Warrell Creek to Nambucca Heads Pacific Highway Upgrade

Commonwealth Approval EPBC 2013/7101 Annual Compliance Report February 2022 – February 2023

Transport for NSW | May 2023

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
DoEE	Federal Department of Environment and Energy
DPIE	State Department of Planning 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 TfNSW'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 New South Wales (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 Condition 19 and 20. This report covers the eight reporting period from February 2022 to February 2023.

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 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: 9th April 2021
- 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 eight reporting period (February 2022 – February 2023).

2. Compliance Tracking Tables

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.

2.1. Condition 1

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	Record of clearing numbers provided in monthly report from Contractor to TFNSW. Refer to Table 1.1 below for clearing quantities for the reporting period.
1.2	Confirm clearing limitation targets have been met	Post-construction	Compliant	As built survey of actual clearing area. Table 1.1

Table 1.1: Clearing Quantities for the reporting period.

Habitat Type	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 2021. Clearing quantities for all habitat types are below the limits as specified in condition one.

No further clearing will be undertaken as part of the project.

2.2. Condition 2

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.	Apr 2021	Complete	Report & supporting mapping
2.2	Calculate final clearing quantity and include in summary table.	Apr 2021	Complete	Report & supporting mapping
2.3	Provide written notification (letter) of completion of construction and report to Dept. of the Environment	Apr 2021	Complete	This Report Completed document transmittal form or equivalent

Completion of construction works was on 9th April 2020. A report was provided in the 2020/21 Annual report that demonstrated that TfNSW are compliant with condition one and two.

2.3. Condition 3

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 Koala Monitoring Reports Roadkill Quarterly/Annual Reports Biodiversity Offset Strategy Underpass Monitoring Reports Urban Design and Landscape Plan See summary below
3.2	Implement the Grey-Headed Flying Fox Management Plan	Pre-construction, Construction and Operation	Compliant	Sensitive Area Plans Ecological Monitoring Report Roadkill Quarterly/Annual Reports Biodiversity Offset Strategy Urban Design and Landscape Plan See summary below
3.3	Implement the Spotted-tail Quoll Management Plan	Pre-construction, Construction and Operation	Compliant Ongoing	Roadkill Quarterly Reports Biodiversity Offset Strategy Urban Design and Landscape Plan Underpass Monitoring Reports See summary below

3.4	Implement the Giant Barred Frog Management Plan	Pre-construction, Construction and Operation	Compliant Ongoing	Giant Barred Frog Monitoring Reports Roadkill Quarterly/Annual Reports Biodiversity Offset Strategy Urban Design and Landscape Plan Underpass Monitoring Reports See summary below

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 have been located in areas where clearing is minimal.	Design Drawings
Pre-construction	All ancillary sites to be located outside of mapped Koala habitat.	Ancillary sites have been 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 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 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/	The limits of clearing are to be clearly marked on all relevant work plans and protective	The clearing limits have been included on the Sensitive Area Plans and	Sensitive Area Plans

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Construction	fencing erected to mark these limits (i.e. 'no-go' areas).	marked in the field using yellow flagging.	Early Works Permits Pre-clearing and Ground Disturbance Permits
Detailed Design/Pre-construction	Areas for Koala habitat restoration/connectivity are to be 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
	For any areas of vegetation to be cleared during the pre-construction stage of the Project, a suitably qualified ecologist will undertake 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	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
	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 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.	No Koala roadkill has been identified on the Project during Pre-construction and Construction Phase of the Project. No concrete barriers have been placed through Koala habitat areas.	Roadkill records and quarterly/annual reports.

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	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.		
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 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	Progressive rehabilitation of the site has commenced. The worksite will be rehabilitated in accordance with the Urban Design and Landscape Plan. Landscape rehabilitation is monitored monthly with a quarterly report developed during the third year of construction. Weed management is undertaken in accordance with the Weed and Pathogen Management Plan (WPMP).	Urban Design and Landscape Plan Site Inspection Records TFNSW Specification G36 Weed Management Records

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	crossing structures to optimise utilisation of these structures. - Monitoring and maintenance of plantings. - Managing and controlling weeds.		
Pre-Construction Detailed Design/ 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 /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 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 has made prototype panels to demonstrate different types of stone pitching that was to be placed in the low flow channel of Butchers Creek. 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	Detailed Design Drawings ERG Minutes Fauna Connectivity Report Underpass Monitoring Reports

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
		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 during known food bottle necks (i.e. winter period).	The width of the road corridor through the flying fox 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 sources and flying-fox movements areas.	Ancillary sites have been located away from the GHFF roost area and potential habitat.	Consistency review documents for Ancillary site facilities. Ancillary Facility Register
Construction	Pre-clearing and clearing surveys of all vegetation within the clearing footprint conducted as per protocol. Implement contingency plan for moving flying-fox out of the clearing corridor during vegetation	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	Pre-clearing and ground disturbance checklists.

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	clearing/construction, refer to Appendix C of the GHFF Management Plan.	from the Project site for clearing operations	
Detailed Design	To minimise the risk of flying-fox vehicle strike during take-off from roosting/foraging, road corridor revegetation and ornamental planting 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 have 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.	No Ancillary Site Facilities have been placed in the vicinity of 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 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, refer to Appendix C of the GHFF Management Plan.	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. During the last reporting period, 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.	GHFF Monitoring Reports
Construction	Implement water quality procedures from the CEMP.	Regular inspections of the erosion and sediment controls in the area is ongoing throughout construction. Water quality	Inspection records Water Quality

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
		monitoring is currently ongoing.	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 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 STQ habitat was removed during Pre-construction activities.	Early Works Permits
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 STQ habitat restoration/connectivity are to	Habitat connectivity planting has been included in the	Urban Design and

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	be identified and included in the detailed design.	Urban Design and Landscape Plan	Landscape Plan
Construction	Preparation of an EWMS would be 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 will undertake 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 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.	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
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. - Plantings are to be undertaken around fauna crossing structures to optimise utilisation of these structures. - Monitoring and maintenance of plantings. Managing and controlling weeds.	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
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 /placement of scour rock & treatment of the substrate e.g.	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.	Detailed design drawings

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	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 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 3.4 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
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) (4.4.2)	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 has been installed prior to the commencement of clearing. The Project Ecologist undertakes inspections of all	EWMS Project Induction Pre-clearing and Ground Disturbance Permit Site Inspection Record Urban Design and Landscape Plan

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	Pre-clearing Survey for Giant Barred Frogs (4.4.3) Clearing Supervision in Giant Barred Frog areas Dewatering Procedures in Giant Barred Frog areas (4.5.5) Permanent Frog Fencing (4.5.6) Unexpected Finds Procedure (4.5.7) (4.5.4) All mitigation measures applied during construction as per Table 5-1	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 are undertaken with input sought from the Project Ecologist when the frog fencing is reinstated after a flood event.	
Construction	Giant Barred Frog road kill to be reported to the Project Ecologist during daily/weekly monitoring 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 - Giant Barred Frog road kill is detected	No GBF roadkill has been identified on the Project.	Roadkill records and quarterly report.
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/ rehabilitation during construction Use of locally endemic native species representative of those currently growing along Upper Warrell Creek	Progressive rehabilitation of the site has commenced. The site will be 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 Giant Barred Frog Monitoring Reports.

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	Monitoring and maintenance of plantings Managing and controlling weeds		

The Ecological Monitoring Annual Report 2022 - 2023 provided in Attachment 1 contains the results of the monitoring undertaken for the Management Plans during the reporting period.

2.4. Condition 4

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 Complete	Compliance with the FFMP and CEMP is continuously monitored on site. The Project has an independent Environmental Representative to monitor compliance with these documents.

2.5. Condition 5

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	Compliant Complete	No discrepancies noted

2.6. Condition 6

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

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 Phase	Compliant Ongoing	Translocation Annual Report Ecological Monitoring Report

Further details on the monitoring undertaken during the reporting period are provided in the Annual Ecological Monitoring Report in Attachment 1.

2.8. Condition 8

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	TBA	Written agreement with the Department

2.9. Condition 9

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

Prior to **commencement**, all **management plans** must be made publicly available on the **approval holder's website**, 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.
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.

2.11. Condition 11

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, 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.

https://www.pacifichighway.nsw.gov.au/project-sections/port-macquarie-to-coffs-harbour/warrell-creek-to-nambucca-heads

2.12. Condition 12

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

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 has been implemented. The Norton offset site was secured as a BioBanking Agreement on 18 February 2019 and the Swain offset site was secured as a BioBanking Agreement on 22 February 2019. Ecosystem credits from the WC2NH area of both Norton and Swain were retired on 2 September 2021. See Attachment 2 for the BioBanking Credit Retirement Reports. The Boambee SF offset area was gazetted as the Yuraarla Flora Reserve on 15 April 2020.

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

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, TFNSW 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, DoEE have not raised any concerns with this approach.

2.15. Condition 15

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	The BOP was approved by DoEE on 5 July 2017 and has been implemented (see table below).

The WC2NH Biodiversity Offset Package was approved by DoEE in July 2017. TFNSW has finalised 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.Ecosystem credits from the WC2NH area of the property were retired on 2 September 2021.
Boambee (Forestry Corporation NSW)	Newly declared Flora Reserve which provides a legally binding conservation mechanism under the Forestry Act.	The Boambee SF offset area was gazetted as the Yuraarla Flora Reserve on 15 April 2020.
Swain (private)	Bio Banking Agreement.	BioBanking Agreement have been executed by OEH and registered on title on 22 February 2019. Ecosystem credits from the WC2NH area of this site were retired on 2 September 2021. See Attachment 2.

TFNSW 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

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 the entire 23.50 ha roosting habitat critical to survival within 24 months, rather than 3.10 ha required by Condition 1.

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 30th September 2023 (pending Commonwealth Approval)	Ongoing	Monitoring of the Macksville Greyheaded Flying-fox Camp found it to be abandoned by the Grey-headed Flyingfox, between September and May for two consecutive years on 31 May 2017. DAWE conditionally approved the offset proposal for the Bellingen Island Camp and Ainsworth foraging site on 25 November 2021. The Bellingen Island Camp Management Plan has been provided to the Commonwealth Post Approvals on 9th March 2023 for Delegate Approval. The BSA for the Ainsworth Foraging Site is on track to be submitted to the BCT in June 2023.

2.17. Condition 17

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 prior to the commencement of the action.	14 days prior to 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

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 Operation	Compliant Ongoing	No non-compliances were identified or reported to the Department during the reporting period.

2.19. Condition 19

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.**

	Action	Timing	Status	Compliance evidence
24.1	Prepare compliance report and upload to project website	By 9 May 2016	Compliant	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	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	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	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	Report uploaded to project website. Advice provided to Dept. on date of publication.
24.6	Prepare compliance report and upload to project website	By 9 May 2021	Compliant	Report uploaded to project website. Advice provided to Dept. on date of publication.
24.7	Prepare compliance report and upload to project website	By 9 May 2022	Compliant	This report uploaded to project website. Advice provided to Dept. on date of publication.
24.8	Prepare compliance report and upload to project website	By 9 May 2023	Compliant	This report uploaded to project website. Advice provided to Dept. on date of publication.

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

2.20. Condition 20

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, 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, available on the Project Website.
20.2	Maintain compliance records for the Biodiversity Offset Strategy	Construction, operation	Ongoing	Compliance records regarding offset security mechanisms and credit retirement reports are maintained on the relevant TfNSW document management systems. The Norton property was on-sold on 11 March 2021. Both the Norton and Swain properties are protected under stewardship agreements managed by the Biodiversity Conservation Trust. This involves annual 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

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

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

	Action	Timing	Status	Compliance evidence
22.1	Provide updated management plan or package for approval	Construction Operation	Compliant Ongoing	STQ Management Plan and Koala Management Plan varied on 22 January 2015. STQ Management Plan and Koala Management Plan varied on 3 October 2016. 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

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, package** required by the conditions and submit the revised **management plan, package** for the **Minister's** written approval. The **approval holder** must comply with any such request. The revised **management plan, package** must be implemented. Until the **Minister** has approved a revised **management plan, package**, the **approval holder** must continue to implement the previously approved **management plan, 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

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

Unless otherwise agreed to in writing by the **Minister**, the **approval holder** must publish the **management plans, package**, monitoring data in these conditions of **approval** on its **website**. Each **management plans, package**, 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	Complete Compliant	Management Plans uploaded onto the project website
25.2	Publish the Biodiversity Offset Package on the Project Website	Construction Operation	Complete Compliant	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

The **approval holder** must notify the **Department** within 5 business days of publishing the **management plan, package**, monitoring data on their website and the **management plan, package**, monitoring data must remain on the website for the life of this **approval**.

	Action	Timing	Status	Compliance evidence
26.1	Management plans uploaded on TFNSW website	With 5 days	Compliant Complete	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	Within 2 months of receipt	Compliant Ongoing	TFNSW provides email notification to the Department's 'EPBC Monitoring' mailbox within 5 days of publishing relevant information onto the project website

Attachment 1 Ecological Monitoring Report 2023 - 2023

Operational Phase Monitoring of Threatened Flora Translocations, In-situ Threatened Plants and Slender Marsdenia and Woolls' Tylophora Habitat Condition on the Warrell Creek to Nambucca Heads Highway Project – Year 5 (2022)

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14/4/2023

Contents

Executive Summary

The Warrell Creek to Nambucca Heads (WC2NH) project is a 19.6 km section of the Pacific Highway upgrade on the NSW Mid North Coast. Construction of the project began in February 2015 and it was opened to traffic in July 2018. The project's Threatened Flora Management Plan (RMS 2016) set out measures designed to minimise impacts on threatened flora during highway construction and operation, including (i) threatened flora translocation (ii) protection of in-situ threatened flora populations within the road reserve, (iii) maintaining Slender Marsdenia and Woolls' Tylophora habitat in good condition, and (iv) a monitoring program and annual monitoring report to assess the effectiveness of threatened flora management measures.

This annual threatened flora monitoring report describes the fifth and final year of operational phase monitoring carried out in December 2022. Monitoring has been carried out for a total of approximately eight years, including three years during the construction phase.

Five threatened and one rare plants species impacted by the project were translocated to nine recipient sites located in the road reserve within the WC2NH project boundary: -

- 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).

The translocations were carried out by transplanting impacted plants. Survival rates of the five threatened species in 2022 eight years after translocation were as follows: Slender Marsdenia 55%, Woolls' Tylophora (17%), Spider Orchid 100%, Rusty Plum 86% and Floyds Grass (small amount remaining). Koala Bells had already died out and no new plants appeared (Table 1). The translocation project generated new information on the translocation response, population dynamics and ecology of Slender Marsdenia and the other species, as described in this report.

Table 1: Percent survival of five threatened and one rare species translocated to nine recipient sites after 8 years (2015-2022)

Species/Recipient Sites	Number Translocated	Survival (%) after 8 years (to Dec 2022)
Slender Marsdenia		
Recipient Site 1 - Cockburns Lane	27	74
Recipient Site 2 (3) – Old Coast Rd	17	82
Recipient Site 3 (5a) – Old Coast Rd	22	57
*Recipient Site 4 (5b) – Old Coast Rd	10	60
Recipient Site 5 (7a) – Old Coast Rd	57	39
Recipient Site 6 (8a) – Old Coast Rd	8	50
Recipient Site 8 (8c) – Old Coast Rd	28	52
Total/All Sites	163	55

Species/Recipient Sites	Number Translocated	Survival (%) after 8 years (to Dec 2022)
Woolls Tylophora		
Recipient Site 6 (8a) – Old Coast Rd	6	17
Rusty Plum		
Recipient Site 1 - Cockburns Lane	7	86
Spider Orchid		
Recipient Site 5 (7a) – Old Coast Rd	2	100
Floyds Grass		
Recipient Site 9a – Warrell Creek	54 clumps	Small cover-abundance
Recipient Site 9b – Warrell Creek	61 clumps	Small cover-cover abundance
Koala Bells		
Recipient Site 7 (8b) – Old Coast Rd	16	0
Recipient Site 9 – Warrell Creek	14	0

* Note – Site 5b included 6 *Marsdenia liisae* (rare, not a threatened species) and 10 *M. longiloba*

In-situ threatened plants in the WC2NH road reserve maintained satisfactory survival rates at the end of Year 8. Spider Orchid, and Rusty Plum were 100%, although the condition of the two Spider Orchid clumps had declined, as observed in the translocated clumps. The small Rusty Plum trees were in good condition, and some fruited during the eight year monitoring period. The stand of in situ Maundia on the Nambucca River floodplain declined from 40% crown-cover in 2018 to <1% at the peak of the drought in 2019. In 2020 after the drought broke, Maundia recovered to about 20% crown-cover, 40% by late 2021 and over 50% in 2022, returning to its pre-drought abundance. All in situ Slender Marsdenia were small plants (<1 m high) and most died back and reshot during the monitoring period, as recorded for many small transplanted stem-individuals. Koala Bells plants appeared spontaneously at one location in the road reserve of Old Coast Road in 2021 and persisted in 2022.

Threatened flora habitat condition

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

1 Introduction

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

A Threatened Flora Management Plan was prepared for the WC2NH project (RMS 2016 updated), which included a monitoring program aimed at documenting and assessing three sets of measures designed to manage threatened flora recorded within the WC2NH project boundary: (i) threatened flora translocation (ii) protection of in-situ threatened flora populations within the road reserve, and (iii) maintaining Slender Marsdenia habitat in good condition. These measures were monitored during construction and operation of the project.

This annual threatened flora monitoring report describes the fifth and final year of operational phase monitoring carried out in December 2022. Results of construction phase monitoring are described in Ecos Environmental (2016), Ecos Environmental (2017) and Ecos Environmental (2018a), and previous operational phase monitoring in Ecos Environmental (2018b), Ecos Environmental (2019), Ecos Environmental (2020) and Ecos Environmental (2021). Results for the current annual monitoring period (Year 8) are described and discussed in the following sections below:-

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

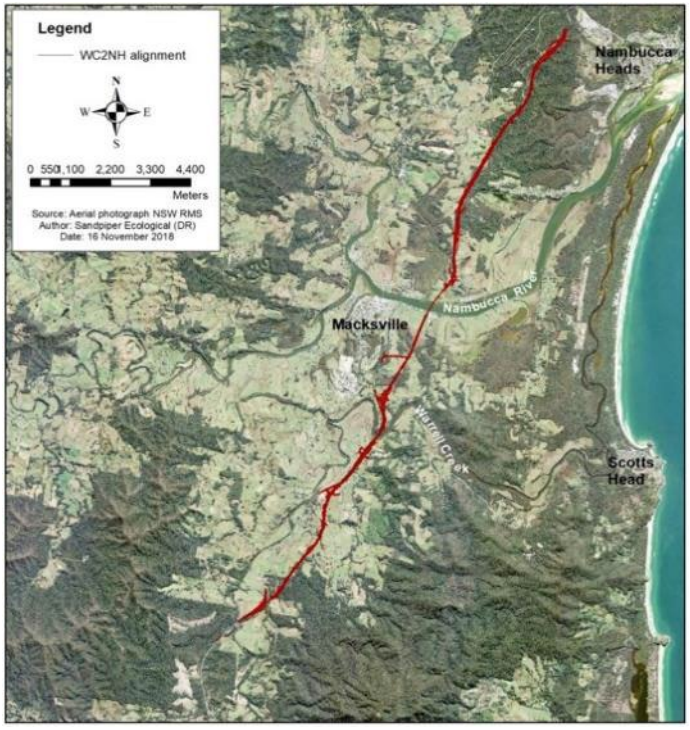

Figure 1: Location of the WC2NH Pacific Highway upgrade.

2 Threatened Flora Translocation

2.1 Aim and Species Translocated

The translocation component of the Threatened Flora Management Plan (TFMP) is described in detail in the section containing the Translocation Plan. The format and content of the Translocation Plan generally follows ANPC (2004), *Guidelines for Planning Threatened Flora Translocations in Australia*

The aims of threatened flora translocation for the WC2NH project were:

- to maintain population size of threatened species and avoid loss of population due to direct or indirect impacts of highway construction.

- to rescue and re-establish individuals of threatened species impacted by construction in suitable habitat within the project boundary.

Translocation involved three main actions:

- Rescue or salvage transplanting of impacted individuals and their re-establishment at recipient sites containing habitat closely approximating the impacted/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 habitat remains in good 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).

A sixth threatened species, *Maundia triglochinoides* was also translocated, although not required by RMS (2016).

2.2 Methods

2.2.1 Recipient Sites

Nine recipient sites located in the highway road reserve were selected for re-establishing threatened species moved from the highway construction footprint. Seven recipient sites are in the section of highway corridor where it crosses Nambucca State Forest, one site is near the new highway bridge over Warrell Creek, and one near the southern end of the project

(Table 1 and Figure 2). Further details of recipient site selection and site descriptions are provided in Ecos Environmental 2016, 2017 and 2018a.

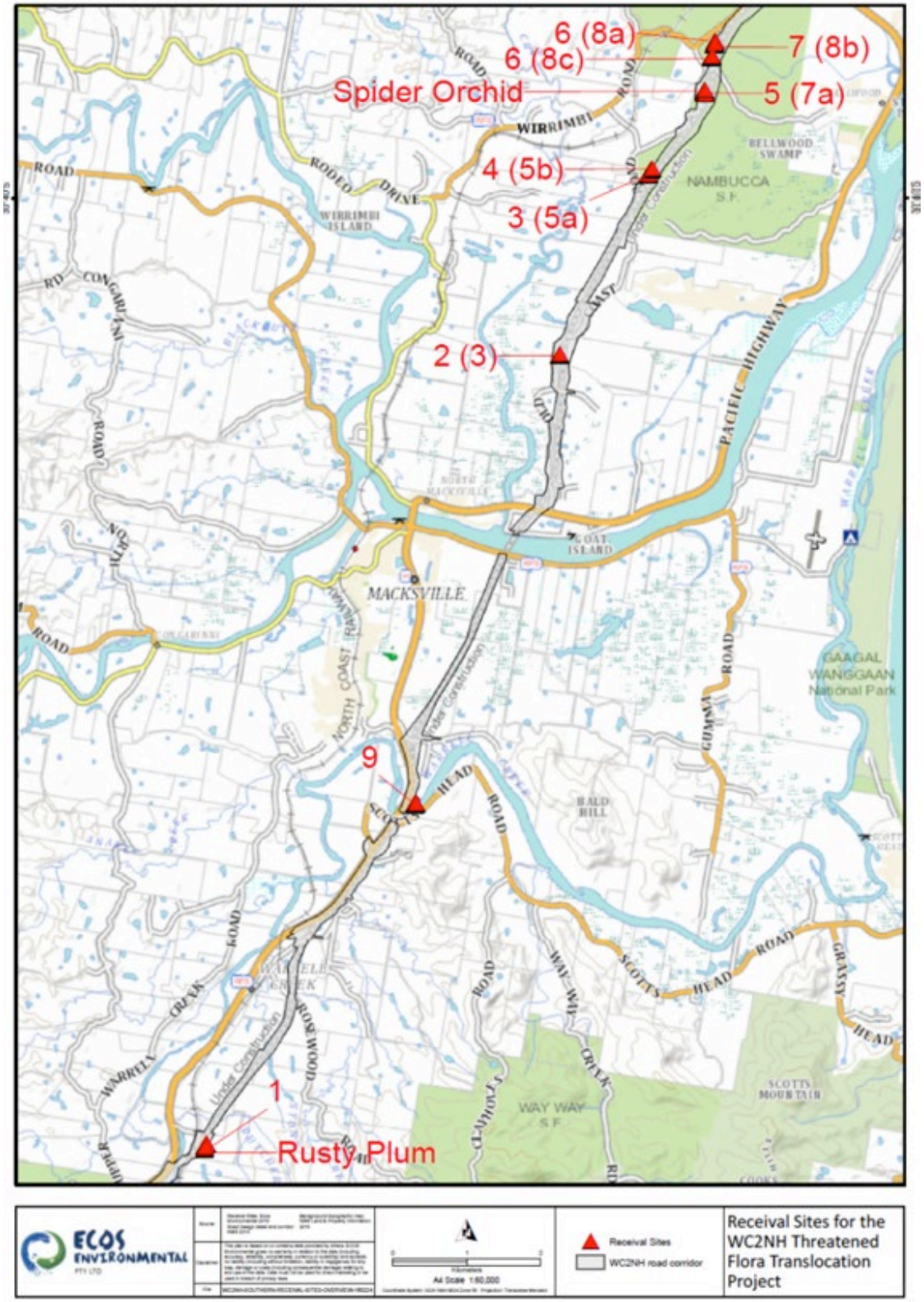

Figure 2: Location of threatened flora translocation recipient sites on the Warrell Creek to Nambucca Heads (WC2NH) project.

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

Recipient 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. This involves excavation, transport to the recipient site and replanting as a single operation, which is carried out as quickly as practical to minimise stress on plants. Trees and saplings are removed using an excavator or back-hoe and small plants with hand tools. The method entails excavation of a substantial amount of the root system in in a soil-root ball and pruning of the shoot system to reduce evapotranspiration stress.

Direct transplanting may have advantages over other translocation methods such as propagation and gradual excavation (i.e. trenching and root pruning), including:

1. Transplanted mature plants produce flowers and seed sooner and in greater quantity than propagated plants.
2. A short period of physiological stress during transplanting is better for survival and healthy growth than a prolonged period of stress using other methods.
3. Reduces risk of transferring microbial pathogens from a nursery environment, or in extraneous materials (e.g. soil ameliorants), to the translocated plants or soil at the recipient site.
4. Naturally occurring mycorrhizae and soil microflora which are important for natural, healthy growth are maintained by moving plant and soil together.
5. Method is practical for translocating large numbers of small to medium size individuals and limited numbers of large individuals.
6. Cost-effective.

Primack (1996) pointed out other advantages: - "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".

2.2.3 Slender Marsdenia

2.2.3.1 Plant Rescue - Salvage Transplanting

Transplanting of Slender Marsdenia from the construction footprint to seven recipient sites was carried out in February 2015 (Table 1). The recipient sites were located near the donor sites to maintain roughly the original distribution. Stem and root system were moved in small slabs of soil approximately 30 cm x 30 cm x 20 cm in depth. Transplanting retained some of the original root system including rhizomatous roots. The original extent of rhizomes and the root system is unknown.

Plants and soil were kept damp during transport and watered as soon as they were planted. The 'stem-individuals' were planted at 5 m intervals along lines to reduce potential bias in selecting planting points, and also to facilitate monitoring. Additional plants were translocated in 2016 due to a modification in the road design. In total, 163 stem-individuals were translocated.

The transplants were watered once every two days for the first week then once a week for four weeks. Chicken wire cylinders (90 cm high) were installed to prevent animal digging and 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 for checking if stems that had died back were still alive. Flagging tape with a monitoring number and the plant's source code as per the translocation plan (TFMP) was attached to each cage. Where there was more than one stem-individual at a mapped/donor point, the stem individuals were indicated by numbers added to the original plant source code e.g. ML 46-6, ML46-7.

2.2.3.2 No Fertiliser

As translocation of Slender Marsdenia on the Bonville Project south of Coffs Harbour (Ecos Environmental 2016) found slow-release fertiliser appeared to adversely affect the survival of transplanted Slender Marsdenia. This could be due to the fertiliser leaching out of the pots and not remaining in the soil in proximity to the root zone. In the field it could remain in the soil and available for uptake for longer periods, in higher concentration. No fertilisers or mulch were applied during the WC2NH translocation of this species. (Note – on the NH2U project, a translocation trial was designed to compare fertiliser and no fertiliser treatments on Slender Marsdenia, as well as other variables. The fertiliser treatment was very light but still appeared to decrease growth (Ecos Environmental 2016). Unfortunately, the writer was unable to continue the experiment as another consultant was appointed.

2.2.3.3 Propagation of Population Enhancement Plants

Propagation of Slender Marsdenia was attempted from rhizome pieces that broke off during transplanting. The strike rate of rhizome cuttings was <5% and the growth rate of cuttings that struck was very slow. The same result for attempted rhizome propagation was recorded on the NH2U project. The few propagated plants on WC2NH were grown-on for two years and planted out in November 2017 at Recipient Site 7a. (Note – although this species in the wild appears to reproduce vegetatively by producing shoots from its thin tuberous rhizomes,

these stem shoots are not common. The poor results of propagation from root cuttings in a nursey, suggest this form of reproduction does not play a major role in increasing population number in the wild.)

With the aim of propagating more plants from seed, searches for seed pods of Slender Marsdenia were carried out in December 2016, focusing on locations of large plants previously recorded by the author on the WC2NH, NH2U, Bonville and S2W sections of the Pacific highway, but no pods were found. A single pod was found in summer 2014/2015 during pre-construction flora surveys for the WC2NH project near the southern boundary of the NH2U project. The pod contained about 100 seeds which had a high germination rate. The seedlings were used in a translocation experiment on the NH2U project (Ecos Environmental 2016).

2.2.4 Woolls' Tylophora

2.2.4.1 Species Identification

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

2.2.4.2 Salvage Transplanting

Individuals tentatively identified as Woolls' Tylophora were transplanted using the same methods applied to Slender Marsdenia. Both species are vines with tuberous roots. Woolls' Tylophora was translocated to Recipient Site 8a, which also received Slender Marsdenia (Table 1).

2.2.5 Rusty Plum

2.2.5.1 Transplanting

Rusty Plum occurred on the footprint in the Cockburn's Lane section at the southern end of the project. Rescued plants were transplanted into the adjacent road reserve at Recipient Site 1, also used for Slender Marsdenia. An excavator was used to trench around two Rusty Plum trees about 12 m high, forming a soil-root ball about 0.7 m deep and 1-1.5 m wide. The vibration of the excavator carrying the trees caused the root ball to fall apart, so the trees were transplanted bare-rooted and trunks were cut off 1-1.5 m above the ground. This prevented evapotranspiration stress and re-balanced the root-stem system.

Transplanted trees and saplings were watered for about one month by the construction contractor. Sugar cane mulch was spread around each plant. Hessian screening was erected to reduce exposure to the afternoon sun. No fertilisers were used. Several Rusty Plums remained in-situ within the project boundary next to the construction footprint.

2.2.5.2 Population Enhancement by Direct Seeding

To enhance population size, a trial introduction of Rusty Plum by direct seeding was carried out at Recipient Site 7(a), using 50 fruits collected in Nambucca State Forest in November 2017. The outer fleshy layer of each fruit was removed and the single, golf-ball sized seed planted in leaf litter on the 7th December 2017. The introduction site is in a minor gully supporting Flooded Gum wet sclerophyll forest with a mesic understorey. Seeds were placed inside metal mesh cylinders held in place with a wooden stake, because in a similar direct seeding trial on the NH2U project, seeds were taken by animals and germinated seedlings heavily browsed (Ecos Environmental 2015). Fourteen cylinders were set out and three seeds placed in each cylinder and lightly covered with leaf litter. The cylinders were tagged for monitoring and locations recorded with a GPS.

2.2.6 Spider Orchid

2.2.6.1 Transplanting

Two clumps of Spider Orchid growing on the branches of Prickly Paperbark (*Melaleuca styphelioides*) were rescued from the WC2NH footprint. A section of branch about 0.8 m long was sawn off so the orchids were moved with minimal root disturbance. The branch was tied onto the trunk of a small tree in a shaded gully at Recipient Site 7a. Plants were watered during transport, but no further watering was carried out after introduction to the site.

The Spider Orchid clumps flowered in September each year from 2015 to 2022, but no seed pods were produced. At the November-December monitoring, shrivelled up floral axes at the apex of pseudobulbs indicated that flowering had occurred and there was no evidence of the seed pod which is about 5 cm long. In-situ plants were also monitored and flowers, but no seed pods recorded. Many flowers were produced in each clump, so it appears the flowers require cross-pollination by an insect that was absent from the translocation site.

The orchid clumps declined in size (number of pseudobulbs) between 2020 and 2022. As observed with the in-situ plants, pseudo-bulbs were being grazed, stripping off the surface green tissue layer and hollowed out, probably by an insect or mollusc. A few new pseudobulb shoots were present in 2021 and 2022, compared to many in previous years. Decline may have been due solely to the grazer, or the branch substrate may have been supplying less nutrient. More than half the pseudobulbs in each clump flowered in 2022, so they must still be in reasonable condition, despite grazing.

2.2.6.2 Population Enhancement

The WC2NH threatened flora management plan proposed to propagate Spider Orchid for introduction to enhance the local population of this species. Vegetative propagation by division of clumps was not a suitable option due to the rarity of wild plants. Propagation from seed was possible and a propagator was organised of known Spider Orchid locations at previously observed seeding time (see below) failed to find any seed pods.

On the NH2U project, one pod was produced in a translocated population of 55 Spider Orchids. Unfortunately, the pod opened between site visits in November 2016 and the seeds dispersed before they could be collected for propagation.

2.2.7 Koala Bells

2.2.7.1 Salvage Transplanting

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

2.2.7.2 Population Enhancement

Cuttings of Koala Bells were propagated at Ecos Environmental's nursery in summer 2015-2016. The cuttings formed roots and flowered over summer-autumn 2016, died back in winter then reshot in spring 2016, while still in pots. Regrowth in spring 2016 was less vigorous and small adventitious shoots (vegetative reproduction) were produced around the edge of the pots. (Vegetative reproduction was also observed in some transplants in the field on NH2U.) Twenty plants were introduced to Recipient Site 9b (Floyds Grass translocation site) at Warrell Creek in January 2017. This site had alluvial soil and an open ground layer with little competition.

2.2.8 Floyds Grass

2.2.8.1 Removal of topsoil containing weed seedbank

Floyds Grass was introduced to two 20 m x 20 m areas about 30 m apart located on the northern side of Warrell Creek (Recipient Sites 9a & 9b), 50-100 m from the donor site at the highway bridge over Warrell Creek. The soil type was clay alluvium suitable for Floyds Grass but the vegetation was very weedy, being dominated by Broad-leaved Paspalum (BLP) and Lantana.

A novel grass-topsoil stripping procedure was carried out to prepare the site for introduction of Floyds Grass. As the site appeared to be on deep alluvium, it was assumed there would be sufficient depth of alluvial topsoil left after the stripping operation. The other alternative was to spray out weeds with herbicide, but they were likely to regrow from the soil seedbank and follow-up spraying would be difficult without hitting Floyds Grass, which spreads by surface runners. The strategy was therefore to physically remove BLP and topsoil containing its seedbank, then plant Floyds Grass into a weed-free site.

Preparation of the site was carried out as follows. Firstly, BLP and Lantana were scrapped off with an excavator bucket. After exposing the soil surface, the top 10 cm of soil was also scrapped off. The soil beneath the uppermost 10 cm had a higher clay content, but soil texture and drainage still reasonable for plant growth. Sed fencing was installed around the site to prevent sediment run-off into Warrell Creek and to deter wallaby grazing.

2.2.8.2 Transplanting

Small clumps of Floyds Grass growing on the edge of Warrell Creek at the bridge site were dug out with a spade and planted into Recipient Site 9a. The plants were watered, and sugar cane mulch (weed free) spread lightly to reduce raindrop compaction. Follow-up watering was carried out as conditions were dry. 'Seasol fertiliser was applied two weeks after introduction to stimulate growth. As the site was exposed to the afternoon sun, 1 m high shade-cloth fences were erected to provide additional shade. These were removed in 2021.

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

2.2.8.3 Population Enhancement

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

2.2.9 Monitoring and Data Analysis

Monitoring of the translocations was carried out quarterly for the first year, six monthly for the second year and once a year thereafter, including operational phase monitoring from 2018 to 2022.

The following data were recorded to assess survival and growth:

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

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

Plant condition was scored on a scale of 0 to 5, where zero = dead and 5 = fully mature, reproductive (Table 2-4).

Floyds Grass crown cover was measured by visual assessment of crown cover in metres squared.

Slender Marsdenia individuals that died back to the ground were scored as 1 rather than 0 (dead) because new stems were often produced, regrowing from the root crown. Plants with above ground stem growth (i.e. condition score of 2 or higher) were included in the calculation of % survival.

Percent survival of Slender Marsdenia = no. number of plants in condition classes 2+3+4+5/total number x 100; or number of plants with height >0/total number of plants x 100.

Mean plant height was used as a measure of how well Slender Marsdenia performed at each recipient site after translocation. Mean height was calculated by averaging across all individuals, including those with zero height (i.e. condition class 1 or 0). In effect, this provided an approximate measure species performance weighted by number of mortalities.

The relationship between the mean height of Slender Marsdenia and openness of understorey habitat was examined using linear regression. The relative openness and light

intensity in understorey habitat at the recipient sites was scored on a scale of 1 to 3, as follows:-

1 = dense (i.e. understorey habitat more shaded due to a more well-developed rainforest component in the mid to lower strata);
2 = medium (i.e. understorey habitat somewhat more open - between 1 and 2)
3 = open (i.e. understorey habitat relatively open, exposed to breezes, rainforest elements sparse, higher light level in the understorey).

Linear regression examined if a significant relationship existed between Mean Height, Habitat Openness and Survivorship, using Excel.

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

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

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

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

Table 4: Condition scores applied to Spider Orchid.

Score	**Condition**
0	Dead

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

2.3.10 Analysing stem growth phenology in Slender Marsdenia

Slender Marsdenia showed a wide range of response to translocation in terms of stem regrowth. Temporal patterns of stem growth in translocated Slender Marsdenia were classified into different categories of stem height change over eight years. These were derived by examining stem height data over 8 years in a spreadsheet and identifying characteristic syndromes of height change in the 163 stem individuals (Table 5).

Stem height change pattern was allocated to three primary categories: (i) 'D' - stem height zero, recorded 2022 (i.e. most of these plants were probably dead, but some may reshoot); (ii) 'S' - small stem-individual (i.e. little height growth over eight years); and (iii) 'T' - stem-individual tall (i.e. relatively vigorous height growth). Individuals in the primary categories were then allocated to four sub-categories as defined in Table 5.

Individuals showing one or more cycles of stem dieback to ground level then reshooting over 8 years, referred to as oscillations, were recorded along with the number of oscillations in eight years. (Note – a decrease in height to zero at the last monitoring (i.e. category D) was not counted as an oscillation as the plant had to regrow again to be a full oscillation.)

Numbers of individuals in each category were tallied and expressed as percentages of the total number of stems at each recipient site.

Table 5: Categorisation of response of Slender Marsdenia to translocation in terms of stem growth phenology over 8 years. Individuals were placed in three primary categories: 'D' stem height zero; the majority of these plants were probably dead, some may reshoot; 'S' stem-individual small, little height growth over eight years; and 'T' stem-individual tall, relatively vigorous height growth. Primary categories were divided into four sub-categories as shown below. Those with "(O)" indicate some stems oscillated in stem height, having one or more cycles of stem dieback to ground level then reshooting.

