise the likelihood of recording duplicate road kills. The vehicle was equipped with an amber (flashing) light and warning sign. All surveys commenced within three hours of sunrise, with an interval of 6-7 days between samples. During each survey, both the driver and ecologist 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 position behind wire rope and perpendicular to the specimen. 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.

Data collected on each roadkill included (Appendix A1):

- Geographic coordinate
- Presence/absence of fauna exclusion fence
- Species/fauna group
- Date of survey
- Roadkill location – north or southbound carriageway

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act* (EPBC) *1999* and/or the *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 (determined from GIS); distance to a drop-down structure if applicable (determined from GIS); 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 preceding weeks results to identify duplicate records. 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 were uploaded to Microsoft excel and compared with results from the previous sample period to identify duplicate records. Three records obtained during the first October 2019 sample were deemed as duplicates and subsequently removed from the dataset. These included: a macropod spp., a red fox and a medium mammal. Graphs have been produced showing the total number of road kills in October 2019 and the number of road kills in different fauna groups each week of the October 2019 survey. The location of road kills has been overlaid on the WC2NH alignment to show their distribution. The October 2019 data are compared to the number of road-kills recorded in summer, autumn, winter and spring 2018, and summer, autumn, and winter 2019 (Sandpiper Ecological 2018; Sandpiper Ecological 2019).

2.2.1 Statistical analysis

The primary aim of statistical analysis is to determine if there is a statistical difference in the frequency of road kills between fenced and unfenced sections of the alignment. A secondary aim is to determine if the frequency of road kill varies through time in fenced and unfenced sections of the alignment.

Roadkill 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. 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 roadkill 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”. Sections of the alignment with a single fence may be included as a separate category in future analysis as sample size increases.

Table 1: Fauna groups included in comparison of fenced and unfenced sections of alignment.

Group	Species included
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

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.

3. Results

3.1 October 2019 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 occurred on 1 October prior to the first sample.

Table 2: Weather conditions in the 24hrs preceding each sample event. Data obtained from BoM South West Rocks weather station.

Date	Average Relative Humidity (%)	Total Rainfall (mm)	Max Temperature (^{0}C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
1/10/19	71	13	22.7	7	Good	Nil
8/10/19	99	0	24.3	2	Good	Nil
15/10/19	82	0	NR	15	Good	Nil
21/10/19	68	0	24.8	4	Good	Nil

3.1.2 Species richness and abundance

Fifty-three road killed fauna were recorded during the October 2019 sample period. This included 17 native species, and seven fauna groups (Table 3; Table A1, Appendix A). Birds were the most diverse group represented with 10 species and two groups recorded. Five species of mammal and two species of reptile were recorded (Table 3). No frogs or introduced species were recorded.

Grey-headed flying-fox (*Pteropus poliocephalus*) was the most frequently recorded species with five records, followed by tawny frogmouth (*Podargus strigoides*) with four records (Appendix A) and red-necked wallaby (*Macropus rufogriseus*), Laughing kookaburra (*Dacelo novaeguineae*), and galah (*Eolophus roseicapilla*) with three records each. Collectively, six road-killed bandicoots were recorded, two northern brown bandicoot (*Isodoon macrourus*) and four unidentified individuals. Medium and large mammals accounted for an additional six records (Table 3).

Grey-headed flying-fox was the only target species recorded in October 2019. That species is listed as vulnerable under the *Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and state *Biodiversity Conservation (BC) Act 2016*.

Of the 53 road-kill records 19 (or 36%) were individuals expected to be blocked by exclusion fence. The remaining 34 records included birds and snakes that readily move through or over exclusion fence.

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 2018**	Win 2018**	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Total
Birds									
Australian magpie	6	1		1				2	10
Grey butcherbird			1						1
Magpie-lark	2		1		1		1		5
Australian white ibis			1						1
Cattle egret				1					1
Little pied cormorant					1				1
Buff-banded rail					1				1
Purple swamphen	3		2	2		1		2	10
Crested pigeon	2								2

Species	Sum 17/18**	Aut 2018**	Win 2018**	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Total
Galah	7				1			3	11
Rainbow lorikeet								1	1
Eastern grass owl*				1					1
Australian boobook			1	1			1		3
Masked owl*	1				1		1		3
Eastern barn owl			11	3		1	5	2	22
Tawny frogmouth	1	3	1	2		6		4	17
Australian owlet-nightjar					1				1
Laughing kookaburra	3		2	1		2		3	11
Forest kingfisher	1								1
Australian wood duck	20			2	2		1	2	27
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
Black bittern*						1			1
Eastern yellow robin						1			1
Pheasant coucal							1		1
Masked lapwing							1		1
Welcome swallow								1	1
Duck spp.						1			1
Small bird								2	2
Medium bird				1	2	2	2	2	9
Unidentifiable bird	5	4	1		3				13
Mammals									
Short-beaked echidna				3				2	5
Black flying-fox	2	1			6	1	1		11
Grey-headed flying-fox*					8			5	13
Pteropus spp.					3	8	1		12
Common brushtail possum			1	2					3
Common ringtail possum					1			1	2
Eastern grey kangaroo				3			1		4
Red-necked wallaby	1		6		8	2	8	3	28
Swamp wallaby	2	1		1		1	1		6
Wallaby spp.						2			2
Macropod spp.	3		2	1	1				7

Species	Sum 17/18**	Aut 2018**	Win 2018**	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Total
Northern brown bandicoot	1		1		1	1	1	2	7
Bandicoot spp.						1		4	5
Chalinolobus spp. (microbat)				1					1
Microbat spp.					1				1
Rodent spp.						2			2
Small mammal					2				2
Medium mammal				2	4	2	4	5	17
Large mammal				1	1			1	3
Unidentified Mammal	1			3					4
Reptiles									
Common blue-tongued skink	1			2	1				4
Carpet python	1			2	1	1		1	6
Common tree snake	1	2						1	4
Eastern long-neck turtle	1			6					7
Macquarie river turtle	5	1					1		7
Unidentified *Chelidae* spp.	6							1	7
Red-bellied black snake	1								1
Eastern water dragon	1			1					2
Blackish blind snake						1			1
Yellow-faced whipsnake				1					1
Unidentified reptile								2	2
Frogs									
Green tree frog	2								2
Striped marsh frog	3								3
Medium frog				3					3
Large frog				1					1
Introduced species									
Cat	1								1
European fox	3	1	1	2	1	1	2		11
European hare	2			1					3
Rabbit	1								1
Black rat	1					1			2
House mouse					1				1
Rock pigeon			1	1					2
Domestic goose				1					1
Total	93	14	34	55	57	40	33	53	379

The number of road kill recorded each week varied during the sample period. A trend of decreasing roadkill abundance was recorded over the first three sample weeks but roadkill abundance increased sharply in week four (Figure 2). Twenty-five road killed fauna were recorded in week one and 12 were recorded in week four. 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.

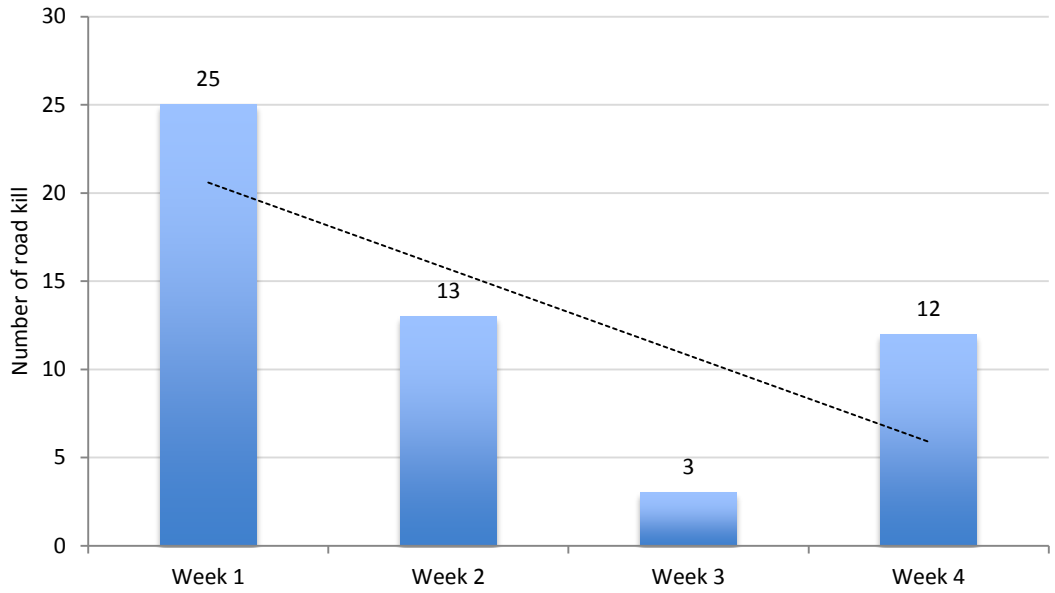

Figure 2: Number of road kills recorded in each sample week during the October 2019 (spring) sample period.

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 15 in week one to none in week three and eight in week four. The number of road-killed birds was consistent in weeks one, two and four but decreased substantially in week three. Two reptiles were recorded in each of weeks one and two, with one recorded in week three and none in week four (Figure 3).

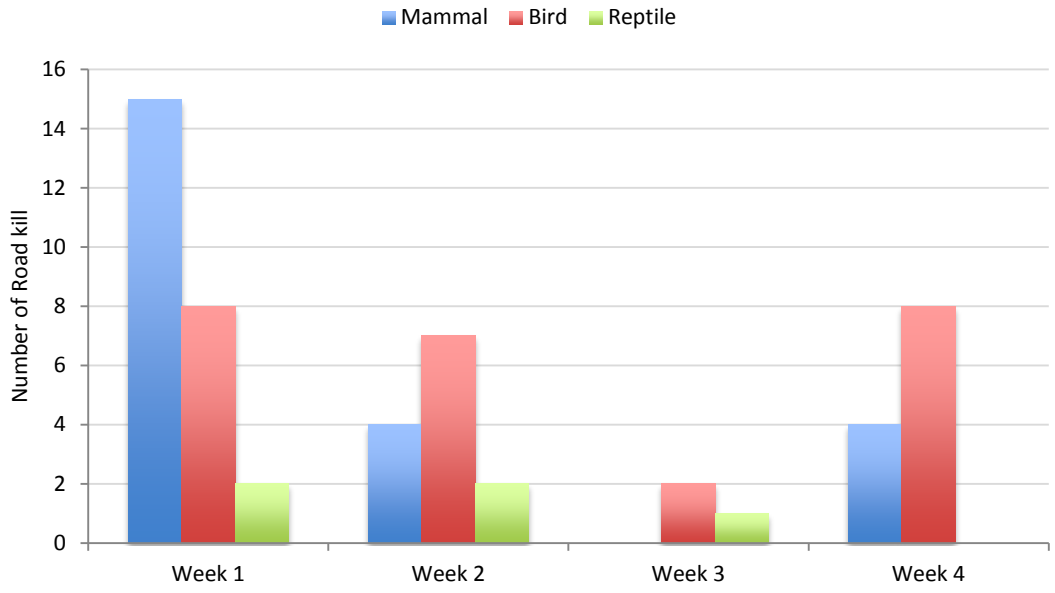

Figure 3: Number of road-killed fauna from four vertebrate classes during each sample week in October 2019.

3.1.3 Opportunistic road-kill information

No opportunistic roadkill records were obtained during the October 2019 sample period.

3.1.4 Distribution of road-kill

In October 2019 road-killed fauna was recorded over the entire WC2NH alignment (Figure 4-9), although the majority of records (83%) occurred south of Mattick Road. Of the nine road-kills recorded north of Mattick Road 66% were birds. Despite the broad distribution of road-kill a distinct cluster was evident between the Nambucca River and Mattick Road (13 individuals; 6.2 ind/km). Eight of the 13 individuals (or 62%) recorded in that area were birds. A comparable density of road-kill was recorded in vicinity of Rosewood Road.

In October 2019, 20 road-kills were recorded in areas with exclusion fence, and 33 were recorded in areas without exclusion fence (Figures 4-9). Road-kills in areas with exclusion fence on one side of the carriageway were classed as fence absent. Six records (or 30%) in sections with fence were species that should have been blocked by the fence (i.e. medium and large mammals & reptiles). In contrast, 39% of road-kills in sections without fence were of species that should be blocked by a fence.