Code	Response syndromes of transplanted individuals (outcome after 8 years)
D	**Stem height zero at last monitoring in Dec/2022; plant died back to ground; may be dead or may reshoot**
D1	Never reshot
D2	Small shoot for one or more years then died back to ground, probably dead
D3 (O)	Reshot, reached small (<10 cm) to medium height (<1.2 m) then died back to ground, some fluctuated (i.e. dieback-reshoot-dieback)
D4 (O)	Reshot, grew tall (~2 m+) then died back to ground, some fluctuated, probably dead
S	**Small, growing very slowly, or declining**
S1	Stayed small, mostly less than 10 cm high, occasionally to 50 cm, little change in height in 8 years
S2 (O)	Died back to ground and reshot once or twice, continuously small (mostly <50 cm)
S3	Declining or bell shaped (increase-decrease), some to ~130cm at peak, continuously alive but stem mostly small (<50 cm)
S4 (O)	Fluctuating – e.g. 'small-medium/tall-small'; or 'grew medium/tall then died back to small
T	**Thriving, plant relatively tall, continuing to grow, or maintaining size, healthy**
T1	Tall (1.5 m+), substantial increase in height/number of leaves, or maintained tall height
T2	Moderately tall (0.75 – 1.5 m +), moderate increase in height (0.5 m to 1 m or more), or height constant
T3 (O)	Died back to ground then reshot vigorously (>1 m)
T4	Small for several monitoring events then suddenly grew taller (>1 m)

2.3 Translocation Results

2.3.1 Species Survival Summary

Survival rates of the five translocated threatened species after eight years were as follows: Slender Marsdenia 55%, Woolls' Tylophora (17%), Spider Orchid 100%, Rusty Plum 86% and Floyds Grass (small amount remaining) (see Table 6). Koala Bells had already died out and no new plants appeared.

Slender Marsdenia survival decreased from 68% in 2021 to 55% in 2022. Woolls' Tylophora continued to decrease to 17% in 2022. Only a small cover of Floyds Grass remained in terms of crown cover. Spider Orchid percent survival was constant. Rusty Plum maintained survival and relatively good condition. Further details below.

Table 6: Survivorship (percent) of five threatened and one rare species translocated to eight recipient sites over 8 years (2015-2022)

		Time since translocation/Survivorship (%)							
Recipient Site	**No.**	**Aug 2015 (6 mth)**	**Jan 2017 (2 Yrs)**	**Nov 2017 (3 Yrs)**	**Nov 2018 (4 Yrs)**	**Nov 2019 (5 Yrs)**	**Nov 2020 (6 Yrs)**	**Nov 2021 (7 Yrs)**	**Dec 2022 (8 Yrs)**
Slender Marsdenia(*Marsdenia longiloba*)									
Recipient Site 1 - Cockburns Lane	27	93	75	63	59	59	56	78	74
Recipient Site 2 (3) – Old Coast Rd	17	91	93	88	88	88	88	88	82
Recipient Site 3 (5a) – Old Coast Rd	22	81	91	73	77	68	68	77	57
*Recipient Site 4 (5b) – Old Coast Rd	10	94	81	69	69	50	71-	75	60
Recipient Site 5 (7a) – Old Coast Rd	57	90	72	71.5	72	56	61	53	39
Recipient Site 6 (8a) – Old Coast Rd	8	75	75	75	88	86	93	75	50
Recipient Site 8 (8c) – Old Coast Rd	28	100	86	82	79	70	67	59	52
Total/All Sites	163	91	80	74	74	68	68	68	55
Wooll's Tylophora (*Tylophora woollsii* – unconfirmed)									
Recipient Site 6 (8a) – Old Coast Rd	6	100	100	83	67	67	67	33	17
Rusty Plum(*Niemeyera whitei*)									
Recipient Site 1 - Cockburns Lane	7	100	86	86	86	86	86	86	86
Spider Orchid (*Dendrobium melaleucaphilum*)									

		Time since translocation/Survivorship (%)							
Recipient Site	**No.**	**Aug 2015 (6 mth)**	**Jan 2017 (2 Yrs)**	**Nov 2017 (3 Yrs)**	**Nov 2018 (4 Yrs)**	**Nov 2019 (5 Yrs)**	**Nov 2020 (6 Yrs)**	**Nov 2021 (7 Yrs)**	**Dec 2022 (8 Yrs)**
Recipient Site 5 (7a) – Old Coast Rd	2	100	100	100	100	100	100	100	100
Floyds Grass (*Alexfloydia repens*)									
Recipient Site 9a – Warrell Creek	54 clumps	94	Substantial cover	Substantial cover	Substantial cover	Substantial cover	Fair cover	Fair cover	Small cover
Recipient Site 9b – Warrell Creek	61 clumps	Not planted yet	98	93	70	Reasonable cover	Fair cover	Fair cover	Small cover
Koala Bells (*Artanema fimbriatum*)									
Recipient Site 7 (8b) – Old Coast Rd	16	63	25	13	6	0	0	0	0
Recipient Site 9 – Warrell Creek	14	Not planted yet	Not yet planted	57	86	75	0	0	0

* Note – Site 5b included six *Marsdenia liisae* (a rare, not threatened species) and ten *M. longiloba*.

2.3.2 Slender Marsdenia (*Marsdenia longiloba*)

2.3.2.1 Survival rate

The survival rate of Slender Marsdenia after eight years was 55%, a decline of 13% since last year. Decrease in survival was more pronounced at Sites 5a, 7a and 8a, and less at Sites 1, 3 and 8c (Table 6).

Three individuals flowered in 2022 compared to only one individual in all previous years.

2.3.2.2 Change in mean height per recipient site

In 2021-2022, mean stem height decreased in five sites and increased in one site (Site 1) (Figure 3). However, from inspection of Figure 3 it appears there was little synchronisation between sites in the pattern of stem growth over 8 years. In a given year, it was common for mean height to increase in some sites and decrease in others. (Figure 3).

Mean height of Slender Marsdenia per site after eight years ranged from 32.6 cm to 127.9 cm (Table 7), which suggested that height growth was affected by differences in one or more habitat variables which vary between sites.

In sites 5a and 7a, after increasing in the first year, mean height did not change much for five years (Figure 3). In sites 1 and 8c, there was a small to moderate increase in mean height, and in sites 3 and 8a, a large increase in mean height then a decline in mean height in 8a in the last two years (Table 7). Possible reasons for different patterns of mean height change include:

- Variation in understorey light intensity or other fine-scale, microhabitat differences between recipient sites (note - landscape-scale habitat variables such as vegetation type, soil type and topography were relatively uniform across sites).
- Differences in the plants introduced to each site.
- Herbicide spray drift from maintenance of the watermain easement track may have affected Site 8a.

Mean height of Slender Marsdenia tended to be lower at recipient sites with a more shaded understorey. Leaf size was also often smaller in the latter habitat. Linear regression indicated a statistically significant relationship between mean height and understorey openness amongst the recipient sites ($R^2 = 0.75$; $F = 16.32$; $p = 0.01$). Removing site 8a, which appeared to be affected by spray drift, R^2 increased to 0.93. However, there was no relationship between survivorship and mean height, or between survivorship and understorey openness, which suggested that individuals were able to survive despite relatively low growth rate.

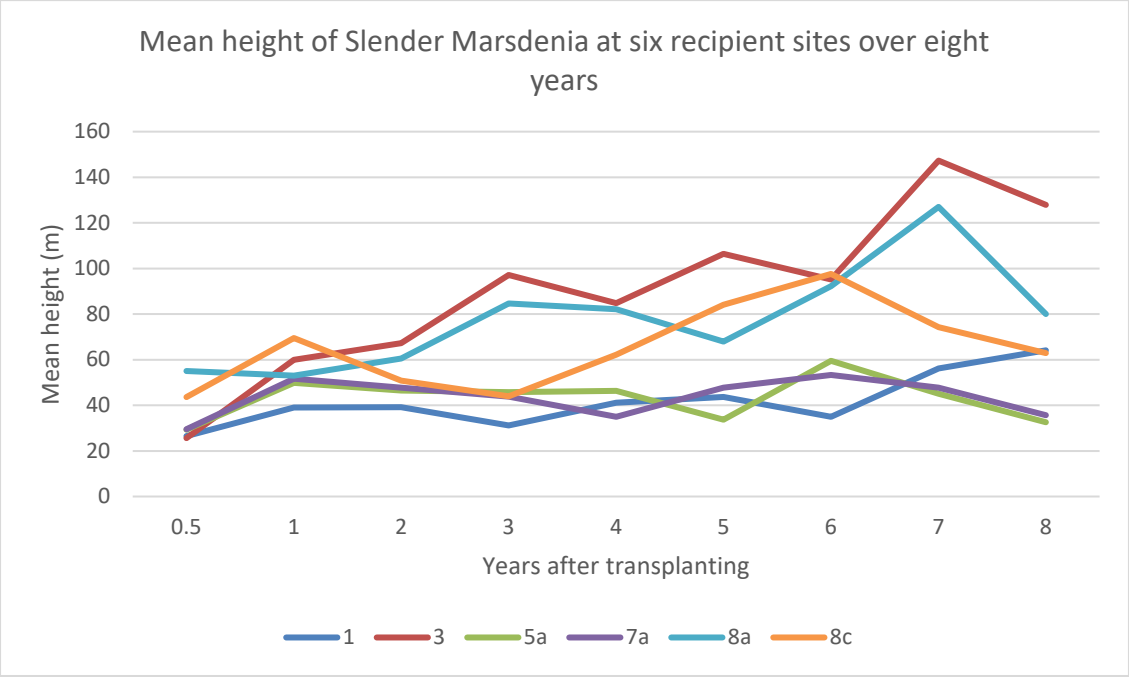

Figure 3: Mean height of Slender Marsdenia at 6 recipient sites between 2015 and 2022.

Table 7: Mean height (cm) ± standard error of Slender Marsdenia at 6 recipient sites from June 2015 to December 2022 (approx. 8 years after translocation). This data is plotted in Fig 3. Decline in mean height this year is party related to decrease in survivorship and more zero's in the height data.

Recipient site	n	June 2015 (0.5 yr)	Feb 2016 (~1 yr)	Jan 2017 (~2 yrs)	Nov 2017 (~3 yrs)	Nov 2018 (~4 yrs)	Nov 2019 (~5 yrs)	Nov 2020 (~6 yrs)	Nov 2021 (~7 yrs)	Dec 2022 (~8 yrs)	Understorey Openness	Site Openness/Geology Description
Recipient Site 1	27	26.5±6.5	39.0±10.4	39.2±10.6	31.1±10.3	41.13±9.5	43.7±8.8	35.0±12.0	56.2±14.60	64.1±20.4	2	Medium, upper slope, sth facing, few big eucalypts, low regrowth wsf /rf on intermediate igneous
Recipient Site 2 (3)	11	25.6±10.1	60.8±15.5	67.3±13.6	97.1±14.2	84.8±12.7	106.4±13.2	95.2±15.9	147.3±23.1	127.9±30.5	3	Open, upper slope, east facing, open forest with open understorey, always breezy; metasediment
Recipient Site 3 (5a)	22	29.3±7.5	49.8±11.2	46.4±9.5	45.7±9.3	46.3±10.8	33.7±9.5	59.5±15.0	45.1±10.5	32.6±12.7	1	Dense, Blackbutt wsf-rainforest lower slope, east facing, thick barky litter; metasediment
Recipient Site 5 (7a)	57	29.5±3.7	51.7±6.9	47.7±7.6	43.8±8.1	35.0±6.3	47.7±5.7	53.3±10.6	47.7±11.5	35.7±9.0	1	Dense, lower slope, south facing, wsf-rainforest; metasediment
Recipient Site 6 (8a)	8	55.1±22.2	53.0±17.9	60.5±17.5	84.7±18.3	82.1±19.1	68.0±17.7	92.2±25.9	126.9±42.6	80.0±46.0	3	Open, next to track and highway (clearing), fairly exposed to north east, lower slope; metasediment
Recipient Site 8 (8c)	27	43.6±6.3	69.5±9.1	50.8±5.9	43.9±5.4	62.2±10.6	84.1±9.6	97.6±26.1	74.2±22.3	62.9±20.1	2	Medium, mid slope, south facing, open forest understorey; metasediment

2.3.2.3 Pattern of stem growth in Slender Marsdenia individuals

Mean height per site provided no indication of how stem growth varied between individuals. within sites. Translocated individuals in fact showed wide variation in degree and timing of stem regrowth. Combining all individuals, after eight years, 45% of individuals were in stem height category D (height=0), 24% in category S (small) and 31% in stem height category T (tall).

Overall, around 40% of stems showed oscillatory stem growth, meaning stems after increasing in height, died back to ground level, then reshot again. Of stems in categories D and S, about half showed oscillatory stem growth. Some went through two or three oscillations in 8 years. Some stems took two to three years to reshoot again. Some oscillations were probably missed as monitoring was carried out once a year for the last 6 years. Very thin stems that had died were visible on the wire cage mesh. Lesser fluctuations in height where the plant did not dieback all the way to ground level were also common (not classed as an oscillation).

Some small stems recorded very little change in height in eight years and no oscillation (Table 8 – S1 5%). In the T category (31%), most stems maintained or increased height over eight years without declining much in height. Oscillations in the T category were 4%, much lower than D and S.

Figure 4 shows the percentage of D, S and T plants within recipient sites. The percentages are fairly constant amongst the 7 sites except for sites 3 and 8(a). Site 8 (a) was probably affected by herbicide spray drift. Site 3 was exceptional in the rapid growth and height of plants, suggesting that the greater openness of this site promoted stem growth. It is possible that variation in height growth response was due to the size of plants introduced. However, the initial size of rescued plants in terms of volume of soil supporting stem and root system (i.e. ~30 cm x 10 cm x 10 cm) did not vary greatly. Large stems were rare and only a few transplanted. It is interesting that for the other 5 sites, percentages of D, S and T plants are similar in each site (Figure 4). This could be interpreted as the effect of random variation in plant size when transplanted, or random variation in planting microsites within the recipient site. The thickness or volume of rhizomatous roots within the slab (not recorded) may have affected individual performance.

Table 8: Number of individuals of Slender Marsdenia in different stem height growth categories at seven recipient sites and all sites combined, eight years after translocation. Actual number of stems and the percentage per site and overall are shown. Categories S and T are considered surviving (survivorship 55%).

	Recipient Sites/ Height Growth Categories	**Cb**	**%**	**3**	**%**	**5**	**%**	**5a**	**%**	**7a**	**%**	**8a**	**%**	**8c**	**%**	**All**	**%**
	Total Slender Marsdenia	27		17		10		21		57		8		27		167	100%
D	**Ht = 0 at Dec/2022, may be dead or may reshoot**																
D1	Never reshot	1	4%	0	0%	0	0%	1	5%	3	5%	0	0%	0		5	3%
D2	Small shoot then died back to ground, probably dead	4	15%	2	12%	2	20%	0	0%	5	9%	1	13%	2	7%	16	10%
D3 (O)	Reshot, reached small to medium height (<1.2 m) then died back to ground, some fluctuated (i.e. dieback-reshoot-dieback)	2	7%	1	6%	2	20%	8	38%	27	47%	2	25%	6	22%	48	29%
D4	Reshot, grew tall (~2 m+) then died back to ground, probably dead	0	0%	0	0%	0	0%	0	0%	0	0%	1	13%	5	19%	6	4%
	All D	7	26%	3	18%	4	40%	9	43%	35	61%	4	50%	13	48%	75	45%
D	oscillations	2	7%	1	6%	1	10%	4	19%	16	28%	0	0%	7	26%	31	19%
S	**Small, growing very slowly, or declining**															0	
S1	Stayed small, mostly less than 10 cm high (some to 50 cm), little height change in 6 yrs	1	4%	0	0%	1	10%	3	14%	2	4%	0	0%	2	7%	9	5%
S2 (O)	Died back to ground and reshot once or twice, continuously small (mostly <50 cm)	5	19%	0	0%	2	20%	1	5%	3	5%	0	0%	2	7%	13	8%

S3	Declining or bell shaped (increase-decrease), some to ~130cm at peak, continuously alive but stem mostly small (<50 cm)	1	4%	0	0%	0	0%	1	5%	3	5%	0	0%	2	7%	5	3%
S4 (O)	Fluctuating – e.g. 'small-medium/tall-small'; or 'grew medium/tall then died back to small	4	15%	0	0%	0	0%	4	19%	2	4%	0	0%	1	4%	10	6%
	All S	11	41%	0	0%	3	30%	9	43%	10	18%	0	0%	7	26%	40	24%
S	oscillations	9	33%	0	0%	2	20%	6	29%	3	5%	0	0%	3	11%	23	14%
T	**Thriving, plant relatively tall, continuing to grow, or maintaining size, healthy**																
T1	Tall (1.5 m+), substantial increase in height/no. of leaves, or maintained height	1	4%	5	29%	1	10%	1	5%	5	9%	1	13%	3	11%	17	10%
T2	Moderately tall (0.75 – 1.5 m +), moderate increase in height (δ = 0.5 – 1 m or more), or height constant	1	4%	7	41%	2	20%	2	10%	7	12%	3	38%	4	15%	26	16%
T3 (O)	Died back to ground then reshot vigorously (>1 m)	6	22%	2	12%	0	0%	0	0%	0	0%	0	0%	0	0%	8	5%
T4	Small for several monitoring events then suddenly grew taller (>1 m)	1	4%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	1%
	All T	9	33%	14	82%	3	30%	3	14%	12	21%	4	50%	7	26%	52	31%
T	oscillations	5	19%	0	0%	0	0%	1	5%	1	2%	0	0%	0	0%	7	4%
																0	
	Oscillating individuals	**16**	59%	**1**	6%	**3**	30%	**11**	52%	**20**	35%	**0**	0%	**10**	37%	61	37%
	1 oscillation	**12**	44%	**1**	6%	**3**	30%	**7**	33%	**17**	30%	**0**	0%	**4**	15%	44	26%
	2 oscillations	**4**	15%	**0**	0%	**0**	0%	**4**	19%	**3**	5%	**0**	0%	**6**	22%	17	10%
	Survivorship	**74%**		**82%**		**60%**		**57%**		**39%**		**50%**		**52%**			

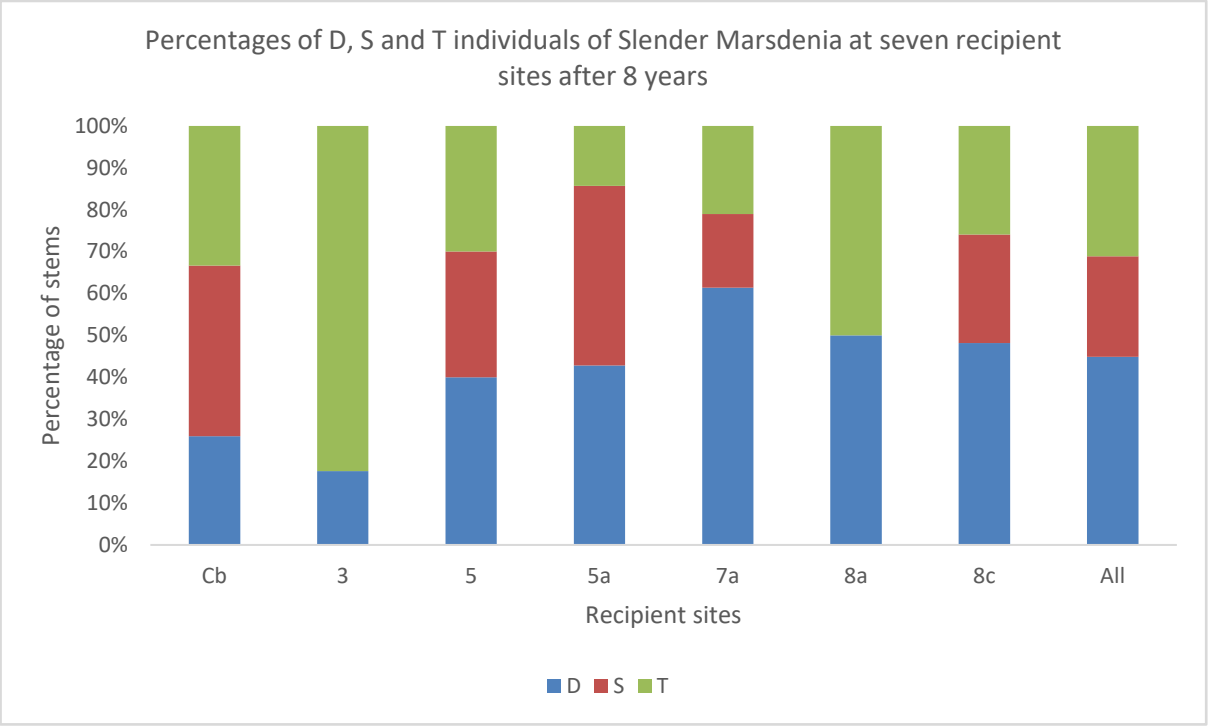

Figure 4: Percentage of D (ht = 0), S (small) and T (tall) plants at each of the recipient sites and all sites combined at the Dec/2022 monitoring, 8 years after translocation. The percentages are fairly constant amongst the sites except for sites 3 and 8(a).

Possible causes of oscillatory stem growth in Slender Marsdenia include seasonal variation in growth conditions (e.g. understorey shading, nutrient availability) resulting in cycles of new shoot growth and stem dieback, and exploratory gauging of the environment before committing to expenditure of stored resources in stem and leaf growth,

2.3.2.4 Comparison with stem height dynamics in in-situ plants

Monitoring of in-situ plants of Slender Marsdenia on the NH2U and WC2NH projects found that stem height fluctuation was present to much of the same extent in naturally occurring in situ populations, and the size class distribution of stems was also much the same in in-situ plants. Most plants were small stem shoots and died back at least once. Large in-situ plants (>2.5 m) with foliage in the forest mid-stratum were very rare.

2.3.2.5 Reproduction

Flowering

A total of four out of 163 translocated plants flowered in eight years, which included three plants that flowered this year. The number of flowers per inflorescence was very small.

A low incidence of flowering in translocated Slender Marsdenia was also recorded on the NH2U project (one individual) and Bonville project (three individuals) (Ecos Environmental 2016 and 2013).

No flowering was recorded in in-situ plants. Flowering is rarely observed in naturally occurring Slender Marsdenia. However, flowers and pods have a neutral green/cream colour that blends in with mid-stratum foliage so are easily overlooked.

Vegetative reproduction

Oscillating stem growth was common in Slender Marsdenia but there was little evidence of clonal or vegetation reproduction. Rare shoots were observed toward the edge of the wire cylinder or just outside (30-40 cm from the centre), which appeared to represent root suckers, but it was difficult to be certain without digging them up and risk killing plants. One or two stem shoots were produced further out (0.5m), which may have been connected to the plant inside the wire cylinder. Overall, there was little evidence of vegetative or clonal reproduction in Slender Marsdenia after transplanting to the recipient sites, which was unexpected as the species is thought to be clonal. Other factors may trigger development of stem clones.

2.3.3 Rusty Plum (*Niemeyera whitei*)

Survival rate of transplanted Rusty Plums at Recipient Site 1 remained at 86% after eight years. All seven plants increased in height and were in good condition. A seedling was recorded at the base of the largest tree, which was cut back to 1.5 m during transplanting and has regrown to about 4.5 m from an original height of about 10 m. Although only one seedling has been recruited, this tree has clearly reached reproductive maturity after being transplanted, which has taken 6-7 years.

Direct seeding of Rusty Plum for population enhancement had a moderate success rate. In November 2021, four years after sowing, single seedlings (from 3 seeds) were present in 5 cylinders and 2 seedlings in one cylinder, at total of 6/14 cylinders (43%), the tallest seedling was 30 cm. Results were affected by poor quality seed, being collected in a drought year and loss of a few cylinders to persons unknown.

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

Woolls' Tylophora survival declined from 67% to 33% in 2020-2021, and 33% to 17% in 2021-2022. This may be due to herbicide spray drift from track maintenance carried out by the local water supply authority. Remaining plants were in good condition.

2.3.5 Large-flowered Milk Vine (*Marsdenia liisae*)

Some of the Marsdenia vines salvaged to Recipient Site 5b were *Marsdenia liisae*, not *Marsdenia longiloba.* The leaves of this species are larger, thicker and often darker green. *Marsdenia liisae* is a rare species ranging between the Hastings River (Pt Macquarie) and the Nightcap Range, although is not listed as threatened. The survival rate of *Marsdenia liisae* was similar to *Marsdenia longiloba*.

2.3.6 Spider Orchid (*Dendrobium melaleucaphilum*)

The two Spider Orchid plants rescued from the footprint declined in condition between 2020 and 2021, apparently due to grazing of pseudobulbs by an unknown insect or mollusc. There was little new pseudobulb growth. Persistent terminal flower axes indicated most pseudobulbs had flowering in spring (August - September) but as in previous years, there was no evidence of seed set, possibly due to absence of pollinators.

2.3.7 Floyds Grass (*Alexfloydia repens*)

Area 9a

There was a marked decrease in Floyds Grass cover-abundance in Recipient Site 9a in December 2022 compared to 2021. Last year's report stated: "About half of the fenced area comprising Area 9a contained at least some Floyds Grass in Nov/2021, seven years after translocation. This is the same cover recorded last year, which has been approximately stable for about 3-4 years, although subject to maintenance (removal of Broad-leaved Paspalum) for the last 12 months. Plants are found on the side of the recipient site closest to Warrell Creek, about 10 m from the creek edge. The other half has a high percentage of Broad-leaved Paspalum (BLP), although this has been reduced by herbicide treatment and hand weeding in 2021 and hopefully will allow Floyds Grass to spread into it. A high density of native Ottochloa grass is present with Floyds Grass and tends to overtop it. Floyds Grass is favoured where there are low woody plants which it can climb to get above Ottochloa (only 20-30 cm high)."

In December 2022, the total area of Floyds Grass was estimated at 10 m² or about 5% of the fenced area referred to above. Rather than a continuous cover of Floyds Grass, as recorded in previous years, occurrence in the 10 m² was fragmented. The section in the southeast corner of the fenced area where Floyds Grass had been dominant, was dominated by Ottochloa this year – see Plates 25 to 31. Overall, Floyds Grass appears to have declined by more than 50% compared to last year.

There was no obvious cause for the decline. The site experienced flooding in 2021-22 but Floyds Grass habitat being on creekbanks is often flooded. Ottochloa has been observed competing strongly with Floyds Grass at other locations. The population dynamics and interaction of these two species are poorly understood. It is possible that natural fluctuations in cover-abundance of both species occur naturally, and it will swing back to Floyds Grass next year. Growing conditions appear to have been particularly favourable for Ottochloa this year.

The site has been subject to a weed control program focusing on Broad-leaved Paspalum for two years. No adverse effects were observed last year after implementation of the program for a year, so it appears that the natural population dynamics of Floyds Grass and Ottochloa are driving the changes in species abundance. As the site was inspected only once a year, it is difficult to assess when and how quickly species abundance changed, if it corresponded with a certain season or weather event, or what other factors may have influenced the decrease in Floyds Grass.

Area 9b

A small amount of Floyds Grass was still present in Area 9b in 2022. A total of 12 small clumps of Floyds Grass, 5 cm x 10 cm up to 20 cm x 20 cm, were counted.

Last year's report stated: - "Floyds Grass is still present in this section in small clumps along the rows and has declined since 3 years ago. In 2021, the area was intensively treated with the aim of removing BLP, which was smothering remaining Floyds Grass. Selective herbicide was tried but found to be ineffective."

A buffer around the two areas has been planted with local native species, which are establishing well.

The cover-abundance of Floyds Grass remaining in Sites 9a and 9b in December 2022 is greater than the small amount of Floyds Grass impacted on the bank of Warrell Creek at the bridge construction site.

2.3.8 Koala Bells (*Artanema fimbriatum*)

Koala Bells transplanted from the footprint to Recipient Site 8a died out after two years. Flowering and seeding occurred in the first and second years. Seed was produced and dormant seed may be present in the soil seedbank. The Site 8a is located next to a watermain easement that appears to be maintained by annual herbicide spraying (not evident when the translocations were carried out) which may have affected the Koala Bells planted next to the track (as well as Slender Marsdenia Recipient Site 8a).

Propagated Koala Bells were introduced to Recipient Site 9b in autumn 2017 when the plants were flowering and seeding. Recruitment of more plants, apparently from seed although they could have been root suckers, was recorded a few months later in spring 2017. These plants persisted until spring 2019 then all died out by spring 2020. No more plants appeared in 2021 as the site became overgrown with BLP or were seen in 2022 after weeding had been carried out.

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.	Mostly Yes
3. At the end of the monitoring program at least 50% of surviving individuals have a Condition Class of 3.	Yes
4. Habitat at recipient sites in good condition conducive to medium term survival (i.e. 10 years)	Yes

2.5 Work Schedule

No further works are proposed for the Translocation Recipient Sites on the WC2NH project as the requirements of the Threatened Flora Management Plan have been completed.

3 In-Situ Threatened Flora Populations

3.1 Methods

In-situ Threatened Flora Populations comprise the following threatened 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 project began. All individuals occurred within the project boundary but outside the clearing limit (Figures 5-9).

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

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

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

Ecos Environmental conducted the first yearly operational phase monitoring of the in-situ threatened species in November 2018. All tagged plants were located and the same condition data as recorded by GeoLINK were collected. Additionally, Ecos Environmental recorded the height of each individual to assess plant growth and performance throughout the monitoring program. In November 2021, Ecos Environmental conducted the fourth yearly operational phase monitoring, which is described in this report.

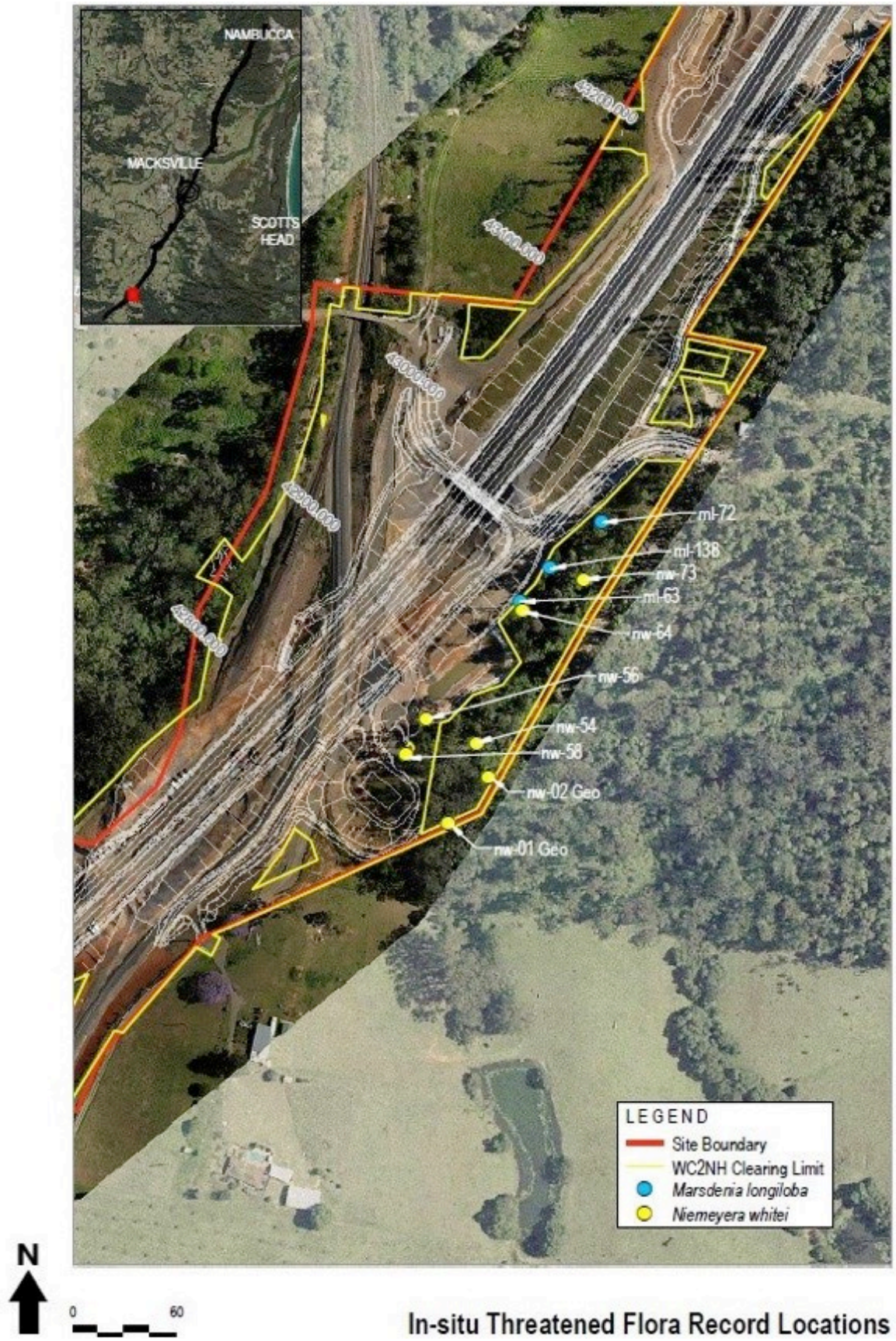

Figure 5: In-situ Slender Marsdenia and Rusty Plum at Cockburns Lane, WC2NH. Map sourced from GeoLINK (2017).

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

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

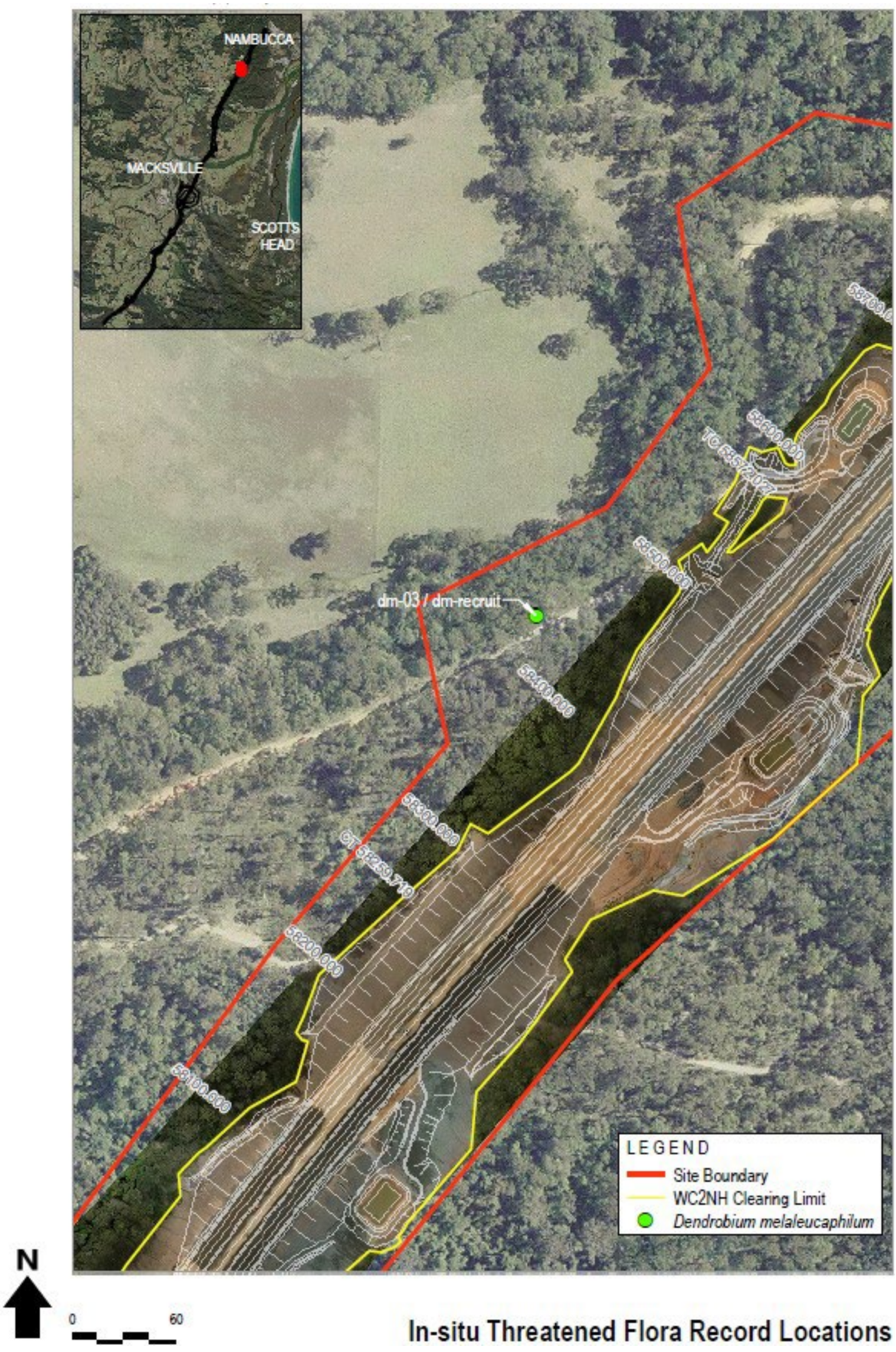

Figure 8: In-situ Spider Orchid, WC2NH. Map sourced from GeoLINK (2017).