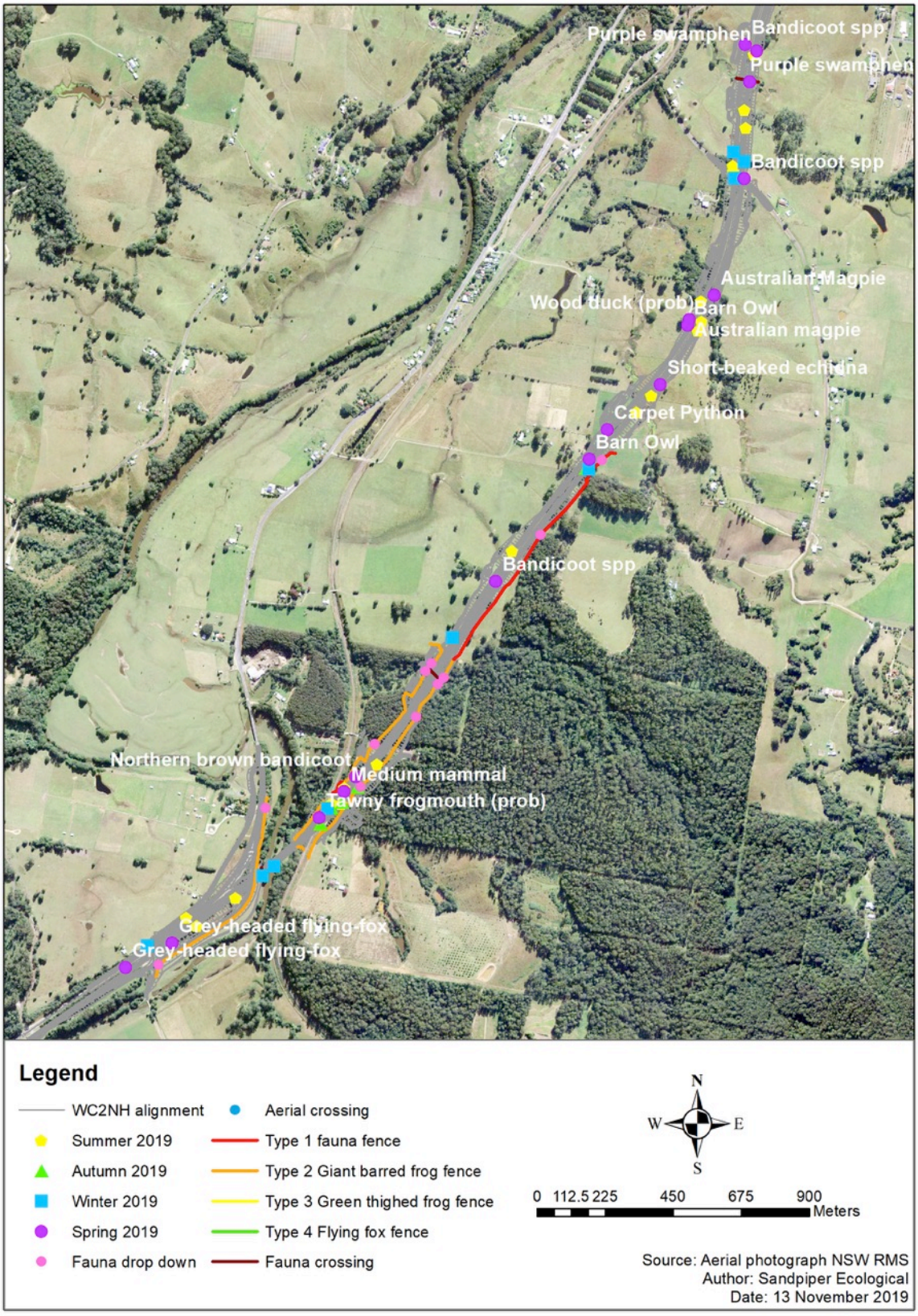

Figure 4: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

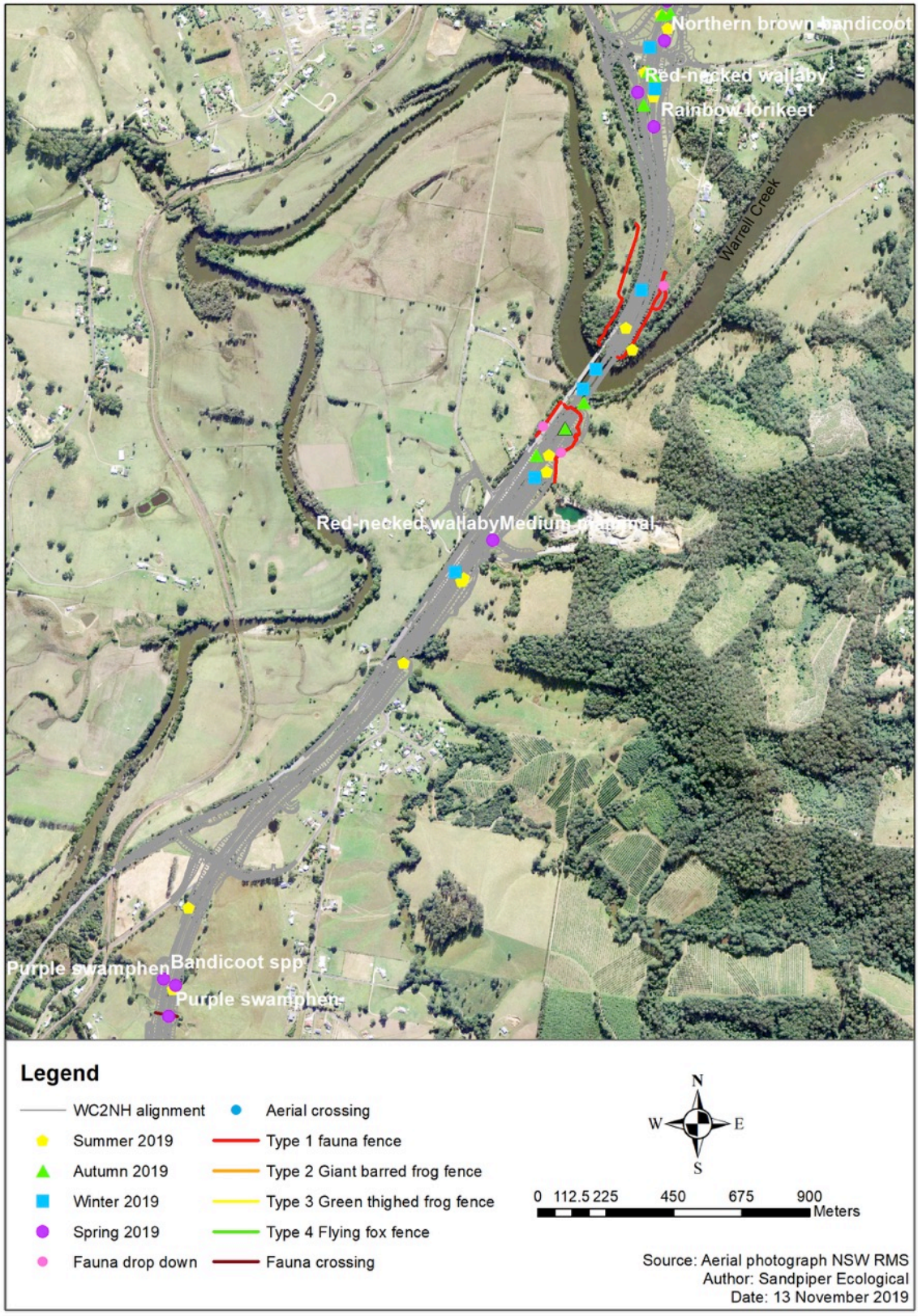

Figure 5: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

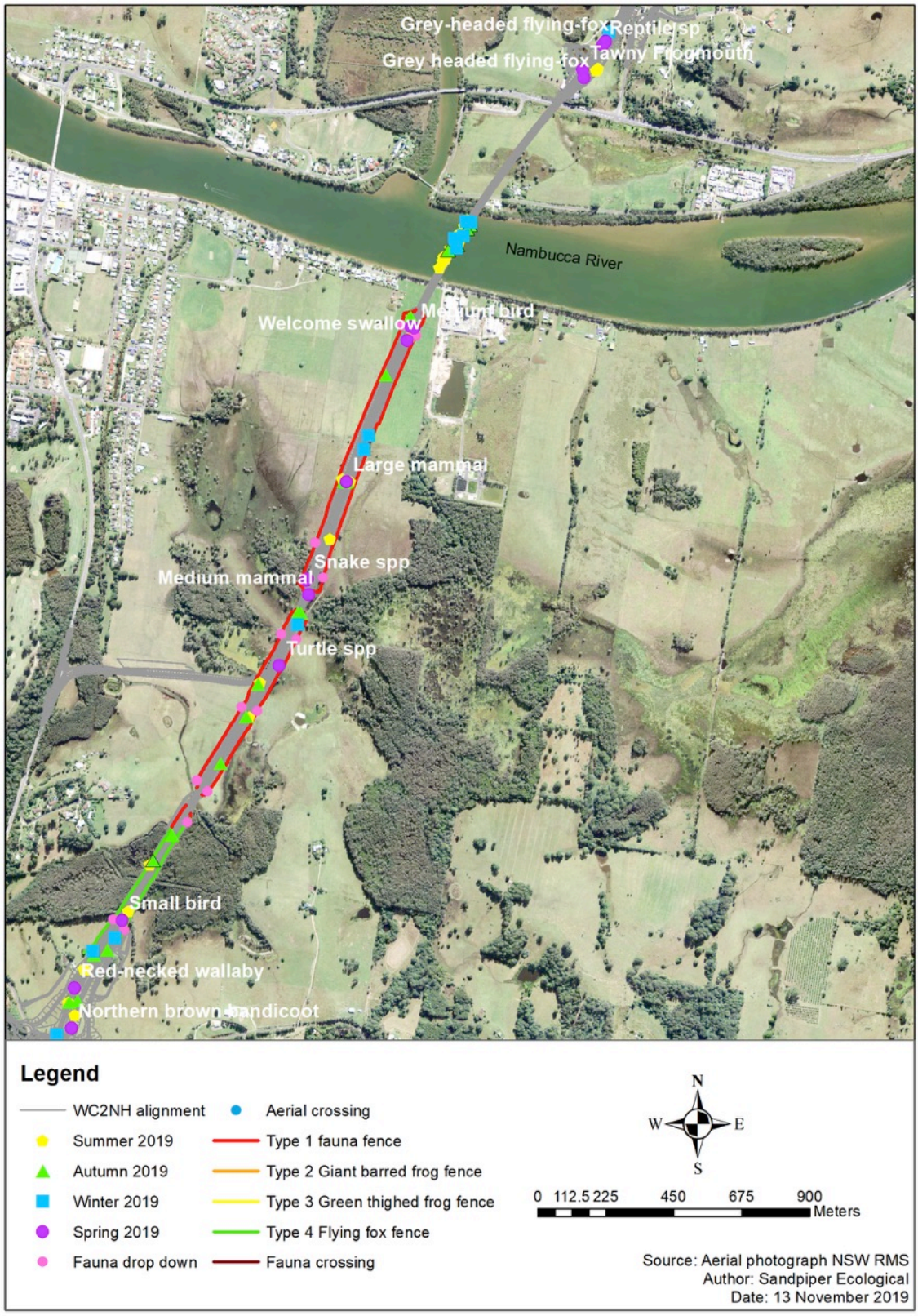

Figure 6: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

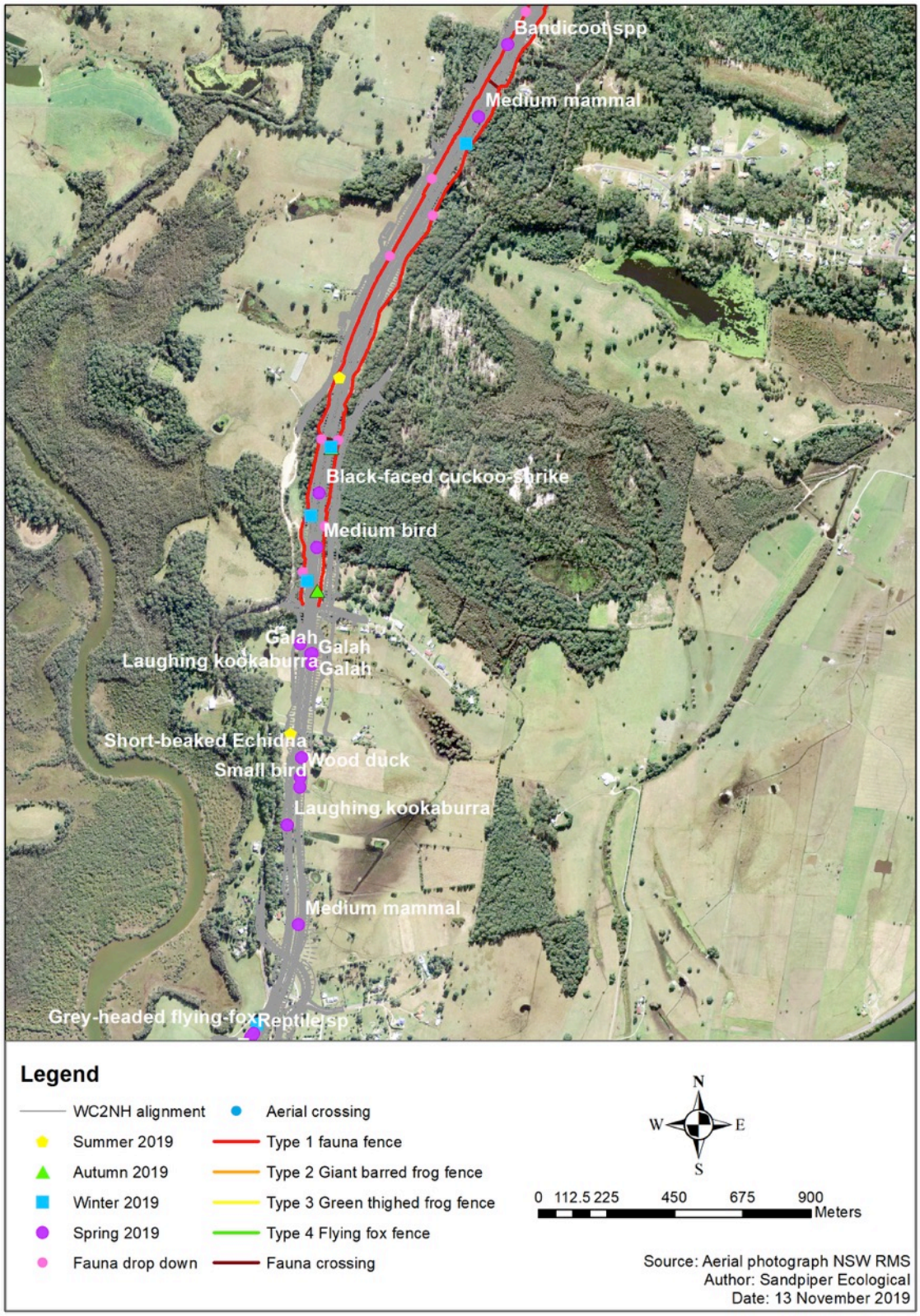

Figure 7: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

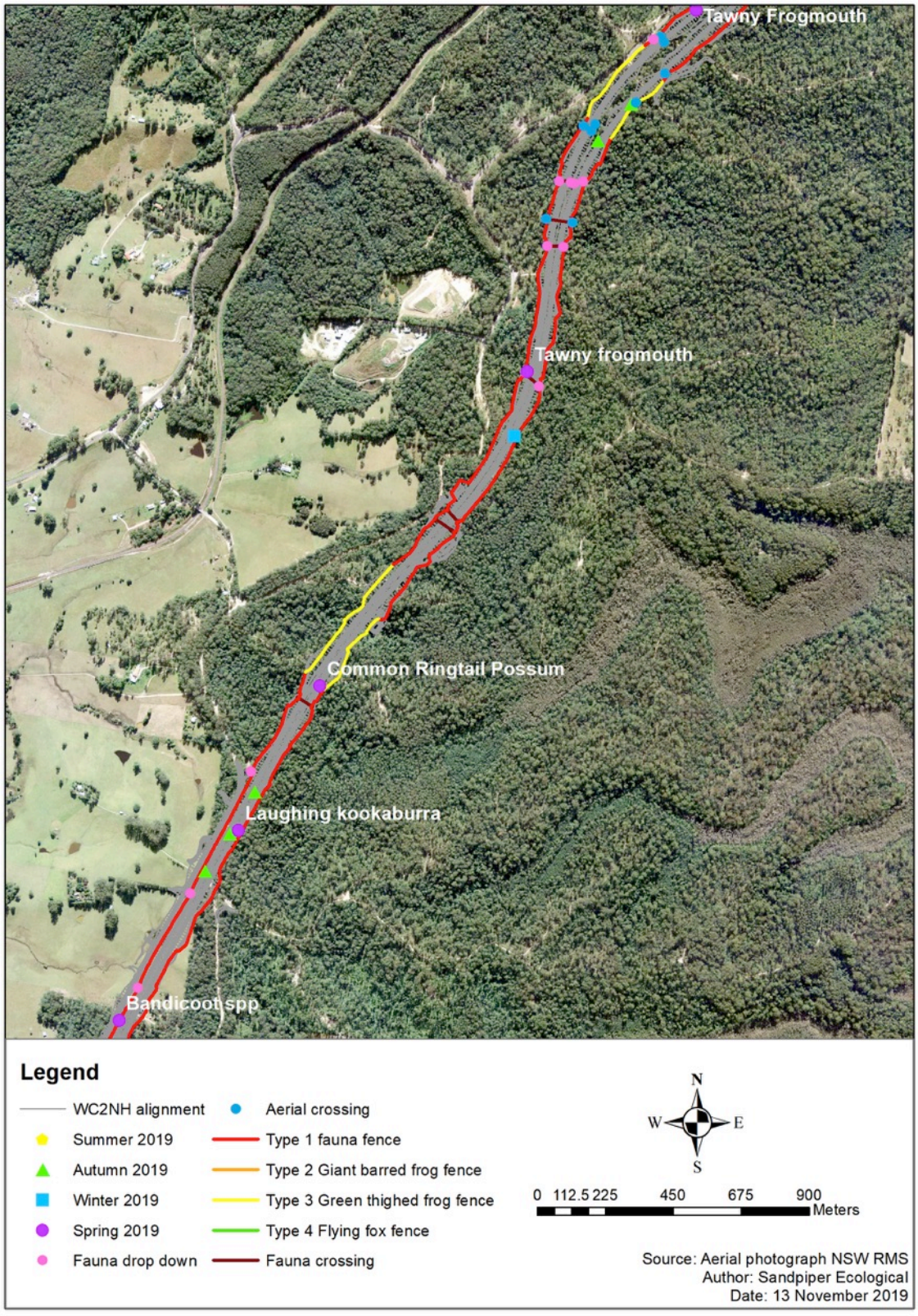

Figure 8: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

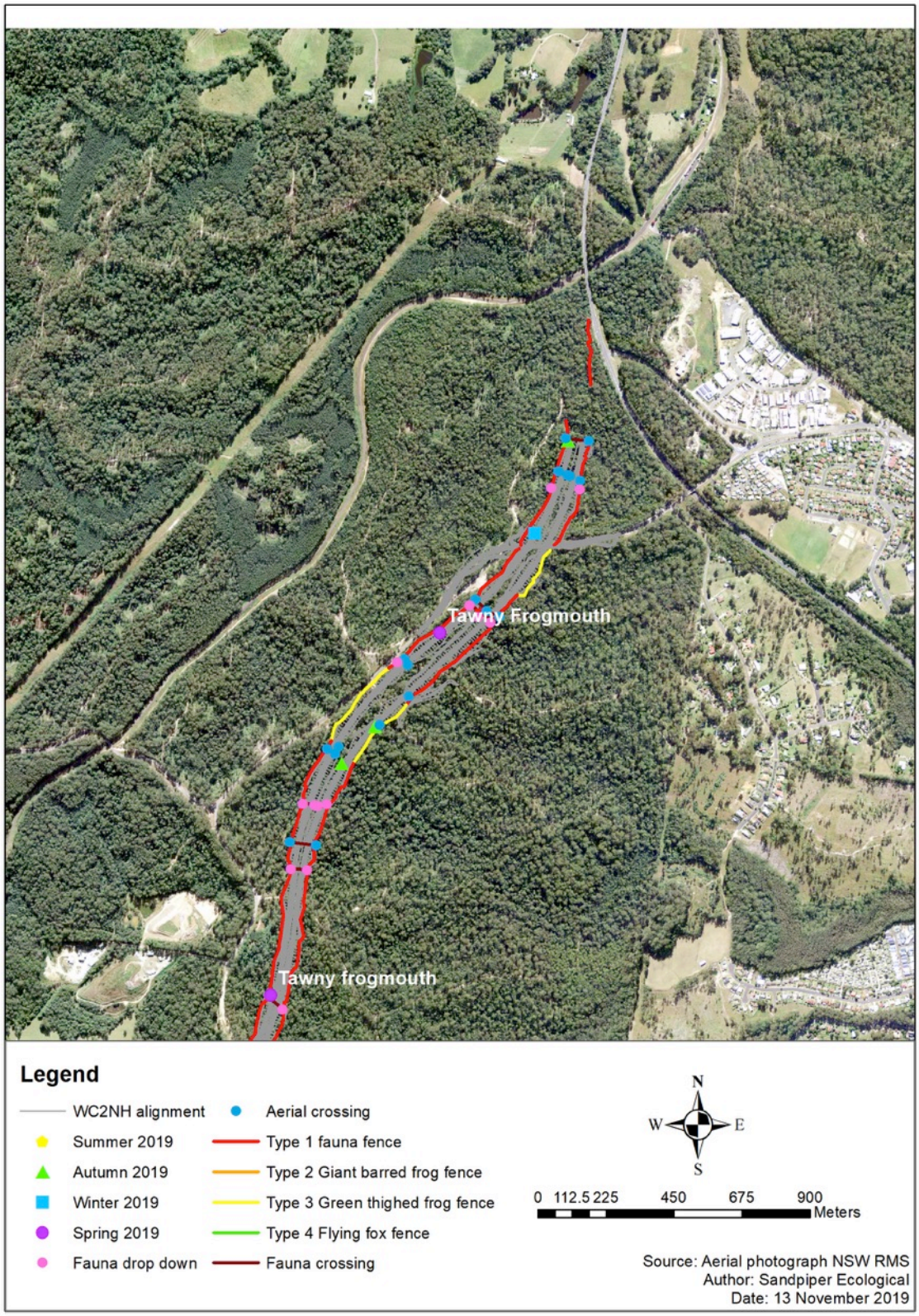

Figure 9: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

3.2 Annual results 2018

3.2.1 Statistical analysis

The G-test was run on two sets of data, all species (from Table 1), and all species excluding introduced species (Table 4). A statistically significant difference in the number of roadkill between fenced and unfenced areas was recorded for both data sets (Table 4). The number of road-kills was significantly higher 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=0.132).

Table 4: Results of G-test on road-kills in fenced and unfenced sections of the alignment.

Group	Category	No. road-kill	Expected proportion	Expected N°.	Df	G statistic	P (2-tail)
All species	Fence	21	0.55	35.2	1	12.77	0.0003
	No fence	43	0.45	28.8			
No introduced	Fence	19	0.55	33	1	13.28	0.0002
	No fence	41	0.45	27			

3.2.2 Species richness and abundance