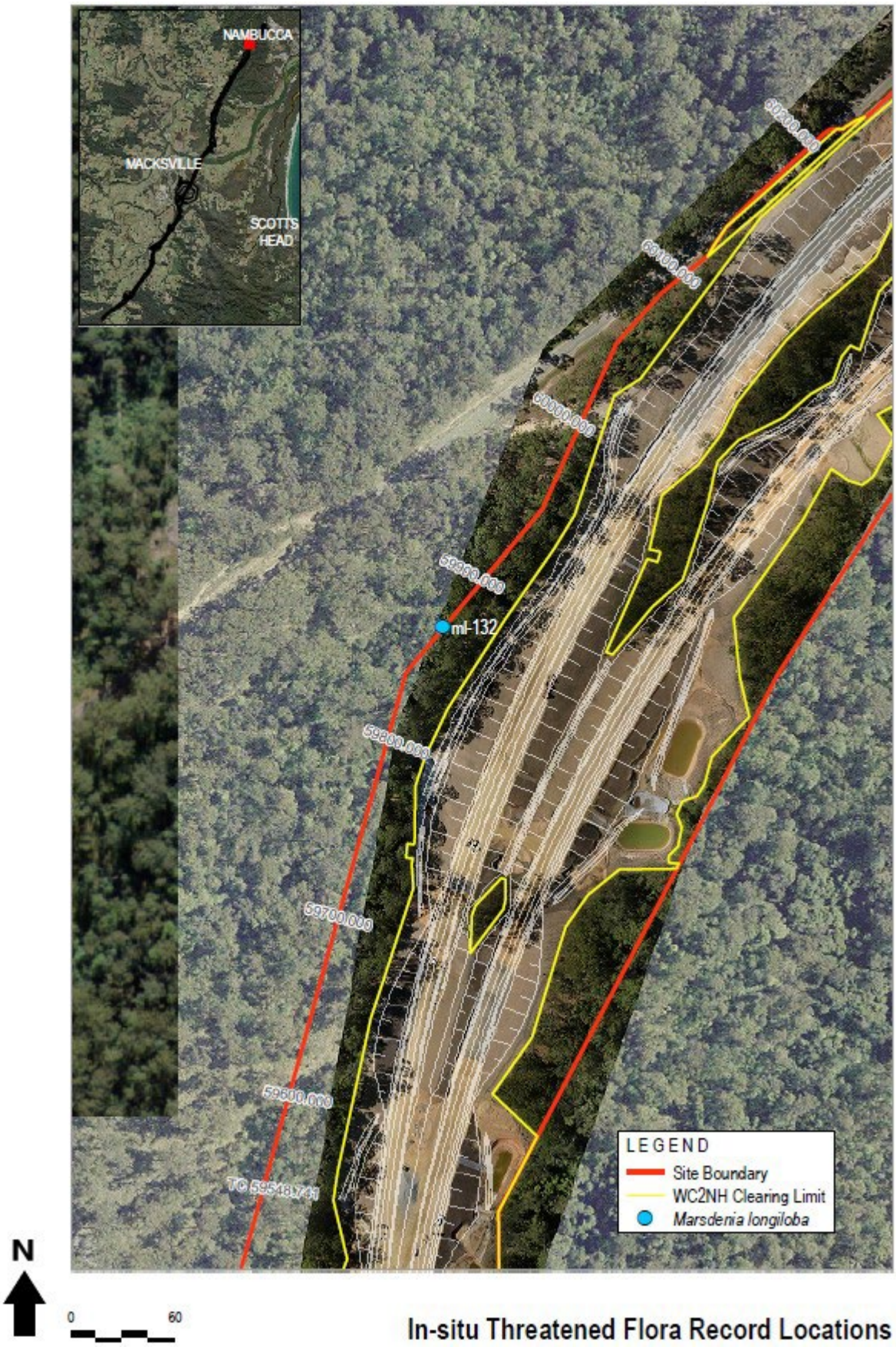

Figure 9: In-situ Slender Marsdenia, WC2NH. Map sourced from GeoLINK (2017).

3.2 Results

See Appendix 2 for photos of the in-situ threatened plant species in December 2022.

3.2.1 Maundia (*Maundia triglochinoides*)

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

Following the end of the drought in 2020 and flooding rains, Maundia began to recover and by December 2022 had a crown cover of 50-60%, similar to or more than recorded in 2018. Flowering Maundia plants were common.

3.2.2 Spider Orchid (*Dendrobium melaleucaphilum*)

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

3.2.3 Rusty Plum (*Niemeyera whitei*)

All seven in-situ Rusty Plums at Cockburns Lane were alive and in reasonable condition in November 2021 (Table 13). A few fruits were observed this year.

Habitat condition at the Cockburns Lane site in November 2021 was generally good. Lantana was scattered throughout the site although did not appear to be having a negative effect on Rusty Plum or Slender Marsdenia, which also occurs at site.

3.2.4 Slender Marsdenia (*Marsdenia longiloba*)

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

In December 2022, Slender Marsdenia was present at all five in-situ locations. In most locations there was more than one stem and so height and plant condition was recorded for the largest stem. The height (of the largest stem) of individuals ranged from 10 cm to 2m and condition score ranged from 2 to 4 (Table 14).

The largest in situ Slender Marsdenia occurrence being monitored - ML93 - consists of a clonal patch of small stem-individuals growing across the fence line along Old Coast Road in remnant forest in the road reserve and adjoining property. In December 2022, this patch consisted of about 12 stems within an area approx. 15 m x 10 m, extending from the edge of Old Coast Road to the base of a large Tallowwood (*Eucalyptus microcorys*) and several more in grass on the roadside. Most stems were small (<20 cm high) and none exceeded one metre high. No flowering or fruiting was observed. Recruitment in this patch is mostly likely vegetative or asexual by production of stems from underground tuberous roots.

At ML132 shoots remained small (<10 cm high). Stems at ml-72, ml-138 and ml-63 occur at Cockburns Lane (same site as in-situ Rusty Plum) were small and one 1 m high.

Table 11: In-situ threatened flora monitoring results for Maundia (*Maundia triglochinoides*) recorded by Ecos Environmental 2019-2022

Maundia (*Maundia triglochinoides*)																
Population	Cover-Abundance and (Condition Class Score)			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions (Spr 2022
	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	
Nambucca Floodplain	<1%	20%	60%	N	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	Canopy height 10-14m m with *Melaleuca quinquenervia* dominant species; ground stratum 100% crown-cover; water to 20 cm deep; exotic grass spp. along fauna fenceline with road.

Table 11: In-situ threatened flora monitoring results for Maundia (*Maundia triglochinoides*) recorded by Ecos Environmental 2019-2022.

Maundia (*Maundia triglochinoides*)																
Population	Cover-Abundance and (Condition Class Score)			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions (Spr 2022)
	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	
Nambucca Floodplain	<1%	20%	60%	N	Y	Y	Y	Y	Y	Y	N	Y	N	N	N	Canopy height 10-14m m with *Melaleuca quinquenervia* dominant species; ground stratum 100% crown-cover; water to 20 cm deep; exotic grass spp. along fauna fenceline with road.

Table 12: In-situ threatened flora monitoring results for Spider Orchid (*Dendrobium melaleucaphilum*) recorded by Ecos Environmental 2018 – 2022.

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 2022)
	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022			
3	35	35	25	5	5	2	50+	50	12	N	Y	N	N	N	N	N	N	N	Canopy height 25 m and crown-cover approx 90% comprised of Eucalyptus spp.	Very healthy with signs of increased flowering activity.	Fairly healthy, effect of dry conditions evident in many dead and ratty pseudobulbs
DM Recruit	12	12	6	3	3	2	4	4	2	N	N	N	N	N	N	N	N	N		This new recruit was first observed during Spring 2016.	

Table 13: In-situ threatened flora monitoring results for Rusty Plum (*Niemeyera whitei*) recorded by Ecos Environmental 2018 – 2022.

Plant ID #	Height (cm)			Leaf Condition			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions (Spr 2022)
	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 20222	
NW58	800	820	920	4	4	4	N	N	N	Y	Y	Y	N	N	N	N	N	N	Canopy height 20 m with crown-cover 70%; some medium to large patches of Lantana scattered throught site.
NW56	120	130	140	4	4	4	N	N	N	Y	Y	Y	N	N	N	N	N	N	
NW73	700	750	760	5	4	4	Y	N	N	N	Y	Y	N	N	N	N	N	N	
NW54	600	640	650	4	4	4	N	N	N	N	Y	Y	N	N	N	N	N	N	
NW64	800	850	870	5	4	4	Y	N	N	N	N	N	N	N	N	N	N	N	
NW01-Geo	450	450	480	4	4	4	N	N	N	N	Y	Y	N	N	N	N	N	N	
NW02-Geo	500	530	570	4	4	4	N	N	N	N	Y	Y	N	N	N	N	N	N	

Table 14: In-situ threatened flora monitoring results for Slender Marsdenia (*Marsdenia longiloba*) recorded by Ecos Environmental 2018 - 2022

Plant ID	Height (cm)			Leaf Condition			Flower/ Fruit Present			New Growth			Recruitment			Damage/ Disturbance			Site Conditions	GeoLINK notes (PC 2015-Spr 2017)	Ecos Environmental notes (Spr 2018-to Spr 2022)
	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022	Spr 2019	Spr 2020	Spr 2022			
ML93	130	18	6	2	3	3	Spr 2098	Spr 2020	N	Y	Y	N	N	Y	N	N	N	N	Canopy height 20 m; crown-cover 100% with Eucalyptus microcorys dominant species.	15 live plants now within 1 m radius of subject plant. All range from 2 – 4 in condition class. Some plants recorded during spring 2016 have died back however new recruits have also been recorded and are now at a count of 23 flagged individual plants.	Clonal patch, no. variable 15-30 individuals in an area 15m x 10 m, from the base of E. microcorys to the edge of O)ld Coast Rd. In 2018, most plants small (<20cm high), a few >1 m high. In 2021, all small.
ML132	10	5	25	2	3	3	N	N	N	Y	Y	Y	N	N	N	N	N	N	Canopy height 25 m; crown-cover 80%	During Spring 2016 partially natural die back was recorded. The plant recorded during spring 2017 is fresh, green with new growth indicating possibly a new plant to the one previously recorded.	Most shoots tagged 2018 had died off. Two small shoots (<10 cm tall) in 2021 about 1 m apart
ML72	10	10	0	2	3	3	N	N	N	N	N	N	N	N	N	N	N	N	Canopy height 20 m; crown-cover 70%	Natural die back of the stem, possibly live stem bulb. No obvious signs of construction related impacts.	Died back and reshot
Ml138	90	10	141	3	3	3	N	N	N	Y	N	Y	N	N	N	N	N	N		Tall plant with mature leaves some yellowing.	Died back and reshot

ML63	10	300	150	2	4	4	N	N	N	N	Y	Y	N	N	N	N	N	N		Healthy

3.3 Conclusion

The survival rate of in-situ threatened flora species after approximately eight years (Dec 2022) was 100% for Spider Orchid, Rusty Plum and 70% for Slender Marsdenia. (Table15). Maundia does not occur as discrete individuals but as a sward of stems, so its abundance was measure just as crown-cover. The plot crown-cover of Maundia had increased from <1% at the peak of the drought to 50-60% in Dec 2022, the level of cover-abundance recorded before the drought. The survival rate of Slender Marsdenia remained stable although some stems had died back and reshot.

No signs of adverse effects on threatened flora related to highway operation were observed in Dec 2022. The monitoring results meet the performance criteria – *survival rate at the end of Years 4-8 is >70%* and *of surviving plants at end of each year >75% are in good condition (class 3 or >)* – for Spider Orchid, Rusty Plum and Slender Marsdenia and therefore no corrective actions are required for these species. Note that >75% of in-situ Slender Marsdenia plants do not have a class score of 3 or > as they were not taller than 75 cm, but this is not of concern for this species because of the tendency for stems to dieback and regrow again.

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

Species	Survival rate at finish of clearing (October 2015/ Spring 2015) is 100%, no accidental damage due to clearing	Survival rate at end of Years 1-3 is >80%	Survival rate at end of Year 4 (2018)	Survival rate at the end of Years 4-8 is >70%	Of surviving plants at end of each year >75% are in good condition (class 3 or >)			
					Year 3 - 2017	Year 5 - 2019	Year 6 - 2020	Year 8 - 2022
Spider Orchid (*Dendrobium melaleucaphilum*)	Yes - 100% survival No accidental damage due to clearing	Yes - 100% survival	Yes - 100%	Not applicable yet	Yes - 100% in good condition, with new recruit. recorded also in good condition (score 3)	Yes - 100% (including new recruit) in good condition (Score 4)	Yes - 100% with one plant reproductive	Yes - 100% with one plant reproductive
Maundia (*Maundia triglochinoides*)	Yes - 100% survival No accidental damage due to clearing	Yes - 83% survival	No - <1% survival (trace)%	Not applicable yet	Yes - 100% in good condition (score 5)	Yes - 100% of visible plants in good condition (score 3)	No – poor condition (score 1)	Yes – good recovery after the drought, flowering (score 3)
Rusty Plum (*Niemeyera whitei*)	Yes - 100% survival No accidental damage due to clearing	Yes - 100% survival	Yes - 100%	Not applicable yet	Yes - 80% in good condition (score 2 - 5)	Yes - 100% in good condition (score 3 - 5)	Yes - 100% with some plants reproductive	Yes - 100% with some shoot growth
Slender Marsdenia (*Marsdenia longiloba*)	No - 62% of plants were recorded as living But no construction related impacts were recorded	No - 60%	Yes - 100%	Not applicable yet	Yes - 100% (5 of 5 records) recorded scores 3 - 4	No - 60% (3 of 5 records) recorded scores 1 - 4	No - 40% in good condition	Yes - 70% in good condition

4 Slender Marsdenia and Woolls' Tylophora Habitat Condition

4.1 Methodology

This component of the Threatened Flora Management Plan aims to monitor Slender Marsdenia and Woolls' Tylophora habitat in 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 and monitored the plots again in autumn and spring 2016 and spring 2017 (GeoLINK 2017).

Ecos Environmental carried out the first yearly operation phase monitoring of the ten plots in November 2018. Native vegetation structure was measured according to the following guidelines: "Structure consists of the height, crown-cover and dominant species in each vegetation layer and will be recorded according to the current OEH Native Vegetation Interim Type Standard (www.environment.nsw.gov.au/research/VISplot.htm)." - p27.

Ecos Envrionmetal carried out the fifth yearly operation phase monitoring in December 2022, 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

Since spring 2015 the level of weed incursion has increased in some plots and decreased in others (Table 17). All changes, however, are minor with weed crown-cover remaining far below the performance measure threshold of 25%. The data also indicates that the microclimate of some plots in spring 2021 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 was collected by two different observers – GeoLINK from 2015-2017 and Ecos Environmental in 2018-2022 – and therefore likely reflects observer variability.

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

Plot	Weed Level (crown-cover)	Microclimate Class
1	Lantana	
Spring 15 (GeoLINK)	<5	5
Autumn 16 (GeoLINK)	5	5
Spring 16 (GeoLINK)	5	5
Spring 17 (GeoLINK)	5	5
Spring 18 (Ecos)	<5	5
Spring 19 (Ecos)	5	5
Spring 20 (Ecos)	5	5
Spring 21 (Ecos)	4	4
Spring 22 (Ecos)	4	4
2	Lantana, Whisky Grass	
Spring 15 (GeoLINK)	<5	5
Autumn 16 (GeoLINK)	5	5
Spring 16 (GeoLINK)	10	5
Spring 17 (GeoLINK)	10	5
Spring 18 (Ecos)	<5	5
Spring 19 (Ecos)	<5	5
Spring 20 (Ecos)	5	5
Spring 21 (Ecos)	2	4
Spring 22 (Ecos)	2	4
3	Lantana	
Spring 15 (GeoLINK)	<5	1
Autumn 16 (GeoLINK)	<5	1
Spring 16 (GeoLINK)	<5	1
Spring 17 (GeoLINK)	<5	1
Spring 18 (Ecos)	<5	2
Spring 19 (Ecos)	<5	2
Spring 20 (Ecos)	<5	3
Spring 21 (Ecos)	<5	3
Spring 22(Ecos)	<5	3
4	Lantana	
Spring 15 (GeoLINK)	0	2
Autumn 16 (GeoLINK)	0	2

Plot	Weed Level (crown-cover)	Microclimate Class
Spring 16 (GeoLINK)	0	2
Spring 17 (GeoLINK)	0	2
Spring 18 (Ecos)	<5	2
Spring 19 (Ecos)	<5	2
Spring 20 (Ecos)	<5	2
Spring 21 (Ecos)	<3	2
Spring 21 (Ecos)	<3	2
Spring 22 (Ecos)	<3	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
Spring 20 (Ecos)	<5	5
Spring 21 (Ecos)	<5	5
Spring 22 (Ecos)	<5	5
6	Lantana	6
Spring 15 (GeoLINK)	5	4
Autumn 16 (GeoLINK)	5	4
Spring 16 (GeoLINK)	5	4
Spring 17 (GeoLINK)	5	4
Spring 18 (Ecos)	<5	5
Spring 19 (Ecos)	10	5
Spring 20 (Ecos)	10	5
Spring 21 (Ecos)	5	4
Spring 22 (Ecos)	5	5
7	Broad-leaved Paspalum	
Spring 15 (GeoLINK)	0	1
Autumn 16 (GeoLINK)	0	1
Spring 16 (GeoLINK)	0	1
Spring 17 (GeoLINK)	0	1
Spring 18 (Ecos)	<5	2
Spring 19 (Ecos)	0	2
Spring 20 (Ecos)	0	2
Spring 21 (Ecos)	0	2
Spring 22 (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

Plot	Weed Level (crown-cover)	Microclimate Class
Spring 20 (Ecos)	<5	2
Spring 21 (Ecos)	<5	2
Spring 22 (Ecos)	<5	2
9	Lantana, Broad-leaved Paspalum, Coastal Morning Glory	
Spring 15 (GeoLINK)	5	1
Autumn 16 (GeoLINK)	5	1
Spring 16 (GeoLINK)	<5	1
Spring 17 (GeoLINK)	<5	1
Spring 18 (Ecos)	<5	2
Spring 19 (Ecos)	<5	2
Spring 20 (Ecos)	<5	2
Spring 21 (Ecos)	<5	2
Spring 22 (Ecos)	<5	2
10	Lantana, Billygoat Weed, Setaria	
Spring 15 (GeoLINK)	<5	4
Autumn 16 (GeoLINK)	<5	4
Spring 16 (GeoLINK)	<5	4
Spring 17 (GeoLINK)	<5	4
Spring 18 (Ecos)	<5	5
Spring 19 (Ecos)	<5	5
Spring 20 (Ecos)	<5	5
Spring 21 (Ecos)	<5	2
Spring 22 (Ecos)	<5	4

Table 18: Vegetation structure of ten Slender Marsdenia and Woolls' Tylophora habitat monitoring plots, WC2NH. Data recorded December 2022 by Ecos Environmental.

Stratum	Dominant species	Cover (% crown-cover)	For the entire		
Plot 1					
Upper	*Eucalyptus grandis*	10	Upper stratum Height to crown (m) min-mode-max		
Upper	*Syncarpia glomulifera*	20			
Upper			20	20	30
Mid	*Lophostemon confertus*	20	Mid stratum Height to crown (m) min-mode-max		
Mid	*Cissus hypoglauca*	65			
Mid	*Acacia binervata*	15	4	5	10
Lower	*Blechnum cartilagineum*	30	Lower stratum Height to crown (m) min-mode-max		
Lower	*Dodonaea triquetra*	15			
Lower	*Cordyline stricta*	10	0.5	2	4
Plot 2					
Upper	*Syncarpia glomulifera*	50	Upper stratum Height to crown (m) min-mode-max		
Upper	*Eucalyptus microcorys*	20			
Upper	*Allocasurina torolosa*	15	15	24	28
Mid	*Cissus hypoglauca*	40			

Stratum	Dominant species	Cover (% crown-cover)	For the entire		
Mid	*Calicoma seratifolia*	15	Mid stratum Height to crown (m) min-mode-max		
Mid	*Trochocarpa laurina*	15	2	8	15
Lower	*Blechnum cartilagineum*	20	Lower stratum Height to crown (m) min-mode-max		
Lower	*Morinda jasminoides*	25			
Lower	*Cryptocarya rigida*	30	0.5	1	2
Plot 3					
Upper	*Syncarpia glomulifera*	15	Upper stratum Height to crown (m) min mode max		
Upper	*Eucalyptus grandis*	30			
Upper	*Eucalyptus anchorphylla*	10	28	28	30
Mid	*Cryptocarya rigida*	50	Mid stratum Height to crown (m) min mode max		
Mid	*Callicoma seratofolia*	30			
Mid	*Cissus hypoglauca*	40	4	5	12
Lower	*Blechnum cartilagineum*	30	Lower stratum Height to crown (m) min mode max		
Lower	*Livistonia australis*	30			
Lower	*Ripognum forcetianum*	15	0.5	1	3
Plot 4					
Upper	*Eucalyptus grandis*	30	Upper stratum Height to crown (m) min mode max		
Upper	*Eucalyptus glomulifera*	25			
Upper	*Eucalyptus acmenoides*	10	20	30	30
Mid	*Livistonia australis*	5	Mid stratum Height to crown (m) min mode max		
Mid	*Alphitonia excelsa*	20			
Mid	*Synoum glandulosum*	10	4	5	15
Lower	*Cissus hypoglauca*	50	Lower stratum Height to crown (m) min mode max		
Lower	*Gahnia sieberana*	20			
Lower	*Lepidosperma laterale*	5	0.5	1	2
Plot 5					
Upper	*Syncarpia glomulifera*	40	Upper stratum Height to crown (m) min mode max		
Upper	*Glochidion ferdinandii*	10			
Upper	*Gmelina leichhardtii*	10	15	18	20
Mid	*Livistonia australis*	15	Mid stratum Height to crown (m) min mode max		
Mid	*Guioa semiglauca*	30			
Mid	*Cissus hypoglauca*	20	7	10	12
Lower	*Cordyline stricta*	20	Lower stratum Height to crown (m) min mode max		
Lower	*Gahnia aspera*	15			
Lower	*Lomandra longifolia*	10	0.8	1	1.5
Plot 6					
Upper	*Eucalyptus pilularis*	40	Upper stratum Height to crown (m) min mode max		
Upper	*Lophostemon confertus*	20			
Upper	*Eucalyptus microcorys*	20	15	22	27
Mid	*Trochocarpa laurina*	15	Mid stratum Height to crown (m) min mode max		
Mid	*Acacia melanoxylum*	15			

Stratum	Dominant species	Cover (% crown-cover)	For the entire		
Mid	*Tabernaemontana pandacaqui*	20	5	8	12
Lower	*Cordyline stricta*	20	Lower stratum Height to crown (m) min mode max		
Lower	*Livistonia australis*	20			
Lower	*Blechnum cartilagineum*	10	0.5	1	2
Plot 7					
Upper	*Eucalyptus microcorys*	80	Upper stratum Height to crown (m) min mode max		
Upper	*Eucalyptus grandis*	10			
Upper			14	20	22
Mid	*Leptospermum polygalifium*	35	Mid stratum Height to crown (m) min mode max		
Mid	*Archirhodomyrtus beckleri*	10			
Mid	*Glochidion ferdinandi*	10	1.5	3	5
Lower	*Calochlaena dubia*	80	Lower stratum Height to crown (m) min mode max		
Lower	*Lomandra longifolia*	5			
Lower	*Blechnum cartilagineum*	5	0.5	0.7	1
Plot 8					
Upper	*Eucalyptus grandis*	70	Upper stratum Height to crown (m) min mode max		
Upper					
Upper			30	24	18
Mid	*Cissus hypoglauca*	20	Mid stratum Height to crown (m) min mode max		
Mid	*Rubus moluccanus*	20			
Mid	*Guioa semiglauca*	20	12	8	7
Lower	*Blechnum cartilagineum*	25	Lower stratum Height to crown (m) min mode max		
Lower	*Oplismenus imbecilis*	30			
Lower	*Morinda jasminoides*	15	2	1	0.3
Plot 9					
Upper	*Eucalyptus grandis*	15	Upper stratum Height to crown (m) min mode max		
Upper	*Corymbia intermedia*	30			
Upper	*Eucalyptus microcorys*	10	14	25	32
Mid	*Cryptocarya rigida*	30	Mid stratum Height to crown (m) min mode max		
Mid	*Livistonia australis*	15			
Mid	*Synoum glandulosum*	10	1.5	2.5	7
Lower	*Gahnia siberana*	5	Lower stratum Height to crown (m) min mode max		
Lower	*Lastreopsis* sp.	25			
Lower	*Cordyline stricta*	2	0.1	0.5	1
Plot 10					
Upper	*Eucalyptus grandis*	70	Upper stratum Height to crown (m) min mode max		
Upper					
Upper			20	25	28
Mid	*Melaleuca stypeloides*	10	Mid stratum Height to crown (m) min mode max		
Mid	*Lophostemon confertus*	10			
Mid	*Cissus antarctica*	20	2	8	10

Stratum	Dominant species	Cover (% crown-cover)	For the entire		
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 indicate there have been no declines in Woolls' Tylophora and Slender Marsdenia habitat condition along the edge of clearing. Different microclimate exposure scores assigned for some plots by GeoLINK (2017) most likely reflect observer variability rather than physical changes. Plot crown-cover of exotic species in Dec/2022 ranged from 0 to 10% or well below the performance threshold of 25%. Vegetation structure appeared to have remained the same. Therefore, no corrective actions are required (Table 19).

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

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

5 Recommendations

No further management measures are recommended for the translocation recipient sites and in situ threatened flora on the WC2NH project based on this final monitoring report.

Given the marked decline of Floyds Grass at Recipient Site 9a and 9b at Warrell Creek, little gain is likely to result by carrying out further maintenance at the site.

After eight years of maintenance and monitoring, both translocated and in situ threatened species have been given a substantial boost to their chances of surviving over the long-term and establishing viable populations.

The only recommendation is for TfNSW to consider installing signage at each of the translocation recipient sites, clearly identifying them as **"Threatened Flora Translocation Sites**" to inform local government, agencies and the general public, which will reduce the risk of accidental damage occurring in future.

6 References

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Appendix 1: Photos Translocated Threatened Flora

Slender Marsdenia (*Marsdenia longiloba*)

Plate 1: Recipient Site 8a, plant no. 9, growing on wire tree guard, 6 leaves yellow-green, stem dying back.

Plate 2: Recipient Site 8a, plant no. 13, tall, healthy stem 3.2 m in height.

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Slender Marsdenia (*Marsdenia longiloba*)

Plate 3: Top left. Recipient Site 8c, plant no. 12, flowering.

Plate 4: Top right. Recipient Site 8c, plant no. 20, tall plant, many leaves, in forest mid-stratum, flowering.

Plate 5: Bottom left. Recipient Site 8c, no. 21 growing out of top of cage.

Plate 6: Bottom right. Recipient Site 8c, small plant 10 cm hjgh.

Slender Marsdenia (*Marsdenia longiloba*)

Plate 7: Top left. Recipient Site 7b no. 3, healthy, tall.

Plate 8: Top right. Recipient Site 7b no. 32, small plant 20 cm high, healthy.

Plate 9: Bottom left. Recipient Site 7b, view of habitat showing shady understorey with dense ground layer of Gristle Fern (*Blechnum cartilagineum*).

Slender Marsdenia (*Marsdenia longiloba*)

Plates 10 and 11: Recipient Site 5a. Top left plant no. 11, healthy tall. Top right plant no. 2, a small shoot. Bottom left plant no. 1, tall with few leaves. Bottom right plant no. 13, small plant with two leaves after eight years (this may be a recent shoot, but the plant hasn't grown any higher in eight years).

Slender Marsdenia (*Marsdenia longiloba*)

Plates 12 and 13: Recipient Site 5b. Approximately half the Marsdenia's translocated to this site turned out to be Large-flowered Marsdenia (*M. liisae*), a rare species, but not listed as threatened. It has larger leaves than *M. longiloba*. Three photos are *M. liisae*, bottom right is *M. longiloba*, plant no. 14.

Slender Marsdenia (*Marsdenia longiloba*)

Plates 14 to 16: Recipient site 3.

Top left – plant no. 2 about 5 metres high with the assistance of a dead sapling placed for it it to climb up into young trees.

Top right – plant no. 4, stem has grown out of top of cage, a previous stem now dead is hanging down on the right.(not a stem oscillation as it did not die back to the ground and reshoot).

Bottom left – this dumped car and other rubbish have been removed, but there is no sign identifying the site as a Threatened Flora Translocation Area, increasing the risk of this happening again.

Slender Marsdenia (*Marsdenia longiloba*)

Plate 17 and 18: Recipient Site 1. Left - plant no. 19 about 80 cm high. Right - plant no. 14 consisting of two small shoots that shot from roots underground in the last 12 months.

Rusty Plum (*Niemeyera whitei*)

Plates 19 to 21: Left – transplanted Rusty Plum after eight years has regrown from stump of bare rooted tree.

Top right – seedling recruited from one of the transplanted trees two years ago, still surviving, growing very slowly.

Bottom right – transplanted Rusty Plum, multiple coppice stems have shot from a stump about 0.7 m high

Rusty Plum (*Niemeyera whitei*)

22and 23: Recipient Site 7a. Rusty Plum translocated by direct seeding locally collected seed into protective wire mesh cylinders. Threes seeds were placed in each cylinder. After five years, two seedlings survive in one cylinder and one in the other. The seedlings are about 25 cm high and healthy, but slow growing. .

Large-flowered Spider Orchid (*Dendrobium melaleucaphyllum*)

Plate 24: Translocated Spider Orchid (*Dendrobium melaleucaphyllum*) in Recipient Site 7b. The clump of orchid pseudobulbs was moved attached to the small paperbark branch it was growing on and tied onto the tree trunk behind. The number of pseudobulbs or orchid stems has decreased by half since being moved, but remaining pseudbulbs are still in fair condition. The pseudobulbs have flowered in spring every year since being moved (as indicated by dried up flower spikes) but no seed pods formed, probably due to absence of an insect pollinator. Two orchid clumps were translocated, the second with fewer pseudobulbs than this one.

Floyds Grass (*Alexfloydia repens*)

Plates 25 to 27: Floyds Grass Recipient Site 9a

Top – southeast end of Recipient Site 9a with dense *Ottochloa gracillima* (a native mat forming grass) suppressing Floyds Grass

Middle – close-up of photo above showing *Ottochloa gracillima*. This is a native species.

Bottom – close-up of some Floyds Grass which has a flattened stem and arching, blunt tipped leaf blades. Ottochloa is in the bottom left bottom corner of this photo and has more pointed, straight leaf blades.

Floyds Grass (*Alexfloydia repens*)

Plate 28: Recipient Site 9a. Another plant displacing Floyds Grass since last year is the native ground fern *Hypolepis muelleri* (Harsh Ground Fern), which overops and smothers Floyds Grass.

Plate 29: Recipient Site 9a.

Floyds Grass tries to escape smothering Ottochloa and Harsh Ground Fern by using the stems of small woody plants for support to climb above them, seen here.

Floyds Grass (*Alexfloydia repens*)

Plate 30 and 31: Recipient Site 9b

Top – After weeding Site 9b has a low cover-abundance of exotic Broad-leaved Paspalum but small amounts of remaining Floyd Grass showslittle response.

Bottom – Site 9b, one of the larger, original patches of Floyds Grass. The grass appears stunted and discoloured, possibly due to residual effect of selective herbicide treatment to control Broad-leave Paspalum

APPENDIX 2:

PHOTOS OF IN SITU THREATENED FLORA, DECEMBER 2022

Maundia (*Maundia triglochinoides*) (in situ)

Plate 32: Maundia in-situ site on Nambucca floodplain next to highway at Macksville, Maundia regrew rapidly after the drought ended in early 2020.

Plates 33 and 34: Left - Maundia gowing in open paperbark swamp, sprayed grass on fauna fence and highway on right hand side. Right – spike of Maundia seed capsules ripening December 2022.

Slender Marsdenia (*Marsdenia longiloba*) (in situ)

Plates 35 and 36: Slender Marsdenia no. 132 off Old Coast Road next to the highway.

This small patch of stems has maintained similar height for eight years, The plant in the photo to the right grew about 1.5 m high then died back to the ground. The small plant above had grown where the previous stem had died back so is probably from the same plant's root system.

These stem dynamics are similar to those observed in the translocated plants.

Large-flowered Spider Orchid (*Dendrobium melaleucaphyllum*) (in situ)

Plates 37 to 39: Top left – in situ orchid clump growing low down on a *Melaleuca stypheloides* trunk, the same situation as the translocated clump above.

Top right – small orchid recruits growing on the trunk below the main clump above. Unless these are vegetative shoots from the orchid's roots on the tree bark, they must be seedlings, indicating a pollinator was present during flowering and a pod formed. As no pods have been recorded in eight years, the seed event was probably 10 years ago or more, indicating the seedlings grow very slowly.

Bottom right – pseudobulbs heavily damage by grazing insects or slugs, similar to the transplanted plants.

Rusty Plum (*Niemeyera whitei*) (in situ)

Plate 40: In situ Rusty Plum growing close to a turpentine with stringy bark behind, near Recipient Site 1

Koala Bells (*Artamema fimbriata*) (in situ)

Plates 41 and 42. In situ Koala Bells growing on small creek bank next to Old Coast Rd.

APPENDIX 3: PHOTOS OF SLENDER MARSDENIA AND WOOLLS' TYLOPHORA HABITAT CONDITION MONITORING PLOTS, NOVEMBER 2022

Plate 43: Habitat Condition Plot No. 7. Habitat in good condition, no exotic plants present.

Plate 45 and 46: Habitat Condition Plots No. 5 and 6. Habitat in good condition, healthy native regrowth on forest edge, few exotics, minor Lantana.

Plates 47 and 48: Habitat Condition Plot No.10. Habitat in good condition, healthy native regrowth on forest edge, no exotics inside forest, outside forest on cleared edge minor exotic grasses and weeds.

Plates 49 and 50: Habitat Condition Plot No.9. Habitat in good condition, healthy native regrowth on forest edge, no exotics inside forest.

Transport for
New South Wales

Warrell Creek to Nambucca Heads

Koala Monitoring Interim Report – Operational Phase, Year four (2022)

Transport for New South Wales | October 2022 |

Pacific Highway upgrade: Warrell Creek to Nambucca Heads (WC2NH)

Koala Monitoring Interim Report – Operational Phase, Year four (2022)

SANDPIPER ECOLOGICAL SURVEYS

Final Report

20 December 2022

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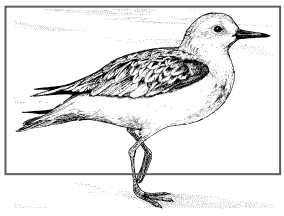

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Cover Photo: Koala recorded in the Nambucca state forest during nest box inspections.

Disclaimer:

This report has been prepared in accordance with the scope of services described in the contract or agreement between Sandpiper Ecological Surveys (ABN 82 084 096 828) and TfNSW. The report relies upon data, surveys and measurement obtained at the times and locations specified herein. The

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1. Introduction

In 2015, Transport for New South Wales (TfNSW), in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages: stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and stage 2b 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018.

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

The following interim report details the methods and results of spring year five operational phase koala population monitoring. Year one operational phase monitoring was conducted in spring 2018 (Sandpiper 2018) and year 3 in spring 2020 (Sandpiper 2021). The aim of koala monitoring is to identify changes in resident koala activity (abundance, home range and movements) in response to construction of WC2NH and the effectiveness of koala habitat connectivity mitigation measures (i.e. fauna underpasses and exclusion fencing). The following report focuses on targeted koala surveys on replicate transects and nearby management trails and includes general comment on the effectiveness of mitigation measures. Detailed analysis of koala use of underpasses and a summary of all koala records will be provided in the annual (year 5 operational phase) koala report, which is due in August 2023.

1.1 Background

The impact of the upgrade on koala (*Phascolarctos cinereus*) was assessed in the Project Environmental Assessment (Sinclair Knight Merz [SKM] 2010a, SKM 2010b), and following its listing on the *Environment Protection and Biodiversity Conservation Act 1999*, a supplementary assessment in accordance with the *EPBC Act Policy Statement 1.1 Significant Impact Guidelines* (Geolink 2016). The supplementary assessment found that the Proposal would have negative impacts on koalas utilising the Nambucca State Forest/ Old Coast Road area, mainly through habitat removal and fragmentation. The Project, with effective implementation of proposed mitigation measures, was found to be unlikely to result in a significant impact to the local koala population. Notwithstanding, as the Project adversely affected habitat that satisfied the SEWPaC (2012) definition of 'habitat critical to the survival of the species' (including direct removal of approximately 86.5 ha of vegetation that satisfies this criteria); the Project was considered to constitute a significant impact on the koala as per the DSEWPaC (2012) and DoE (2013a) guidelines.

Measures implemented to minimise impacts on koalas include:

- Ecological monitoring to determine the effectiveness of mitigation measures undertaken as part of the Project.
- Installation of fauna crossings, and fauna exclusion fencing to allow for safe passage of fauna (including the koala) crossing the Pacific Highway.
- Installation of 'floppy-top' fauna exclusion fencing to minimise road strike.

Prior to construction a pre-clearance baseline koala monitoring methodology was prepared and baseline surveys conducted in autumn and spring 2014 (SKM 2014). Construction phase koala monitoring surveys were conducted in spring 2015 (year 1) and spring 2017 (year 3) (Geolink 2017). Operational phase koala monitoring surveys were conducted in spring 2018 (year 1) and spring 2020 (year 3; Sandpiper Ecological 2018, 2021).

1.2 Study area

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

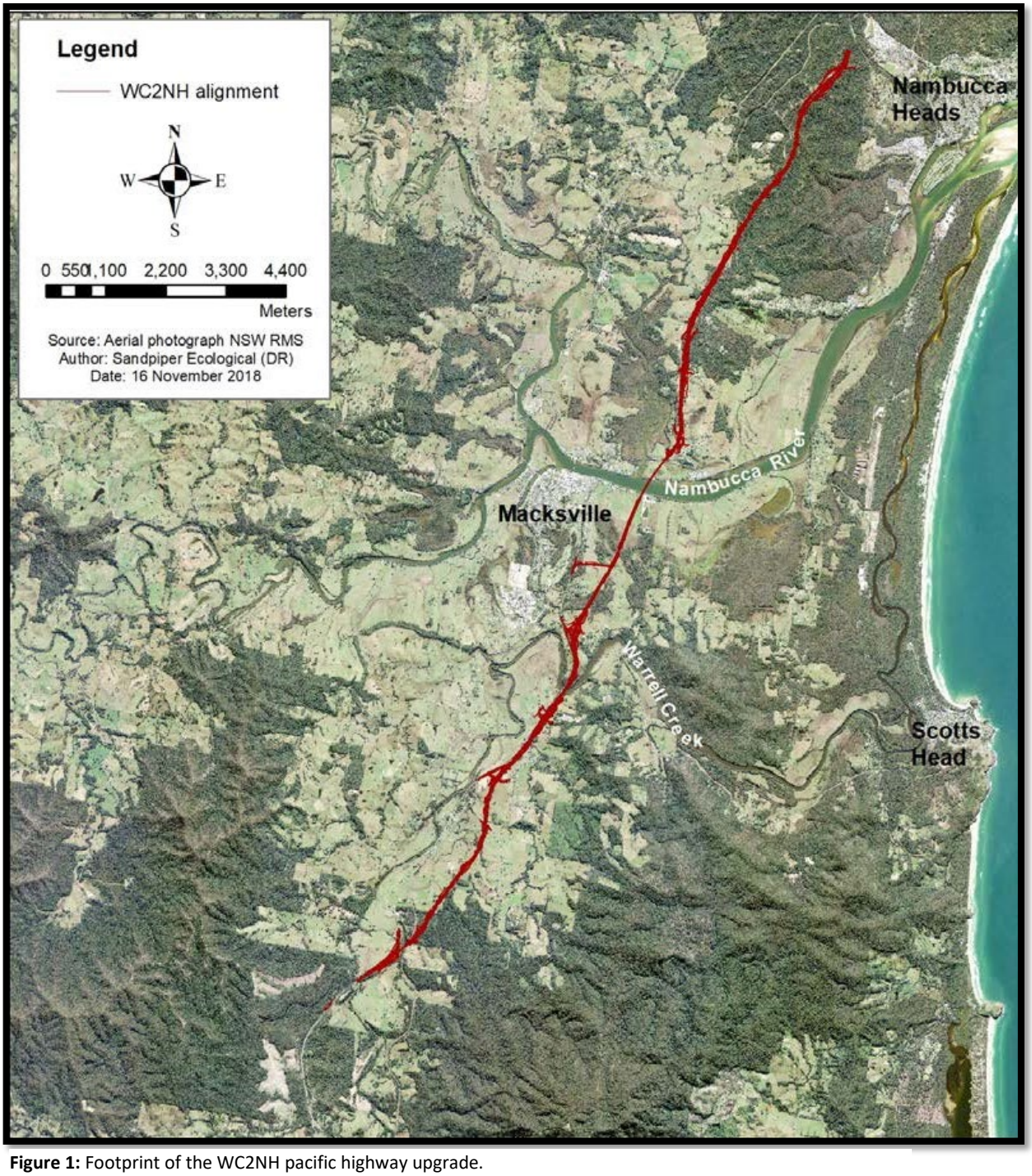

Figure 1: Footprint of the WC2NH pacific highway upgrade.