A total of 40 species were recorded during road-kill surveys in 2019 (Table 3). This was comprised of 37 native species and three introduced species. Three threatened species were recorded in 2019, including two masked owl, one black bittern, and 13 grey-headed flying fox. The two former species are listed as vulnerable under the BC Act (2016). In addition to the 13 confirmed grey-headed flying-fox 12 individuals were identified to Genus only. Most of these occurred on the Nambucca River bridge where they could not be inspected.

The highest species richness of road-kill was recorded in summer (20 species; 8 groups), followed by spring (17 species; 7 groups), autumn (15 species; 7 groups) and winter (14 species; 3 groups). The most commonly recorded species were red-necked wallaby (21 records), grey-headed flying-fox (13 records, Pteropus spp. (12 records), tawny frogmouth (10 records), eastern barn owl (8 records), and black flying-fox (8 records) (Table 3). There were a further 15 records of medium mammal, which could have been bandicoots or wallaby remains.

A total of 183 individuals were recorded across the 16 road-kill samples (Table 3). Native mammals were the most commonly recorded group with 96 records, followed by birds (72 records), reptiles (10 records) and introduced mammals (6 records). Road-kill abundance has fluctuated between sample weeks (Figure 10). The number of road-kill typically peaks in the first sample week/season (i.e. weeks 1, 5, 9 and 13 in Figure 10) 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 2, 3 and 4 in each sample period. The number of road-kill/km sampled was strongly correlated with the total number of road-kill recorded (Pearson correlation co-efficient 0.99). The trendline suggests a slight temporal decrease in number of road-kill over the sample period (Figure 10).

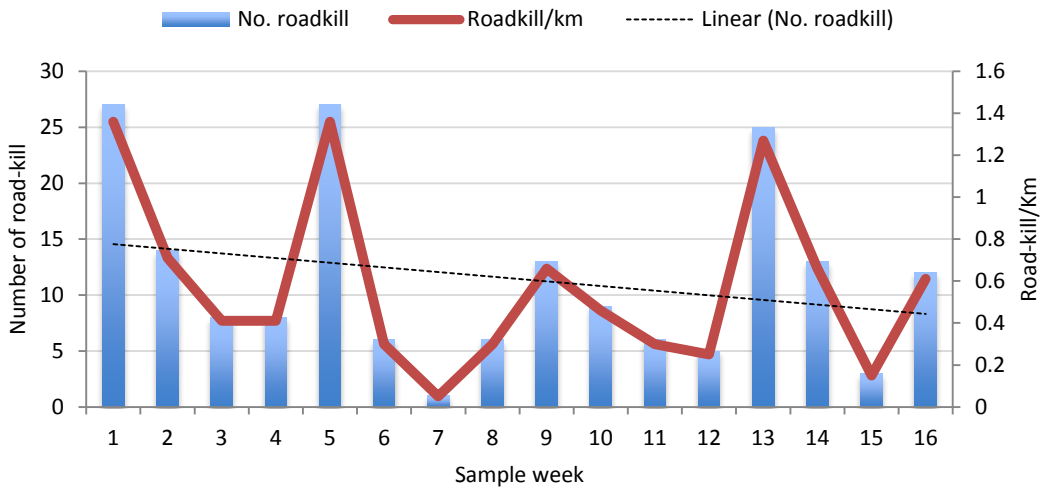

Figure 10: Number of road-kill recorded each week expressed as a total (Left axis) and number/km sampled (right axis).

The mean number of road-kills in each sample period shows a trend of decreasing numbers in autumn and winter and peaks in spring and summer (Figure 11). The large standard deviations reflect variations in road-kill number between weeks and the higher number recorded in the first week of each sample period.

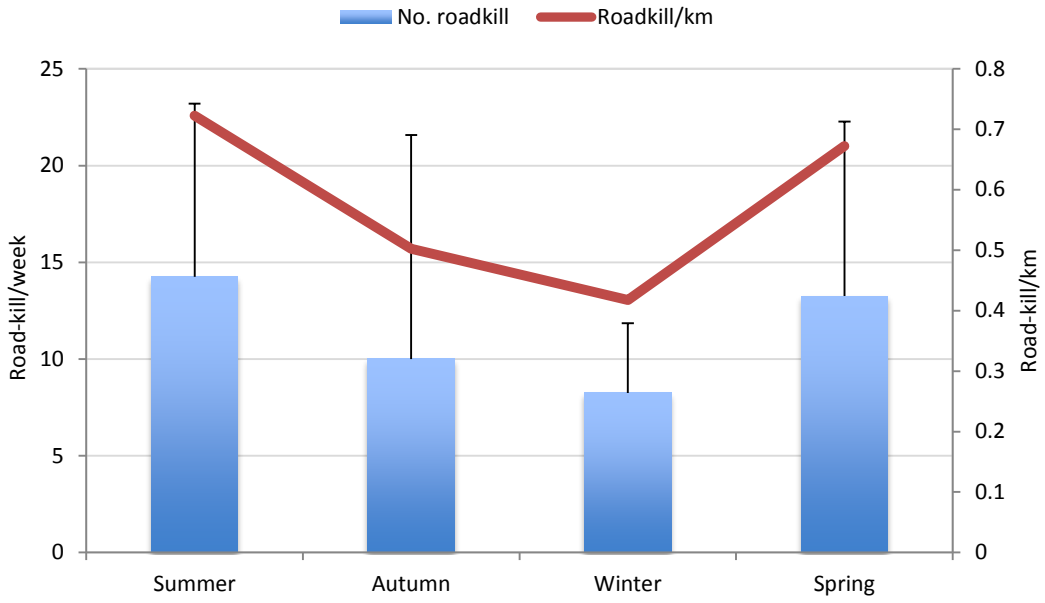

Figure 11: Mean number of road-kills/sample (+SD) and mean number/km/sample in 2019.

Comparison of road-kill numbers between 2018 and 2019 show that despite a similar overall total value the contribution of different fauna groups has varied substantially between years (Table 5). Substantially fewer birds, reptiles, amphibians and introduced species were recorded in 2019. In contrast, the number of mammals increased substantially from 39 in 2018 to 96 in 2019. This increase was due mainly to higher numbers of flying-foxes and macropods in 2019. Differences in survey method and site coverage, due to project staging, between 2018 and 2019 compromise direct comparisons, however, the scale of difference suggests that it is not due solely to survey effort. The

decrease in birds in 2019 is largely due to fewer Australian magpie, eastern barn owl, Australian wood duck, and galah, with numbers of these species decreasing from 51 in 2018 to 19 in 2019 (Table 3).

Table 5: Comparison of road-kill numbers between 2018 and 2019 sample periods.

Year	Total	Birds	Mammals	Reptiles	Amphibians	Introduced
2018	196	102	39	32	7	16
2019	183	72	96	10	0	6

3.2.3 Distribution of road-kill

Road-killed fauna have been recorded over the entire study area (Figures 4-9). There were substantially fewer road-kills in areas with continuous fauna fence north of Mattick Road. Road-kill density north of Mattick Road across all samples in 2019 was 3.73ind/km, which is substantially less than the 13.2ind/km recorded on the Gumma Floodplain, 11.2ind/km between the southern extent and just north of Rosewood Road, and 76.7ind/km on the Nambucca River Bridge. Notable road-kill hotspots include:

- South end of project to Albert Drive (46 records).
- Gumma floodplain (37 records).
- Nambucca River to Mattick Road (15 records).
- Nambucca River Bridge (23 records).

3.2.4 Flying-fox road-kill

Flying-fox road-kill data were interrogated further to gain a better understanding on the scale of impact. The distribution of flying-fox records was compared against the distribution of fauna exclusion fence types (Table 6). Results show one record of a black flying-fox within the Type 4 flying-fox exclusion fence area, six records with the type one fence and one within type 2 fence. A further two grey-headed flying-fox records were obtained in areas with Type 1 and 2 fence on one side of the carriageway only.

Table 6: Number of flying-fox road-kill records in sections of highway with different types of exclusion fence.

Species	Type 1 Fauna fence	Type 2 Giant barred frog	Type 3 Green-thighed frog	Type 4 Flying-fox
Grey-headed flying-fox	2	1		
Black flying-fox	1			1
Pteropus spp.	3			

The average number of flying-foxes killed per week was calculated by summing the number of individuals recorded in weeks 2, 3 and 4 of each sample period and dividing by three. Data from week one of each sample period were excluded as they are not representative of a week-long sample period. The total of 33 flying-fox records in 2019 was reduced to 22 records by excluding week one data. Weekly averages correspond to total counts and show a peak of 5.33 individuals in summer, low mortality in autumn and winter, and increasing mortality in spring. The “All flying-fox” value includes black flying-fox, grey-headed flying-fox and *Pteropus* spp. At least some of the *Pteropus* spp. could be grey-headed flying-fox.

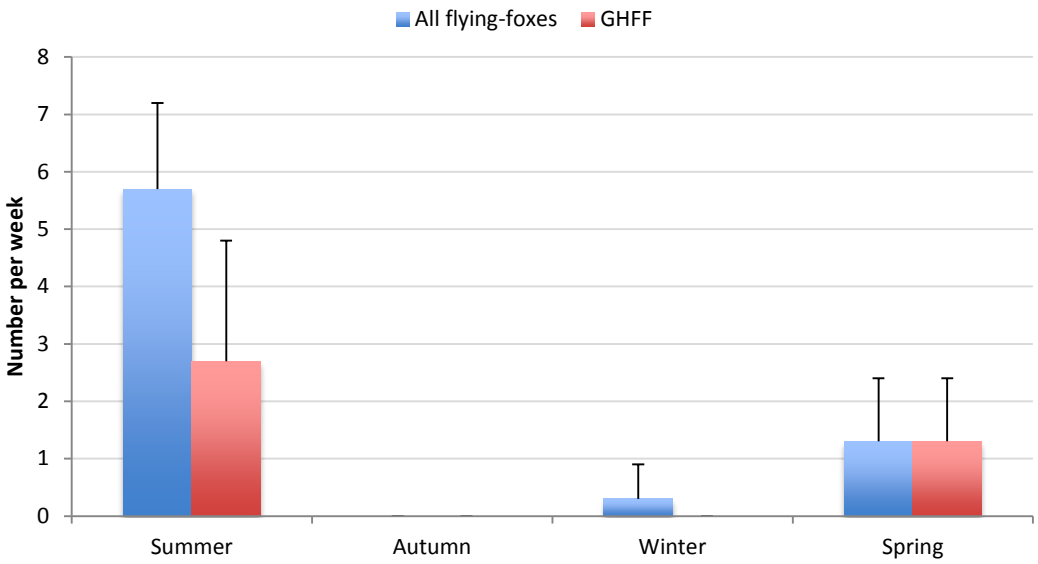

Figure 12: Average (+SD) weekly number of flying-foxes recorded during road-kill surveys on the Wc2NH upgrade in summer, autumn, winter and spring 2019. n = 3 for each season.

4. Discussion

4.1 October 2018

Road-kill monitoring over the entire WC2NH alignment in October 2019 indicates that a substantial number of fauna continue to be killed by vehicles 15 months after the entire alignment was opened to traffic. Road-kill abundance increased substantially from 33 individuals in winter to 53 individuals in spring (October). Species richness increased from 14 to 17 over the same period. As for previous samples the number of road-kill peaked in week one due to the accumulation of kills between samples. This trend is likely to occur in all 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. Any calculation of road-kills/week should exclude week one of each sample period. Despite the peak in week one there was noticeable variation in abundance between weeks 2, 3 and 4. Similar variation was evident in autumn 2019 and spring 2018 (Sandpiper Ecological 2018; 2019b). Such variation may be due to subtle changes in environmental conditions that cause changes in animal behaviour and habitat use.

Monitoring identified a distinct clustering of road-kill consistent with previous samples (see Sandpiper Ecological 2019a, b, c). Areas around the Nambucca River, Gumma Floodplain, and southern extent to Rosewood Road had a high incidence of road-kill in spring 2019. Of particular note in spring 2019 was five grey-headed flying-fox, six bandicoots, five medium mammals and three red-necked wallabies. The absence of amphibians is attributed to dry conditions, which were unsuitable for dispersal.

4.2 Seasonal and temporal variation

Monitoring in 2019 confirmed the seasonal effect identified in 2018 (see Sandpiper Ecological 2018). Road-kill abundance peaked in spring and summer and decreased from autumn to winter. This trend

is likely due to seasonal changes in food availability and reproductive demands. There have been some notable increases and decreases in abundance of some species between 2018 and 2019. Notable decreases were recorded for:

- Eastern barn owl
- Australian magpie
- Australian wood duck
- Freshwater turtles
- Amphibians

These decreases are attributed to a combination of drought (eastern barn owl, amphibians, freshwater turtles), changes in habitat within the road corridor (Australian wood duck, freshwater turtles), and possibly reduced population size (Australian magpie). The substantial decrease in abundance of introduced species between 2018 and 2019 (see Table 5) is attributed to habituation to the highway, and reduced population size of some species. Introduced species are often the first group to regularly utilise underpasses (Sandpiper Ecological 2015).

Species/groups displaying notable increases in abundance in 2019 include:

- Flying-foxes
- Macropods
- Bandicoots

The abundance of road-killed flying-foxes increased from three in 2018 to 33 in 2019. Both black and grey-headed flying-foxes were identified, with 1/3rd of all individuals identified as *Pteropus* spp. Flying-fox road-kill is discussed further in Section 4.4.

Drought has likely contributed to the high incidence of macropod road-kill in 2019 when 27 individuals were recorded. At least some of the 17 medium and large mammals recorded in 2019 would also have been macropods. During droughts macropods are attracted to the road verge to forage and road-kill tends to increase (Klocker *et al.* 2006). Macropod road-kill may decrease once drought conditions ease. Continued road-kill at present rates is likely to reduce the abundance of wallabies in habitat adjoining the road (Huijser & Bergers 2000). 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.

Sites with notable decreases in the frequency of road-kill in 2019 were:

- Gumma Floodplain – total number decreased by 40% primarily due to lower number of turtles.
- Nambucca River to Mattick Road – total number decreased by 50% primarily due to lower numbers of wood duck and galah.

Sandpiper Ecological (2018) suggested that the occurrence of birds in road-kill might reduce overtime as individuals habituate to the highway. Whilst there was a 30% reduction in the number of road-killed birds in 2019 tawny frogmouth, eastern barn owl, Australian wood duck, and laughing kookaburra continue to be struck regularly. The highway is likely to represent a population sink for

resident territorial species such as frogmouths, owls, and kookaburras, and overtime may affect populations of some species (Loss *et al.* 2014).

4.3 Fenced vs unfenced

Analysis of roadkill data identified contradictory results. The G-test identified a statistically significant difference ($P<0.05$) yet the Kruskal-Wallis test did not record a significant difference ($P=0.132$). The data suggest an obvious difference with twice the number of road-kills recorded in unfenced or single fence sections, and the disparity 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. This result differs to 2018 when no significant difference between fenced and unfenced was recorded.

The difference is attributed to greater numbers of macropods and bandicoots killed in unfenced sections, and lower numbers of turtles killed in fenced sections in 2019. Sandpiper Ecological (2018b) 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 results support this observation, although it will not be confirmed until the condition of wetlands on the Gumma floodplain improves following rain.