2. Methodology

2.1 Transect surveys

Twenty-five paired transects were established perpendicular to the alignment within the Nambucca State Forest/Old Coast Road area between chainages 15600 and 19500. Transects ranged in length from 34m to 500m and were approximately 150m apart (Figure 2). Shorter transects terminated at the forest edge, or at a private property boundary. Each transect was surveyed by one ecologist during the day and night. All surveys were conducted on foot at a speed of 0.5 to 1kph. At night, the male koala call was broadcast for five minutes through a 5-8 watt speaker or megaphone from the approximate centre-point of each transect. Additional spotlighting was conducted along tracks and roads whilst moving between transects. All nocturnal surveys were conducted using 200+ lumen spotlights.

Four ecologists conducted surveys on 28 and 29 September 2022. Weather conditions during the survey were suitable for sampling koalas with mild to warm temperatures and light winds. Survey time for 500m transects ranged from 26 to 39 minutes/transect. The following data were collected for each koala detected:

- Location (using global positioning system GPS)
- Distance from transect (GIS).
- Occupied tree species.
- Habitat type.
- Height of occupied tree.
- Diameter at breast height of occupied tree.
- Sex.
- Behaviour.
- Evidence of disease.
- Reproductive status.

2.2 Survey limitations

The survey design has substantial limitations when considered in the context of the monitoring aim. The aim of monitoring is to identify changes in resident koala activity (abundance, home range and movements) in response to construction of WC2NH and the effectiveness of koala habitat connectivity mitigation measures (i.e. fauna underpasses and exclusion fencing). The second part of the aim “the effectiveness of koala habitat connectivity mitigation measures” is addressed in a separate component of the WC2NH operational phase monitoring program and is not a focus of population monitoring. The first part of the aim “to identify changes in resident koala activity (abundance, home range, and movements) in response to construction” is covered by the transect surveys and addressed in this report.

The survey design is unsuitable to obtain information on abundance, home range or movement. As noted by Geolink (2017) the dense mid-storey vegetation present on many transects substantially reduces koala detectability. The detection probability on some transects is likely to be less than 25%. The difficult terrain also means that a substantial amount of time is spent looking at the ground rather than the canopy. In addition, transects are not independent and there is a strong likelihood that the same koala could be recorded on adjoining transects making estimates of abundance difficult. Individuals moving beneath the highway exacerbate this problem.

Detection limitations were noted during previous surveys and sampling along tracks was included to supplement transect surveys (Geolink 2017). However, the lack of well-defined spatial and temporal survey effort for the supplementary surveys introduces another potential bias.

3. Results

3.1 Transect surveys

Two koalas were recorded while completing transect surveys during the spring 2022 sample event (Table 1; Figure 2). Both individuals were healthy and were recorded during night surveys (Table 1). One male koala was recorded on the eastern side of the alignment on transect E13 foraging on a small fruited grey gum tree (*Eucalyptus propinqua*) on 28 September 2022 (Table 1). The second individual could not be sexed and was found resting in a black sheoak *(Allocasuarina littoralis*) on the western side of the alignment on transect W10 (Table 1). Koala scats were also recorded beneath a tallowwood tree (*Eucalyptus microcorys*) on transect E14, and beneath a grey gum tree (*Eucalyptus propinqua*) on transect W10 (Table 2).

3.2 Tracks and easements

No koalas or scats were recorded on adjacent tracks or easements during the spring 2022 sample event.

3.3 Habitat use and distribution

Based on the location of koala and scat records during the summer 2022 survey, koala use of adjoining forest was largely evident on ridges and mid-slope within Open Blackbutt Forest located between the central transects 10 and 14 (Figure 1). The combination of scat and koala records confirms use on both sides of the highway.

Table 1: Details of koalas recorded during the spring 2022 survey. M = male. A. littoralis = *Allocasuarina littoralis*. Uk= unknown. OBF = Open Blackbutt Forest.

Date	Easting	Northing	Time	Closest transect & distance (m)	Habitat type	Sex	Behaviour	Health	Side of alignment
28/9/22	496638	6609355	Night	E13; 3m	OBF	M	Foraging in *E. propinqua*	Healthy	East
29/9/22	496603	6609565	Night	W10; 5m	OBF	Uk	Resting is *A. littoralis*	Healthy	West

Table 2: Location of koala scats recorded during spring 2022 transect and track/easement surveys. Datum – GDA 94.

Transect	Evidence	Distance from alignment (m)	Easting	Northing	Date
E14	Old scat beneath tallowwood	70	496879	660881	29/9/22
W10	Fresh scat beneath grey gum	45	497131	6609905	28/9/22

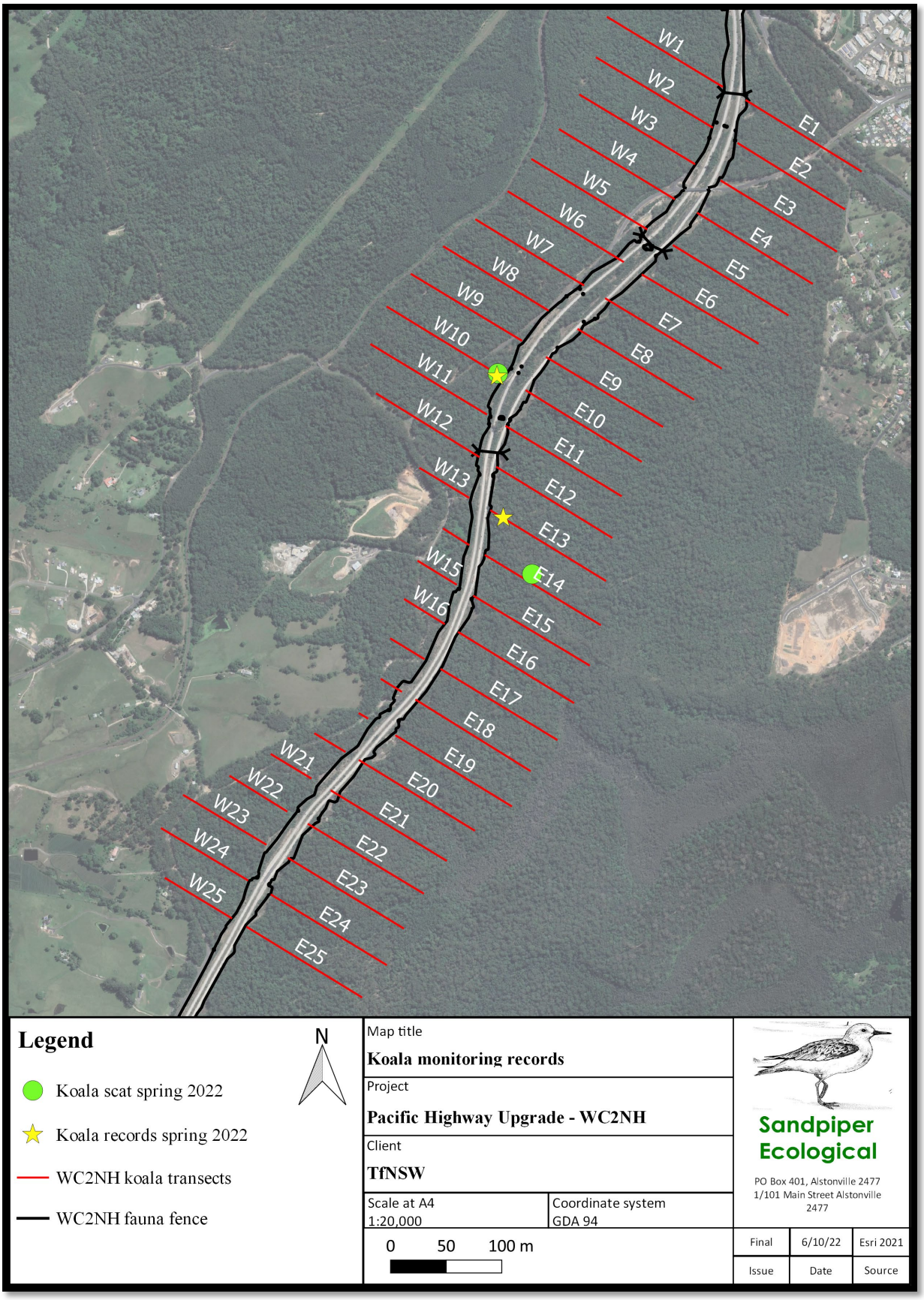

Figure 2: Location of koala records during spring 2022 monitoring at WC2NH.

4. Discussion

4.1 Koala population

The two koalas recorded on transect E13 and W10 was the highest number of transect records to date (Table 3). Nonetheless, fewer koalas were recorded during current surveys (2 individual) compared to spring 2018 and spring 2017 surveys (3 individuals; Table 3). Further, no individuals were recorded on track and easements where most koalas have been recorded previously (Table 3). Inconsistencies in survey method, particularly the effort expended on tracks and easements where most koalas have been recorded, precludes a robust assessment of possible changes in koala abundance and whether this is associated with the WC2NH upgrade.

Notwithstanding, this report is interim and additional koala data will be collated from underpass monitoring, yellow-bellied glider surveys and adjacent habitat surveys and presented in the year five annual report.

Analysis of all koala records gathered during years 4 and 5 of the operational phase will enable a more robust analysis of koala abundance in the locality.

Table 3: Comparison of koala records during the baseline, construction, and operational phases of the WC2NH upgrade. * individual recorded on four occasions.

Phase & year	Transect Surveys (diurnal & nocturnal)		Track & Easement Surveys (nocturnal)	Total koalas recorded
	Koalas observed	Koala evidence (scats)	Koalas observed	
Baseline autumn 2014	0	0	1	1
Baseline spring 2014	0	0	1	1
Construction spring 2015	1	1	1	1*
Construction spring 2017	0	2	3	3
Operation spring 2018	1	3	2	3
Operation spring 2020	0	6	1	1
Operation spring 2022	2	2	0	2

Results of 2017 construction phase surveys and 2018 operation phase showed that at least three koalas were residing within the survey area, estimated to be approximately 104 ha (Sandpiper Ecological 2021). Home range areas of koalas residing in moderate to high habitat quality habitat on the north coast is reportedly in the range of 23-37 ha (see Lassau *et al.* 2008; Goldingay & Dobner 2014). Home range areas of koalas residing in Nambucca State Forest (NSF) would likely be larger than these estimates due to the lower habitat quality and NSF's forest management history. As such, the study area probably supports few individuals.

The impact of clearing for the upgrade on the local koala population is difficult to ascertain. As discussed above, clearing impacts are both compounded and confounded by several exogenous factors acting concurrently on the local koala population. Positive signs of koala persistence include the broad distribution of

scats across the study area, especially adjacent to the upgrade corridor and the presence of at least two healthy individuals.

4.2 Habitat use and distribution

Available data suggest that the highway corridor is not a barrier to movement between habitat east and west of the alignment (Sandpiper 2021). The ability to move beneath the highway is particularly important in areas of poor habitat quality, during drought, or even bushfires when individuals need to extend or shift their home range area. Confirmed underpass crossings in 2018/19, 2019/20 and 2020/21 and the number of repeat crossings suggest that some individuals occupy home ranges that include both sides of the highway and utilise the dedicated underpasses to move within their home range (Sandpiper 2021). Individuals recorded in the recent 2022 surveys were located around underpass 9/10 amongst open blackbutt forest on the ridgelines, which has previously been noted as a preferred habitat type for koalas at WC2NH, particularly when tallowwood is also present (Sandpiper 2021).

5. Recommendations

Recommendations from the year 4 operational koala monitoring are summarised in Table 4.

Table 4: Recommendations based on findings from operational phase monitoring and response from TfNSW.

Number	Recommendation	Transport for NSW Response
1.	Findings of the year five annual report will enable a more robust analysis of koala abundance and distribution in the study area.	

6. References

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Warrell Creek to Nambucca Heads

Giant Barred Frog Monitoring Annual Report – year four operational phase 2021/2022

Transport for New South Wales | April 2023 | Final report

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1. Introduction

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

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

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species monitored include koala (*Phascolarctos cinereus*), yellow-bellied glider (*Petaurus australis*), giant barred frog (*Mixophyes iteratus*), green-thighed frog (*Litoria brevipalmata*) slender marsdenia (*Marsdenia longiloba*), rusty plum (*Niemeyera whitei*) and Floyds grass (*Alexfloydia repens*). Mitigation measures monitored included green-thighed frog breeding ponds, fauna underpasses, vegetated median, and exclusion fence. Sandpiper Ecological Surveys (SES) has been contracted by Transport for NSW (TfNSW) to deliver the WC2NH operational ecological and water quality monitoring program in accordance with the Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief (the Brief).

The following report details the methods and results of the year four operational phase giant barred frog 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 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).

The following report presents results of year 4 (2021/22) operational phase sampling, which was a recommendation of the year 3 monitoring report (see Sandpiper Ecological 2021).

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, extending either side of the upgrade alignment, in spring, summer and autumn of Year 1 and 3 of the construction phase and years 1, 3 and 5 of the operational 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 2014b). Geolink (2018) recalculated population size for baseline (using the same data and methods as Lewis 2014b), 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 the baseline (2013/14) and year one of construction (2015/16).

Operational phase surveys recorded a population estimate of 7 individuals (95% CI of 4.8) in year 1 and 19 individuals (95% CI of 21.5) in year 3 (Sandpiper Ecological 2019, 2021). The recorded population increase in year 3 was attributed to favorable breeding conditions between February 2020 and April 2021 (Sandpiper Ecological 2021). To track population trends more closely Sandpiper Ecological (2021) recommended that additional surveys be undertaken in year 4 (i.e. 2021/22). These surveys were to apply the same methods and effort as previous operational samples focusing only on the Upper Warrell Creek site.

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

1.2 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest. The two sample sites, Butchers Creek and Upper Warrell Creek, are situated near the southern end of the alignment.

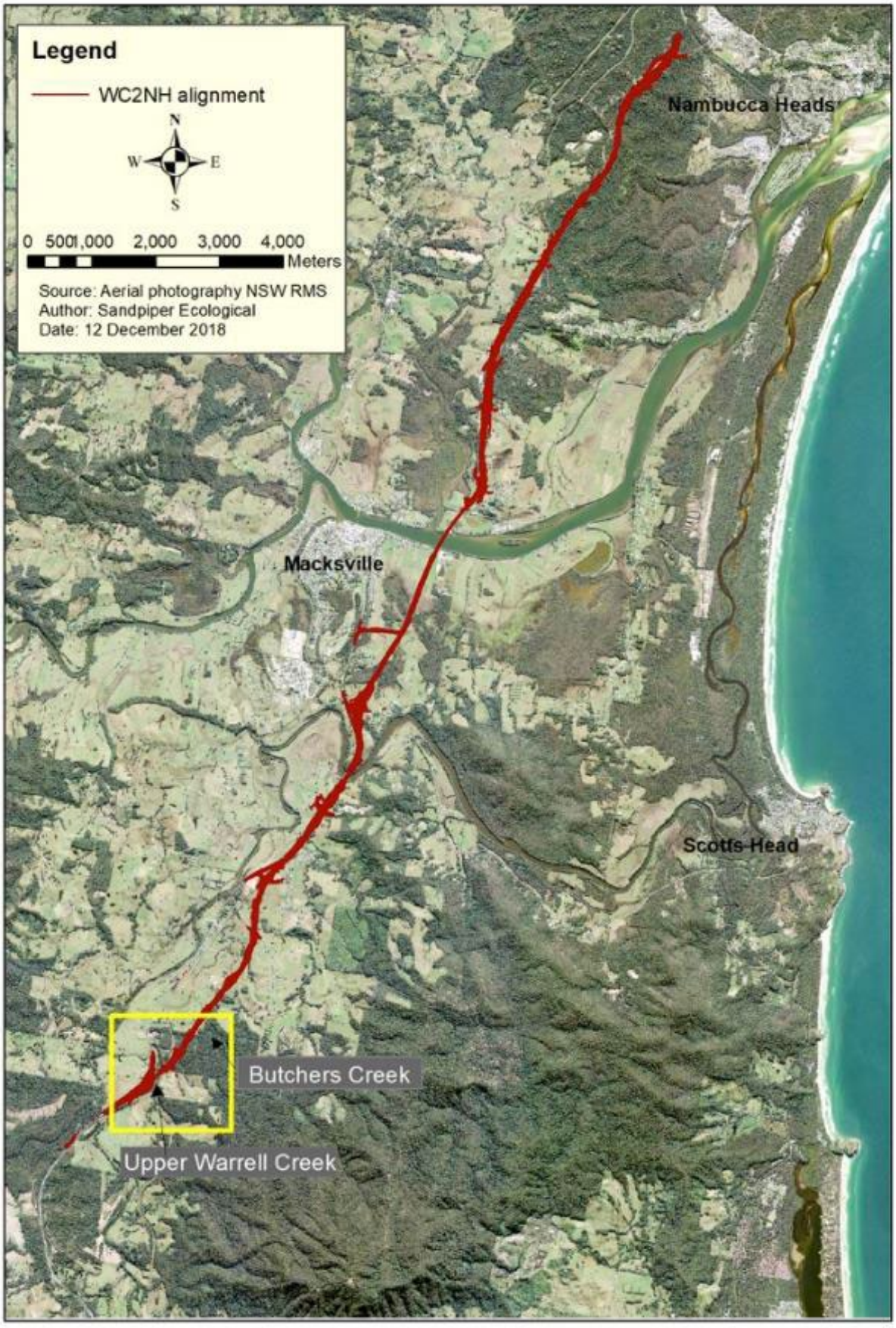

Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment.

2. Methods

2.1 Frog survey

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

1. Surveys were conducted on 17 and 18 November 2021 (spring survey), 9 February and 3 March 2022 (summer survey), 11 April 2022 (autumn survey, with a minimum of 16 person hours spent searching for frogs during each sample. The March 2022 survey was intended to occur in summer and was delayed due to widespread flooding on the North Coast of NSW.
2. Two-three ecologists conducted a nocturnal meandering foot-based traverse of 40 x 50m survey zones, 20 on each side of the watercourse at Upper Warrell Creek (20/side; Figure 2).
3. 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.
4. 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 a sub-adult or older (i.e. >40mm snout-vent length) a tag was inserted beneath the skin on the left side and the insertion hole sealed with vet bond. The insertion point was swabbed with disinfectant (Betadine) prior to the tag being inserted. During operational surveys prior to autumn 2021 only frogs with a SV length greater than 60mm were PIT tagged. In autumn 2021 the size limit was reduced to 40mm to ensure consistency with baseline and construction phase surveys.
5. The dorsal pattern of all captured frogs was photographed during each sample. Comparison of dorsal pattern is a way to distinguish individual frogs and was done to enable identification of untagged frogs captured in autumn 2021 and March 2022. Some frogs were not tagged in autumn 2022 due to insufficient tags, and in March 2022 due to equipment malfunction. The dorsal pattern of untagged frogs captured in autumn 2021 were compared to frogs captured in each of the 2021/22 sample periods, and the dorsal pattern of untagged frogs captured in summer 2022 was compared to frogs captured in autumn 2021 and autumn 2022.
6. Data collected on each captured frog included: Survey zone (20x50m); Distance from the stream edge measured to the nearest 0.1m; Position within the microhabitat (i.e. under litter, above litter, exposed, on rock/log); Sex (male, female, unknown); Age class (adult=>60mm; sub-adult=40-60mm; juvenile=<40mm); Snout-vent length (mm); Weight (grams); Breeding condition:
    i. males assessed on the colouration of their nuptial pads (i.e. no colour, light, moderate, dark) in accordance with the classification developed by Lewis (2014b);
    ii. females assessed on whether they are gravid (i.e. egg bearing, with the typically adult weighing > 100 grams) or not gravid.
    iii. frogs with a snout vent length of <60 mm were classified as immature.

2.2 Chytrid sampling

Each captured giant barred frog (23 individuals) and two striped marsh frogs (*Limnodynastes peronii*) were swabbed for chytrid fungus. The swabbing method was consistent with Figure 3 and upon completion of the swab samples were placed in a cooler bag and transferred to a freezer as soon as possible. Swabs were analysed by Alex Callen from the Conservation Biology Research Group at the University of Newcastle.

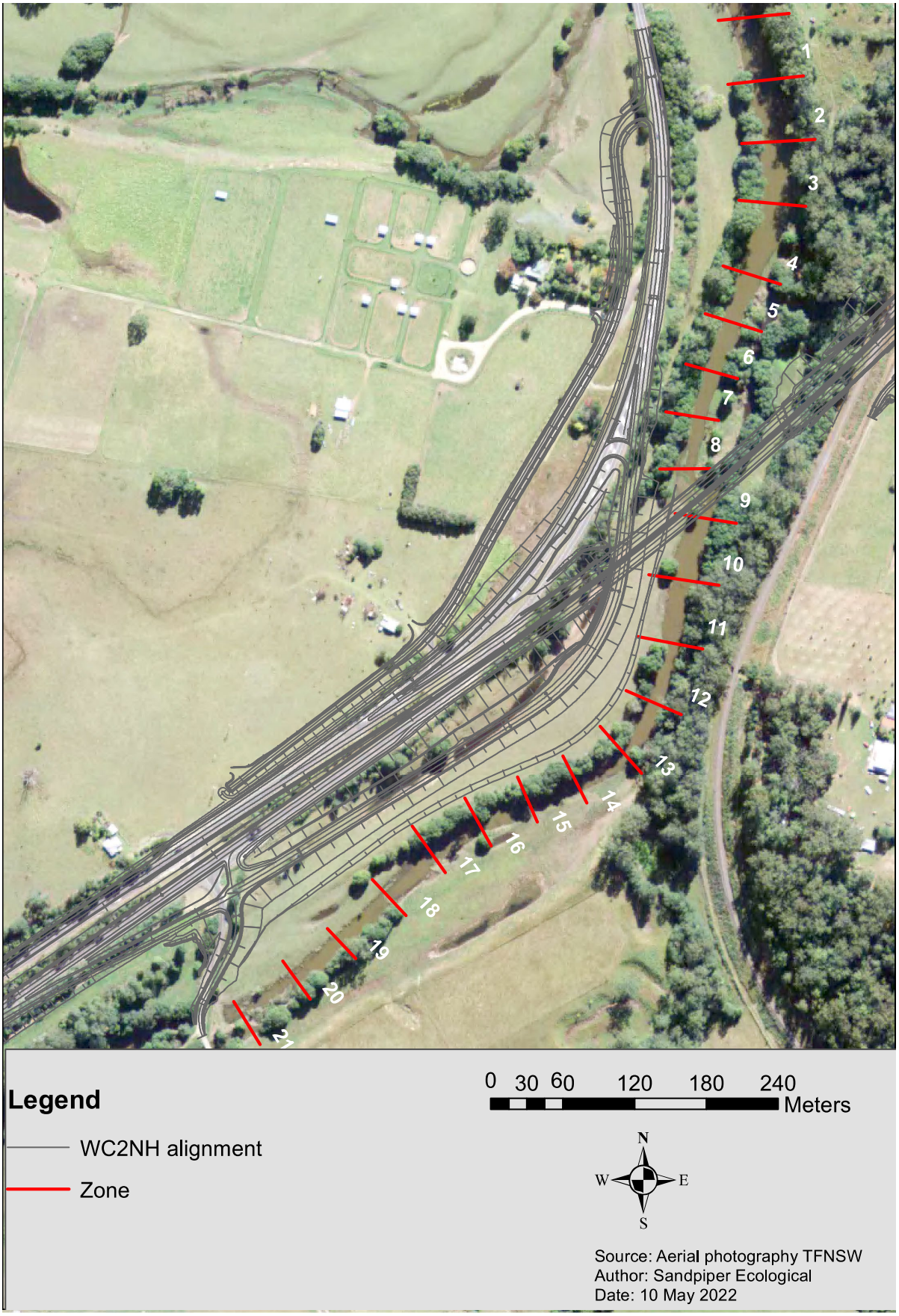

Figure 2: Survey zones within the Upper Warrell Creek and Butchers Creek sample sites.

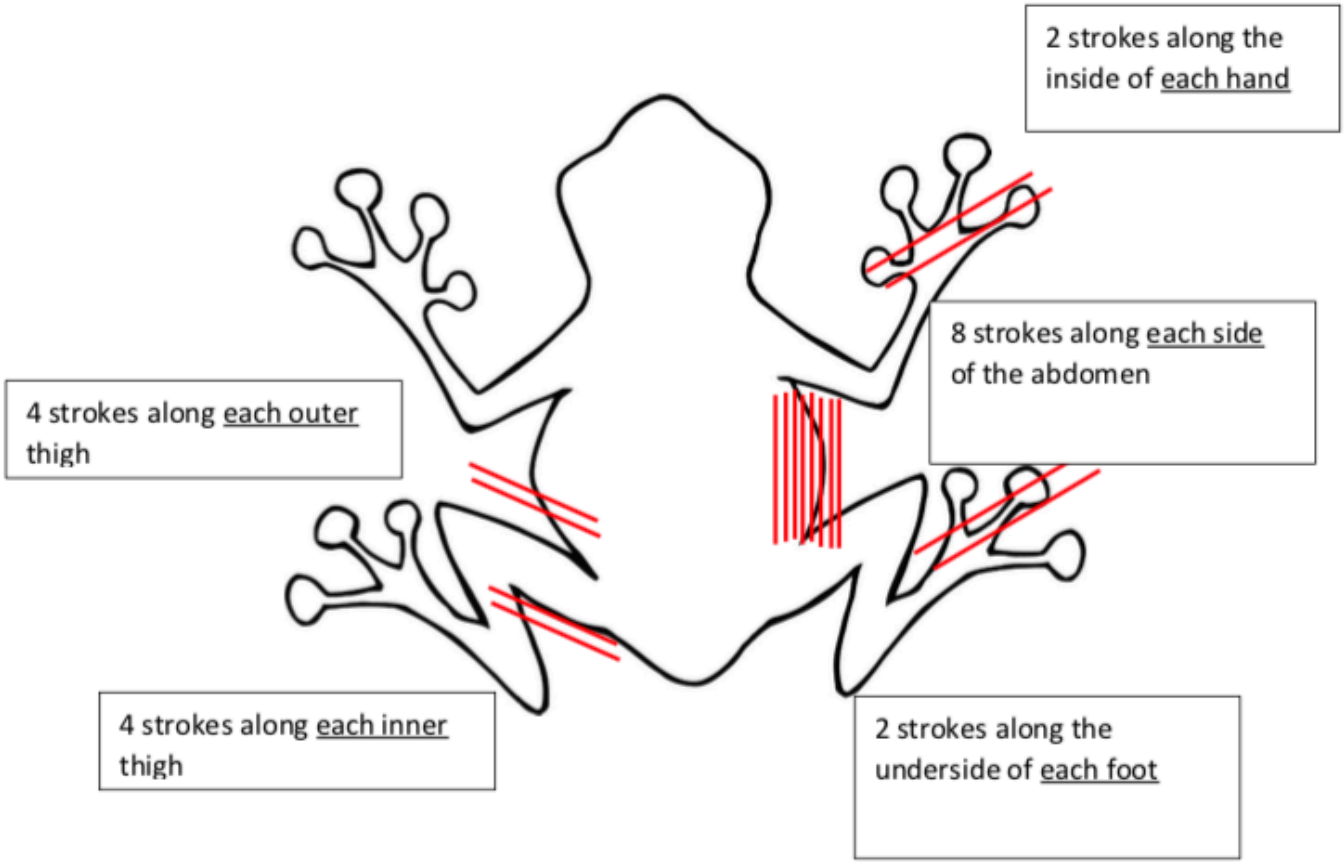

Figure 3: Chytrid swabbing protocol.

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 four operational phase. The method follows that applied during previous surveys (Lewis 2014; Geolink 2018; Sandpiper Ecological 2019, 2021). Juveniles, sub-adult, and non-captured individuals (i.e. calling males) were not included in the equation which is consistent with the baseline and construction phase surveys. Population estimates were calculated for all survey combinations, including spring/summer, spring/autumn and summer/autumn. The baseline population estimate was based on summer and autumn data. 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

To account for uncertainty around the population estimate the confidence interval of the standard error was determined. The confidence interval is the range of values that we expect the population estimate to fall between if the survey was conducted again. For this assessment the confidence level was set at 95%. The 95% confidence interval was calculated using the following formulae:

- 95% confidence interval = N ± (1.96)(SE)

The standard error (SE) of the estimate of N was calculated using the following formulae:

- SE = sqrt { [(M+1)(C+1)(M-m)(C-m)] / $(m+1)^2(m+2)$ }

The population estimate derived using spring and summer data has been used in various figures as that sample included one recapture and was mostly completed before major flooding in early March 2022.

2.7 Data summary and analysis

Rainfall data for the year four survey and historical records were sourced from the Bellwood weather station. Individual frogs were identified by comparing PIT tag numbers recorded during this survey with those reported by Sandpiper Ecological (2019, 2021), Geolink (2018) and Lewis (2014), and dorsal photographs taken in autumn 2021 and summer 2022. 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 four operational phase were compared to previous operational surveys, 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 Survey timing, weather conditions and effort

Weather conditions were suitable for giant barred frog surveys during all sample events (Table 1). Above average rainfall was recorded over the sample period (i.e. November 2021 to April 2022), with 574 mm falling in the 30 days prior to 3 March and 641 mm in the 30 days prior to the survey on 11 April. Several flood events occurred during the sample period, with major events prior to surveys on 9 February, 3 March and 11 April. Air temperature ranged between 17.5^{0}C and 20^{0}C in November, 21.8 and 23.8^{0}C in February/March and 22.4^{0}C in April. Wind was either absent or light (i.e. rustled leaves; Table 1). Rain or showers occurred during the spring survey only. Survey effort at Upper Warrell Creek ranged from 15.5 person hours in summer (Feb & Mar combined) to 18 person hours in autumn (Table 1).

Table 1: Weather conditions and survey effort recorded during the year 4 2021/22 giant barred frog survey at Upper Warrell Creek. Rainfall data were sourced from the Bellwood weather station. PH = person hours; Wind categories = 0 - no wind, 1 - rustles leaves, 2 - branches moving, 3 - canopy moving; RH = relative humidity; Rainfall = mm; Temp = ^{0}C; Dew Point = ^{0}C

Season	Date	Start/ Finish	Observers	PH	Rainfall	Rainfall (prev 24hr)	Rainfall (prev 7 days)	Rainfall (prev 30 days)	RH	Temp	Dew point	Wind
Spring	17/11/21	2000-2400	DR/LA	8	Showers	Nil	0	49	NR	17.5	14.8	0
	18/11/21	2000-0015	DR/LA	8.5	Nil		0	49	NR	20	16	1
Summer	9/2/22	2000-2345	DR/LA	7.5	Nil	1	90	184	NR	23.8	18	0
	3/3/22	1945-2345	LA/AE	8	Nil	4	349	574	NR	21.8	18.9	0
Autumn	11/4/22	1745-2345	DR/LA/AE	18	Nil	22	46	641	75	22.4	18.2	0

3.2 Frog surveys

3.2.1 Abundance

A total of 25 giant barred frogs were recorded at Upper Warrell Creek during the year four operational phase surveys (Tables 2 & 3). Captures included 17 adults (Snout-vent length >60mm), six sub-adults (S-V length 40-60mm), and two juveniles (S-V length <40mm). Two individuals, both calling males, were not captured. Both were recorded calling from concealed positions on the opposite creek bank to that being sampled.

The age of frogs was biased towards adult frogs with 17 of the 25 individuals falling in the adult class (i.e. S-V >60mm). All sub-adult frogs had a SV length between 50 and 60 mm. (Table 2). The number, sex and age-class of individuals recorded during each survey included:

- 8 (4M & 4F all adults) in spring 2021;
- 11 (3 adult male, 4 adult female, 2 juvenile, 2 sub-adult) in summer 2022; and
- 12 (1 adult male, 1 adult female, 4 sub-adult) in autumn 2022.

Confirming the sex of non-calling adult frogs is difficult and, in the absence of calls, the sex of adult frogs was based on snout-vent length and weight. Using these criteria, nine adult female frogs were recorded. Seventeen frogs were PIT tagged, eight in spring, three in summer, and six in autumn. An additional four individuals (2 adults, 1 sub-adult & 1 juvenile), captured on 3 March 2022 had their dorsal pattern photographed due to equipment malfunction (Plates 1 & 2).

Table 2: Data recorded for giant barred frogs captured or heard calling during the year 4 (spring 2021 to autumn 2022) operational phase monitoring survey at Upper Warrell Creek. + = positive chytrid detection; - = possible chytrid detection; NC = not captured; NA = not applicable.

Season	Date	Frog # & Chytrid	Sex**	Age***	S/V length	Weight	Breeding condition#	New tag or recapture	Microchip ID (new or re-capture)
Spr	17/11/21	1 +	Female	Adult	98.1	122	Gravid	New tag	956000010433901
Spr	11/7/21	2	Female	Adult	87.3	88		New tag	00077E8fef
Spr	18/11/21	3 +	Male	Adult	66.8	36	Moderate	New tag/recapture	11419351 (nil)
Spr	18/11/21	4 -	Male	Adult	63.5	42	Dark	New tag/recapture	11425829
Spr	18/11/21	5 +	Male	Adult	65.8	38	Dark	New tag	11423017
Spr	18/11/21	6 -	Male	Adult	73.8	48	Dark	New tag	11408672
Spr	18/11/21	7 -	Female	Adult	76.1	50	Moderate	New tag	11459761
Spr	18/11/21	8 +	Female	Adult	92.5	122	Gravid	New tag	11432455
Sum	9/2/22	9	Ukn	Juvenile	38.5	17	N/A	NA	NA
Sum	9/2/22	10	Female	Adult	86.4	95	Gravid	Recapture	11459761
Sum	9/2/22	11	Ukn	Sub adult	53.9	18	N/A	New tag	11425922
Sum	9/2/22	12	Male	Adult	76	58.3	Dark	New tag	11427483
Sum	9/2/22	13	Male	Adult	N/A	N/A		N/A	N/A
Sum	9/2/22	14	Female	Adult	79.5	80		New tag	11431052
Sum	3/3/22	15	Male	Adult	N/A	N/A		N/A	N/A
Sum	3/3/22	16 -	Ukn	Sub adult	50.3	23.5	N/A	no tag	N/A
Sum	3/3/22	17	Female	Adult	119	96.3		no tag	N/A
Sum	3/3/22	18	Ukn	Juvenile	36.6	19	NA	N/A	N/A
Sum	3/3/22	19	Female	Adult	104	90.6	Gravid	no tag	N/A
Aut	11/4/22	20	Ukn	Sub adult	52.9	22	N/A	New tag	11423778
Aut	11/4/22	21	Female	Adult	91.4	130	Gravid	New tag	11432288
Aut	11/4/22	22	Ukn	Sub adult	53.1	23	N/A	New tag	11450114
Aut	11/4/22	23 -	Ukn	Sub adult	55.2	25	N/A	New tag	11427302
Aut	11/4/22	24 -	Male	Adult	68.5	42	Moderate	New tag	11433481
Aut	11/4/22	25 +	Ukn	Sub adult	59.7	32	N/A	New tag	11421640

Table 3: Data recorded for Frog # 10-21 captured or heard calling during the autumn 2021 survey at Upper Warrell Creek. HC – heard calling; NC – not captured; NR = not recorded

Frog ID	Easting	Northing	Zone	Creek side	Distance to edge (nearest 0.1m)	Position in micro-habitat*	Comments
Frog 1	489317	6594399	6	Middle island (south)	4.0	On leaf litter beneath sticks	
Frog 2	489315	6594411	6	Middle island (South bank)	0.3	Beneath *Persicaria* spp.	
Frog 3	489264	6594375	7	South bank	9.0	Leaf litter	Recapture - Frog #20 originally caught in autumn 21; identified from dorsal pattern
Frog 4	489302	6594463	5	South bank	3.0	Leaf litter	Recapture - Frog #21 originally caught in autumn 21; identified from dorsal pattern
Frog 5	489303	6594464	5	South bank	6.0	Leaf litter	
Frog 6	489318	6594476	4	Southern	0.8	Leaf litter	
Frog 7	489316	6594480	4	South	0.1	Waters edge	
Frog 8	489265	6594355	7	South	7.0	Leaf litter	
Frog 9	489304	6594471	4	South bank	6.4	Leaf litter	
Frog 10	489320	6594483	4	South bank	0.5	Bare ground on bank	
Frog 11	489312	6594467	4	South bank	0.9	Leaf litter, base of tree	
Frog 12	489320	6594508	4	South bank	2.3	Leaf litter	
Frog 13	498347	6594463	4	Middle island	Calling	N/A	Not captured heard calling
Frog 14	489261	6594334	8	South bank	8.0	Leaf litter	
Frog 15	489326	6594489	4	South bank past island northern point	Calling	N/A	Calling, waypoint estimated
Frog 16	489302	6594240	10	northern bank	8.5	Leaf litter beneath fallen branches	photo taken, copper blotches present
Frog 17	489281	6594173	11	northern bank	3.2	Leaf litter covered in mud from flood	photo taken, copper blotches present
Frog 18	489269	6594152	11	northern bank	4.5	Bare ground in flood area beneath tree	photo taken, copper blotches present
Frog 19	489259	6594087	12	northern bank	0.6	Bare ground beneath log	photo taken, copper blotches present
Frog 20	489261	6594348	7	South bank	8.5	Leaf litter	Copper blotches, photo DR
Frog 21	489293	6594459	5	South bank	3.6	Scattered leaf litter	Copper blotches, photo DR
Frog 22	489266	6594367	7	South bank	6.0	Leaf litter beneath foliage	Copper blotches, photo DR
Frog 23	489265	6594124	12	North bank	4.5	Bare dirt beneath log	Copper blotches, photo DR
Frog 24	489257	6594076	13	North bank	9.0	Bare dirt, sparse litter	Lots of copper blotches, photo DR
Frog 25	489279	6594147	11	North bank	7.0	Scattered leaf litter beneath debris	Copper blotches, photo DR

***Microhabitat: under leaf litter, under veg, on leaf litter, exposed, on a log/rock etc.**

Plate 1: Dorsal photographs of frog #16 (left) and 17 (right) taken during the summer 2022 giant barred frog survey at Upper Warrell Creek.