Reasons for the high incidence of macropod and bandicoot road-kill were discussed in the previous section, and mortality of both groups is likely to decrease once the drought eases. Continuation of mortality at 2019 rates is likely to have a detrimental impact on the local populations of both groups.

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 section shows that the exclusion fence is having a positive effect on road-kill frequency in that area.

At this stage of monitoring no modifications to exclusion fence design or extent is recommended. Due to the influence of drought on road-kill further monitoring is recommended to confirm the presence of hotspots and the overall frequency of road-kill within the WC2NH alignment.

A visual analysis of the data suggests 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 2019e).

4.4 Threatened fauna

Three threatened species were recorded during road-kill surveys in 2019, grey-headed flying fox (13 individuals), black bittern (1 individual) and masked owl (1 individual), which brings the total number of threatened species recorded to four. 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 large bridges. Mortality of flying-foxes on the WC2NH upgrade in 2019 is attributed to both

situations. Numerous flying-foxes were struck at the Nambucca and Warrell Creek Bridges, with small numbers recorded elsewhere on the alignment.

There was a distinct seasonal pattern to flying-fox road-kill with numbers peaking in summer and decreasing substantially in winter, which is consistent with breeding and dispersal. A large number of dead flying-foxes, including grey-headed, were recorded along the Pacific Highway in late winter/spring 2019 (D. Rohweder pers obs). This was attributed to drought conditions forcing individuals to forage in medians and along roadsides. Low food abundance may have also affected the agility and strength of flying foxes making them more vulnerable to being struck by vehicles. The incidence of flying-fox road-kill in areas with low shrubs highlights an important issue regarding the type of plants used to landscape highway upgrades.

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 contribute to mortality during times of heat and food stress.

The number of grey-headed flying-foxes recorded during road-kill surveys in 2019 is concerning. Whilst the unseasonal dry weather has contributed to mortality across northern NSW the strikes at the Nambucca River Bridge could be related to barrier effect rather than food and is therefore unlikely to be ameliorated by a change in weather. It appears that flying-foxes moving along the river are not gaining sufficient elevation to pass safely over the bridge. It is uncertain if this is due to reduced flying ability associated with food stress or unfamiliarity with the bridge. It is possible that flying-foxes will fly higher over the bridge once they habituate to its presence. There is no easy solution to road strike at highway bridges and continued road-kill monitoring is required before actions are implemented.

5. Conclusion and recommendations

The 2019 road-kill monitoring program for the WC2NH upgrade has identified a distinct seasonal trend in road-kill frequency with numbers peaking in spring/summer and declining in autumn and winter. Drought conditions in NSW have undoubtedly affected road-kill rates with notable increases in the number of macropods and flying-foxes recorded. Whilst mortality rates for these groups are of concern further monitoring is required to confirm if rates will remain high. Whilst mortality rates for some species increased in 2019 there was notable declines in Australian wood duck and freshwater turtles, a result attributed to changing habitat inside the highway corridor. The high rate of mortality at the Nambucca River Bridge, including several flying-foxes, will require careful assessment in future monitoring. Importantly, no spotted-tailed quoll, koala, or giant barred frog was recorded as road-kill during the 2019 sample period. Whilst 13 grey-headed flying-foxes were confirmed no individuals were recorded near the former camp, or inside the flying-fox exclusion fence. The following recommendations are proposed:

1. Continue seasonal roadkill surveys during year three (2020) of the operational phase using the same methods applied in year one and two.
2. Maintain vegetation on road verges to reduce suitability for macropods.
3. Avoid planting fruit and blossom producing plants and dense vegetation around highways.
4. Examine flying-fox road-kill following the summer (January) 2020 sample.
5. Explore correlations between drop-downs and the distribution of target species in the year three annual report.

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Appendix A – Field Survey Data

Table A1: October 2019 road-kill results. NB = northbound; SB = southbound; C'way = carriageway.

Date	Observers	Start time	End time	C'way	Species	Sex & age class	Presence of pouch or back young	General location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to x-ing structure	Proxmity to drop-down
2/10/19	NP & NM	920	1125	SB	Common Ringtail Possum	Unknown		Adjacent poplar trail	495776	6607732	No	Present	Good	50m	
2/10/19	NP & NM	920	1125	SB	Short-beaked Echidna	Adult		530m Sth Mattick Rd	494430	6604265	Yes	Absent	NA	2.30km	615m
2/10/19	NP & NM	920	1125	SB	Wood duck	Adult		570m Sth Mattick Rd	494426	6604201	Yes	Absent	NA	NA	NA
2/10/19	NP & NM	920	1125	SB	Small bird	Adult		580m Sth Mattick Rd	494424	6604167	No	Absent	NA	NA	NA
2/10/19	NP & NM	920	1125	SB	**Grey headed flying-fox**	Adult		10m Nth Nambucca Bridge	494200	6603232	No	Absent	NA	NA	NA
2/10/19	NP & NM	920	1125	SB	Large mammal	Unknown		750m Sth NB	493413	6601895	No	Present	Good	0.41km	340m
2/10/19	NP & NM	920	1125	SB	Medium mammal	Unknown		1m before floodplain Bridge 2	493288	6601521	No	Present	Good	0	70m
2/10/19	NP & NM	920	1125	SB	Northern brown bandicoot	Adult		25m Nth Bald Hill Rd	492503	6600086	No	Absent	NA	0.88km	365m
2/10/19	NP & NM	920	1125	SB	Rainbow lorikeet	Adult		240 Sth Bald Hill Rd	492468	6599801	Yes	Absent	NA	NA	NA
2/10/19	NP & NM	920	1125	SB	Medium mammal	Unknown		Scott's Head Rd overbridge	491934	6598434	Yes	Absent	NA	0.58km	370m
2/10/19	NP & NM	920	1125	SB	Purple swamphen	Adult		415 Nth Rosewood Rd	490884	6596960	Yes	Present	Good	NA	NA
2/10/19	NP & NM	920	1125	SB	Bandicoot spp	Unknown		Rosewood Rd	490843	6596539	No	Absent	NA	0.32km	1100m
2/10/19	NP & NM	920	1125	SB	Australian Magpie	Adult		490 Sth Rosewood Rd	490744	6596152	Yes	Absent	NA	NA	NA
2/10/19	NP & NM	920	1125	SB	Short-beaked echidna	Adult		700 Sth Rosewood Rd	490565	6595857	No	Absent	NA	1.07km	320m
2/10/19	NP & NM	920	1125	NB	Tawny frogmouth (prob)	Unknown		Railway bridge	489437	6594423	No	Present	Good	NA	NA
2/10/19	NP & NM	920	1125	NB	Medium mammal	Unknown		50 Sth Cockburns	489520	6594510	No	Present	Good	0.37km	59m
2/10/19	NP & NM	920	1125	NB	Bandicoot spp	Adult		900 Nth Cockburns Bridge	490021	6595206	No	Present	Good	1.25km	192m
2/10/19	NP & NM	920	1125	NB	Red-necked wallaby	Adult		720 Sth Rosewood Rd	491934	6598434	No	Absent	NA	0.55km	357m
2/10/19	NP & NM	920	1125	NB	Bandicoot spp	Adult		360 Sth Albert Dv	490845	6596982	Yes	Absent	NA	0.13km	1520m
2/10/19	NP & NM	920	1125	NB	Red-necked wallaby	Unknown		50 Sth Bald Hill Rd on offramp	492415	6599915	No	Absent	NA	0.91km	547m

Date	Observers	Start time	End time	C'way	Species	Sex & age class	Presence of pouch or back young	General location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to x-ing structure	Proxmity to drop-down
2/10/19	NP & NM	920	1125	NB	Green tree snake	Adult		Floodplain Bridge 2	493281	6601568	Yes	Present	Good	0.05km	40m
2/10/19	NP & NM	920	1125	NB	Snake spp	Adult		Floodplain Bridge 2	493283	6601573	No	Present	Good	0.05km	40m
2/10/19	NP & NM	920	1125	NB	Laughing kookaburra	Adult		Mattick Rd	494426	6604641	No	Present	Good	NA	NA
2/10/19	NP & NM	920	1125	NB	Bandicoot spp	Unknown		2km n Mattick Rd	495111	6606623	No	Present	Good	0.13km	104m
2/10/19	NP & NM	920	1125	NB	Tawny frogmouth	Adult		Next to C7	496463	6608773	No	Adjacent	NA	NA	NA
9/10/19	NP & NM	900	1100	SB	Laughing kookaburra	Adult		600M s C5/6	495506	6607253	No	Present	Good	NA	NA
9/10/19	NP & NM	900	1100	SB	Medium bird	Adult		100M N Mattick Rd	494481	6604960	No	Present	Good	NA	NA
9/10/19	NP & NM	900	1100	Sb	Medium mammal	Adult		200 m N S old coast	494419	6603712	No	Present	Good	1.10km	1200m
9/10/19	NP & NM	900	1100	Sb	Small bird	Adult		N Bald Hill road 500	492671	6600443	No	Present	Good	NA	NA
9/10/19	NP & NM	900	1100	NB	**Grey-headed flying-fox**	Adult		On Warrell Creek Bridge	488950	6594009	No	Present	Good	NA	NA
9/10/19	NP & NM	900	1100	NB	Northern brown bandicoot	Adult		50 m s Cockburns Bridge	489557	6594560	No	Present	Good	0.40km	40m
9/10/19	NP & NM	900	1100	Nb	Carpet Python	Adult		770 South Rosewood	490390	6595707	No	Absent	NA	1.00km	98m
9/10/19	NP & NM	900	1100	NB	Australian magpie	Adult		600M S Rosewood Rd	490657	6596053	Yes	Absent	NA	1.43km	540m
9/10/19	NP & NM	900	1100	NB	Barn Owl	Adult		600M S Rosewood Rd	490655	6596053	Yes	Absent	NA	NA	NA
9/10/19	NP & NM	900	1100	NB	**Grey-headed flying-fox**	Adult		150 m S south old coast road	494272	6603352	No	Absent	NA	NA	NA
9/10/19	NP & NM	900	1100	NB	Reptile sp	Adult		150 m S south old coast road	494262	6603340	No	Absent	NA	0.72km	1540m
9/10/19	NP & NM	900	1100	NB	Laughing kookaburra	Adult		500 m north of south old coast road	494383	6604042	Yes	Present	Good	NA	NA
9/10/19	NP & NM	900	1100	NB	Tawny Frogmouth	Adult		700m south of north old coast road	497023	6609971	No	Present	Good	NA	NA
16/10/19	NP&NM	920	1010	SB	Turtle spp	Adult		200m S Nambucca flood plain bridge 2	493191	6601286	Yes	Present	Good	0.20km	106m
16/10/19	NP&NM	920	1010	SB	Purple swamphen	Adult		300m N Rosewood Rd	490861	6596858	No	Absent	NA	NA	NA
16/10/19	NP&NM	920	1010	NB	Tawny Frogmouth	Adult		235m S south old coast Rd	494196	6603258	Yes	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	SB	Medium mammal	Unknown		250M S culvert 3	495015	6606383	No	Present	Good	0.11km	260m
22/10/19	NP&NM	800	915	SB	Black-faced cuckoo-shrike	Adult		300M N Mattick Rd	494488	6605139	Yes	Present	Good	NA	NA
22/10/19	NP&NM	800	915	SB	Galah	Adult		140M s Mattick Rd	494466	6604609	Yes	Absent	NA	NA	NA

Date	Observers	Start time	End time	C'way	Species	Sex & age class	Presence of pouch or back young	General location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to x-ing structure	Proxmity to drop-down
22/10/19	NP&NM	800	915	SB	Galah	Adult		140M s Mattick Rd	494461	6604607	Yes	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	SB	Galah	Adult		160m s Mattick Rd	494463	6604574	No	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	SB	**Grey-headed flying-fox**	Male Adult		South end Nambucca bridge	493628	6602406	No	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	SB	Welcome swallow	Juvenile		30M S Nambucca Bridge	493614	6602362	Yes	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	SB	Medium bird	Unknown		South end Nambucca bridge	493638	6602404	Yes	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	NB	**Grey-headed flying-fox**	Adult		150M s upper Warrell Crk Bridge	488796	6593928	No	One side	Good	NA	NA
22/10/19	NP&NM	800	915	NB	Barn Owl	Adult		1050M s Rosewood Rd	490330	6595609	Yes	One side	Good	NA	NA
22/10/19	NP&NM	800	915	NB	Wood duck (prob)	Adult		480M s Rosewood Rd	490661	6596072	Yes	One side	Good	NA	NA
22/10/19	NP&NM	800	915	NB	Red-necked wallaby	Adult		190M N Bald Hill Rd	492512	6600218	No	Absent	Good	250m	100m

Table A2: Grey-headed flying-fox road-kill data collected in October 2019. Proximity to camp was measured from the Nambucca Heads camp to road-kill location.