Plate 2: Dorsal photographs of frog #18 (left) and 19 (right) taken during the summer 2022 giant barred frog survey at Upper Warrell Creek.

3.2.2 Recaptures

Three recaptures were recorded, two in spring, and one in summer. The two recaptures in spring were individuals initially captured in autumn 2021, and identified from dorsal pattern. The recapture in summer 2022 was initially captured (and tagged) in spring 2021. The spring recaptures were likely male frogs and the summer recapture was a female. Spring recaptured frogs had increased in S/V length by 3.7 and 3.8 mm respectively and in weight by 10 and 11.5gr respectively (Table 4). The female frog recaptured in summer had increased in S/V length by 10.3 mm (13%), and weight by 45gr (90%). This individual was recaptured less than 5m from the original capture location. The two frogs initially captured in autumn 2021 and recaptured in spring 2021 were both recaptured on the same bank and had both moved 120m and 10m upstream.

Table 4: Recaptured frogs recorded in year 4 at Upper Warrell Creek. S/V = snout/vent length (mm), Wgt = weight (gr), Breed Cond = breeding condition, Mod = moderate.

Frog No.	Frog ID	Initial capture data						Recapture data					
		Date	Easting	Northing	S/V	Wgt	Breed	Date	Easting	Northing	S/V	Wgt	Breed
3	#20/11 419351	15/4/21	489307	6594481	63.1	26	NA	18/11/21	489264	6594375	66.8	36	Mod
4	#21/11 425829	15/4/21	489302	6594475	59.7	30.5	NA	18/11/21	489302	6594463	63.5	42	Dark
7 & 10	114597 61	18/11/21	489316	6594480	76.1	50	NA	9/2/22	489320	6594483	86.4	95	Gravid

3.2.3 Capture location

All frogs were captured within riparian forest on the primary bank. The capture distance from water ranged from 0.1m to 9m with a mean of 4.51m. There was a notable difference in the mean capture distance from water for the three age classes. Mean values were 3.83m for adults, 5.9m for sub-adults and 5.45m for juveniles. All individuals were captured on bare earth, scattered leaf litter or leaf litter (Table 3).

3.2.4 Distribution

In year four, giant barred frogs were recorded in nine of the 21 survey zones, with individuals distributed from zone 4 to zone 13 a distance of approximately 470m (Figure 3). The highest number of frogs was recorded in zone 4 (9 frogs), followed by zone 7 with four frogs. Two individuals were recorded in zones 6, 11, 12 and 13. Eighteen of the 25 captures were recorded downstream of the alignment. Frogs were recorded on both the north and south banks. Upstream of the alignment all individuals were on the north bank, whilst downstream most were on the south bank.

Three recaptures (frogs 1, 2 & 3) were recorded during the survey, all in spring 2021. Frog number 3, an adult male, was recaptured in zone 20, 880m upstream from its original capture point in zone 3. Frogs two and three were initially tagged during the construction phase and have been captured on four occasions. Both individuals have always been captured in zone 5 or on the boundary of zones 4 and 5.

3.2.5 Population estimate

The adult giant barred frog population estimate for Upper Warrell Creek in year four operational phase using the spring and summer samples was estimated at 21.5 with a 95% confidence interval of 17.38

(Table 4). This suggests there is a 95% chance that the adult population within the 1km transect at Upper Warrell Creek is between 4.12 and 38.88.

The population estimate using the summer and autumn data was 29 with a 95% confidence interval of 26.28, and the population estimate using spring and autumn data was 26 with a 95% confidence interval of 28.79 (Table 5).

Table 5: Population estimate of adult giant barred frogs and 95% confidence interval after the conclusion of year four operational phase giant barred frog monitoring at Upper Warrell Creek.

Comparison	Population estimate	95% confidence interval
Spring and summer	21.5	17.38
Summer and autumn	29	26.28
Spring and autumn	26	28.79

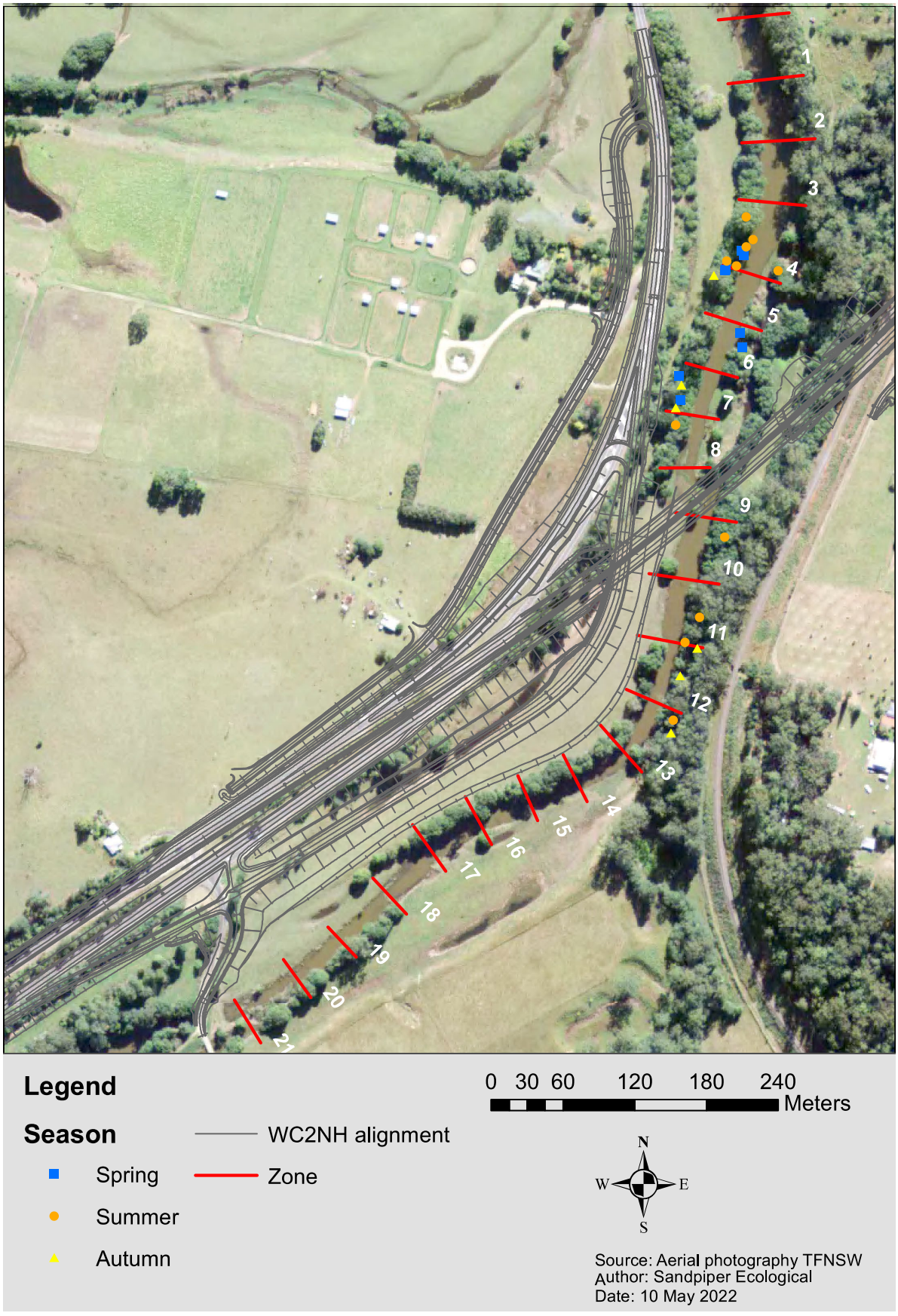

Figure 4: Location of frogs captured during the year 4 giant barred frog survey at Upper Warrell Creek.

3.5 Temporal comparison

3.5.1 Frog surveys

The total number of giant barred frogs captured during each sample period declined substantially between baseline and year one of the construction phase. A more gradual decline was evident from year one construction phase, where 16 detections occurred, to year one operational phase, where 12 detections occurred. Captures during the operational phase have increased from 12 in year one to 21 in year 3 and 25 in year 4 (Figure 4).

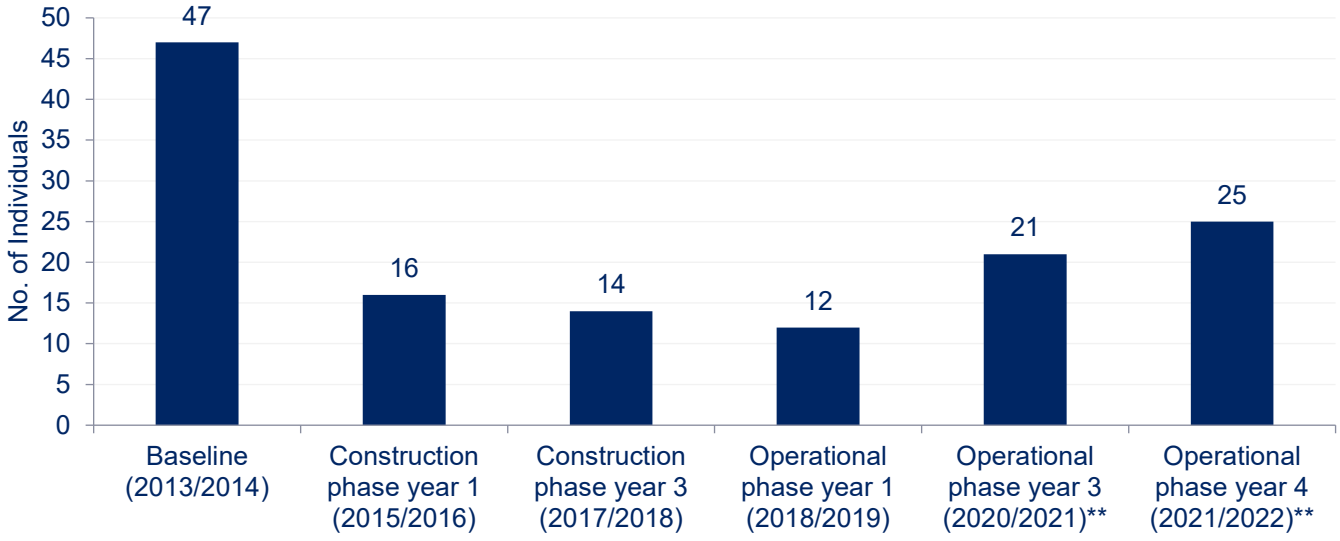

Figure 5: Total number of giant barred frog recorded in each of five sample periods at Upper Warrell Creek. Values include multiple recaptures of the same individual and calling males that were not captured. ** could include recapture of unmarked sub-adults.

The number of individual frogs captured between baseline and year one construction phase surveys declined from 38 to eight and remained stable over the construction and year one operational phase surveys. The number of individual frogs increased to 21 during the year three operational phase survey and to 24 in year 4 operational phase (Figure 5).

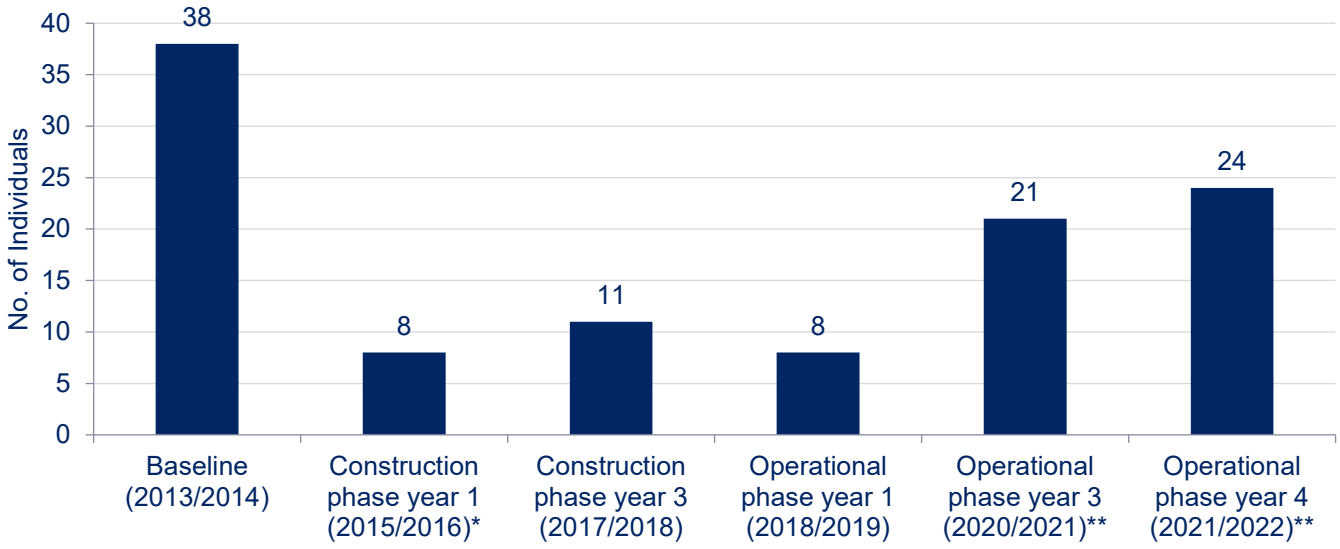

Figure 6: Number of individual giant barred frogs recorded over five sample events at Upper Warrell Creek. *Year one construction phase number may be an underestimate as it does not include frogs recorded in autumn 2015 (GeoLink 2018); ** could include recapture of unmarked sub-adults from summer survey.

3.5.2 Population estimate

Comparison of adult population estimates across the five sample periods shows a decline at the Upper Warrell Creek site from baseline through the construction phase and into year one of the operational phase (Table 6, Figure 6). 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 6, Figure 6). The population increased in years three and four of the operational phase with population estimates of 19 and 21 adult frogs respectively.

Table 6: 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 CP (2015/2016)	Year 3 CP (2017/2018)	Year 1 OP (2018/2019)	Year 3 OP (2020/2021)	Year 4 OP (2021/2022)
GBF population estimate	43	7	8	7	19	21.5
95% confidence interval	26.6	9.77	10.46	4.8	21.46	17.38

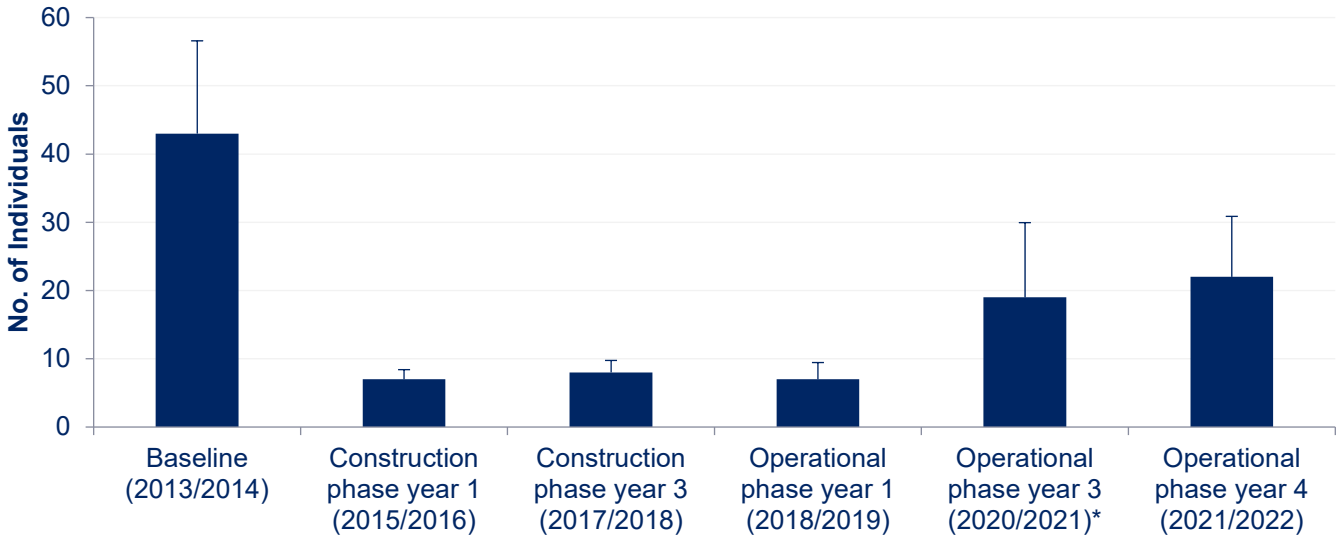

Figure 7: Adult population estimates (+ standard error) at Upper Warrell Creek during baseline (Lewis 2014), construction phase (GeoLink 2018), year one operational phase (Sandpiper Ecological 2019), year three operational phase monitoring (Sandpiper Ecological 2021) and year four operational phase (this study). Note: Operational phase year 3 population estimate is based on spring/autumn data, operational phase year 4 population estimate is based on spring/summer data, all other estimates based on summer/autumn data.

3.6 Chytrid sampling

Analysis of swabs identified five confirmed positive samples and six possible positive samples (Table A1, Appendix A). All samples were contaminated with dirt and organic material, which hampered the analysis (A. Cullen pers comm). Contamination presumably occurred from soil and organic material collected whilst catching the frogs. Four of the eight frogs captured in spring (November) returned positive results, with a further three returning possible results. Three of the remaining four positive (1 sample)/possible (2 samples) results were recorded in autumn (April). Of the three recaptured frogs one (Frog #3) returned a positive result, and one (Frog #4) returned a possible result. Both these individuals were originally captured in autumn 2021 (i.e. year three survey).

4. Discussion

4.1 Giant barred frog population

Year four operational phase giant barred frog monitoring at Upper Warrell Creek has provided further evidence of a population increase initially documented in year three (Sandpiper Ecological 2021). Using all possible sample combinations, the year four population estimate ranged from 21.5 to 28.79 individuals. The lower estimate of 21.5 individuals calculated from surveys in spring and summer has been adopted as it is based on data predominantly collected before the onset of flooding in autumn and it included one recapture. Using data collected prior to flooding reduces the potential influence of flood movement on calculations.

The cohort of similarly sized immature frogs that dominated samples in summer and autumn 2021 had most likely moved into the adult size class in 2021/22, with most adult frogs in the 60-90mm S-V range. Maas and Passioura (1999) suggested that giant barred frogs reach maturity at the end of their first year. This is consistent with our findings at Upper Warrell Creek where most of the adult frogs recorded in spring and summer 21/22 had likely metamorphed in spring 2020. Based on growth rates it was suggested that the age cohort recorded in 2021 may breed in the 2021/22 breeding season. Whilst this is possible minimal evidence of breeding, such as calling males, was recorded. Nonetheless, the population contained individuals from all size classes, including two juvenile frogs.

A high abundance of invertebrates, the main prey for giant barred frogs (see Lemckert & Shoulder 2008), over the previous 12 months (pers obs), is likely to have increased growth rates. The female frog captured in November 2021 and again in February 2022 provides evidence of the rapid growth of adult frogs. Over a period of 82 days this frog almost doubled in weight and increased in length by 10mm.

Uncertainty remains about whether frogs within the study area have breed in that area or emigrated from upstream. Movement of frogs into the study area by flood remains likely and it stands to reason that more frogs will wash into the study area during productive breeding years, such as 2020 and 2021. The decline in recaptures in 2021/22 may also be due to flood movement with frogs equally likely to be washed out of the study area. Juvenile frogs may be particularly susceptible to flood transportation due to their small size (Koch & Hero 2007).

Results from the 20/21 and 21/22 breeding seasons are contrary to the year one operational phase surveys when recaptures accounted for 50%, 75% and 33% of all captures in spring, summer and autumn respectively (Sandpiper Ecological 2019a), and all individuals captured in spring 2020, prior to flooding, were recaptures (Sandpiper Ecological 2020). There appears to be a correlation between declining recaptures and flood frequency. Prior to December 2020 the majority of captures occurred on the north bank of zones 4, 5 and 6, particularly in the low-lying part of zone 6. Since that time occurrence of frogs in that area has been patchy and there have been no recaptures. Not surprisingly, floods heavily impact the low-elevation north bank in zones 4, 5 and 6.

A key assumption of the population estimate procedure is limited immigration, emigration and mortality during the sample period (Fowler *et al.* 1999). Movement of frogs into and out of the sample population is a limitation of the monitoring program. However, such movement has been consistent across all samples including the baseline. Given the variability of the frog population within the study area it seems likely that repeat sampling over many years both within and upstream of the study area would be required to determine how floods and insitu recruitment influence local abundance. Determining larger scale population trends is typically beyond the scope of normal operational phase monitoring programs.

Notwithstanding the above limitation movement of frogs in and out of the study area should be expected given the obvious connection with suitable habitat upstream. The importance of movement on the abundance of frogs in the study area is secondary to determining if the area can support at least part of the local giant barred frog population in the long-term. Since construction of the highway obvious changes in

habitat have occurred. Some of which has been directly due to construction, whilst others are due to the exclusion of cattle and clearing by land owners.

4.2 Distribution and movement

No frogs were recorded to have moved beneath the highway in year four of the operational phase. The presence of frogs in nine of the 21 zones in 2021/22 indicates that the species continues to occur throughout the study area, albeit in fewer zones than baseline surveys. The majority of records occurred within zones 4-7, which is consistent with previous surveys (Lewis 2014, Geolink 2016, 2018; Sandpiper Ecological 2019). Contrary to years 1-3 of operational phase monitoring six individuals were captured on the north bank of zones 11-13. The sudden appearance of frogs in those zones is attributed to flood movement.

4.3 Chytrid analysis

Lewis (2014) swabbed 17 frogs for chytrid in summer 2014, and Geolink (2018) swabbed 10 frogs in spring/summer 2015/16, and 11 frogs in spring/summer 2017/18. Four of the 38 individuals swabbed between 2014 and 2018 tested positive for chytrid fungus, however, only five of the 38 tests were collected in spring, with two collected in autumn. All remaining samples were collected in summer. As chytrid prefers cooler temperatures (DoEE 2016) it is likely that at low elevation sites, such as Upper Warrell Creek, infection rate will be higher in late winter and early spring (A. Cullen pers comm). To date, no samples have been collected in late winter/early spring, although, the 2021 samples were collected towards the end of what was a cool spring. Importantly, the bias of pre-construction and construction phase sampling towards summer (when 82% of samples were collected) may have masked the true scale of infection. During 2021/22 sampling only one possible detection occurred from the nine frogs swabbed in summer, compared to seven of the eight frogs swabbed in spring.

The results of chytrid analysis suggest that amphibian chytrid fungus (*Batrachochytrium dendrobatidis*) could be playing a role in the declining abundance of giant barred frogs at Upper Warrell Creek. The impact of chytrid fungus on amphibian populations is complex and, whilst there have been some extinctions (Lips 2016), other species continue to persist with stable infection rates following an initial die-off (Retallick et al. 2004; Newell et al. 2013). The impact of chytrid on a frog population is likely influenced by synergistic interactions with other threats (Buck et al. 2015*).* In addition to chytrid frogs at Upper Warrell Creek likely experience threats from pesticides, high nutrient levels, drought, changing vegetation structure, clearing of habitat and regular handling. Collectively these factors may contribute to the noted population decline. How chytrid was introduced into the population is unknown, however, its presence during the baseline survey suggests that it was introduced to the population prior to commencement of monitoring or construction.

5. Conclusion and Recommendations

The year four operational phase giant barred frog survey recorded an increase in abundance on year three, with a total of 25 individuals recorded. The adult population was estimated at 21 individuals, an increase of two on the year three estimate, and the highest since baseline surveys in the 2013/14 breeding season. The year four survey achieved its goal by enabling the cohort of juvenile frogs recorded in the 2020/21 breeding season (i.e. year 3 operational phase) to be tracked more closely. Data collected in year four suggests that those frogs had matured and most likely bred in the 2021/22 breeding season. The year four survey has also confirmed the continued presence of *B. dendrobatidis* infection within the population. Analysis of previous survey data suggests that the level of infection may have been underestimated.

Based on available evidence it seems likely that the giant barred frog population at Upper Warrell Creek persists with a background level of *B. dendrobatidis* infection. Chytrid is not considered to be the sole

reason for population decline, however, it may be a contributing factor with its impact exacerbated by the range of other threats present at the site.

Recommendations are included in Table 7.

Table 7: Recommendations

Number	Recommendation	Transport for NSW Response
2.	Continue to focus survey effort at Upper Warrell Creek as agreed following the summer 2021 population survey.	Agree.

6. References

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Appendix A - Chytrid results

Table A1: Results of chytrid analysis of 25 frogs swabbed at Upper Warrell creek in the 2021/22 breeding season.

Frog No. (sample code)	Date	Cq	Cq Mean	Cq Std. Dev	Mean Bd molecules/ul	Result Interpretation
23	11/4/22		0.00	0.000	43	
		43.31	43.31	0.000		
			0.00	0.000		Non-confident detection
24	11/4/22		0.00	0.000	16	
			0.00	0.000		
		49.03	49.03	0.000		Non-confident detection
19	3/3/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Inhibited
22	11/4/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
21	11/4/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
20	11/4/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
13	10/2/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
15	10/2/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
25	11/4/22	37.05	37.05	0.000	52255	
		36.23	36.23	0.000		
		37.80	37.80	0.000		Positive
16	3/3/22	45.28	45.28	0.000	138	
			0.00	0.000		
			0.00	0.000		Non-confident detection
18	3/3/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
11	9/2/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
9	9/2/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
10	9/2/22	49.75	49.75	0.000	10	
			0.00	0.000		
			0.00	0.000		Non-confident detection

Frog No. (sample code)	Date	Cq	Cq Mean	Cq Std. Dev	Mean Bd molecules/ul	Result Interpretation
2	10/2/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
17	3/3/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
12	9/2/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
14	9/2/22		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
8	18/11/21	35.18	35.18	0.000	20728	
			0.00	0.000		
			0.00	0.000		Positive
6	18/11/21	42.79	42.79	0.000	109	
		43.03	43.03	0.000		
			0.00	0.000		Non-confident detection
SM2	18/11/21		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
4	18/11/21	40.40	40.40	0.000	328	
		42.05	42.05	0.000		
		46.61	46.61	0.000		Non-confident detection
SM1	17/11/21		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
1	19/11/21	42.66	42.66	0.000	801402	
		29.80	29.80	0.000		
			0.00	0.000		Positive
3	18/11/21	39.55	39.55	0.000	1068	
			0.00	0.000		
			0.00	0.000		Positive
2	17/11/21		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
7	18/11/21		0.00	0.000	0	
			0.00	0.000		
			0.00	0.000		Negative
5	18/11/21	38.76	38.76	0.000	24563	
		37.91	37.91	0.000		
		38.08	38.08	0.000		Positive

Transport for New South Wales

Warrell Creek to Nambucca Heads

Interim Giant Barred Frog Monitoring Report –spring year five operational phase (2022-2023)

Transport for New South Wales | April 2023 |

Pacific Highway upgrade: Warrell Creek to Nambucca Heads (WC2NH)

Giant Barred Frog – operational phase Year Five (2022-2023)

Sandpiper Ecological Surveys

Final Report

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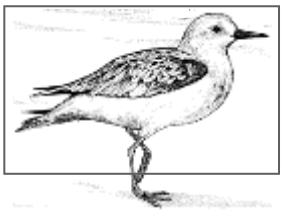

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1. Introduction

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

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

Approvals for the WC2NH upgrade required monitoring of several species and mitigation measures during the operational phase. Species monitored include koala (*Phascolarctos cinereus*), yellow-bellied glider (*Petaurus australis*), giant barred frog (*Mixophyes iteratus*), green-thighed frog (*Litoria brevipalmata*) slender marsdenia (*Marsdenia longiloba*), rusty plum (*Niemeyera whitei*) and Floyds grass (*Alexfloydia repens*). Mitigation measures monitored included green-thighed frog breeding ponds, fauna underpasses, vegetated median, and exclusion fence. Sandpiper Ecological Surveys (SES) has been contracted by Transport for NSW (TfNSW) 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 interim report details the methods and results of the spring year five operational phase giant barred frog 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 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 2014b).

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 2014a). A population of giant barred frog was subsequently confirmed at Upper Warrell Creek and a management strategy prepared (see Lewis 2014b).

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, extending either side of the upgrade alignment, in spring, summer and autumn of Year 1 and 3 of the construction phase and years 1, 3 and 5 of the operational phase using the methods applied during preconstruction baseline surveys.

Preconstruction 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 frogs 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).

2. Methodology

2.1 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest. The two sample sites, Butchers Creek and Upper Warrell Creek, are situated near the southern end of the alignment (Figure 1). Following completion of the spring year 3 operational phase survey it was agreed with TfNSW that future monitoring at Butchers Creek be discontinued following refused entry from the landowner in response to severe flooding that had increased the risk of tree-fall at the site in combination to the absence of giant barred frog records during construction and operational surveys. As such, monitoring in year 5 spring survey was focused at Upper Warrell Creek along a 1km transect, extending either side of the upgrade alignment divided into 21 zones per baseline monitoring (Figure 2).

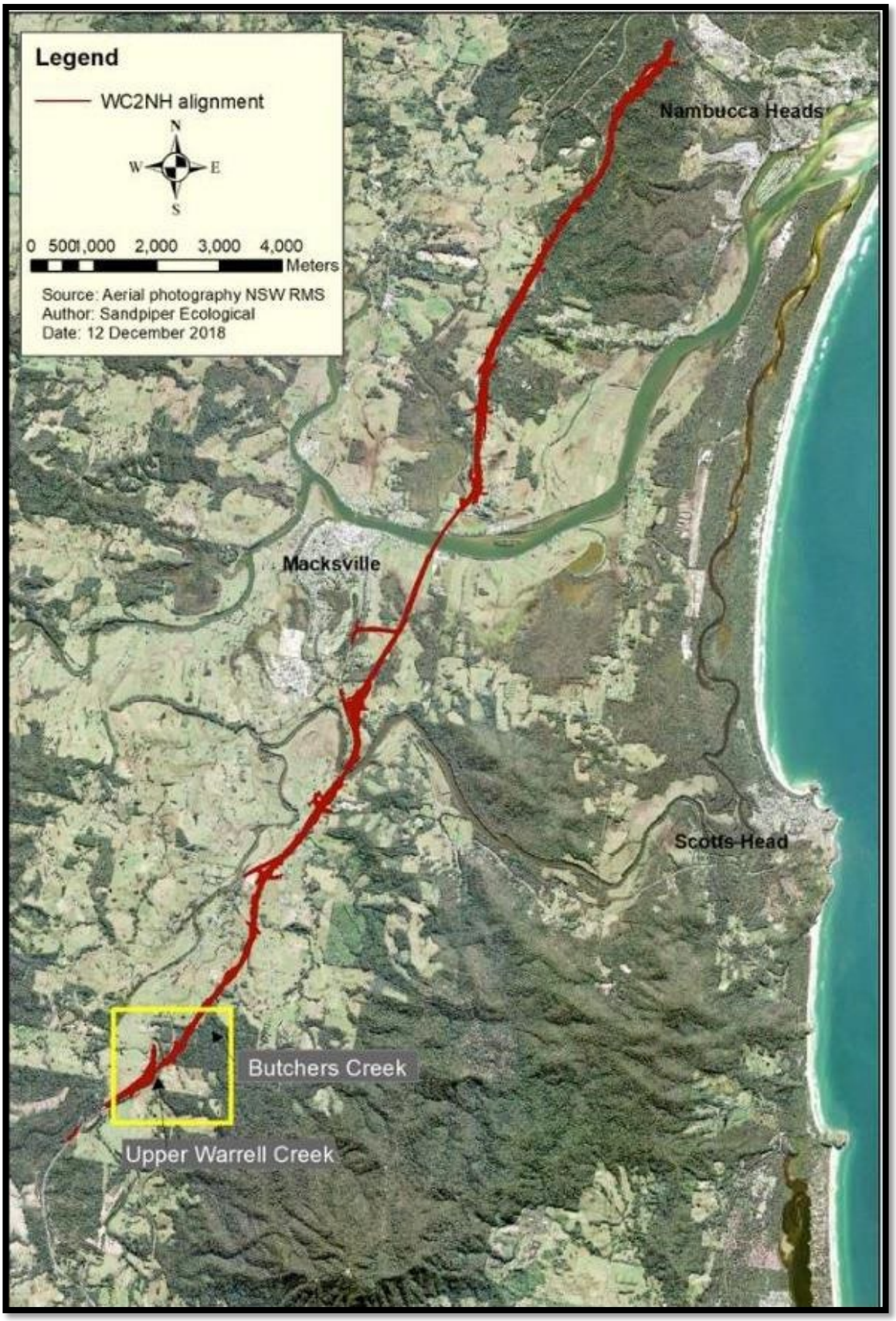

Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment.

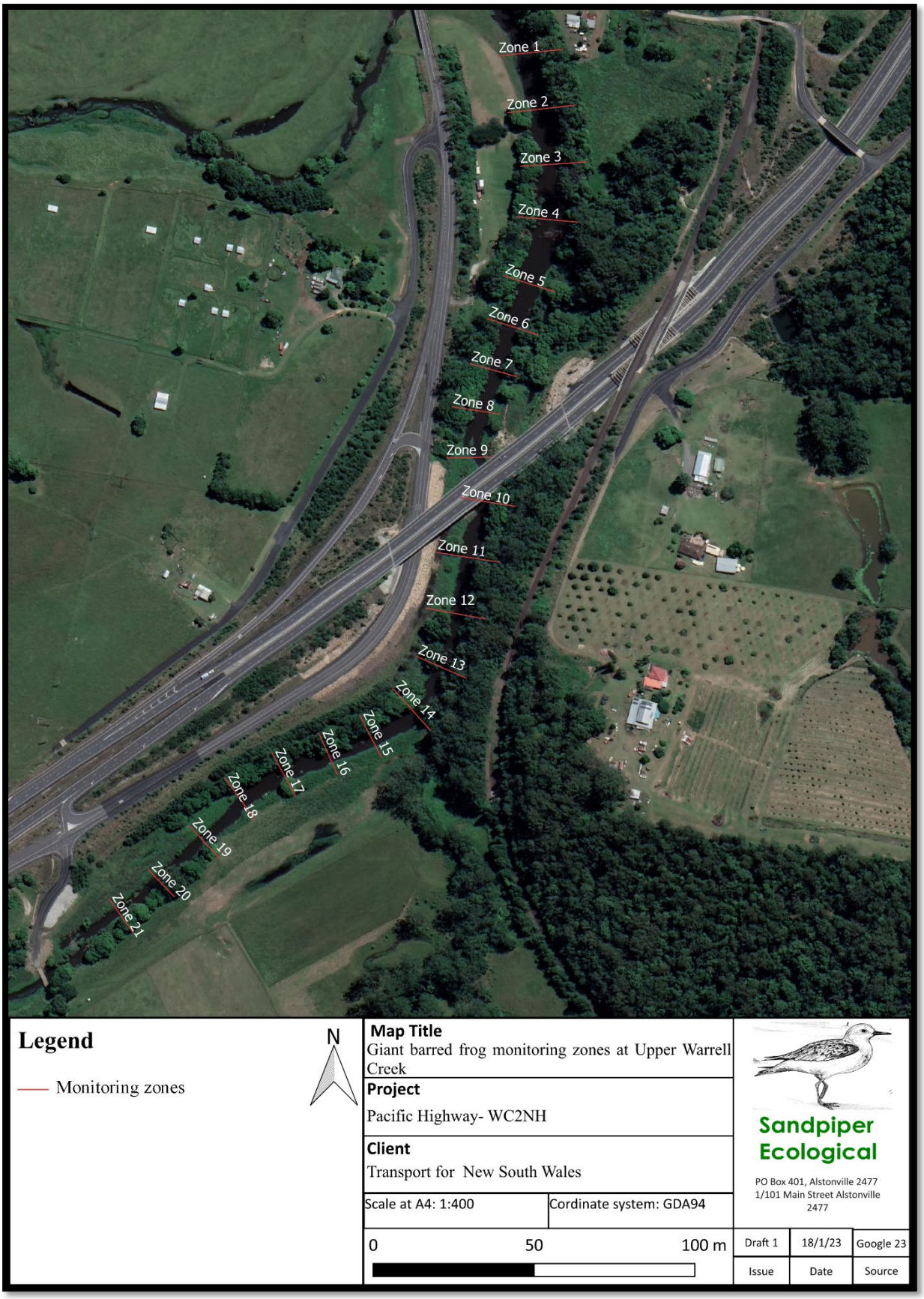

Figure 2: Survey monitoring zones within Upper Warrell Creek.

2.2 Frog surveys

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

1. Surveys were conducted on 1 and 2 December 2022 (spring survey), with 16 person-hours spent searching for frogs at Upper Warrell Creek. The December 2022 survey was intended to occur in spring and was delayed due an extended dry period where the survey trigger value of >10mm 24hrs prior to the sample was not met (Lewis 2014).
2. Two ecologists conducted a nocturnal meandering foot-based traverse of 40 x 50m survey zones, 20 on each side of the watercourse at Upper Warrell Creek (20/side; Figure 2).
3. Each ecologist was equipped with a 200-700 lumen spotlight and slowly traversed the riparian zone searching for frogs and listening for calls. Giant barred frog calls were broadcast through a 2-watt bluetooth speaker for five minutes within each zone. Both ecologists listened for call responses during and immediately after call broadcast.
4. 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 a sub-adult or older (i.e. >40mm snout-vent length) a tag was inserted beneath the skin on the left side and the insertion hole sealed with vet bond. The insertion point was swabbed with disinfectant (Betadine) before the tag was inserted. During operational surveys prior to autumn 2021, only frogs with a SV length greater than 60mm were PIT tagged. In autumn 2021, the size limit was reduced to 40mm to ensure consistency with baseline and construction phase surveys.
5. The dorsal pattern of all captured frogs was photographed during spring. A comparison of dorsal pattern is a way to distinguish individual frogs and was done to identify untagged frogs captured in autumn 2021 and March 2022.
6. Data collected on each captured frog included: Survey zone (20x50m); Distance from the stream edge measured to the nearest 0.1m; Position within the microhabitat (i.e. under litter, above litter, exposed, on rock/log); Sex (male, female, unknown); Age class (adult=>60mm; sub-adult=40-60mm; juvenile=<40mm); Snout-vent length (mm); Weight (grams); Breeding condition:
    i. males assessed on the colouration of their nuptial pads (i.e. no colour, light, moderate, dark) in accordance with the classification developed by Lewis (2014b);
    ii. females assessed on whether they are gravid (i.e. egg-bearing, with the typically adult weighing > 100 grams) or not gravid.
    iii. frogs with a snout-vent length of <60 mm were classified as immature.

2.3 Tadpole survey

Tadpole surveys will be undertaken during the summer and autumn surveys of year five monitoring and will be undertaken using the following procedure:

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

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

2.4 Habitat assessment

Key habitat components in each survey zone are required to be sampled annually (i.e. once/year). Habitat sampling is scheduled to be conducted during the summer sample period. Habitat data recorded in each zone at each site will include:

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 (>100 mm); Moderate (20-100 mm); Shallow (>0-20 mm); or Absent (0 mm).

2.5 Water quality sampling

Water samples and field measurements are to be taken within the sample transect at Upper Warrell Creek during the summer and autumn surveys. Due to a change in property ownership, the sample collection site has been moved approximately 100m upstream. Field physicochemical measurements, including Conductivity, pH, Temperature, dissolved oxygen and turbidity, will be measured using a Horiba Laqua PC110 portable water quality meter.

Water quality parameters to be analysed from the collected sample/s include:

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. 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.

3. Results and discussion

3.1 Survey timing weather conditions and effort

Below average rainfall was recorded 30 days before the sample period, with 36 mm falling before 2 December, 17 mm of which was recorded to 9 am on 1 December. Rainfall was present during both spring surveys, with heavy rainfall occurring on 1 December, which may have affected frog activity and detectability (Table 1). The air temperature was slightly cool and ranged between 16.8^{0}C and 18.2^{0}C (Table 1). Overall conditions were not ideal for giant barred frog detection but were considered reasonable. The combined survey effort at Upper Warrell Creek during the spring sample was 15.75 person-hours.

Table 1: Weather conditions and survey effort recorded during the year five spring giant barred frog survey at Upper Warrell Creek. Rainfall data were sourced from the Bellwood weather station. PH = person hours; Wind

categories = 0 - no wind, 1 - rustles leaves, 2 - branches moving, 3 - canopy moving; RH = relative humidity; Rainfall = mm; Temp = ^{0}C; Dew Point = ^{0}C

Season	Date	Time	Observers	PH	Rainfall	Rainfall (prev 24hr)	Rainfall (prev 7 days)	Rainfall (prev 30 days)	Temp	RH	Dew point	Wind
Spring	1/12/22	2000-2345	LA/AE	7.75	Heavy rain present	0	0	17	16.8	86	14.9	2
	2/12/22	2000-0000	LA/AE	8	Present	19	19	36	18.2	69	14.2	1

3.2 Giant barred frog records and distribution

Four individual giant barred frogs were recorded at Upper Warrell Creek during the year five spring survey (Table 2). Captures included three adults (snout-vent length >60mm), none of which were recaptured and were tagged as new individuals (Table 2). Confirming the sex of non-calling adult frogs is difficult and in the absence of calls, the sex of adult frogs was based on the snout-vent length and weight. Using these criteria, two of the captured individuals (Frog 3 and 4) were deemed male and the larger individual (Frog 1) was deemed female (Table 2). An additional male giant barred frog (Frog 2) was heard calling on the southern bank and was unable to be captured (Table 2). The record of a calling male is encouraging as it provides evidence of breeding in the current population at Upper Warrell Creek.

Giant barred frogs were recorded both downstream and upstream of the alignment (Figure 3). Giant barred frog records were concentrated between zones 6 and 13 (Figure 3) and tended to be within 200m of the alignment, consistent with recent operational monitoring surveys (Sandpiper, 2021 and 2022). Upstream of the alignment, two individuals were captured on the north bank, whilst downstream, two were recorded on the south bank. All captured individuals were positioned within 10m of the stream sitting on leaf litter (Table 2). No recaptures were recorded; hence, no individuals were found to have crossed the alignment.

Table 2: Data recorded for giant barred frogs captured or heard calling during the year 5 spring operational phase monitoring survey at Upper Warrell Creek. HC = Heard call. S = South. N= North. UK= unknown. S/V = snort-vent length.

Frog ID	Season	Date	Zone	Side	Distance to water edge	Position in micro-habitat	Sex	Age	S/V length	Weight	Condition	New or recapture	Microchip ID
1	Spring	1/12/22	8	S	5m	Leaf litter	F	Adult	91	132	Gravid	New	956000011426414
2 (HC)	Spring	1/12/22	6	S	UK	UK	M	Adult	UK	UK	UK	UK	UK
3	Spring	2/12/22	11	N	6m	Leaf litter base of tree	M	Adult	71.5	61	Moderate	New	956000010454481
4	Spring	2/12/22	13	N	10m	Leaf litter	M	Adult	68.4	59	Moderate	New	956000010427117

3.3 Giant barred frog abundance

Adult giant barred frogs continue to persist at Upper Warrell Creek almost five years after completion of construction. Uncertainty remains about whether frogs within the study area have bred in that area or emigrated from upstream (Sandpiper 2022). During year four monitoring, there appeared to be a correlation between declining recaptures, detection of new individuals, and flood frequency (Sandpiper 2022). Movement of frogs into the study area by flood remains likely, and it stands to reason that more frogs will wash into the study area during productive breeding years, such as 2020 and 2021 (Sandpiper 2022). Regarding flood movements, frogs are equally likely to be washed out of the study area. Juvenile frogs may be particularly susceptible to flood transportation due to their small size (Koch & Hero 2007). It appears this trend has continued into year five with no recaptures or juvenilles recorded to date, while Bellwood weather station recorded five days of >100mm rainfall, conducive to intense floods at Upper Warrell Creek, since the most recent monitoring in autumn 2022. Further monitoring in year five will assist in determining the status of the giant barred frog population at Upper Warrell Creek and may assist in elucidating population trends associated with flood movements.

Figure 3. Location of giant barred frogs recorded during spring year five monitoring at Upper Warrell Creek. The giant barred frog individual (F2) is recorded as an approximate location as it was only heard calling.

4. Recommendations

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

Number	Recommendation	Transport for NSW Response
1.	Continue monitoring in summer and autumn to determine the status of the GBF population at WC2NH	Noted.

5. References

Geolink (2018). Annual report – WC2NH giant barred frog population monitoring 2017/2018 – year 3. Report prepared for Pacifico.

Geolink (2015). WC2NH Butchers Creek – Mixophyes unexpected find summary. Letter report prepared for Pacifico.

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Transport for
New South Wales

Warrell Creek to Nambucca Heads

Annual Underpass Monitoring Report - Operational Phase, Year Four (2021-2022)

Transport for New South Wales | October 2022 |

Pacific Highway upgrade: Warrell Creek to Nambucca Heads (WC2NH)

Underpass monitoring – operational phase Year four (2022)

Sandpiper Ecological Surveys

Final Report
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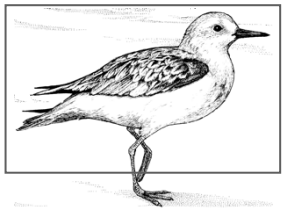

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1. Introduction

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

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

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

As part of the project's approval (MCoA B1, B2, B3) fauna underpasses were installed "to maintain the viability of local terrestrial fauna populations by facilitating wildlife movement between proximate areas of habitat either side of the upgrade corridor and to accommodate use by several threatened fauna species including the spotted-tailed quoll, koala and giant barred frog" (RMS 2018). To assess the effectiveness of the fauna underpasses the EMP specified that operational phase monitoring should take place bi-annually (i.e., spring/summer and autumn/winter) for 5 years. The seasonal timing of monitoring was intended to align with the breeding and dispersal periods of targeted threatened species (i.e., koala, spotted-tailed quoll and giant barred frog).

The following report presents methods and the results of year four operational phase underpass and adjacent habitat monitoring. The objective of fauna underpass monitoring is "to assess use of underpasses by threatened and common fauna and to assess the effect of exclusion fencing on movement of small mammals, reptiles and frogs" (RMS 2018). Effectiveness of exclusion fence is assessed in the annual road-kill report (see Sandpiper Ecological 2022a). The results are discussed in relation to the potential indicators of success detailed in the WC2NH EMP (RMS 2018) and recommendations regarding future monitoring are provided. The potential indicators of success used to assess the performance of the WC2NH underpasses include:

1. Low rates of use of fauna underpasses and adjacent habitats by feral predators.
2. High levels of fauna underpass use by a wide variety of native fauna species.
3. No change to densities, distribution, habitat use, and movement patterns compared to baseline population data of target species.
4. Evidence of use by dispersing individuals and different age cohorts.
5. Use by cover-dependent species and species with low mobility.

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

2. Methods

2.1 Study area

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

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

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

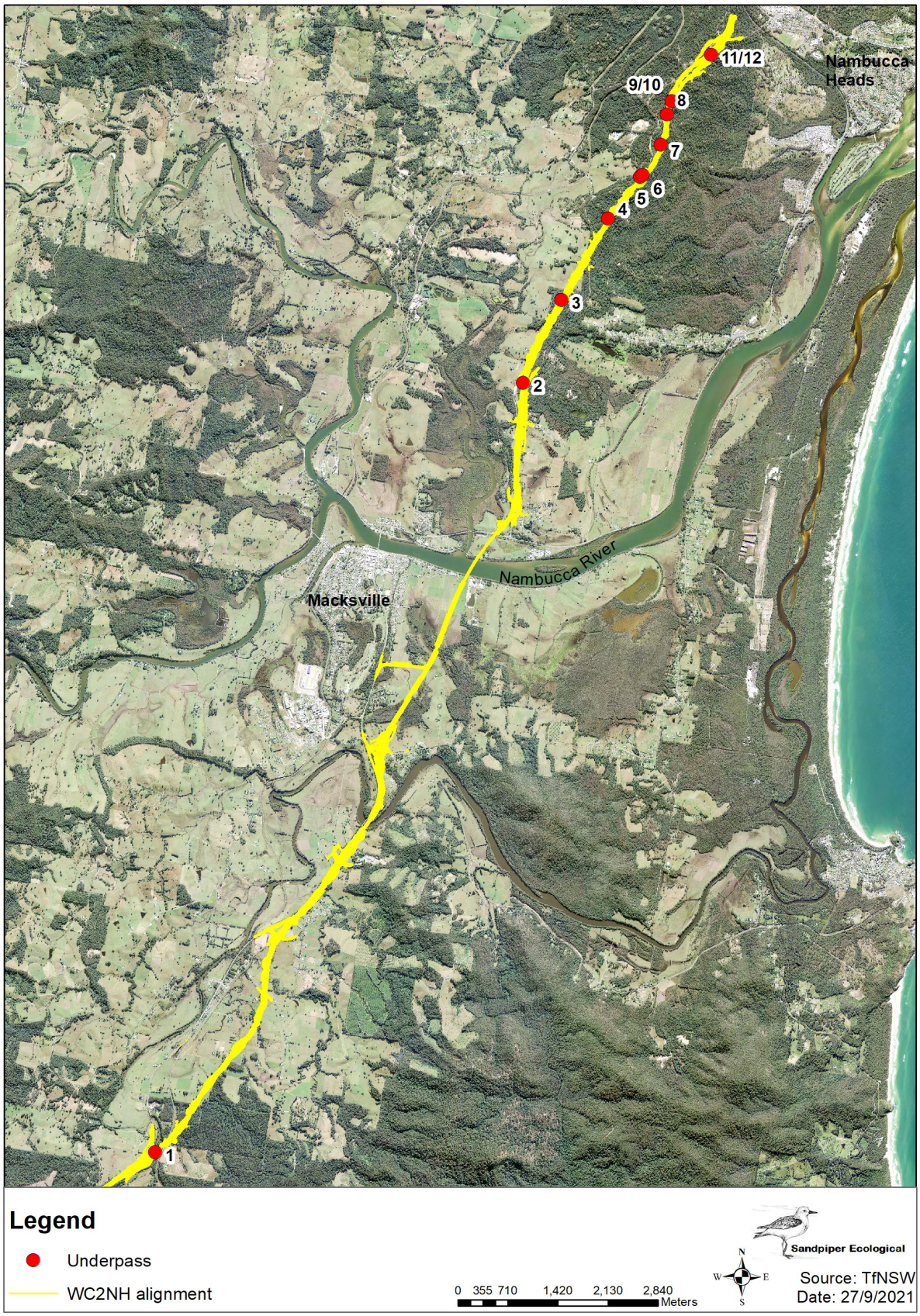

Figure 1: Underpass locations along the WC2NH alignment.

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

2.2 Timing and weather conditions

Year 4 spring/summer operational phase underpass and adjacent habitat surveys were conducted between 15 November 2021 to 2 February 2022. Wet conditions prevailed during this period, with a total of 581 mm of rainfall recorded at the Bureau of Meteorology (BOM) Bellwood weather station (059150) (BOM, 2022). Conditions were warm, with maximum temperatures ranging from 20.1 to 34.1 ^{0}C (BOM, 2022a).

Winter surveys were conducted between 1 July and 31 August 2022. Conditions during this period were typically cool to mild with maximum temperatures ranging from 15.6 to 25.6 ^{0}C (Table 2). A total of 336 mm of rainfall was recorded, most of which was recorded on 6 (118mm) and 7 (104mm) July (BoM 2022).

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

Monitoring period	Total rainfall (mm)	No. rain days	Max temp range (^{0}C)	Min temp range (^{0}C)
Spring/Summer	581	36	21.7-32.1	6.7-25
Winter	336	18	15.6 to 25.6	1.9-15.6

2.3 Underpass monitoring

2.2.1 Sand pads

Sand pads were installed using a 50:50 mix of brickies sand and washed beach sand. One sand pad was installed centrally in culverts, whilst at the bridge (site 1), two pads were installed on the northern side of Warrell Creek. Each pad was approximately 50 mm deep by 1m wide and extended for the entire culvert width or 3-4m at site 1. The sand pad covered both the floor and ledge at sites with a concrete ledge (Plate 2). The exception was site 5, where the pad covered the ledge only due to standing water over the culvert floor. Sand pads were installed at the commencement of both the spring/summer and winter sample periods.

Sand pads were inspected on eight consecutive days during the spring/summer and winter sample periods. 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, fair, poor). Tracks were identified with reference to Triggs (2004) and advice from senior ecologists. Tracks that could not be identified insitu were photographed and referred to a senior ecologist for identification.

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

2.2.2 Scat and track searches

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

2.2.3 Tile checks

In autumn 2020, two roof tiles (300x200) were installed 5 m from both ends of each underpass, excluding site 1, to target small mammals, reptiles and frogs. Tiles were inspected on eight occasions during the spring/summer and winter sample periods.

2.2.4 Cameras

Two motion-activated infra-red cameras (Swift 3C, Swift Enduro or Reconyx HC500) were installed centrally in each culvert or were housed in security boxes and attached to concrete posts for the bridge underpass at site 1. A total of 24 cameras were installed with 22 in culverts and two at the site 1 bridge. In culverts, both cameras were installed centrally, one on the fauna furniture, and one approximately 300mm above the culvert floor. All cameras in culverts were installed facing east with the exception of site 10 ground which was reorientated west due to repeated false triggers from southbound traffic. At the bridge underpass at site 1, Reconyx cameras were installed at approximately 200 mm above ground near the water's edge attached to a concrete post on each side of Upper Warrell Creek (site 1). Cameras were oriented perpendicular to the creek on the north and south banks.

Swift cameras were set on high sensitivity and programmed to take 10 seconds of video on activation. Reconyx cameras in culverts were set to high sensitivity and programmed to take a three-photo burst on activation. Reconyx cameras at site 1 were set on time-lapse mode and programmed to take a picture at 1-minute intervals between 6 pm and 6 am each day throughout the spring/summer and winter sample periods. Time-lapse mode is better suited to targeting frogs and was used successfully to monitor frog pipes on the Sapphire to Woolgoolga Pacific Highway Upgrade (Sandpiper Ecological 2017a, 2018a). Cameras at site 1 were originally installed during autumn, however flooding led to the disruption of monitoring with cameras being reinstalled during the winter survey period to satisfy monitoring requirements.

During the spring/summer sample period, cameras at sites 1-12 were installed on 23-25 November 2021 and were retrieved on 2 February 2022 following a total sample period of 71 days (Table 3). During the winter sample period, cameras at sites 1-12 were installed on 1 July 2022 and were retrieved on 31 August 2022 following a total sample period of 61 days (Table 3). On fourteen occasions camera effort was hindered by battery failure (six occasions), SD card error (six occasions) and flooding (2 occasions) (Table 3). As specified within the EMP at least two cameras were active for a minimum of 60 days per sample period at sites 2, 3, 5/6, 8, 9/10 and 11/12. Camera effort was reduced at sites 1 (spring/summer and winter), 4 (spring/summer only) and 7 (spring/summer and winter) during year four operational monitoring (Table 3). To resolve future issues with SD card errors new SD cards have been obtained.

Table 3: Camera survey effort during year four operational phase monitoring. SS = spring/summer. W= Winter [!] **=** SD card error * = Camera malfunction/battery failure. F = flooding.

Site	Camera type	Camera location	Number of days active		
			Spring/summer	Winter	Total Year 4
1	Reconyx	North	56*[F]	51*	107
	Reconyx	South	52*[F]	43*	95
2	Reconyx	Furniture	68	61	129
	Swift enduro	Ground	71	61	132
3	Swift enduro	Furniture	71	61	132
	Swift enduro	Ground	71	61	132
4	Swift 3c	Ground	36[!]	61	97
	Swift enduro	Furniture	29*	61	90
5	Swift enduro	North	71	36[!]	107
	Swift enduro	South	71	25[!]	96
6	Reconyx	Furniture	71	61	132
	Reconyx	Ground	71	61	132
7	Swift 3c	Ground	29[!]	56	85
	Swift enduro	Furniture	71	61	132
8	Swift enduro	Furniture	71	61	132
	Swift enduro	Ground	71	61	132
9	Swift 3c	Ground	71	36[!]	107
	Swift enduro	Furniture	12*	61	73
10	Swift enduro	Furniture	71	61	132
	Swift enduro	Ground	71	61	132
11	Swift enduro	Furniture	71	25[!]	96
	Swift enduro	Ground	71	61	132
12	Swift enduro	Furniture	71	61	132
	Swift enduro	Ground	71	61	132

Image review

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

Fauna were scored making a complete or incomplete crossing:

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

Crossing definitions are consistent with those used at other Pacific Highway monitoring sites (e.g. Sandpiper Ecological 2017b, 2018b, 2019) and crossing structure research programs (e.g. Soanes *et al.* 2015). Further, it represents a conservative approach to identification of complete crossings. Data recorded for fauna records included movement direction (i.e.,, east, west or no-directional movement - NDM) and a tally of crossing types. A hierarchical approach was adopted to species identification, including species, genus or group. Microbats were recorded as present only due to their transient nature and non-reliance on underpasses for thoroughfare.

Data analysis and interpretation

To adequately assess "use of underpasses" as per the monitoring aim, complete crossings were used as the standard measure for fauna activity as it encompasses the purpose of fauna underpasses (i.e.,, A structure that allows fauna to access habitat that has been fragmented by the construction of a road or highway). To account for variations in survey effort between sites, complete crossings/week and complete crossings/week/underpass were adopted. Complete crossings have been pooled and presented in relation to monitoring periods (i.e., year 1 vs year 2), taxa (i.e., bandicoots, possums, and wallabies), and sites (i.e 1, 2, 3). Survey effort and complete crossings at underpasses 5/6 (proximity), 9/10 (split median), and 11/12 (split median) were combined during data analysis as they function as a single site and lack independence if treated separately. While pooling data, complete crossings of fauna have been averaged according to the number of cameras per underpass (i.e., 11/12 n=4). This same approach has been applied to data from previous monitoring years and projects. Birds and microbats were excluded from analysis as they do not require underpasses for thoroughfare.

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

2.3 Adjacent habitat survey

2.3.1 Survey design

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

2.3.2 Trapping

Trapping methods applied during the survey included: cage traps, ground Elliott traps (Type A), arboreal Elliott traps (Type B), pitfall traps, and hair funnels. Trapping occurred within a 1 ha area immediately adjacent to each culvert entrance and was conducted over three nights at each site. All sites were sampled concurrently, with trapping occurring between 17 and 19 November 2021.

Traps were set in an "X" formation with five ground and five arboreal traps set at 20 m intervals on one axis, two cage traps, and two hair funnels set at 50 m spacing on the other axis (Plate 3). A line of three pitfall traps with a drift fence set at the intersection of both lines (Plate 3). Pitfall traps typically followed the contour and were set near fallen logs and dense ground cover. The trap effort is summarised in Table 4.

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

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

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 sampling aimed 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 100 m 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.

2.3.4 Nocturnal active search

Nocturnal surveys were conducted by one or two ecologists and involved a meandering traverse of habitat within 100 m of the culvert entrance using hand-held Led Lenser P14 spotlights. Fauna were detected by sight and call and identified to species or genus where possible. Each site was sampled twice during each sample period for a minimum of 30 person minutes/sample.

2.3.5 Opportunistic records

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

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

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

3. Results

3.1 Underpasses

3.1.1 Year four camera monitoring

Species diversity and underpass use

Twenty-three species/unique genera and eight fauna groups were confirmed using (complete crossings) underpasses at WC2NH during year four operational phase monitoring (Table 5). Fauna groups included eight taxa that could only be identified to a genus or group, including *Antechinus* spp. rodent spp., *Rattus* spp. bandicoot spp., wallaby spp., lizard spp., *Chelidae* spp., and *Trichosurus* spp. (Table 5). Rodent, Rattus, bandicoot, wallaby and *Trichosurus* spp. likely belong to confirmed species in Table 5 (i.e., *Trichosurus* spp. either short-eared brushtail possum or common brushtail possum). Of the fauna recorded, eighteen were native species and six were introduced including cat, wild dog, red fox, black rat, house mouse and European hare (Table 5). Native fauna diversity was highest at sites 9/10 and 11/12 with thirteen species/groups, followed by sites 7 and 8 with twelve species/groups (Table 5). Native fauna diversity was lowest at site 1 with three species recorded (Table 5). Sites 2, 3, 4, and 5/6 recorded between seven and eleven native fauna species/groups (Table 5).

Underpass use by native species was recorded at all sites during year four camera monitoring at an overall rate of 2.57 ± 0.52complete crossings (cc)/week/site (Figure 2, Figure 4). Sites 7 and 8 featured the highest use by native fauna with an average of 4.7cc/week and 3.86cc/week, respectively (Figure 2). Sites 1 and 5/6 exhibited the lowest use by native fauna, recording 0.11cc/week and 0.93cc/week respectively (Figure 2). Native fauna use was higher than that of feral predators and rodent spp. across all sites (Figure 2).

Short-eared brushtail possum was the most frequently recorded native species, with a total of 11.83cc/week across all sites (Table 5, Plate 4). This was followed by bandicoot species, including long-nosed and northern brown with 9.75cc/week, *Antechinus* spp. (6.57cc/week, Plate 4) swamp wallaby (5.58cc/week), wallaby spp. (4.30cc/week) and *Trichosurus* spp. (2.69cc/week) (Table 5).

Noteworthy detections included koala using the culvert floor (ground) at sites 2 (one occasion), 4 (two occasions Plate 4) and 11/12 (two occasions, Plate 4) to make a complete crossing of the alignment (Table 5, Figure 2).

Use by cover-dependent species

Cover-dependent fauna (see classification in methods) were recorded at all sites (Table 5). In order of underpass use, rodent spp. recorded a total of 20.2 cc/week, bandicoots 9.75cc/week, *Antechinus* spp. 6.57 cc/week and the introduced black rat with 4.25cc/week (see total Table 5). Confirmed rodent species were black rat (underpasses 2,4,5,7,8,9/10, 11/12), fawn-footed melomys (site 2, 5/6, 7, 8, 9/10), water rat (site 5) and bush rat (site 9/10) (Table 5). Other cover-dependent species included the eastern blue-tongue lizard using the culvert floor on one occasion at site 9/10 and *Egernia* spp. with complete crossings at sites 2, 7, 8, and 9/10 (Table 5). No frogs were recorded using underpasses during camera monitoring. Most cover-depended species favoured the fauna furniture over the culvert floor (Table 5).

Furniture vs Floor

Fauna were recorded using (complete crossings) both the culvert floor (55% of complete crossings) and furniture (45%) during year four operational phase monitoring (Table 5, Figure 3). Native fauna accounted for most complete crossings on both the culvert floor (58%) and fauna furniture (50%) (Figure 3). Rodent spp. and introduced rodents ((i.e., house mouse and black rat) tended to favour using the fauna furniture whereas feral predators showed preferential use of the culvert floor with only a few records of cat using the furniture at sites 3 and 8 (Figure 3, Table 5). Most of the native fauna usage on the furniture can be attributed to high preferential use by brushtail possums (combined short-eared brushtail possum, common brushtail possum and *Trichosurus* spp.) and *Antechinus spp.* particularly at sites 4, 7 and 8 (Table 5, Plate 4). Of the threatened fauna, koalas were recorded using the floor only (Table 5, Plate 4).

Feral predator activity

Feral predators were recorded in all underpass sites except for site 1 and site 7 and accounted for 18% of all complete crossings (Figure 2, Table 5). Cat recorded the highest combined use (9.58cc/week), followed by red fox (5.13 cc/week) and dog (0.03 cc/week) (Figure 2, Table 5). Cat activity was recorded across seven of nine sites at an overall rate of 0.53 ± 0.4 cc/week/underpass, with the highest activity (combined total of 6.89 cc/week) occurring at site 3 (Table 5, Figures 2 and 5). Fox activity was recorded at seven of the nine sites at an overall rate of 0.29 ± 0.1 cc/week/underpass, and no records at site 7 or site 1 (Table 5, Figures 2 and 5). Dog activity was only recorded at site 11/12, with one crossing contributing to an overall rate of 0.001 ± 0.001 cc/week/underpass (Table 5, Figures 2 and 5, Plate 4). No instances of predation were recorded in underpasses during year four operational monitoring.

Plate 4: Koala recorded travelling west at site 4 during spring/summer monitoring (Top left). Koala using the culvert floor to travel east at 11/12 split median during winter (Top right). Antechinus spp. using the furniture at site 7 (Middle left). Short-eared brushtail possum travelling west at site 8 on the furniture (Middle right). Fox heading west at split median 9/10 (Bottom left). Wild dog travelling west at split median 11/12 (Bottom right).

Table 5: Mean number of complete crossings/week/site made by each species/group at nine underpass sites monitored on the WC2NH upgrade during year 4 operational monitoring. FF= fauna furniture and G= ground (culvert floor). Site 1 did not contain fauna furniture. Species in bold denote threatened species, ^=Cover-dependent species. * = Introduced species. See appendix B, Table B1 for all data.

Species/fauna groups	Site and camera location																	Cumulative total cc/week/species
	1	2		3		4		5/6		7		8		9/10		11/12		
	G	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	
Mammals																		
Short-beaked echidna	-	-	-	-	-	-	-	-	0.04	-	-	-	0.05	-	0.14	-	0.03	**0.26**
Antechinus spp.^	0.07	1.52	-	-	-	0.14	-	0.58	-	2.14	-	1.22	-	0.70	0.07	0.12	-	**6.57**
Long-nosed bandicoot^	-	-	-	-	0.05	-	-	-	0.36	-	0.37	-	0.21	-	0.34	-	0.88	**2.21**
Northern brown bandicoot^	-	-	-	-	0.05	-	-	-	0.02	-	0.11	-	0.16	-	-	-	0.45	**0.79**
Bandicoot spp.^	-	-	1.01	-	0.32	-	0.93	-	0.21	-	1.17	-	0.85	-	1.23	-	1.03	**6.75**
Koala	-	-	0.05	-	-	-	0.16	-	-	-	-	-	-	-	-	-	0.05	**0.26**
Common brushtail possum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	**0.03**
Short-eared brushtail possum	-	-	-	0.11	-	2.45	0.16	0.27	-	5.44	0.05	1.80	-	0.76	0.03	0.71	0.05	**11.83**
Trichosurus spp.	-	-	0.11	0.11	-	0.51	-	-	-	0.33	0.05	0.37	-	0.21	0.27	0.74	-	**2.69**
Eastern grey kangaroo	-	-	-	-	1.54	-	-	-	-	-	-	-	-	-	-	-	-	**1.54**
Red-necked wallaby	-	-	-	-	0.05	-	-	-	-	-	-	-	-	-	-	-	-	**0.05**
Swamp wallaby	0.07	-	0.74	-	0.21	-	2.41	-	-	-	0.48	-	1.54	-	0.10	-	0.03	**5.58**
Wallaby spp.	-	-	1.38	-	0.95	-	-	-	-	-	0.64	-	1.22	-	0.03	-	0.08	**4.30**
Fawn-footed melomys^	-	0.05	-	-	-	-	-	0.11	-	0.25	-	0.05	-	0.09	-	-	-	**0.55**
Water rat^	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	**0.29**
Bush rat^	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-	**0.06**
European hare*	-	-	-	-	-	-	-	-	0.1	-	-	-	0.1	-	-	-	0.0	**0.16**
Introduced and rodent spp.																		
House mouse*^	0.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.03**
Black rat*^	-	-	-	-	-	1.59	-	0.42	-	1.32	0.42	0.11	-	0.15	0.24	-	-	**4.25**
Rattus spp.^	-	0.54	-	-	-	-	-	-	0.06	-	-	-	-	-	-	0.03	-	**0.64**
Rodent spp.^	-	1.19	0.16	-	0.16	3.32	0.31	2.55	0.13	2.96	0.58	5.46	-	0.85	1.47	0.95	0.11	**20.20**
Feral predators																		
Red fox*	-	-	0.69	-	0.32	-	0.31	-	0.23	-	-	-	1.22	-	0.82	-	1.59	**5.18**
Wild dog*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	**0.03**
Cat*	-	-	0.11	0.48	6.89	-	0.16	-	0.08	-	-	0.58	1.01	-	0.14	-	0.13	**9.58**
Reptiles																		
Chelidae spp.	-	-	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.05**
Blue-tongue lizard^	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	**0.07**
Eastern crevice skink^	-	0.11	-	-	-	-	-	-	-	0.08	-	0.05	-	0.23	-	0.09	-	**0.57**
Eastern water dragon^	-	-	-	-	-	-	0.08	-	-	-	-	-	-	-	-	-	-	**0.08**
Lace monitor	-	-	-	-	0.11	0.22	-	-	0.08	0.41	0.32	-	0.37	0.03	0.14	-	0.03	**1.70**
Lizard spp.	-	0.05	-	0.05	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.11**
Coastal carpet python	-	-	-	-	-	-	-	-	-	0.08	-	-	-	-	-	-	-	**0.08**
Total cc/week/cam	**0.17**	**3.47**	**4.30**	**0.74**	**10.66**	**8.23**	**4.51**	**3.92**	**1.55**	**13.01**	**4.19**	**9.65**	**6.63**	**3.08**	**4.95**	**2.67**	**4.48**	**86.21**

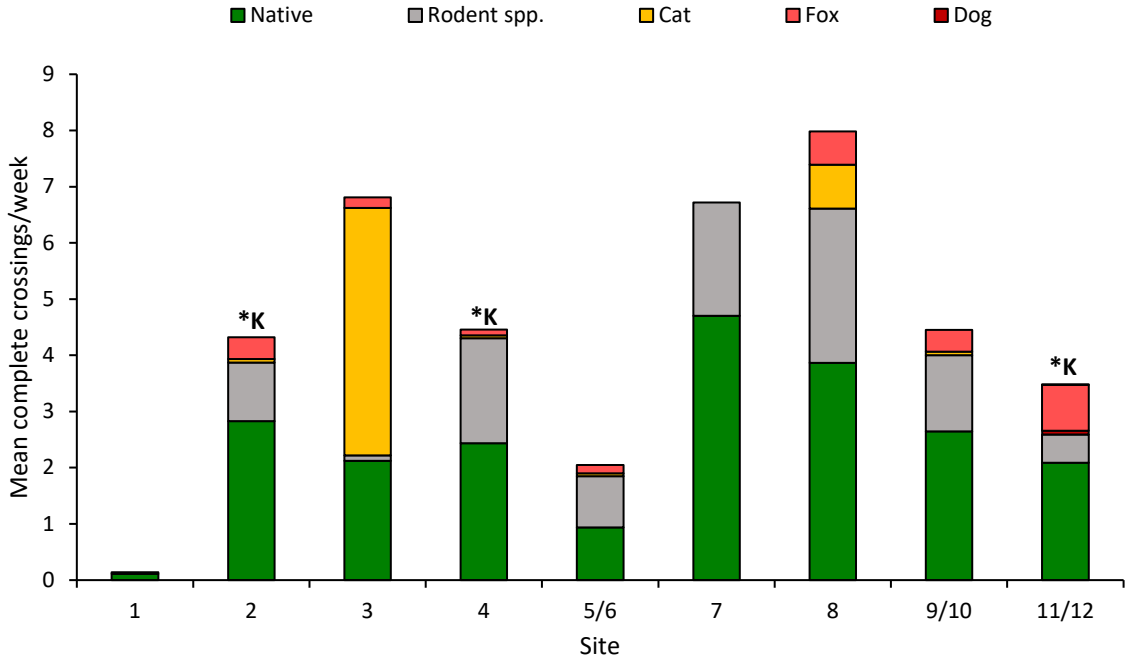

Figure 2: Mean complete crossings (cc)/week/site by native species, feral predators (cat, dog and red fox) rodent spp. (combined black rat, house mouse and rodent spp.) at each site during year four operational monitoring, WC2NH, 2021-2022. *K = indicates complete crossing by koala. European has been removed due to limited records.

Figure 3: The proportion of complete crossings recorded on the culvert floor (ground) vs the fauna furniture by native species, feral predators (cat, dog, and red fox) rodent spp., and introduced species (European hare, black rat and house mouse) at WC2NH during year four operational monitoring, 2021-2022.

3.1.2 Operational camera monitoring

Excluding microbats and birds, underpass cameras during year four operational monitoring yielded 1893 fauna detections (i.e., sum of complete, incomplete and non-directional movement crossings) (See appendix B, Table B1). Complete crossings (cc) accounted for 92% (1743cc) of all fauna detections at an overall rate of 4.7± 0.54 cc/week/site (combined native, feral predator, introduced, and rodent spp.) at WC2NH (Figure 4). The rate of complete crossings/week/site has been the highest recorded since the commencement of operational monitoring in year one and has continued the general trend of the increasing number of complete crossings over time (Figure 4).

Native fauna accounted for most of the complete crossings during year four monitoring with a rate of 2.57 ± 0.52 cc/week/site followed by rodent spp. (1.07 ± 0.29 cc/week/site), feral predators (0.83 ± 0.4 cc/week/site) and introduced species (0.23 ± 0.1 cc/week/site) (Figure 4). Underpass use by native fauna has continued to increase, with the highest mean number of complete crossings recorded during year four monitoring (Figure 4). Similarly, rodent spp. (either melomys, bush rat, black rat or swamp rat) use has tended to increase over time, going from 0.01 ± 0.001 cc/week/site in year one monitoring to 1.01 ± 0.29 cc/week/site during year four (Figure 4). Feral predator use of the WC2NH underpass sites has decreased since year one (1.37 ± 1.02 cc/week/site) and two (1.65 ± 0.29 cc/week/site) monitoring periods and marginally increased from 0.79 ± 0.27 cc/week/site in year three to 0.83 ± 0.4 cc/week/site during year four monitoring (Figure4). The marginal increase in feral predator activity is largely attributed to changes in cat activity which increased from 0.33 ± 27 cc/week/site in year three to 0.53 ± 0.4 cc/week/site during year four (Figure 5). Dog activity declined between years three and four, going from 0.19 ± 0.04 cc/week/site to 0.001 ± 0.001 cc/week/underpass, whereas fox has remained relatively unchanged (Figure 5).

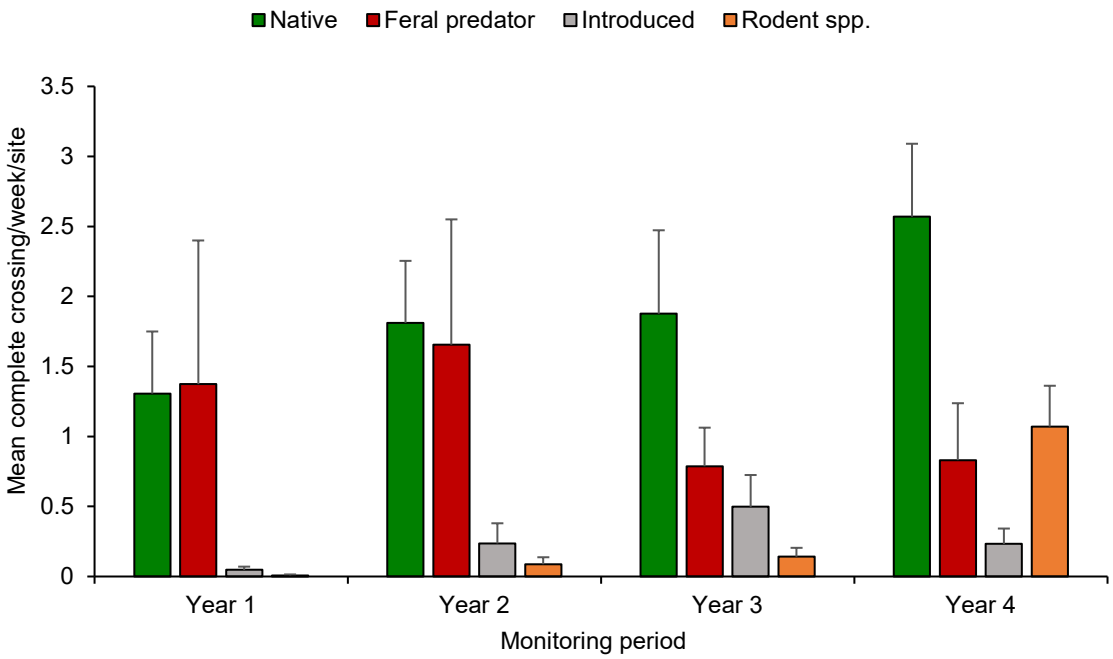

Figure 4: Mean number (n=9) of complete crossings/week/site (+SE) by native species, feral predators (cat dog and red fox) rodent spp. rodents (rodent spp. and *Rattus* spp.) and introduced species (European hare, black rat and house mouse) at WC2NH during operational monitoring, 2021-2022. Birds and microbats have been excluded.