Date	Observers	Carriageway	Sex & age class	General location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to crossing structure	Proximity to drop-down	If Flying Fox, proximity to camp; proximity to canopy veg, proximity to food
2/10/19	NP & NM	SB	Adult	10m Nth Nambucca Bridge	494200	6603232	No	Absent	NA	NA	NA	9.1km; 170m
9/10/19	NP & NM	NB	Adult	On Warrell Creek Bridge	488950	6594009	No	Present	Good	NA	NA	19.6km; 400m
9/10/19	NP & NM	NB	Adult	150 m S south old coast road	494272	6603352	No	Absent	NA	NA	NA	8.99km; 175m
22/10/19	NP&NM	SB	Male Adult	South end Nambucca bridge	493628	6602406	No	Absent	NA	NA	NA	10.13km; 490m
22/10/19	NP&NM	NB	Adult	150M s upper Warrell Ck Bridge	488796	6593928	No	One side	Good	NA	NA	19.79km; 105m

Appendix 3 Summer (January) 2020 monitoring.

Pacific Highway Upgrade Warrell Creek to Nambucca Heads

Operational phase road-kill monitoring – Summer 2020.

Sandpiper Ecological

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Final Report
19 February 2020

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Cover Photo: A northern brown bandicoot (*Isoodon macrourus*) road-killed on 30 January 2020.

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1. Introduction

1.1 Background

In 2015, Roads and Maritime Services (Roads and Maritime), 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 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 Roads and Maritime 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 (*Phascolarctus cinereus*), spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) 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. The

results of monitoring in 2018 and 2019 were analysed and discussed by Sandpiper Ecological (2018, 2019). The following report covers the January (summer) 2020 monitoring event and includes the entire WC2NH alignment. 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 the presence fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

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).

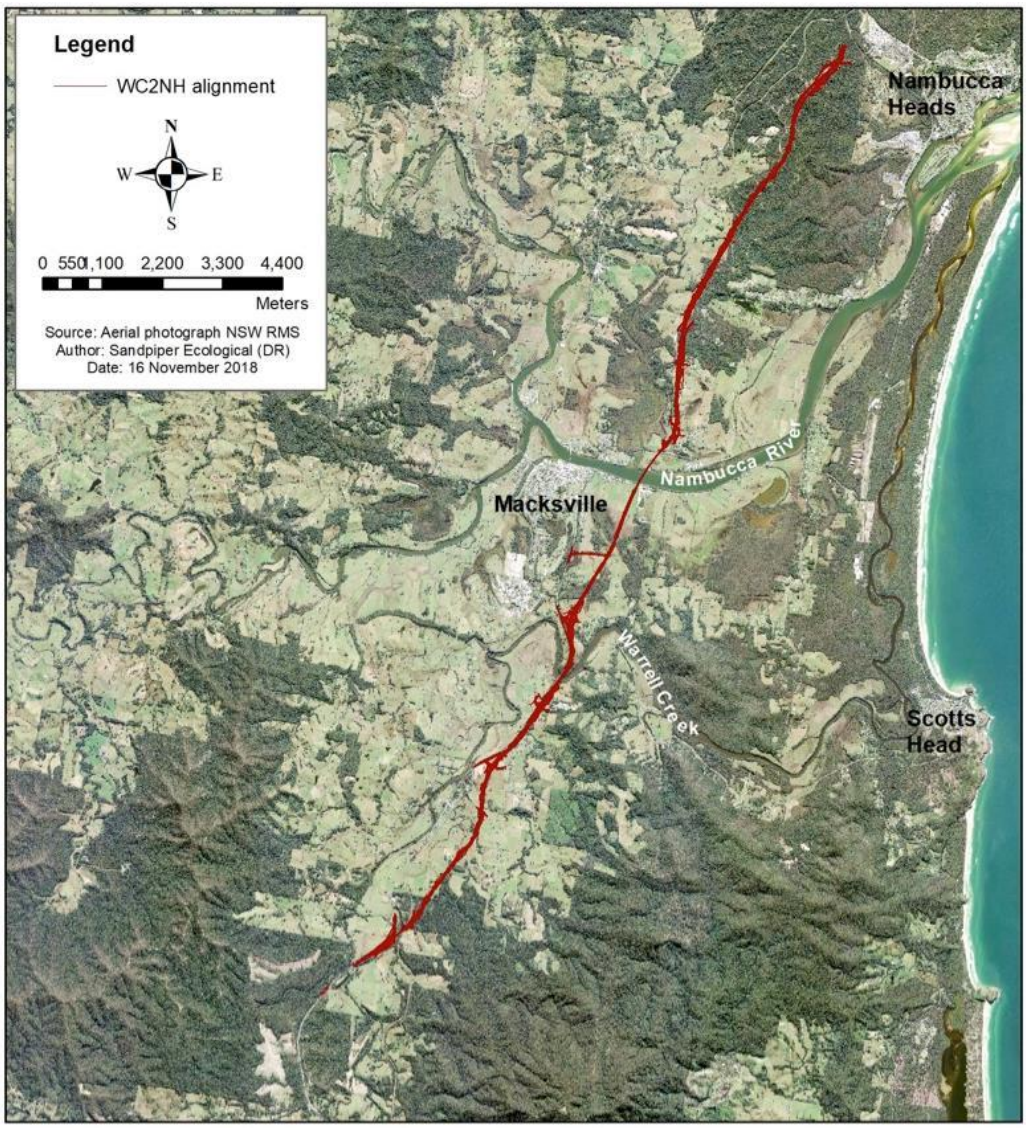

Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Road-kill surveys

Road-kill surveys were conducted by a two-person team from a vehicle driven at 80km/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, both the driver and ecologist 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.

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 *Environment Protection and Biodiversity Conservation Act* (EPBC) *1999* and/or the *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.

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 uploaded to an iPad in the field.

2.2 Data summary and analysis

Data from the January 2020 survey were uploaded to Microsoft Excel. The January data were compared with results from October 2019 to identify duplicate records. Graphs have been produced showing the total number of road-kills in January and the number of road-kills in different fauna groups each week of the survey. The location of January road-kills has been overlaid on the WC2NH alignment to show their distribution. The January 2020 data are compared to the number of road-kills recorded in summer, autumn, winter and spring 2018 and 2019 (Sandpiper Ecological 2018 and 2019; Table 2).

3. Results

3.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses (Table 1). No rain was recorded during survey days.

Table 1: Weather conditions in the 24hrs preceding each sample event. Data obtained from Environdata weather station at the southern compound.

Date	Average Relative Humidity (%)	Total Rainfall (mm)	Average Temperature (^{0}C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
7/1/20	74.1	0	26	4.2	Good	Nil
13/1/20	75.2	0.2	20.2	6.1	Good	Nil
21/1/20	73.5	0	26.7	5.1	Good	Nil
29/1/20	NA	0	NA	NA	Good	Nil

3.2 Species richness and abundance

A total of 36 road-killed fauna were recorded during the January 2020 sample period. This included 11 native species and five fauna groups (Table A1, Appendix A). Birds were the most diverse group represented with six species and one group recorded. Three species of mammal and four groups, and one species of reptile were recorded.

Red-necked wallaby (*Macropus rufogriseus*) was the most frequently detected species with seven records, and medium bird was the most frequently detected group of fauna with six records (Table 2). Degradation of carcasses made identification to species level difficult in some cases. Grey-headed flying-fox was detected twice on the Nambucca River Bridge on 22 and 30 January 2020. The *Pteropus* spp. detected on the Nambucca Bridge on 14 January may have also been a grey-headed flying-fox. Of the 36 road-kill records, 15 (42%) were individuals expected to be blocked by exclusion fence. The remaining 21 records, including birds, flying-foxes and common blue-tongued skink, are species that readily move through or over exclusion fencing.

Plate 2: A road-killed pheasant coucal (*Centropus phasianinus*) (L) and a northern brown bandicoot (*Isoodon macrourus*) (R), both recorded on the 31 January 2020.

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.

Species	Sum 17/18 **	Aut 2018 **	Win 2018 **	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Sum 2020	Total
Birds										
Australian magpie	6	1		1				2	2	12
Grey butcherbird			1							1
Magpie-lark	2		1		1		1		1	6
Australian white ibis			1						1	2
Cattle egret				1						1
Little pied cormorant					1					1
Buff-banded rail					1					1
Purple swamphen	3		2	2		1		2	3	13
Crested pigeon	2									2
Galah	7				1			3		11
Rainbow lorikeet								1		1
Eastern grass owl*				1						1
Australian boobook			1	1			1			3
Masked owl*	1				1		1			3
Eastern barn owl			11	3		1	5	2	1	23
Tawny frogmouth	1	3	1	2		6		4		17
Australian owlet-nightjar					1					1
Laughing kookaburra	3		2	1		2		3	1	12
Forest kingfisher	1									1
Australian wood duck	20			2	2		1	2		27
Pacific black duck	2		1							3
Whistling kite				1						1
Black-shouldered kite					1	1				2
Torresian crow					1					1

Species	Sum 17/18 **	Aut 2018 **	Win 2018 **	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Sum 2020	Total
Pied currawong				1						1
Black-faced cuckoo-shrike								1		1
Dollarbird					2					1
Green catbird					1					1
Black bittern*						1				1
Eastern yellow robin						1				1
Pheasant coucal							1		1	2
Masked lapwing							1			1
Welcome swallow								1		1
Duck spp.						1				1
Small bird								2		2
Medium bird				1	2	2	2	2	6	15
Unidentifiable bird	5	4	1		3					13
Total birds	53	8	22	17	18	16	13	25	16	188
Mammals										
Short-beaked echidna				3				2		5
Black flying-fox	2	1			7	1	1			11
Grey-headed flying-fox*					8			5	2	15
Pteropus spp.					3	8	1		1	13
Common brushtail possum			1	2						3
Trichosurus spp.									1	1
Common ringtail possum					1			1		2
Eastern grey kangaroo				3			1			4
Red-necked wallaby			6		8	2	8	3	7	35
Swamp wallaby	2	1		1		1	1			6
Wallaby spp.						2			3	5
Macropod spp.	3		2	1	1					7
Northern brown bandicoot	1		1		1	1	1	2	2	9
Bandicoot spp.						1		4		5
Chalinolobus spp. (microbat)				1						1
Microbat spp.					1					1
Rodent spp.						2				2
Small mammal					2					2
Medium mammal				2	4	2	4	5	2	19
Large mammal				1	1			1		3
Unidentified Mammal	1			3						4
Total mammals	10	2	10	17	36	20	17	23	18	153
Reptiles										
Common blue-tongued	1			2	1				2	6

Species	Sum 17/18 **	Aut 2018 **	Win 2018 **	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Sum 2020	Total
skink										
Carpet python	1			2	1	1		1		6
Common tree snake	1	2						1		4
Eastern long-neck turtle	1			6						7
Macquarie river turtle	5	1					1			7
Unidentified *Chelidae* spp.	6							1		7
Red-bellied black snake	1									1
Eastern water dragon	1			1						2
Blackish blind snake						1				1
Yellow-faced whipsnake				1						1
Unidentified reptile								2		2
Total reptiles	17	3	0	12	2	2	1	5	2	44
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	9
Introduced species										
Cat	1									1
European fox	3	1	1	2	1	1	2			11
European hare	2			1						3
Rabbit	1									1
Black rat	1					1				2
House mouse					1					1
Rock pigeon			1	1						2
Domestic goose				1						1
Total introduced species	8	1	2	5	2	2	2	0	0	22
Total	93	14	34	55	57	40	33	53	36	415

The number of road-kill recorded each week varied during the sample period. A trend of decreasing road-kill abundance was recorded over the first three sample weeks, with road-kill abundance increasing in week four (Figure 2).

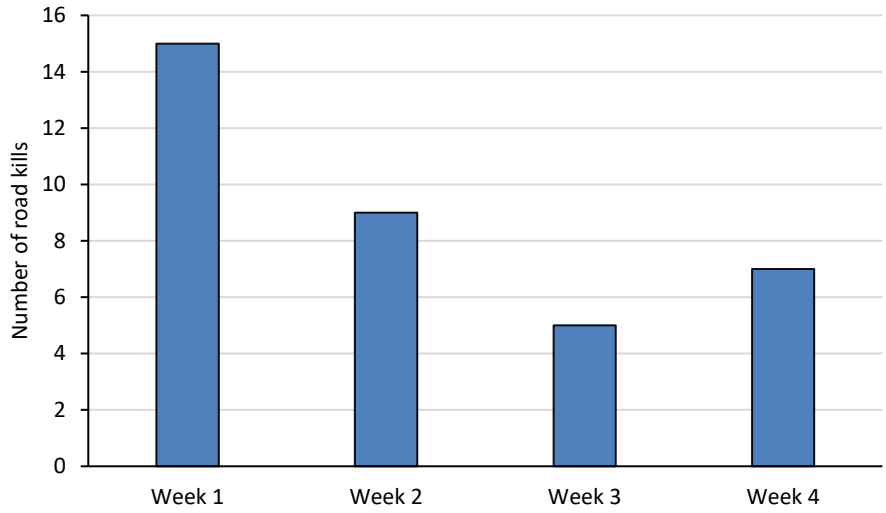

Figure 2: Number of road-kills recorded in each sample week during the January 2020 (summer) sample period.