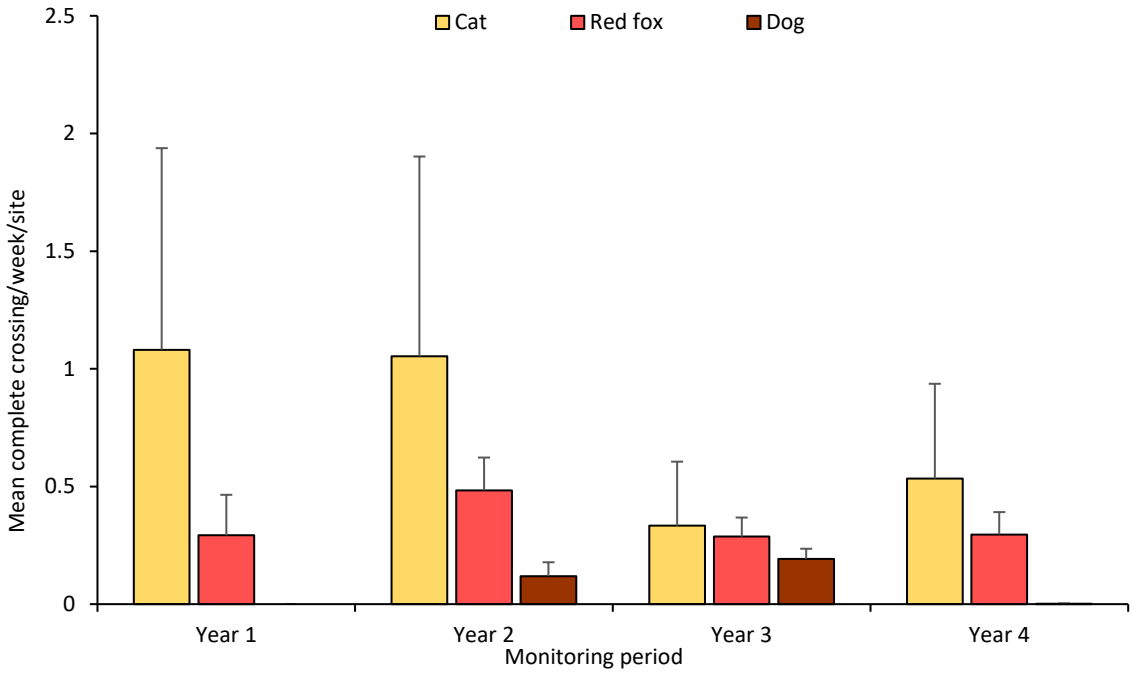

Figure 5: Mean number (n=9) of complete crossings/week/site (+SE) feral predators (cat dog and red fox) at WC2NH during operational monitoring, 2021-2022.

3.1.3 Sand pads

Eleven species and fauna groups were recorded on sand pads in year four operational monitoring (Appendix B, Table B2, Plate 5). Of the native species, swamp wallaby was the most frequently recorded fauna species, with tracks identified at sites 1, 2, 3, 4, 7, 8 and 9/10 (Appendix B, Table B2). Of the smaller cover-dependent fauna groups (i.e.,, small mammals, reptiles and amphibians), probable *Antechinus* spp. (sites 11/12, 9/10, 7, 8 and 5/6), probable frog (site 3 and 11/12) and medium lizard/skink (11/12) were recorded during inspections (Appendix B, Table B2). Other than the medium lizard and probable frog records, no species or groups were recorded in addition to those identified by cameras.

Plate 5: Bandicoot tracks (east and west) and bounding rodent tracks at site 8 during winter surveys (Left). Short-beaked echidna tracks heading east through the culvert at site 2 (Right).

3.1.4 Scat and track searches and tile checks

Seven species and seven fauna groups were recorded during scat and track surveys during year four monitoring of the WC2NH underpasses (Appendix B. Table B3). As seen in camera data, native species/fauna groups were found to be using all underpasses. The presence of feral predators (either cat, red fox or dog) was detected through tracks or scats at all underpasses with the exception of site 5/6 (Appendix B. Table B3). Records of small fauna not detected by cameras included tracks from medium lizard at 11/12 and scats from small/medium reptiles at sites 1,2,3,5/6, 9/10, and 11/12 (Appendix B. Table B3).

No fauna was recorded during tile checks (Appendix B, Table B4).

3.2 Adjacent habitat

Forty species/unique genera and six fauna groups were recorded in habitat adjoining underpasses during year four operational monitoring (Table 6). Most species/groups were detected by diurnal searches (25) and spotlighting (22) (Table 6, Appendix B, Table B5, and B6). Sixteen species were recorded during trapping, while hair funnels recorded four species and two groups (Appendix B Table B7, Table B8). Threatened species records included koala scat on the west side of sites 7 and 8 during active diurnal searches and giant barred frog on the east side of site 1 during spring/summer spotlight surveys (Table 6, Appendix B, Table B5 and B6).

Table 6: Detection of fauna species and groups during year four adjacent habitat monitoring at WC2NH, 2021-2022. Bold denotes threatened species. [I] = Introduced. Birds and sugar gliders have been excluded as they do not require underpasses for thoroughfare.

Species	Active Search	Spotlight	Trapping	Hair funnel
Mammals				
Brown antechinus			*	*
Antechinus spp.	*			*
Northern brown bandicoot			*	*
Long-nosed bandicoot		*	*	
Peramelidae spp. (bandicoot)	*			
Koala	*			
Common brushtail possum			*	
Short-eared brushtail possum	*		*	*
Common ringtail possum		*		
Trichosurus spp.	*			
Swamp wallaby	*	*		*
Wallaby spp.	*	*		
Eastern grey kangaroo	*			
Fawn-footed melomys		*	*	
Bush rat			*	*
Swamp rat			*	
Black rat [I]			*	
House mouse			*	
Rattus spp.	*	*		*
Red fox [I]	*			
Dog [I]	*	*		
Cat [I]	*			
Reptiles				
Lace monitor	*		*	
Eastern water dragon	*			
Calyptotis ruficauda	*	*	*	
Eastern crevice skink	*			
Lampropholis delicata	*	*	*	
Lampropholis guichenoti	*			
Lampropholis spp.	*			

Species	Active Search	Spotlight	Trapping	Hair funnel
Bandy bandy		*		
Yellow-faced whipsnake	*			
Red-bellied black snake	*			
Small-eyed snake		*		
Chelidae spp.				
Small reptile	*			
Frogs				
Litoria gracilenta		*		
Litoria fallax	*	*		
Litoria peronii		*		
Litoria caerulea		*		
Litoria tyleri		*		
Mixophyes iteratus		*		
Crinia signifera	*	*		
Adelotus brevis		*	*	
Uperoleia fusca		*		
Limnodynastes peronii	*	*	*	
Pseudophryne coriacea		*	*	
Total Nº· Species/groups	**25**	**22**	**16**	

3.2.1 Trapping

Twenty-three vertebrate fauna species have been captured during operational monitoring within habitat adjoining underpasses at WC2NH (Table 7). Mammals accounted for the majority of the fauna captured (545 individuals), followed by reptiles (66 individuals), frogs (16 individuals), and birds (3 individuals) (Table 7). Seventeen of the twenty-three species are cover-dependent, and three species captured were introduced, including black rat, house mouse, and cat (Table 7).

Overall captures have increased from 111 individuals in year one to 202 individuals in year four (Table 7). In order of the number of captured individuals, brown antechinus (149), fawn-footed melomys (135), bush rat (105), and black rat (81) have been the most frequently recorded species within the adjacent habitat, accounting for 75% of all captures (Table 7). Over time brown antechinus and bush rat captures have increased, with the highest number of individuals being captured during year four surveys (Table 7). Fawn-footed melomys initially increased from 16 individuals during year one surveys to 43 individuals in year three surveys before stabilising between 36 and 40 individuals in years three and four (Table 7). Black rat captures decreased from 20 and 26 individuals in years one and two of monitoring to 12 individuals in year three before increasing to 23 individuals in year four (Table 7).

Table 7: Temporal comparison of the number of fauna individuals and species recorded within the adjacent habitat at WC2NH during operational monitoring. [I] = Introduced. ^= cover dependent fauna.

Species	Year 1	Year 2	Year 3	Year 4	Total
Mammals					
Brown antechinus^	25	28	38	58	149
Sugar glider	1	6	8	5	20
Long-nosed bandicoot^				1	1
Fawn-footed melomys^	16	43	36	40	135
Northern brown bandicoot^	1	3	2	5	11
Short-eared brushtail possum	4	7	4	4	19
Common brushtail possum				1	1
Bush rat^	9	13	39	44	105
Swamp rat^			1		1
House mouse[I^]	7	7	6	1	21

Species	Year 1	Year 2	Year 3	Year 4	Total
Black rat[I^]	20	26	12	23	81
Cat[I]	1				1
Birds					
Eastern whipbird	1				1
Green catbird	1				1
Yellow-throated scrubwren		1			1
Reptiles					
Lace monitor			3	4	7
Blackish blind snake^	1	1			2
Dwarf-crowned snake^		1	2		3
Marsh snake^		2			2
*Calyptotis ruficauda^*	7	3	4	2	16
*Lampropholis delicata^*	9	3	9	11	32
*Lampropholis guichenoti^*	4				4
Frogs					
*Adelotus brevis^*				1	1
*Limnodynastes peronii^*	2	3			5
*Pseudophryne coriacea^*	2	4	2	2	10
Grand Total	111	151	166	202	630

3.2.2 Species recorded in underpasses and adjacent habitat

With the mentioned exclusions (see Table 8 caption), 43 vertebrate species and unique genera were confirmed within the adjacent habitat, with 24 using underpasses (Table 8). The proportion of species using underpasses from the adjacent habitat was 56% (Table 8). The proportion of mammals recorded in both adjacent habitat and underpasses was 95%, with the common ringtail possum being the only mammal species not recorded in underpasses (Table 8). Notably, a medium frog track was recorded on sand pads at site 11/12 during spring/summer monitoring. However, a species designation is not possible from tracks alone. Further, 12 reptile species/families were recorded during monitoring, with six (50%) confirmed using underpasses, including lace monitor, eastern blue-tongue lizard, eastern crevice skink, coastal carpet python, eastern water dragon, and *Chelidae spp.* (Freshwater turtle) (Table 8).

Table 8: Species and unique genera recorded in adjacent habitat and using underpasses during year four monitoring at WC2NH, 2021-2022. Due to duplication between species and fauna groups (e.g. wallaby spp. includes both red-necked and swamp wallaby), only confirmed species and unique genera have been included. Fauna in bold denotes threatened species. *Denotes presence. + = species designation assumed based on frequent capture of only brown antechinus in adjacent habitat. # = Species presence assumed due to detection in only the underpass. [I] = Introduced. ^= cover dependent fauna.

Species and unique genera	Underpass	Adjacent habitat
Mammals		
Short-beaked echidna	*	#
Brown antechinus ^	+	*
Northern brown bandicoot^	*	*
Long-nosed bandicoot^	*	*
Koala	*	*
Short-eared brushtail possum	*	*
Common brushtail possum	*	*
Common ringtail possum		*
Swamp wallaby	*	*
Red-necked wallaby	*	#
Eastern grey kangaroo	*	*
Water rat	*	#
Fawn-footed melomys^	*	*

Species and unique genera	Underpass	Adjacent habitat
Black rat^[I]	*	*
Red fox[I]	*	*
Cat[I]	*	#
Dog[I]	*	*
House mouse^[I]	*	*
European Hare	*	#
Sub-total mammals	**18**	**19**
Reptiles		
Lace monitor	*	*
Eastern water dragon	*	*
Eastern crevice skink^	*	*
Coastal carpet python	*	#
Eastern blue tongued lizard^	*	#
Calyptotis ruficauda ^		*
Lampropholis delicata ^		*
Lampropholis guichenoti ^		*
Bandy bandy ^		*
Yellow-faced whipsnake ^		*
Small-eyed snake^		*
Red-bellied black snake		*
Chelidae spp.	*	#
Sub-total reptiles	**6**	**13**
Frogs		
*Litoria gracilenta^*		*
Litoria fallax ^		*
Litoria peronii ^		*
*Litoria caerulea^*		*
*Litoria tyleri^*		*
Mixophyes iteratus^		*
*Crinia signifera^*		*
Adelotus brevis ^		*
*Uperoleia fusca^*		*
Pseudophryne coriacea ^		*
Limnodynastes peronii		*
Sub-total frogs	**0**	**11**
Total Nº. Species/unique genera	**24**	**43**

4. Discussion

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

A definition of "low use" by feral predators is not provided in the WC2NH EMP (RMS 2018). Cat, red fox and dog were recorded across seven of the nine underpass sites at an overall rate of 0.83 ± 0.4 cc/week/site and accounted for 18% of complete crossings during year four monitoring. This represents a decrease in comparison to years one and two, where feral predators accounted for ~ 50% of complete crossings (Sandpiper Ecological 2019, 2020).

In particular, dog records have decreased by ~99% from year 3 (0.19 ± 0.04cc/week/site) to year 4 (0.001 ± 0.001 cc/week/site), when only one individual was recorded once at site 11/12. The decline in wild dog records can be attributed to the success of the collaborative trapping program completed at WC2NH during the

autumn of 2021 that removed an individual that frequented the underpass sites (Saltair Flora and Fauna 2021). Wild dogs tend to occupy large home ranges in south-eastern Australia, of between 10,000 and 39 000 hectares (Claridge et al. 2009). Given that the individual at 11/12 was recorded on one occasion and not re-recorded, the individual may be passing through its home range. Monitoring in year five will determine whether further action is warranted, as wild dogs are a known predator of koalas particularly where habitat occurs near residential areas (Gentle *et al.* 2019).

Fox activity initially increased between years one and two of monitoring before declining in year three following the collaborative trapping program and removal of six individuals caught at the culvert entrances (Saltair Flora and Fauna 2021). Since trapping, fox activity has slightly increased between year three (0.29 ± 0.08 cc/week/underpass) and four (0.30 ± 0.09 cc/week/underpass). The slight increase in fox detection despite the removal of six individuals is likely related to improved breeding success and abundance associated with a combination of favourable climatic conditions in year four (high rainfall) and an associated higher abundance of prey items as well lower dog activity (Johnson and Vanderwal 2009). Fox activity is anticipated to increase in year five monitoring. The magnitude of the increase in fox activity in the spring/summer year five surveys will assist in determining whether further control is warranted.

Cat activity has increased from 0.33 ± 27 cc/week/site in year three to 0.53 ± 0.4 cc/week/site, with continued high use at site 3, where a resident cat has been recorded consistently throughout operational monitoring (Sandpiper 2021b). The reason/s for this are unclear but may be associated with lower dog activity, although this is contrary to published studies on the relationship between wild dogs and cats (Fancourt *et al.* 2019; Kreplins *et al.* 2020). As discussed for red fox, it is likely related to the favourable climatic conditions and the associated increase in prey. Removal of the individual at site three would greatly reduce the rate of underpass use by cats at WC2NH. Targeted cage trapping in years two, three and four failed to capture the individual. During the year five surveys cage trapping using alternative baits and 'free feeding' will be continued.

Interestingly, site 7 has not recorded feral predators during either year three or four. However, scat and track searches during year four identified both fox and cat prints in the entrances of the structure. Site 7 has a particularly wet/muddy ground surface throughout the underpass, which may deter feral predators such as cat and fox to some extent.

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

A wide variety (24) of native species and unique genera were recorded using underpasses. Of the 43 species recorded in the adjacent habitat, 57% were recorded using underpasses. The proportion of species using underpasses is encouraging with a higher percentage of species using underpasses than at Sapphire to Woolgoolga (23% to 50%), and comparable to findings at the adjacent Nambucca Heads to Urunga (NH2U, 58%) (Sandpiper Ecological 2018 and 2022). Encouragingly, 95% of the mammals and nearly 50% of the reptiles recorded in the adjacent habitat were found to be using underpasses during year four monitoring. The WC2NH monitoring project observed no usage of underpasses by the eleven frog species in the adjacent habitat, consistent with the NH2U project. However, a single frog track was detected at site 11/12, suggesting some utilisation by certain species. Limited detection may be due to camera trap constraints rather than avoidance behaviour, indicating that more frogs may be using the underpasses.

Camera monitoring has provided further evidence of a temporal increase in underpass use by native species, which has increased from 1.87 cc/week/site to 2.57 cc/week/site or around ~58% between year three and year four of monitoring (Sandpiper Ecological 2021a). The result is not unexpected as use by native fauna is expected to increase over time as site features improve, a trend also recorded at Sapphire to Woolgoolga and recent monitoring at Nambucca Heads to Urunga (Sandpiper Ecological 2018, 2022). Improved weather conditions may have been attributed to the temporal increase with prevailing La Niña conditions experienced between early 2020 and August 2022, providing favourable conditions for improved breeding success for most

native species. The increased number of small mammal captures (particularly brown antechinus and bush rat) during year four monitoring also suggests an increase in breeding success, hence contributing to higher underpass use. Further, vegetation around the culvert entrances has greatly improved (L. Andrews pers obs) in the previous year, likely further encouraging underpass use.

Koalas continue to use underpasses at WC2NH in year four of the operational phase, with individuals recorded making complete crossings on the culvert floor (ground) at sites 2 (one occasion), 4 (two occasions Plate 4) and 11/12 (two occasions). Encouragingly, site 2 has not previously recorded use by koalas and now brings the total number of underpasses used during operational monitoring to six out of nine underpasses or 66% of all sites monitored.

One notable feature of monitoring is the variation in the species richness and level of fauna use between sites at WC2NH. Location seems to be a key feature in determining native fauna use at WC2NH, with higher diversity seeming to occur where culvert entrances adjoin dense ground cover or around creeks and drainage lines. Site features are also likely to play a role in determining underpass use by native species. For instance, site 5/6 at WC2NH typically records low use by native fauna due to adjoining fragmented landscape on the western side of the culvert and pooling of water in the wet passage (culvert 5) side of the culvert. Further monitoring is required to enable a comparison of site features and locations considered optimal for underpass use by native species. At the completion of year five monitoring, a more robust dataset would be available to explore this concept further.

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 EMP, are spotted-tailed quoll, koala and giant barred frog. No spotted-tailed quolls have been detected to date, consistent with baseline monitoring (GeoLink 2014), and population monitoring of giant barred frogs at Upper Warrell Creek is addressed by Sandpiper Ecological (2021b). Koala records at sites 2, 4 and 11/12 in year four show that koalas continue to use underpasses to access habitat on both sides of the alignment.

4.4 Evidence of use by dispersing individuals and different age cohorts

Accurately confirming the age of individuals using underpasses is difficult using the survey methods outlined in the EMP.
Other methods such as mark-release-recapture would likely be required to provide definitive proof of use by dispersing individuals and different age cohorts. Such a survey is not warranted at WC2NH.

4.5 Use by cover-dependent species with low mobility

Several native cover-dependent species (typically small mammals, small reptiles and frogs) were recorded in adjacent habitat, including eleven frog species, four native mammals (brown antechinus, swamp rat, fawn-footed melomys and bush rat) and eight reptile species. Of these, four cover-dependent species (*Antechinus* spp, fawn-footed melomys, eastern blue-tongue lizard and eastern crevice skink) were recorded using underpasses. Encouragingly, a new cover-dependent species, the eastern blue-tongue lizard, was recorded using a culvert to cross the alignment at site 11/12. Consistent with previous surveys, there were limited records of frogs and reptiles in underpasses. The low occurrence of frogs and reptiles is most likely due to the inability of cameras to detect these species as opposed to avoidance. The use of sand pads and scat and track searches cover this shortfall, with records of medium reptiles and a medium frog being recorded at site 11/12.

Tile checks have proved ineffective at detecting cover-depended fauna with no records since their implementation in 2020.

5. Contingency Measures and Recommendations

5.1 Contingency Measures

Contingency measures are summarised in Table 9.

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

Problem	Contingency/Corrective Action	Proposed action
High rates of feral predator activity;	Control program	No action. Fox activity remains equivocal to year three monitoring, and dog activity has declined. Fox and dog visitation in year 5 spring/summer monitoring will be used to determine if further control is warranted.
Low levels of native fauna movement and species diversity in underpasses;	Modify habitat structure near underpass entrances and/or modify underpass fauna furniture	No action is required – monitoring has shown that fauna furniture is functional and underpasses provide safe passage for 95% of mammal species recorded in adjacent habitats.
No use of underpasses by cover-dependent species or species with low mobility or target threatened species	Modify or add potential groundcover resources	Six native cover-dependent species and one threatened species (koala) were recorded using underpasses on several occasions. Tiles have proved ineffective at detecting cover-dependent fauna. No further action is warranted.
High rates of fauna road mortality.	Modify exclusion fencing design, location or extent depending on the species and location of mortalities	Issues relating to road mortality are addressed in the quarterly and annual road-kill reports. At this stage no modifications to the location or extent of exclusion fence is proposed. No mortality of target species has been recorded during the monitoring program.

5.2 Recommendations

Recommendations are summarised in Table 10.

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

Number	Recommendation	Transport for NSW Response
1.	Monitor dog and fox activity during the year 5 spring/summer sample and use the data collected to determine if control is warranted	Noted.

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Appendix A – Species list

Table A1: Common and scientific names for all species recorded during operational monitoring at WC2NH. Species in bold = Threatened species.

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

Common Name	Scientific Name
Frogs	
Eastern dwarf tree frog	*Litoria fallax*
Tyler's tree frog	*Litoria tyleri*
Red-eyed tree frog	*Litoria chloris*
Green tree frog	*Litoria cerulea*
Dusky toadlet	*Uperolia fusca*
Tusked frog	*Adelotus brevis*
Common eastern froglet	*Crinia signifera*
Giant barred frog	*Mixophyes iteratus*
Striped marsh frog	*Limnodynastes peronii*
Red-backed toadlet	*Pseudophryne coriacea*
Medium frog spp.	
Introduced	
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: Underpass camera data recorded during spring/summer and winter of year four operational monitoring WC2NH, 2021-2022.

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	1	North	nil			0			
Spring/Summer	1	South	Swamp wallaby	Native	Macropod	1		1	
Spring/Summer	2	Furniture	Antechinus spp.	Native	Antechinus	17	3		
Spring/Summer	2	Furniture	Eastern crevice skink	Native	Lizard	2	4		
Spring/Summer	2	Furniture	Lizard spp.		Lizard	1			
Spring/Summer	2	Furniture	Rodent spp.	Undefined	Rodent	22	7		
Spring/Summer	2	Ground	Bandicoot spp.	Native	Bandicoot	7			
Spring/Summer	2	Ground	Cat	Introduced	Feral predator	1			
Spring/Summer	2	Ground	Microbat spp.			0		1	
Spring/Summer	2	Ground	Red fox	Introduced	Feral predator	8			
Spring/Summer	2	Ground	Rodent spp.	Undefined	Rodent	2	1		
Spring/Summer	2	Ground	Swamp wallaby	Native	Macropod	3	1	1	
Spring/Summer	2	Ground	Trichosurus spp.	Native	Possum	2			
Spring/Summer	2	Ground	turtle spp.			1			
Spring/Summer	2	Ground	Wallaby spp.	Native	Macropod	22			
Spring/Summer	3	Furniture	Cat	Introduced	Feral predator	9			
Spring/Summer	3	Furniture	Lizard spp.			1			
Spring/Summer	3	Furniture	Microbat spp.			0		1	
Spring/Summer	3	Furniture	Short-eared brushtail possum	Native	Possum	0	1		
Spring/Summer	3	Furniture	Trichosurus spp.	Native	Possum	2			
Spring/Summer	3	Furniture	Welcome swallow	0	Bird	0		1	
Spring/Summer	3	Furniture	Welcome swallow	0	Bird	0			
Spring/Summer	3	Ground	Bandicoot spp.	Native	Bandicoot	6			
Spring/Summer	3	Ground	Cat	Introduced	Feral predator	34	2		
Spring/Summer	3	Ground	Eastern grey kangeroo	Native	Macropod	27			
Spring/Summer	3	Ground	Eastern water dragon	Native	Lizard	0	1		
Spring/Summer	3	Ground	Lace monitor	Native	Lizard	2			
Spring/Summer	3	Ground	Long-nosed bandicoot	Native	Bandicoot	1			
Spring/Summer	3	Ground	Microbat spp.			0		1	

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	3	Ground	Northern brown bandicoot	Native	Bandicoot	1			
Spring/Summer	3	Ground	Red fox	Introduced	Feral predator	2			
Spring/Summer	3	Ground	Rodent spp.	Undefined	Rodent	1			
Spring/Summer	3	Ground	Swamp wallaby	Native	Macropod	1		1	
Spring/Summer	3	Ground	Wallaby spp.	Native	Macropod	17			
Spring/Summer	4	Furniture	Lace monitor	Native	Lizard	3			
Spring/Summer	4	Furniture	Rodent spp.	Undefined	Rodent	11			
Spring/Summer	4	Furniture	Short-eared brushtail possum	Native	Possum	26	2		
Spring/Summer	4	Ground	Bandicoot spp.	Native	Bandicoot	3			
Spring/Summer	4	Ground	Eastern water dragon	Native	Lizard	1			
Spring/Summer	4	Ground	Koala	Native	Koala	1			
Spring/Summer	4	Ground	Red fox	Introduced	Feral predator	3			
Spring/Summer	4	Ground	Rodent spp.	Undefined	Rodent	4			
Spring/Summer	4	Ground	Short-eared brushtail possum	Native	Possum	1			
Spring/Summer	4	Ground	Swamp wallaby	Native	Macropod	10	1		
Spring/Summer	5	North	Bandicoot spp.	Native	Bandicoot	2			
Spring/Summer	5	North	Rodent spp.	Undefined	Rodent	3			
Spring/Summer	5	South	Microbat spp.			0		1	
Spring/Summer	5	South	Northern brown bandicoot	Native	Bandicoot	1		1	
Spring/Summer	5	South	Rodent spp.	Undefined	Rodent	2			
Spring/Summer	5	South	water rat	Native	Native rodent	3			
Spring/Summer	6	Furniture	Antechinus spp.	Native	Antechinus	11	5		
Spring/Summer	6	Furniture	Lace monitor	Native	Lizard	0	1		
Spring/Summer	6	Furniture	Microbat spp.			0		1	
Spring/Summer	6	Furniture	Rodent spp.	Undefined	Rodent	6			
Spring/Summer	6	Furniture	Short-eared brushtail possum	Native	Possum	5			
Spring/Summer	6	Ground	Bandicoot spp.	Native	Bandicoot	5	1		
Spring/Summer	6	Ground	Cat	Introduced	Feral predator	2			
Spring/Summer	6	Ground	Lace monitor	Native	Lizard	4			
Spring/Summer	6	Ground	Long-nosed bandicoot	Native	Bandicoot	9	2		
Spring/Summer	6	Ground	Red fox	Introduced	Feral predator	4	1		
Spring/Summer	6	Ground	wonga pigeon			5			
Spring/Summer	7	Furniture	black rat	Introduced	Introduced rodent	4	2		

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	7	Furniture	Coastal carpet python			1			
Spring/Summer	7	Furniture	Eastern crevice skink	Native	Lizard	1			
Spring/Summer	7	Furniture	Lace monitor	Native	Lizard	5			
Spring/Summer	7	Furniture	Microbat spp.			0		1	
Spring/Summer	7	Furniture	Rodent spp.	Undefined	Rodent	9			
Spring/Summer	7	Furniture	Short-eared brushtail possum	Native	Possum	58	2		
Spring/Summer	7	Ground	Bandicoot spp.	Native	Bandicoot	10	1		
Spring/Summer	7	Ground	black rat	Introduced	Introduced rodent	8			
Spring/Summer	7	Ground	Lace monitor	Native	Lizard	6			
Spring/Summer	7	Ground	Rodent spp.	Undefined	Rodent	8			
Spring/Summer	7	Ground	Short-eared brushtail possum	Native	Possum	1			
Spring/Summer	7	Ground	Swamp wallaby	Native	Macropod	4			
Spring/Summer	7	Ground	Wallaby spp.	Native	Macropod	11			
Spring/Summer	8	Furniture	Antechinus spp.	Native	Antechinus	1	1		
Spring/Summer	8	Furniture	Cat	Introduced	Feral predator	11	4		
Spring/Summer	8	Furniture	Eastern crevice skink	Native	Lizard	1			
Spring/Summer	8	Furniture	Microbat spp.			0		1	
Spring/Summer	8	Furniture	Rodent spp.	Undefined	Rodent	90	8		
Spring/Summer	8	Furniture	Short-eared brushtail possum	Native	Possum	34			
Spring/Summer	8	Ground	Bandicoot spp.	Native	Bandicoot	13			
Spring/Summer	8	Ground	Cat	Introduced	Feral predator	17			
Spring/Summer	8	Ground	Lace monitor	Native	Lizard	7			
Spring/Summer	8	Ground	Red fox	Introduced	Feral predator	13	1		
Spring/Summer	8	Ground	Short-eared brushtail possum	Native	Possum	0	2		
Spring/Summer	8	Ground	Swamp wallaby	Native	Macropod	8			
Spring/Summer	8	Ground	Wallaby spp.	Native	Macropod	19			
Spring/Summer	9	Furniture	Eastern crevice skink	Native	Lizard	1			
Spring/Summer	9	Furniture	Short-eared brushtail possum	Native	Possum	2			
Spring/Summer	9	Ground	Bandicoot spp.	Native	Bandicoot	21	1		
Spring/Summer	9	Ground	black rat	Introduced	Introduced rodent	6			
Spring/Summer	9	Ground	Cat	Introduced	Feral predator	2	1		

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	9	Ground	Eastern blue tongued lizard			2			
Spring/Summer	9	Ground	Lace monitor	Native	Lizard	2			
Spring/Summer	9	Ground	Long-nosed bandicoot	Native	Bandicoot	5			
Spring/Summer	9	Ground	Red fox	Introduced	Feral predator	7	1		
Spring/Summer	9	Ground	Rodent spp.	Undefined	Rodent	40	4		
Spring/Summer	9	Ground	Short-beaked echidna	Native	Echidna	2			
Spring/Summer	9	Ground	snake spp.			0			
Spring/Summer	9	Ground	Trichosurus spp.	Native	Possum	6			
Spring/Summer	9	Ground	Wonga pigeon			21	2		
Spring/Summer	10	Furniture	Antechinus spp.	Native	Antechinus	9	1		
Spring/Summer	10	Furniture	Black rat	Introduced	Introduced rodent	2			
Spring/Summer	10	Furniture	Eastern crevice skink	Native	Lizard	7	5		
Spring/Summer	10	Furniture	Fawn-footed melomys	Native	Native rodent	1			
Spring/Summer	10	Furniture	Lace monitor	Native	Lizard	1			
Spring/Summer	10	Furniture	Rodent spp.	Undefined	Rodent	7	3		
Spring/Summer	10	Furniture	Short-eared brushtail possum	Native	Possum	22			
Spring/Summer	10	Furniture	Trichosurus spp.	Native	Possum	7			
Spring/Summer	10	Ground	Bandicoot spp.	Native	Bandicoot	11			
Spring/Summer	10	Ground	Black rat	Introduced	Introduced rodent	1			
Spring/Summer	10	Ground	Cat	Introduced	Feral predator	2	1		
Spring/Summer	10	Ground	Lace monitor	Native	Lizard	2			
Spring/Summer	10	Ground	Long-nosed bandicoot	Native	Bandicoot	2	2		
Spring/Summer	10	Ground	Red fox	Introduced	Feral predator	6			
Spring/Summer	10	Ground	Rodent spp.	Undefined	Rodent	3			
Spring/Summer	10	Ground	Short-beaked echidna	Native	Echidna	1			
Spring/Summer	10	Ground	Swamp wallaby	Native	Macropod	0	1		
Spring/Summer	10	Ground	Trichosurus spp.	Native	Possum	1			
Spring/Summer	10	Ground	Wonga pigeon			1			
Spring/Summer	11	Furniture	Antechinus spp.	Native	Antechinus	1			
Spring/Summer	11	Furniture	Eastern crevice skink	Native	Lizard	2			
Spring/Summer	11	Furniture	Rodent spp.	Undefined	Rodent	31	5		

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	11	Furniture	Short-eared brushtail possum	Native	Possum	5			
Spring/Summer	11	Furniture	Trichosurus spp.	Native	Possum	3			
Spring/Summer	11	Ground	Bandicoot spp.	Native	Bandicoot	4			
Spring/Summer	11	Ground	Cat	Introduced	Feral predator	1			
Spring/Summer	11	Ground	Northern brown bandicoot	Native	Bandicoot	1			
Spring/Summer	11	Ground	Red fox	Introduced	Feral predator	7			
Spring/Summer	11	Ground	snake spp.			0	1		
Spring/Summer	11	Ground	Wallaby spp.	Native	Macropod	1			
Spring/Summer	12	Furniture	Antechinus spp.	Native	Antechinus	3			
Spring/Summer	12	Furniture	Eastern crevice skink	Native	Lizard	1			
Spring/Summer	12	Furniture	Rodent spp.	Undefined	Rodent	0	2		
Spring/Summer	12	Furniture	Short-eared brushtail possum	Native	Possum	2			
Spring/Summer	12	Furniture	Trichosurus spp.	Native	Possum	20			
Spring/Summer	12	Ground	Bandicoot spp.	Native	Bandicoot	29			
Spring/Summer	12	Ground	Cat	Introduced	Feral predator	2			
Spring/Summer	12	Ground	Lace monitor	Native	Lizard	1			
Spring/Summer	12	Ground	Long-nosed bandicoot	Native	Bandicoot	27			
Spring/Summer	12	Ground	Northern brown bandicoot	Native	Bandicoot	16	2		
Spring/Summer	12	Ground	Red fox	Introduced	Feral predator	12			
Spring/Summer	12	Ground	Rodent spp.	Undefined	Rodent	3			
Spring/Summer	12	Ground	Swamp wallaby	Native	Macropod	1			
Winter	1	North	Swamp wallaby	Native	Macropod	1			
Winter	1	North	House mouse	Introduced	Introduced rodent	1			
Winter	1	North	Antechinus spp.	Native	Antechinus	2			Obscured vision/mud from flood
Winter	1	South	Nil	Nil	Nil	Nil	Nil	Nil	Obscured vision/mud from flood
Winter	2	Furniture	Fawn-footed Melomys	Native	Native rodent	1			
Winter	2	Furniture	Rattus spp.	Undefined	Rodent	10	1		
Winter	2	Furniture	Antechinus spp.	Native	Antechinus	11	2	1	
Winter	2	Ground	Rodent spp.	Undefined	Rodent	1			
Winter	2	Ground	Bandicoot spp.	Native	Bandicoot	12			
Winter	2	Ground	Koala	Native	Koala	1			Heading east 8/7/22 2314
Winter	2	Ground	Swamp wallaby	Native	Macropod	11	2	1	
Winter	2	Ground	Wallaby spp.	Native	Macropod	4			
Winter	2	Ground	Red fox	Introduced	Feral predator	5	1		

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Winter	2	Ground	Cat	Introduced	Feral predator	1			
Winter	3	Furniture	Welcome sparrow			2	5	15	
Winter	3	Furniture	Microbat spp.					2	
Winter	3	Furniture	Short-eared brushtail possum	Native	Possum	2			
Winter	3	Furniture	Cat	Introduced	Feral predator				
Winter	3	Furniture	Possum spp.	Native	Possum			1	
Winter	3	Ground	Cat	Introduced	Feral predator	96	3	4	1 w/ collar (stripes) 1 with white patch under head and white socks carrying ante/rodent spp in mouth (68)
Winter	3	Ground	Rodent spp.	Undefined	Rodent	2			
Winter	3	Ground	Wallaby spp.	Native	Macropod	1			
Winter	3	Ground	Eastern grey kangeroo	Native	Macropod	2			
Winter	3	Ground	Red-necked wallaby	Native	Macropod	1			
Winter	3	Ground	Red fox	Introduced	Feral predator	4			
Winter	3	Ground	Swamp wallaby	Native	Macropod	3			
Winter	4	Furniture	Black rat	Intoduced	Rodent	22	4	1	
Winter	4	Furniture	Possum spp.	Native	Possum	7	1		
Winter	4	Furniture	Rodent spp.	Undefined	Rodent	35	3		
Winter	4	Furniture	Antechinus spp.	Native	Antechinus	2			
Winter	4	Furniture	Short-eared brushtail possum	Native	Possum	8	4		
Winter	4	Ground	Swamp wallaby	Native	Macropod	21	1	1	Can't see anything at night (no night mode/flash?)
Winter	4	Ground	Koala	Native	Koala	1			7/7//22, 1924 heading east
Winter	4	Ground	Bandicoot spp.	Native	Bandicoot	9			
Winter	4	Ground	Short-eared brushtail possum	Native	Possum	1			
Winter	4	Ground	Fox	Introduced	Feral predator	1			
Winter	4	Ground	Cat	Introduced	Feral predator	2			
Winter	5	North	Water rat	Native	Native rodent	3	1		
Winter	5	North	Long-nosed bandicoot	Native	Bandicoot	1			
Winter	5	North	Bandicoot spp.	Native	Bandicoot	1			
Winter	5	North	Rodent spp.	Undefined	Rodent	1			
Winter	5	South	Water rat	Native	Native rodent	5	1		
Winter	5	South	Rattus spp.	Undefined	Rodent	3	1		
Winter	5	North	Water rat	Native	Native rodent	3			
Winter	6	Furniture	Black rat	Introduced	Rodent	8	1		

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Winter	6	Furniture	Rodent spp.	Undefined	Rodent	42	5		
Winter	6	Furniture	Microbat spp.					2	
Winter	6	Furniture	Fawn-footed Melomys	Native	Native rodent	2			
Winter	6	Ground	Fox	Introduced	Feral predator	7			
Winter	6	Ground	Bandicoot spp.	Native	Bandicoot	2			
Winter	6	Ground	Short-beaked Echidna	Native	Echidna	2			
Winter	6	Ground	Cat	Introduced	Feral predator	2			
Winter	6	Ground	Long-nosed bandicoot	Native	Bandicoot	7	1		
Winter	6	Ground	European Hare	Introduced	Hare	4			
Winter	7	Furniture	Black rat	Introduced	Introduced rodent	12	3		
Winter	7	Furniture	Rodent spp.	Undefined	Rodent	27			
Winter	7	Furniture	Possum spp.	Native	Possum	4			
Winter	7	Furniture	Antechinus spp.	Native	Antechinus	26	4		
Winter	7	Furniture	Short-eared brushtail possum	Native	Possum	8			
Winter	7	Furniture	Fawn-footed Melomys	Native	Native rodent	3			
Winter	7	Ground	Bandicoot spp.	Native	Bandicoot	12			
Winter	7	Ground	Long-nosed bandicoot	Native	Bandicoot	7			
Winter	7	Ground	Northern brown bandicoot	Native	Bandicoot	2			
Winter	7	Ground	Swamp wallaby	Native	Macropod	5	2		
Winter	7	Ground	Possum spp.	Native	Possum	1			
Winter	7	Ground	Wallaby spp.	Native	Macropod	1			
Winter	7	Ground	Rodent spp.	Undefined	Rodent	3			
Winter	8	Furniture	Possum spp.	Native	Possum	7	2		
Winter	8	Furniture	Rodent spp.	Undefined	Rodent	13			
Winter	8	Furniture	Black rat	Introduced	Introduced rodent	2			
Winter	8	Furniture	Fawn-footed Melomys	Native	Melomys	1			
Winter	8	Furniture	Microbat spp.				2		
Winter	8	Furniture	Antechinus spp.	Native	Antechinus	22	4		
Winter	8	Ground	Bandicoot spp.	Native	Bandicoot	3			
Winter	8	Ground	Swamp wallaby	Native	Macropod	21			
Winter	8	Ground	Wallaby spp.	Native	Macropod	4			
Winter	8	Ground	Fox	Introduced	Feral predator	10			

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Winter	8	Ground	Northern brown bandicoot	Native	Bandicoot	3			
Winter	8	Ground	Long-nosed bandicoot	Native	Bandicoot	4			
Winter	8	Ground	cat	Introduced	Cat	2			
Winter	8	Ground	Short-beaked Echidna	Native	Echidna	1			
Winter	8	Ground	European Hare	Introduced	Hare	1			
Winter	9	Furniture	Short-eared brushtail possum	Native	Possum	1			
Winter	9	Furniture	Brown antechinus	Native	Antechinus	4			
Winter	9	Furniture	Cat	Introduced	Feral predator		1		
Winter	9	Ground	Wallaby spp.	Native	Macropod	1			
Winter	9	Ground	Red fox	Introduced	Feral predator	3			
Winter	9	Ground	Swamp wallaby	Native	Macropod		1		
Winter	9	Ground	Microbat spp.			1			
Winter	9	Ground	Short-eared brushtail possum	Native	Possum	1			
Winter	9	Ground	Bandicoot spp.	Native	Bandicoot	2			
Winter	10	Furniture	Rodent spp.	Undefined	Rodent	22	1		
Winter	10	Furniture	Black rat	Introduced	Rodent	3			
Winter	10	Furniture	Bush rat	Native	Native rodent	2			
Winter	10	Furniture	Antechinus spp.	Native	Antechinus	11			
Winter	10	Furniture	Fawn-footed Melomys	Native	Melomys	2	1		
Winter	10	Furniture	Possum spp.	Native	Possum		2		
Winter	10	Furniture	Short-eared brushtail possum	Native	Possum	1			
Winter	10	Ground	Swamp wallaby	Native	Macropod	3			
Winter	10	Ground	Red fox	Introduced	Feral predator	8	1		
Winter	10	Ground	Bandicoot spp.	Native	Bandicoot	2			
Winter	10	Ground	Long-nosed bandicoot	Native	Bandicoot	3			
Winter	10	Ground	Antechinus spp.	Native	Antechinus	2			
Winter	10	Ground	Short-beaked Echidna	Native	Echidna	1			
Winter	10	Ground	Possum spp.	Native	Possum	1			
Winter	11	Furniture	Short-eared brushtail possum	Native	Possum	7			
Winter	11	Ground	Red fox	Introduced	Feral predator	28	1		
Winter	11	Ground	Wallaby spp.	Native	Macropod	1			
Winter	11	Ground	Bandicoot spp.	Native	Bandicoot	2			

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Winter	11	Ground	Koala	Native	Koala	1			
Winter	11	Ground	Cat	Introduced	Feral predator	1			
Winter	11	Ground	Long-nosed bandicoot	Native	Bandicoot	4			
Winter	11	Ground	Short-eared brushtail possum	Native	Possum	2			
Winter	11	Ground	European rabbit	Introduced	Hare	1			
Winter	11	Ground	Short-beaked Echidna	Native	Echidna	1			
Winter	12	Furniture	Short-eared brushtail possum	Native	Possum	9			
Winter	12	Furniture	Common brushtail possum	Native	Possum	1			
Winter	12	Furniture	Possum spp.	Native	Possum	1			
Winter	12	Furniture	Rattus spp.	Undefined	Rodent	1			
Winter	12	Ground	Red fox	Introduced	Feral predator	13			
Winter	12	Ground	Wallaby spp.	Native	Macropod	1			
Winter	12	Ground	Bandicoot spp.	Native	Bandicoot	4			
Winter	12	Ground	Loong-nosed bandicoot	Native	Bandicoot	1			
Winter	12	Ground	Rodent spp.	Undefined	Rodent	1			
Winter	12	Ground	Koala	Native	Koala	1			
Winter	12	Ground	Cat	Introduced	Feral predator	1			
Winter	12	Ground	Wild dog	Undefined	Feral predator	1			
Winter	12	Ground	Long-nosed bandicoot	Native	Bandicoot	1	1		

Table B2: Sand pad data recorded over 8 nights in spring/summer (ss) and winter (w) during year four of operational phase monitoring WC2NH, 2022. [I] = Introduced, + = probable records.