The abundance of road-killed fauna in the four vertebrate groups also varied during the sample period (Figure 3). The number of road-killed mammals went from nine in week one to six in week two, and three in week three and four. The number of road-killed birds decreased from five in week one to three in week two and one in week three, and then increased to four in week four. Reptiles were represented by single specimens in weeks one and three. No amphibians were detected during January 2020 monitoring.

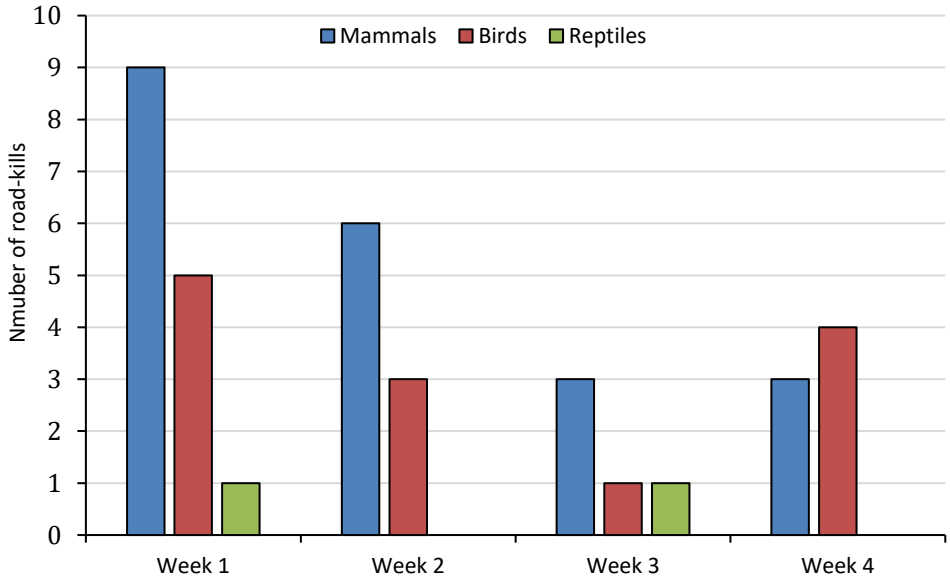

Figure 3: Number of road-killed fauna from three vertebrate classes during each sample week in January 2020.

The number of road-kill flying-foxes have 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. Total number of flying-fox road-kill then decreased to nine in autumn 2019 and two in winter 2019, increasing to five in spring 2019 and decreasing to three in summer 2020.

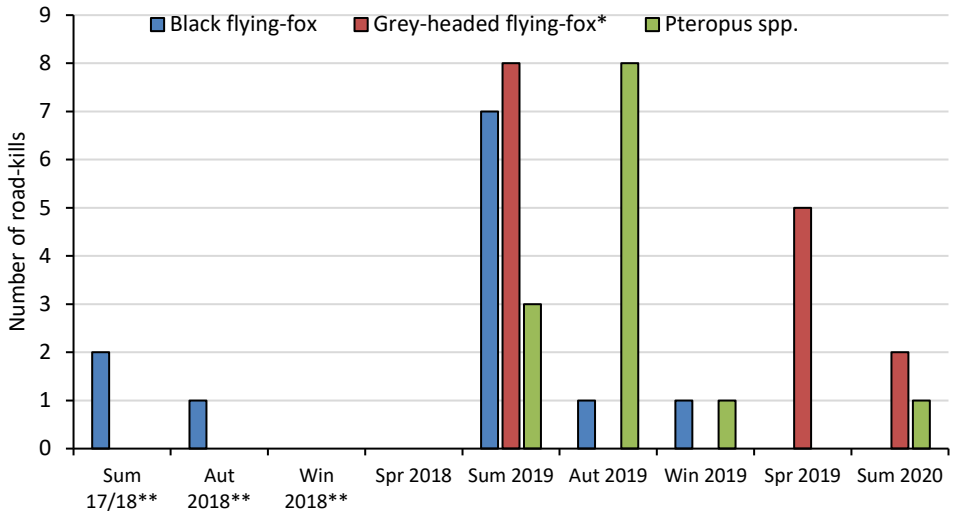

Figure 4: Number of road-killed flying-foxes from all sample periods. * denotes threatened species. **Stage 2a only.

3.1.3 Opportunistic road-kill information

No opportunistic road-kill was recorded within the sample month (January).

3.1.4 Distribution of road-kill

In January 2020, road-killed fauna was recorded over the entire WC2NH alignment (Figures 5-7), although the majority of records (94%) were situated between Mattick Road and the southern end of the project. Within that area, 85% occurred between Mattick Road and Albert Drive (Figures 6-7), and the remaining 15% between the southern end and Albert Drive. The section between the Nambucca River and the southern end of the project traverses predominantly cleared land with three drainage lines and minimal fauna exclusion fence. Two animals (6%) were recorded in the section north of Mattick Road. This section is entirely fenced with floppy top exclusion fence and in places, frog exclusion fence.

In January 2020, 12 road-kills were recorded in areas with exclusion fence, and 24 were recorded in areas without exclusion fence (Figures 5-7). Records were classified as occurring within a fenced area if fence occurred adjacent to the record regardless of whether the record was near the start/end of a fenced section. Two records (17%) (one northern brown bandicoot and one wallaby spp.) in sections with fence were species that would be expected to be blocked by the fence (i.e. medium and large mammals). In contrast, 13 (54%) records in sections without fence were of species that would be expected to be have been blocked by an exclusion fence.

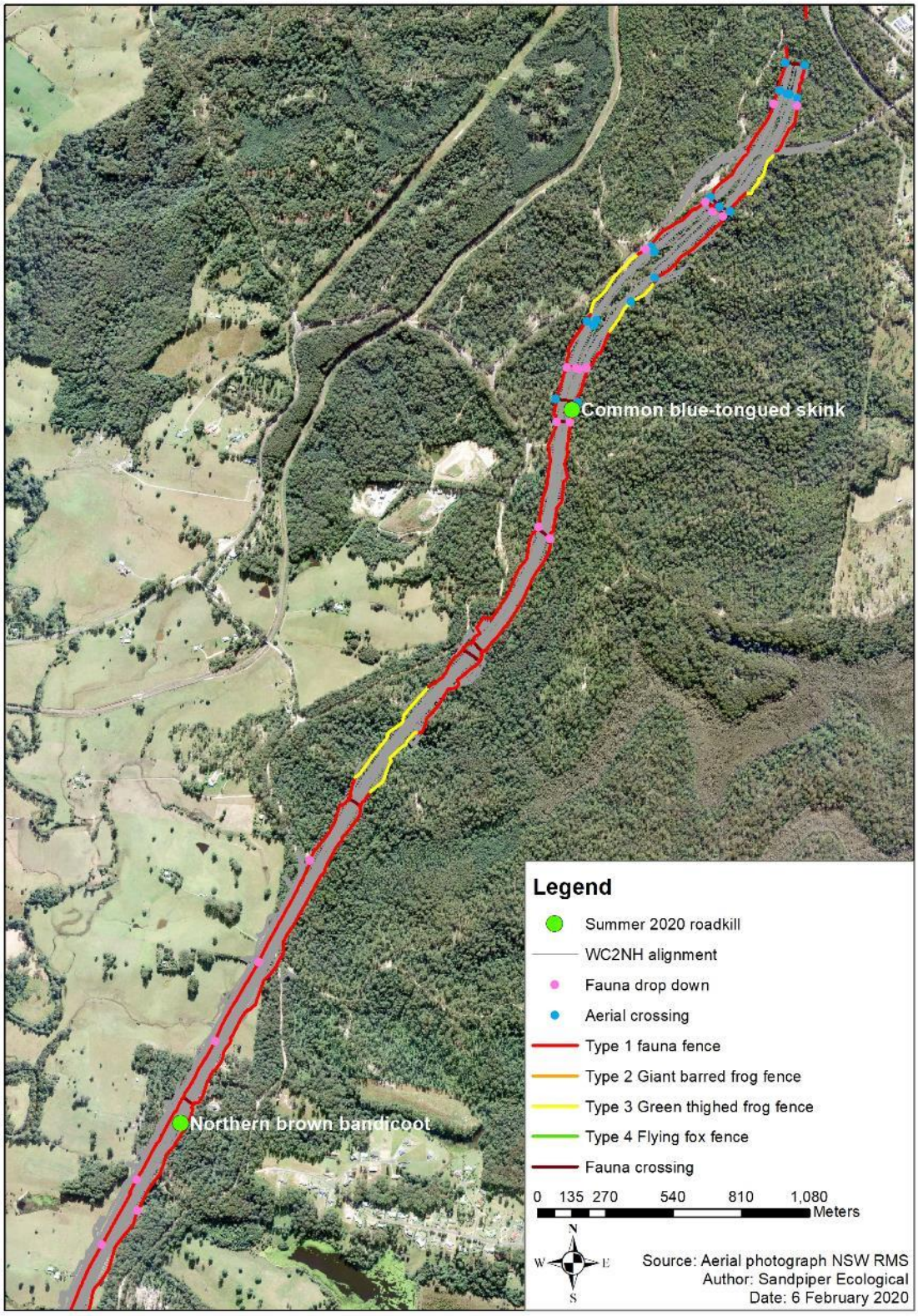

Figure 5: Location of road-killed fauna from January 2020 sample.

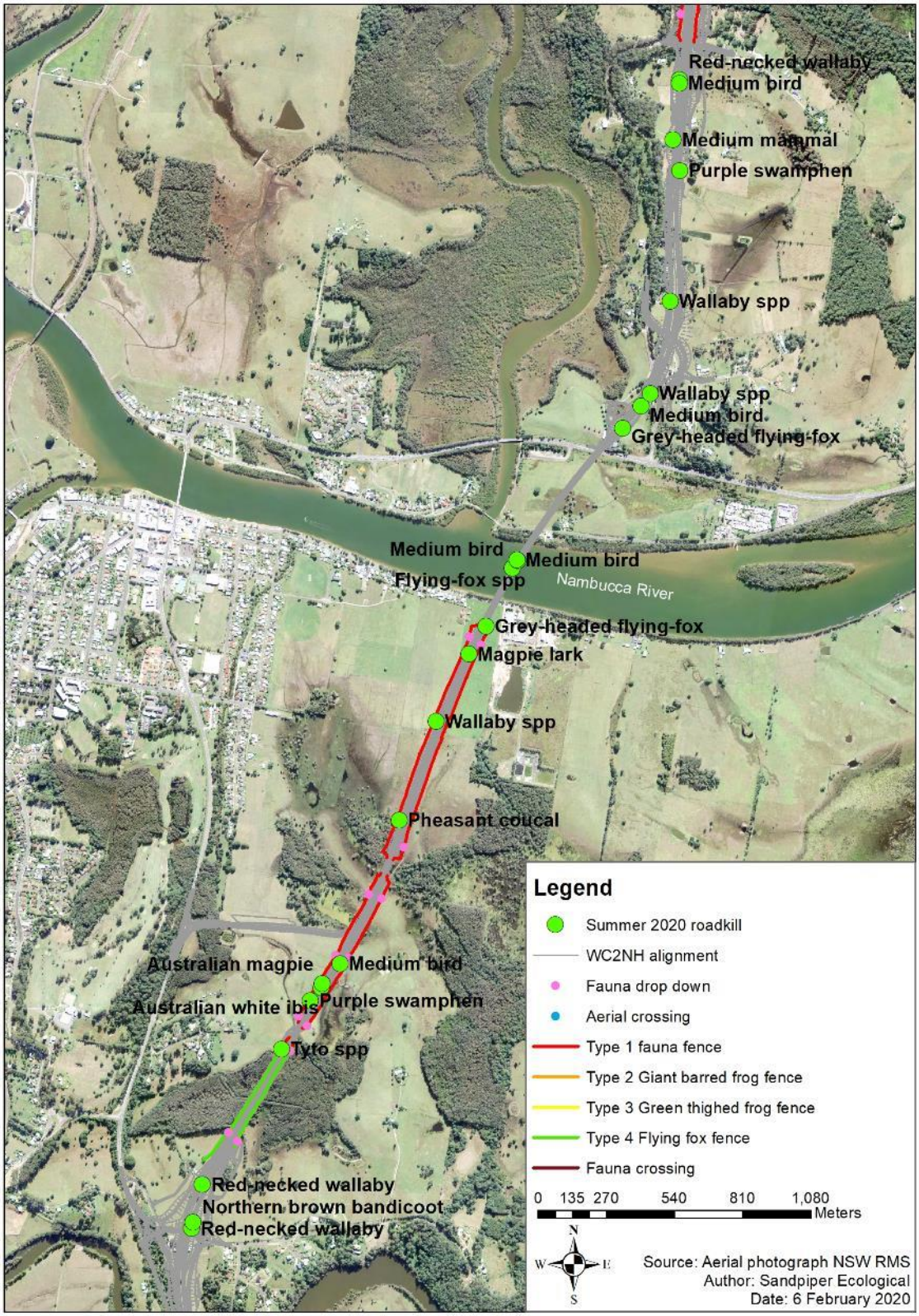

Figure 6: Location of road-killed fauna from January 2020 sample.

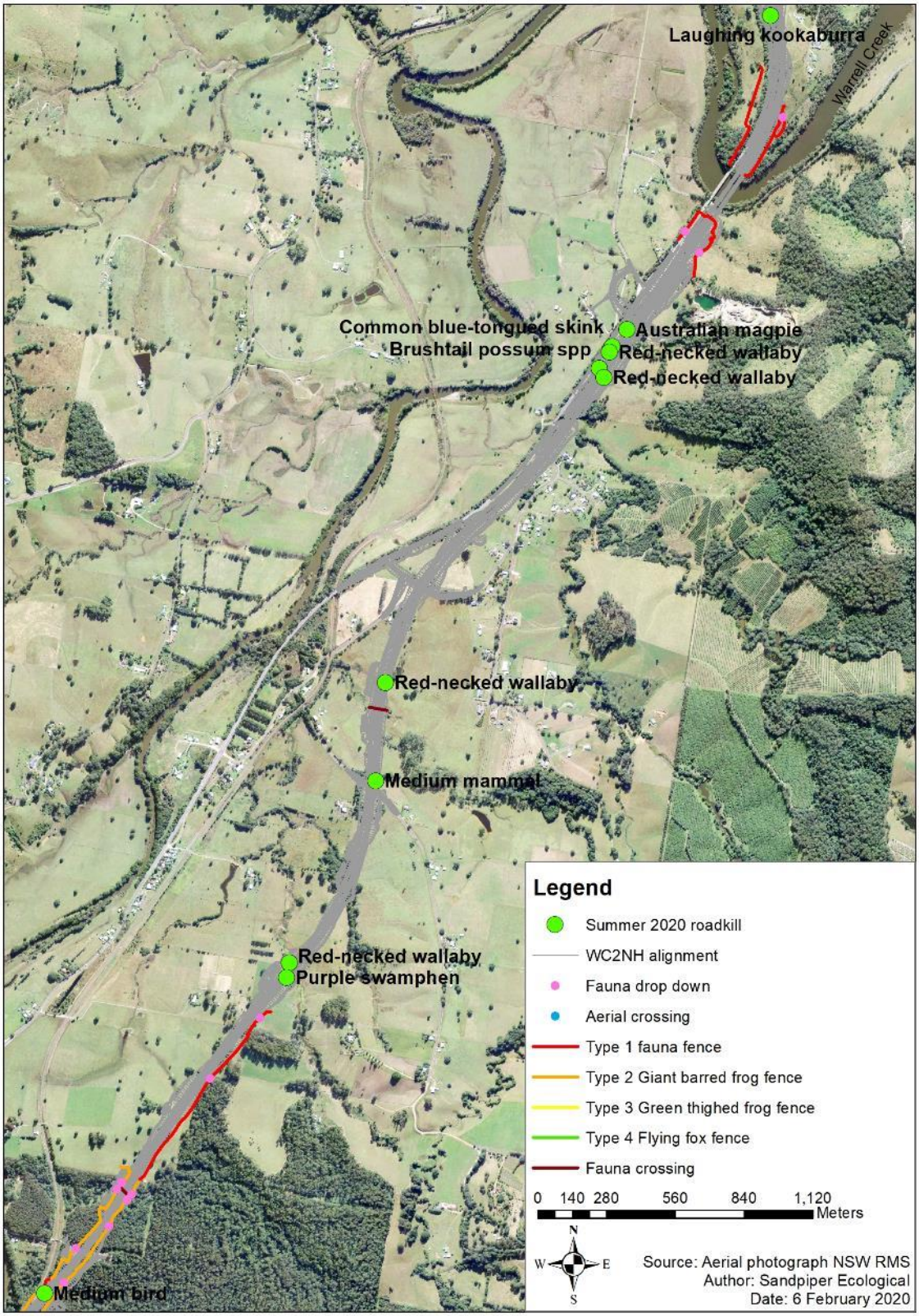

Figure 7: Location of road-killed fauna from January 2020 sample.

4. Discussion

4.1 Summer 2020

Road-kill monitoring over the entire WC2NH alignment in summer 2020 indicates that fauna continue to be killed by vehicles 18 months after the entire alignment was open to traffic. However, with a total of 36 animals killed, summer 2020 monitoring recorded a decrease of 18 individuals when compared to spring 2019, and a decrease of 21 when compared to summer 2019. These results are interesting given that monitoring in 2018 and 2019 identified a seasonal effect where road-kill peaked in spring and summer and decreased in autumn and winter (Sandpiper Ecological 2018, 2019). This seasonal effect was attributed to an increase in traffic volumes during the summer holidays, and an increase in animal movement due to juvenile dispersal and breeding. The lower number of road-kills in summer 2020 is encouraging but may be due to drought conditions, which persisted for most of the January 2020 sample period.

Although total road-kill numbers were lower in summer 2020, the abundance of road-killed wallabies was equivalent to summer and winter 2019. The drought has likely contributed to this by attracting macropods to the road verge to forage. Wallaby road-kill hotspots occur within the vicinity of Bald Hill Road and Albert Drive. Sandpiper Ecological (2018; 2019) raised concerns about the effect of road-kill on the local red-necked wallaby population in the Albert Drive to upper Warrell Creek area, and continued road-kill may have a negative impact on the local red-necked wallaby population. Indeed, road-strike has resulted in population level impacts on several species, including medium sized mammals (see Fahrig & Rytwinski 2009; Huijser & Bergers 2000).

The higher number of road-kills recorded in the first week of all samples reflects the period over which kills could accumulate. This trend is likely to occur in all 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 2020 include Mattick Road to the Nambucca Bridge, the Gumma Floodplain (Albert Drive to Nambucca River bridge), and from the southern end to Albert Drive. The Gumma Floodplain and the southern end to Albert Drive have been identified as road-kill hotspots in previous years (Sandpiper Ecological 2018, 2019) and previous seasonal samples. Birds and mammals comprised the majority of road-kills in all surveys to date.

4.2 Flying-fox impacts

In summer 2020 all road-killed flying-foxes (i.e. two grey-headed flying-foxes and one *Pteropus* spp.) were recorded on or near the Nambucca River Bridge. Whilst the number of road-killed flying-foxes recorded in summer 2020 was substantially less than that recorded in summer 2019 (18 individuals) continued vehicle strike at the Nambucca River Bridge is concerning. Sandpiper Ecological (2019b) attributed the high incidence of flying-fox mortality at the Nambucca River Bridge to individuals moving along the river and not gaining sufficient elevation to pass safely over the bridge. It is uncertain if this is due to reduced flying ability associated with food stress or unfamiliarity with the bridge. The reduced incidence of road strike in summer 2020 may, in part, be due to lower breeding success of grey-headed flying-fox due to drought conditions. There is no easy solution to road strike at highway bridges and continued road-kill monitoring is required to fully understand the scale of impact.

4.2 Effectiveness of fauna fencing

Results obtained in summer 2020 are consistent with all previous seasonal samples, which show that road-kill rate of species expected to be blocked by the fence are lower in areas with exclusion fence than areas without exclusion fence. Importantly, no mortality of target threatened species (expected to be blocked by the fence) was recorded in summer 2020. Monitoring shows that where present exclusion fence is effective in mitigating road-strike for target species.

5. Recommendations

1. Continue seasonal road-kill surveys as per the project ecological monitoring brief.

6. References

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Appendix A – Field Survey Data

Table A1: January (Summer) 2020 roadkill results.

Date	Observers	Start time	End time	Carriageway	Species	Sex & age class	RK general location	Easting	Northing	Cleared off Rd	Fauna fence P/A & prox.	Prox. to xing structure	Prox. to drop-down	If FF: prox. to camp
8/01/2020	LA & SR	915	1115	SB	Red-necked wallaby	Adult	10 N Baldhill road	492496	6600065	N	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	Sb	Northern brown bandicoot	Adult	20M N bald hill road	492501	6600090	Partial	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	SB	Medium mammal	Unknown	50 m N rosewood road	490844	6596571	N	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Medium bird	Unknown	100M N lower Warrell crk bridge	489495	6594483	No	NA	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Red-necked wallaby	Adult	700m south of Rosewood R	490491	6595830	No	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Brushtail possum	Adult	250m sth of quarry access rd	491754	6598251	No	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Blue tongue	Adult	175 S f quarry access rd	491795	6598317	N	NA	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Red-necked wallaby	Adult	175 S f quarry access rd	491795	6598317	N	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Red-necked wallaby	Adult	200 m north of bald hill road	492539	6600239	Yes	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	White Ibis	Adult	500 m south Nambucca bridge	493011	6601018	Yes	NA	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Prob magpie	Adult	500M south Nambucca bridge	493014	6601036	No	NA	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Medium bird	Adult	On Nambucca bridge	493768	6602681	No	NA	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Wallaby spp	Adult	150 m Nth old coast	494393	6603740	No	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Red-necked wallaby	Adult	100m Nth Mattick Road	494430	6604603	No	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Medium bird	Adult	100m Nth Mattick Road	494430	6604603	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	SB	Purple swamp hen	Adult	500m s mattick rd	494431	6604258	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	SB	Med bird	Unknown	10m north nam bridge	494278	6603325	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	SB	Med bird skeleton	Unknown	200m n flood bridge 1	493085	6601114	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	SB	Red-necked wallaby	Unknown	450m n rosewood rd	490883	6596972	Yes	Absent	NA	NA	NA
14/1/20	NM & LA	750	920	NB	Australian magpie	Adult	60m n quarry access rd	491866	6598409	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	NB	Masked owl	Adult	Flood plain bridge 1	492852	6600776	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	NB	Purple swamp hen	Adult	50m north flood plain bridge 1	492966	6600968	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	NB	Flying fox spp	Adult	Nambucca bridge	493789	6602711	No	NA	NA	NA	9.7km to Gordons Park

Date	Observers	Start time	End time	Carriageway	Species	Sex & age class	RK general location	Easting	Northing	Cleared off Rd	Fauna fence P/A & prox.	Prox. to xing structure	Prox. to drop-down	If FF: prox. to camp
14/1/20	NM & LA	750	920	NB	Medium mammal	Unknown	400m s mattick rd	494405	6604379	No	Absent	NA	NA	NA
22/01/2020	SR LA	900	1030	SB	Blue tongue	Adult	500M sth Nambucca rail bridge	496591	6609236	No	NA	NA	NA	NA
22/01/2020	SR LA	900	1030	SB	GHFF	Adult	Start Nambucca bridge	494204	6603236	Yes	NA	NA	NA	NA
22/01/2020	SR LA	900	1030	SB	Wallaby spp	Unknown	Start Nambucca bridge	494314	6603374	No	Absent	NA	NA	NA
22/01/2020	SR LA	900	1030	NB	Wallaby spp	Unknown	150 Sth Nambucca bridge	493466	6602074	Yes	Present	430	356	NA
22/01/2020	SR LA	900	1030	NB	Medium bird	Unknown	Midddle of Nambucca bridge	493785	6602714	Na	Na	NA	NA	NA
30/1/20	SR NM	905	1025	SB	Northern brown bandicoot	Adult	1050m north old coast rd overpass	495035	6606403	No	Present	87	280	NA
30/1/20	SR NM	905	1025	SB	GHFF	Adult	Nambucca bridge southern end	493663	6602452	No	NA	NA	NA	10km to Gordons park
30/1/20	SR NM	905	1025	SB	Red-necked wallaby	Adult	120m north williamson creek	491773	6598214	No	Absent	NA	NA	NA
30/1/20	SR NM	905	1025	SB	Purple swamp hen	Adult	840m south rosewood road	490481	6595770	No	NA	NA	NA	NA
30/1/20	SR NM	905	1025	NB	Laughing kookaburra	Adult	360south bald hill rd	492451	6599688	No	NA	NA	NA	NA
30/1/20	SR NM	905	1025	NB	Pheasant coucal	Adult	160north nambucca river flood plain bridge 2	493319	6601683	No	NA	NA	NA	NA
30/1/20	SR NM	905	1025	NB	Magpie lark	Adult	Nambucca bridge	493595	6602341	No	NA	NA	NA	NA