Species/group	1		2		3		4		5/6		7		8		9/10		11/12	
	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W	SS	W
Short-beaked echidna				*														
Antechinus spp.									*	*		*	*	*		*	*	*
Peramelidae spp. (bandicoot)	*	*	*	*		*	*	*		*	*	*	*	*	*	*		*
Trichosurus spp.		*				*	*		*	*						*	*	
Red-necked wallaby						*												
Swamp wallaby		*	*	*			*	*			*	*	*	*	*			
Wallaby spp.	*				*	*												
House mouse										*						*		*
Water rat										*				*				
Rodent spp.			*				*	*	*	*	*				*	*	*	*
Dog																		
Red fox [I]	*	*	*	*	*	*		*								*	*	*
Cat [I]			*		*	*	*		*				*	*				
Lace monitor					*		*		*				*					
Skink																		*
Medium reptile																	*	
Medium frog spp.					+												+	
Bird spp.										*								
Total no. Species/groups	3	4	5	4	5	6	6	4	5	7	3	3	5	5	3	6	6	6

Table B3: Scat and track data recorded during camera monitoring during winter (w) and summer (ss) year four operational phase monitoring WC2NH, 2022.

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

Table B4: Tile inspection data recorded during year four operational phase monitoring WC2NH, 2022.

Site	No. Tiles	Check no.	Date	Fauna present	Comments
2	1	1	15/11/21	Nil	1 tile destroyed
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	nil	
3	1	1	15/11/21	Nil	1 tile destroyed/missing
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	nil	
4	2	1	15/11/21	Nil	
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	nil	
5N	1	1	15/11/21	Nil	
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	nil	
5S		1		No check	Missing
		2		No check	
		3		No check	
		4		No check	
		5		No check	
		6		No check	
		7		No check	

Site	No. Tiles	Check no.	Date	Fauna present	Comments
		8		No check	
6	2	1	15/11/21	Nil	
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	nil	
7	2	1	15/11/21	Nil	
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	nil	
8	2	1	15/11/21	Nil	
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	nil	
9 East	2	1	15/11/21	Nil	
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	nil	
10 West	2	1	15/11/21	Nil	
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	nil	

Site	No. Tiles	Check no.	Date	Fauna present	Comments
11 East	2	1	15/11/21	Nil	
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	nil	
12 West	2	1	15/11/21	Nil	
		2	16/11/21	Nil	
		3	17/11/21	Nil	
		4	18/11/21	Nil	
		5	19/11/21	Nil	
		6	20/11/21	Nil	
		7	22/12/21	Nil	
		8	2/2/22	Nil	

Table B5: Daytime searches of adjacent habitat data during winter year four WC2NH monitoring, 2022. Msb = moves small branches, Mlb = moves large branches and RL = rustles leaves.

Location	Side	Date	Obs. No.	Observers	Start	Finish	Species	Wind	Cloud	Rain	Air Temp	Humidity	Comment
11&12	E	24/8/22	1	AE EL	2:45	3:00	bandicoot diggings wallaby poo and lampropholis spp.	MSB	0/8	Nil	15.5	53	Nil
	W	24/8/22	1	LA/FM	1445	1500	4 x lampropholis delicata	MSB	0/8	Nil	15.5	53	Nil
	E	29/8/22	2	LA/AE/EL	955	1005	Bandicoot and antechinus spp, short-eared brushtail possum scat	RL	8/8	Nil	16.8	86	Nil
	W	29/8/22	2	LA/AE/EL	1007	1017	Lampropholis wallaby scat	RL	8/8	Nil	16.8	86	Nil
9&10	E	24/8/22	1	LA/FM	1517	1532	Bandicoot diggings, wallaby scat, fox den??	MSB	0/8	Nil	15.5	53	Nil
	W	24/8/22	1	AL EL	3:15	3:30	Swamp wallaby scat striped mash frog bandicoot digs	MSB	0/8	Nil	15.5	53	Nil
	E	30/8/22	2	EL/LA	1505	1520	*Calyptotis ruficauda* 2x lampropholis, wallaby scat	Nil	8/8	Nil	19.3	93	Nil
	W	30/8/22	2	EL/LA	1521	1536	Bandicoot diggings, Crinia signifera	Nil	8/8	Nil	19.3	93	Nil
8	E	24/08/2022	1	FM/LA	1536	1601	Crinia signifera, antechinus scat, swamp wallaby scat	MSB	0/8	Nil	15.5	53	Nil
	W	24/08/2022	1	EL/AE	1536	1601	Wallaby scat	MSB	0/8	Nil	15.5	53	Nil
	E	30/8/22	2	EL/LA	1415	1431	Bandicoot, wallaby spp.	Nil	8/8	Very light	19.3	93	Nil
	W	30/8/22	2	EL/LA	1432	1447	Bandicoot, wallaby spp.	Nil	8/8	Very light	19.3	94	Nil
7	E	30/8/22	1	EL/LA	1517	1532	Bandicoot swamp wallaby	RL	8/8	Nil	16.8	48	Nil
	W	30/8/22	1	EL/LA	1533	1549	Nil	RL	8/8	Nil	16.8	48	Nil
	E	29/8/22	2	LA/AE/EL	1355	1407	EG scat, wallaby, bandicoot scat	ML	8/8	Nil	16.8	48	Nil
	W	31/8/2022	2	AE/EL	1205	1220	No new records	MSB	4/8	Nil	19.8	84	Nil
5&6	E	24/8/222	1	EL/FM	1315	1330	Bandicoot diggings wallaby scat	ML	0/8	Nil	16.8	48	Nil
	W	24/8/222	1	LA/FM	1332	1347	Lace monitor, bandicoot diggings	ML	0/8	Nil	16.8	48	Nil
	E	29/8/22	2	AE LA. EL	1331	1341	Lace monitor, bandicoot	RL	8/8	Nil	16.8	86	
	W	30/8/22	2	EL/LA	1548	1603	Swamy wallaby tracks b diggings	Nil	8/8	Very light	19.3	94	Nil
4	E	24/8/22	1	Ae and EL	205	0.0972	wallaby track and scat fox track and bandicoot digs	MSB	0/8	Nil	15.5	53	Nil
	W	24/8/22	1	Ae and EL	0.07639	0.0868	wallaby scat bandicoot digs	MSB	0/8	Nil	15.5	53	Nil
	E	29/8/22	2	LA/AE	845	900	Bandicoot spp.	Nil	0/8	Nil	14.8	84	Nil
	W	29/8/22	2	LA/AE	8:25	840	Bandicoot, wallaby scat, koala scat	Nil	0/8	Nil	14.8	84	Nil
3	E	30/8/22	1	LA/EL	1515	1530	Bandicoot spp., cat	ML	8/8	Nil	16.8	48	Nil
	W	30/8/22	1	LA/EL	1455	1510	Bandicoot spp., dog, swamp wallaby (tracks)	ML	8/8	Nil	16.8	48	Nil
	E	29/8/22	1	LA/EL/AE	1322	1332	Fox scat, bandicoot diggings, wallaby scat	RL	8/8	Nil	16.8	86	Nil
	W	29/8/22	2	AE/EL	13:05	1320	Crinia signifera	MSB	4/8	Nil	17.9	84	Nil
2	E	30/8/22	1	LA/EL	1408	1422	Bandicoot spp.	ML		Nil	16.8	48	Nil
	W	30/8/22	1	LA/EL	1431	1446	Bandicoot spp.	ML	8/8	Nil	16.8	48	Nil
	E	31/8/22	2	AE LA. EL	12:30	12:40	Red belly black snake, fox scat, gutchonoities, >10 delicata, wallaby scat	MSB	4/8	Nil	19.8	0:00	Nil
	W	31/8/22	2	AE LA. EL	12:45	12:55	*Calyptotis ruficauda* 6x lampropholis delicata wallaby scat and wallaby bandicoot digs litoria fallax calling	MSB	4/8	Nil	19.8	0:00	Nil
1	E	24/8/22	1	Ae and EL	1:00	1:15	bandicoot diggings and lampropholis spp.	Nil	0/8	Nil	Nil	Nil	Nil
	E	29/8/22	1	Ae and EL	1:15	1:30	bandicoot diggings and dog scat	RL	8/8	Nil	16.8	86	Nil
	W	29/08/22	2	AE LA. EL	11:20	11:30	Btp scat	Nil	0/8	Nil	17.9	84	Nil
	W	29/08/22	2	AE LA. EL	11:30	11:40	Eastern water dragon, bandicoot digs wallaby scat lampropholis delicata x3 litoria fallax	Nil	0/8	Nil	17.9	84	Nil

Table B6: Nocturnal spotlight surveys of adjacent habitat during winter year four WC2NH monitoring, 2022. GHFF = grey-headed flying fox, SuG = sugar glider, Lit = Litoria species, A. brevis = Adelotus brevis, ONJ = Owlet-Nightjar.

Location	Side	Date	Obs. No.	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	Humidity	Comment
11&12	E	23/7/22	1	LA/DW	2216	2246	Nil	Nil	Nil	Good	14.5	86	Nil
	W	22/7/22	1	LA/DW	2216	2246	Wallaby spp.	Nil	Nil	Good	14.5	86	Nil
	E	25/7/22	2	LA/DW	1911	1926	Nil	Nil	Nil	Good	12.7	87	Nil
	W	25/7/22	2	LA/DW	1926	1941	FF spp.	Nil	Nil	Good	12.7	87	Nil
9&10	E	23/7/22	1	LA/DW	2144	2214	Nil	Nil	Nil	Good	14.5	86	Nil
	W	22/7/22	1	LA/DW	2144	2214	Nil	Nil	Nil	Good	14.5	86	Nil
	E	25/7/22	2	LA/DW	2026	2056	Nil	Nil	Nil	Good	12.7	87	Nil
	W	25/7/22	2	LA/DW	2026	2056	Rattus spp.	Nil	Nil	Good	12.7	87	Nil
8	E	23/7/22	1	LA/DW	2107	2137	Nil	Nil	Nil	Good	14.5	86	Nil
	W	22/7/22	1	LA/DW	2107	2137	Nil	Nil	Nil	Good	14.5	86	Nil
	E	25/7/22	2	LA/DW	1950	2020	Melomys spp.	Nil	Nil	Good	12.7	87	Nil
	W	25/7/22	2	LA/DW	1950	2020	RTP, Rattus spp.	Nil	Nil	Good	12.7	87	Nil
7	E	23/7/22	1	LA/DW	2031	2101	Swamp wallaby	Nil	Nil	Good	14.5	86	Nil
	W	22/7/22	1	LA/DW	2031	2101	Nil	Nil	Nil	Good	14.5	86	Nil
	E	25/7/22	2	LA/DW	2145	2215	C. Signifera, swamp wallaby	Nil	Nil	Good	12.7	87	Nil
	W	25/7/22	2	LA/DW	2145	2215	Nil	Nil	Nil	Good	12.7	87	Nil
5&6	E	23/7/22	1	LA/DW	1955	2025	C. Signifera, swamp wallaby	Nil	Nil	Good	14.5	86	Nil
	W	22/7/22	1	LA/DW	1955	2025	C. Signifera	Nil	Nil	Good	14.5	86	Nil
	E	25/7/22	2	LA/DW	2103	2133	Nil	Nil	Nil	Good	12.7	87	Nil
	W	25/7/22	2	LA/DW	2103	2133	C. Signifera, long-nosed bandicoots	Nil	Nil	Good	12.7	87	Nil
4	E	23/7/22	1	LA/DW	1912	1942	Melomys spp.	Nil	Nil	Good	14.5	86	Nil
	W	22/7/22	1	LA/DW	1912	1942	Nil	Nil	Nil	Good	14.5	86	Nil
	E	25/7/22	2	LA/DW	1830	1900	Melomys spp.	Nil	Nil	Good	12.7	87	Nil
	W	25/7/22	2	LA/DW	1830	1900	Nil	Nil	Nil	Good	12.7	87	Nil
3 (E only)	E	23/7/22	1	LA/DW	1907	1913	Nil	Nil	Nil	Good	14.5	86	Nil
	E	23/7/22	2	LA/DW	2135	2140	Nil	Nil	Nil	Nil	Nil	Nil	Nil
2	E	23/7/22	1	LA/DW	1836	1906	C. Signifera, GHFF	Nil	Nil	Good	14.5	86	Nil
	W	22/7/22	1	LA/DW	1836	1906	black flying fox	Nil	Nil	Good	14.5	86	Nil
	E	25/7/22	2	LA/DW	2222	2252	Sug	Nil	Nil	Good	12.7	87	Nil
	W	25/7/22	2	LA/DW	2222	2252	Lit fallax	Nil	Nil	Good	12.7	87	Nil
1	E	23/7/22	1	LA/DW	1730	1800	Nil	Nil	Nil	Good	14.5	86	Nil
	W	22/7/22	1	LA/DW	1730	1800	Swamp wallaby	Nil	Nil	Good	14.5	86	Nil
	E	25/7/22	2	LA/DW	1743	1813	Nil	Nil	Nil	Good	12.7	87	Nil
	W	25/7/22	2	LA/DW	1743	1813	Nil	Nil	Nil	Good	12.7	87	Nil

Table B7: Fauna captured during adjacent habitat trapping surveys during year four operational monitoring WC2NH, 2021-2022. Uk = unknown. NR= no record

Season	Site	Side	Date	Trap type	Species	No. individuals	Sex	Weight	Comments
Winter	1	East	27/08/2022	Ground elliot	Black rat		M		Brushtail raided traps both side
Winter	1	East	28/08/2022	Cage trap	Black rat		NR	NR	
Winter	1	West	28/08/2022	Ground elliot	Black rat				Euthanised
Winter	1	West	28/08/2022	Ground elliot	Black rat				Euthanised
Winter	1	East	29/08/2022	Ground elliot	Black rat		Female		
Winter	1	East	29/08/2022	Ground elliot	Black rat		Female	Uk	
Winter	1	West	29/08/2022	Ground elliot	Black rat		Male		
Winter	1	East	29/08/2022	Arboreal elliot	Brown antechinus		Male	Uk	
Winter	1	East	29/08/2022	Ground elliot	Brown antechinus		Female	Uk	
Winter	1	West	28/08/2022	Cage trap	Northern brown bandicoot		NR	NR	
Winter	1	West	29/08/2022	Cage trap	Northern brown bandicoot		Uk	Uk	
Winter	2	West	25/08/2022	Pitfall	Adelotus brevis		Unk		
Winter	2	East	24/08/2022	Arboreal elliot	Black rat		Male		
Winter	2	East	26/08/2022	Arboreal elliot	Black rat		Male		
Winter	2	East	26/08/2022	Ground elliot	Black rat		Unk	Unk	
Winter	2	East	24/08/2022	Ground elliot	Brown antechinus		Female		
Winter	2	West	24/08/2022	Ground elliot	Brown antechinus		Female		
Winter	2	East	25/08/2022	Ground elliot	Brown antechinus		Male	65	
Winter	2	East	24/08/2022	Ground elliot	Brown antechinus		Female		
Winter	2	East	26/08/2022	Ground elliot	Bush rat		Female	109	Stumpy tail
Winter	2	East	26/08/2022	Ground elliot	Bush rat		Female	136	
Winter	2	East	26/08/2022	Ground elliot	Bush rat		Male	79	
Winter	2	East	26/08/2022	Arboreal elliot	Fawn-footed melomys		Female	Nil	
Winter	2	West	26/08/2022	Ground elliot	Fawn-footed melomys		F	90	
Winter	3	West	25/08/2022	Ground elliot	Black rat		Immature		
Winter	3	East	25/08/2022	Ground elliot	Brown antechinus		Female	55	
Winter	3	West	25/08/2022	Ground elliot	Long-nosed bandicoot		Female	300+	Too big for scale
Winter	3	East	26/08/2022	Cage trap	Northern brown bandicoot		uk	uk	
Winter	4	West	27/08/2022	Ground elliot	Brown antechinus				
Winter	4	West	27/08/2022	Cage trap	Bush rat		M	??	Escape
Winter	4	West	27/08/2022	Ground elliot	Bush rat		M	144	
Winter	4	West	28/08/2022	Ground elliot	Bush rat		F	136	
Winter	4	West	28/08/2022	Ground elliot	Bush rat		Male	155	
Winter	4	West	29/08/2022	Ground elliot	Bush rat		Female	111	
Winter	4	West	29/08/2022	Ground elliot	Bush rat		Male	123	
Winter	4	East	29/08/2022	Ground elliot	Bush rat		Female	164	
Winter	4	East	27/08/2022	Arboreal elliot	Fawn-footed melomys		F	62	
Winter	4	East	27/08/2022	Arboreal elliot	Fawn-footed melomys		M	81	
Winter	4	West	27/08/2022	Ground elliot	Fawn-footed melomys		M	71	
Winter	4	West	27/08/2022	Ground elliot	Fawn-footed melomys		F	58	
Winter	4	East	28/08/2022	Arboreal elliot	Fawn-footed melomys		F	68	
Winter	4	East	28/08/2022	Arboreal elliot	Fawn-footed melomys		M	74	

Season	Site	Side	Date	Trap type	Species	No. individuals	Sex	Weight	Comments
Winter	4	West	28/08/2022	Ground elliot	Fawn-footed melomys		F	59	
Winter	4	West	29/08/2022	Arboreal elliot	Fawn-footed melomys		Male	83	
Winter	4	West	29/08/2022	Arboreal elliot	Fawn-footed melomys		Male	86	
Winter	4	East	29/08/2022	Arboreal elliot	Fawn-footed melomys		Male	100	
Winter	7	West	26/08/2022	Ground elliot	Black rat		Male	180	
Winter	7	East	24/08/2022	Ground elliot	Brown antechinus		Unknown	30	
Winter	7	East	24/08/2022	Ground elliot	Brown antechinus		Female	26	
Winter	7	East	25/08/2022	Ground elliot	Brown antechinus		Male	38	
Winter	7	East	25/08/2022	Ground elliot	Brown antechinus		Male	44	
Winter	7	East	26/08/2022	Ground elliot	Brown antechinus		m	38	deceased
Winter	7	East	24/08/2022	Ground elliot	Bush rat		Male	138	
Winter	7	West	24/08/2022	Ground elliot	Bush rat		Female	165	
Winter	7	West	24/08/2022	Ground elliot	Bush rat		Female	128	
Winter	7	West	24/08/2022	Ground elliot	Bush rat		Female	80	Immature
Winter	7	West	24/08/2022	Ground elliot	Bush rat		Male	154	
Winter	7	West	26/08/2022	Cage trap	Bush rat		Na	Na	
Winter	7	West	26/08/2022	Ground elliot	Bush rat		Male	166	
Winter	8	West	25/08/2022	Ground elliot	Black rat				
Winter	8	West	25/08/2022	Ground elliot	Black rat				
Winter	8	West	26/08/2022	Ground elliot	Black rat		m	201	
Winter	8	West	24/08/2022	Ground elliot	Brown antechinus		M	43	
Winter	8	West	24/08/2022	Ground elliot	Brown antechinus		M	39	
Winter	8	West	24/08/2022	Ground elliot	Brown antechinus		M	51	
Winter	8	West	24/08/2022	Ground elliot	Brown antechinus		M	40	
Winter	8	East	24/08/2022	Ground elliot	Brown antechinus		F	26	
Winter	8	West	25/08/2022	Ground elliot	Brown antechinus		Female		
Winter	8	West	25/08/2022	Ground elliot	Brown antechinus		Male	42	deceased
Winter	8	East	25/08/2022	Ground elliot	Brown antechinus		Male	29	
Winter	8	East	25/08/2022	Ground elliot	Brown antechinus		Male	47	
Winter	8	East	25/08/2022	Ground elliot	Brown antechinus		Male		Deceased
Winter	8	West	26/08/2022	Ground elliot	Brown antechinus		m	20	
Winter	8	West	26/08/2022	Ground elliot	Brown antechinus		Female	39	
Winter	8	East	26/08/2022	Ground elliot	Brown antechinus		Female	39	
Winter	8	East	24/08/2022	Ground elliot	Bush rat		M	172	
Winter	8	East	26/08/2022	Ground elliot	Bush rat		Male	175	
Winter	8	West	24/08/2022	Ground elliot	Fawn-footed melomys		F	64	
Winter	8	East	25/08/2022	Ground elliot	Fawn-footed melomys		Male	85	
Winter	8	West	26/08/2022	Ground elliot	Fawn-footed melomys		m	84	
Winter	8	West	24/08/2022	Cage trap	Northern brown bandicoot		F	ND	
Winter	5/6	West	25/08/2022	Cage trap	Black rat		Uk	Uk	
Winter	5/6	West	26/08/2022	Ground elliot	Brown antechinus		m	45	Deceased
Winter	5/6	West	26/08/2022	Ground elliot	Brown antechinus		m	60	
Winter	5/6	West	24/08/2022	Ground elliot	Bush rat		Male	150	
Winter	5/6	West	25/08/2022	Ground elliot	Bush rat		Male	155	
Winter	5/6	West	25/08/2022	Ground elliot	Bush rat		Female	110	

Season	Site	Side	Date	Trap type	Species	No. individuals	Sex	Weight	Comments
Winter	5/6	West	25/08/2022	Ground elliot	Bush rat		Male	175	
Winter	5/6	West	26/08/2022	Ground elliot	Bush rat		m		
Winter	5/6	East	24/08/2022	Arboreal elliot	Fawn-footed melomys		Female	72	
Winter	5/6	East	24/08/2022	Ground elliot	Fawn-footed melomys		Male	82	
Winter	5/6	East	24/08/2022	Ground elliot	Fawn-footed melomys		Female	75	
Winter	5/6	West	24/08/2022	Ground elliot	Fawn-footed melomys		Male	34	
Winter	5/6	East	25/08/2022	Arboreal elliot	Fawn-footed melomys		Male	70	
Winter	5/6	West	26/08/2022	Ground elliot	Fawn-footed melomys		m	119	
Winter	5/6	East	24/08/2022	Pitfall	Pseudophryne coriacea		Unk		
Winter	9/10	West	25/08/2022	Ground elliot	Black rat		??	??	
Winter	9/10	West	25/08/2022	Arboreal elliot	Brown antechinus		male	42	
Winter	9/10	West	25/08/2022	Arboreal elliot	Brown antechinus		male	39	
Winter	9/10	West	25/08/2022	Ground elliot	Brown antechinus		Female	38	
Winter	9/10	East	25/08/2022	Ground elliot	Brown antechinus		Male	39	
Winter	9/10	East	25/08/2022	Ground elliot	Brown antechinus		Male	40	
Winter	9/10	East	25/08/2022	Ground elliot	Brown antechinus		Male	37	
Winter	9/10	West	25/08/2022	Ground elliot	Brown antechinus		Male	35	
Winter	9/10	West	26/08/2022	Ground elliot	Brown antechinus		Male	45	
Winter	9/10	West	26/08/2022	Ground elliot	Brown antechinus		Male	52	
Winter	9/10	East	24/08/2022	Ground elliot	Bush rat		M	175	
Winter	9/10	East	25/08/2022	Ground elliot	Bush rat		Female	105	
Winter	9/10	West	26/08/2022	Ground elliot	Bush rat		Male	140	
Winter	9/10	East	24/08/2022	Ground elliot	Fawn-footed melomys		M	75	
Winter	9/10	West	24/08/2022	Ground elliot	Fawn-footed melomys		M	80	
Winter	9/10	West	25/08/2022	Ground elliot	Fawn-footed melomys		Male	68	
Winter	9/10	West	26/08/2022	Ground elliot	Fawn-footed melomys		m	71	
Winter	9/10	West	26/08/2022	Ground elliot	Fawn-footed melomys		f	73	
Winter	9/10	West	26/08/2022	Ground elliot	Fawn-footed melomys		F	65	
Winter	11/12	East	24/08/2022	Cage trap	Black rat		UK		
Winter	11/12	East	26/08/2022	Cage trap	Black rat		uk	uk	
Winter	11/12	East	24/08/2022	Pitfall	Brown antechinus		M	9	Juvenile
Winter	11/12	East	26/08/2022	Ground elliot	Brown antechinus		m	49	
Winter	11/12	East	26/08/2022	Ground elliot	Brown antechinus		Male	125	
Winter	11/12	East	25/08/2022	Ground elliot	Bush rat		Female	69	Probably carrying young
Winter	11/12	East	26/08/2022	Ground elliot	Bush rat		f	4	
Winter	11/12	East	26/08/2022	Ground elliot	Bush rat		Female	130	
Winter	11/12	West	24/08/2022	Ground elliot	Fawn-footed melomys		M	82	
Winter	11/12	East	26/08/2022	Ground elliot	Fawn-footed melomys		Female	72	
Winter	11/12	East	26/08/2022	Ground elliot	House mouse		Uk	21	
Winter	11/12	East	26/08/2022	Pitfall	Lampropholis delicata		Uk	UK	
Winter	11/12	East	24/08/2022	Arboreal elliot	Sugar glider		F	119	
Winter	11/12	West	25/08/2022	Arboreal elliot	Sugar glider		Male	130	
Winter	11/12	East	26/08/2022	Arboreal elliot	Sugar glider		f	168	
spring/summer	1	E	17/11/21	Cage trap	Black rat	2	Uk	Uk	
spring/summer	1	w	18/11	cage trap	Black rat		F	uk	euthanised

Season	Site	Side	Date	Trap type	Species	No. individuals	Sex	Weight	Comments
spring/summer	1	e	19/11	cage trap	Black rat		f		
spring/summer	1	E	18/11	arboreal	Brown antechinus		F	27	
spring/summer	1	e	19/11	ground	Brown antechinus		f	23	
spring/summer	1	e	19/11	aboreal	Brown antechinus		f	25	
spring/summer	1	w	19/11/21	pitfall	Calyptotis ruficauda				
spring/summer	1	E	18/11	pitfall	Lampropholis delicata				
spring/summer	1	W	17/11/21	cage trap	short-eared brushtail possum				
spring/summer	1	w	19/11/21	cage trap	short-eared brushtail possum		f		
spring/summer	2	E	17/11/21	Arboreal	Brown antechinus		F	26	
spring/summer	2	E	17/11/21	Ground Elliot	Brown antechinus		F	26	
spring/summer	2	E	18/11	Aboreal	Brown antechinus		F	32	
spring/summer	2	E	18/11	Aboreal	Brown antechinus		uk	-	
spring/summer	2	E	19/11	ground	Brown antechinus		F	21	
spring/summer	2	E	19/11	arboreal	Brown antechinus		F	28	
spring/summer	2	W	17/11/21	Ground Elliot	Brown antechinus		F	29	
spring/summer	2	W	18/11	ground elliot	Brown antechinus		F	24	
spring/summer	2	w	19/11	ground	Brown antechinus		f	30	
spring/summer	2	W	17/11/21	Ground Elliot	Bush rat		F	125	
spring/summer	2	W	19/11	Cage	Common brushtail possum		Uk	Uk	
spring/summer	3	e	19/11	black rat	Black rat		f		
spring/summer	3	w	19/11/21	pitfall	Calyptotis ruficauda				
spring/summer	3	W	18/11	pitfall	Lampropholis delicata				
spring/summer	3	w	19/11/21	pitafall	lampropholis delicata				
spring/summer	4	E	17/11/21	Arboreal	Brown antechinus		F		
spring/summer	4	E	18/11	ground	Brown antechinus		uk		
spring/summer	4	W	17/11	Ground elliott	Bush rat		M	140OBJ	
spring/summer	4	w	18/11	ground elliot	Bush rat		f	118	
spring/summer	4	E	17/11/21	Arboreal	Fawn-footed melomys		F	70	
spring/summer	4	W	17/11/21	Ground elliot	Fawn-footed melomys				
spring/summer	4	e	19/11	aboreal	Fawn-footed melomys		f		
spring/summer	7	W	17/11	ground Elliott	Brown antechinus		f	29	
spring/summer	7	E	19/11/2021	ground Elliott	Bush rat		M		
spring/summer	7	w	17/11	ground Elliott	Bush rat		f	96	
spring/summer	7	W	18/11	Ground elliott	Bush rat		F	140	
spring/summer	7	W	19/11	Ground elliott	Bush rat		M	148	
spring/summer	7	W	19/11	Ground elliott	Bush rat		F	130	
spring/summer	7	E	17/11	cage trap	Lace monitor				
spring/summer	8	E	18/11	Ground elliott	Brown antechinus		F		
spring/summer	8	W	17/11	Ground elliott	Bush rat		F	105	
spring/summer	8	W	19/11/21	Ground elliott	Bush rat				
spring/summer	8	E	19/11	Arboreal	Fawn-footed melomys		F	75	
spring/summer	8	E	18/11	Cage	Lace monitor				
spring/summer	8	W	18/11	Cage	Lace monitor				
spring/summer	8	W	19/11/21	Cage	Lace monitor				
spring/summer	8	E	19/11	Cage	Northern brown bandicoot				

Season	Site	Side	Date	Trap type	Species	No. individuals	Sex	Weight	Comments
spring/summer	8	W	19/11/21	pitfall	Pseudophryne coriacea				Deceased
spring/summer	9/10	E	19/11/21	Ground elliott	Fawn-footed melomys		F		
spring/summer	9/10	E	17/11	pitfall	Lampropholis delicata				
spring/summer	9/10	E	18/11/21	Pitfall	Lampropholis delicata	2			
spring/summer	11/12	W	19/11/21	Pitfall	Brown antechinus				
spring/summer	11/12	e	17/11/2021	ground Elliott	Fawn-footed melomys		F	90	
spring/summer	11/12	E	17/11/21	pitfall	Lampropholis delicata				
spring/summer	11/12	E	18/11/21	Pitfall	Lampropholis delicata				
spring/summer	11/12	w	17/11/2021	pit fall	Lampropholis delicata				
spring/summer	11/12	W	18/11/21	Pitfall	Lampropholis delicata				
spring/summer	11/12	W	19/11/21	Pitfall	Lampropholis delicata				
spring/summer	11/12	E	18/11/21	Arboreal	Sugar glider		Pr F		
spring/summer	11/12	W	19/11/21	arboreal	Sugar glider		F		
spring/summer	5&6	W	18/11	Pitfall	Brown antechinus				
spring/summer	5&6	W	17/11	ground	Bush rat		f	135	
spring/summer	5&6	W	18/11	Ground elliott	Bush rat		M	145	
spring/summer	5&6	w	19/11/21	Ground elliott	Bush rat		F		
spring/summer	5&6	w	19/11/21	Ground elliott	Bush rat		M		
spring/summer	5&6	E	17/11	arboreal	Fawn-footed melomys		m		
spring/summer	5&6	E	17/11	arboreal	Fawn-footed melomys		m		
spring/summer	5&6	E	18/11	Ground elliott	Fawn-footed melomys		M		
spring/summer	5&6	E	19/11	Arboreal	Fawn-footed melomys		F	80	
spring/summer	5&6	E	19/11	Ground elliott	Fawn-footed melomys		M	72	
spring/summer	5&6	W	17/11	cage	short-eared brushtail possum				
spring/summer	5&6	W	18/11	Cage	short-eared brushtail possum				

Table B8: Fauna recorded in hair funnel surveys during year four operational monitoring WC2NH, 2022.

Site	Position	Date	Species	Species	Species
1	East 1	31/8/22	Trichosurus vulpecula	Human	
1	East 2	31/8/22	No hair		
1	West 2	31/8/22	Isoodon macrourus		
1	West 1	31/8/22	Isoodon macrourus		
2	East 1	31/8/22	Isoodon macrourus	Antechinus stuartii	
2	West 2	31/8/22	Isoodon macrourus	Rattus fuscipes	
2	West 1	31/8/22	Rattus fuscipes		
2	East 2	31/8/22	Antechinus stuartii		
3	West 2	31/8/22	Wallabia bicolor		
3	West 1	31/8/22	Rattus sp.		
3	East 2	31/8/22	No hair		
3	East 1	31/8/22	Isoodon macrourus		

4	East 1	31/8/22	Rattus fuscipes		
4	East 2	31/8/22	Rattus fuscipes		
4	West 1	31/8/22	Antechinus stuartii		
4	West 2	31/8/22	Antechinus sp.		
6-5	West 1	31/8/22	Isoodon macrourus	Rattus fuscipes	Antechinus stuartii
6-5	West 2	31/8/22	Antechinus stuartii		
6-5	East 1	31/8/22	Rattus fuscipes		
6-5	East 2	31/8/22	Rattus fuscipes	Antechinus stuartii	
7	East 1	31/8/22	Rattus fuscipes		
7	East 2	31/8/22	Rattus fuscipes	Antechinus stuartii	
7	West 1	31/8/22	Rattus fuscipes		
7	West 2	31/8/22	Isoodon macrourus	Rattus fuscipes	
8	West 1	31/8/22	Rattus fuscipes	Antechinus stuartii	
8	East 1	31/8/22	Rattus fuscipes		
8	East 2	31/8/22	Rattus fuscipes		
8	West 2	31/8/22	Isoodon macrourus	Antechinus stuartii	
9-10	West 2	31/8/22	Isoodon macrourus	Antechinus stuartii	
9-10	West 1	31/8/22	Isoodon macrourus	Rattus fuscipes	
9-10	East 2	31/8/22	Antechinus sp.		
9-10	East 1	31/8/22	Antechinus stuartii		
11-12	West 2	31/8/22	Antechinus stuartii	Rattus sp.	
11-12	West 2	31/8/22	Rattus fuscipes		
11-12	West 1	31/8/22	Antechinus stuartii		
11-12	East 2	31/8/22	Rattus fuscipes	Antechinus stuartii	

Transport for
New South Wales

Warrell Creek to Nambucca Heads

Annual road-kill Monitoring Report - Operational Phase, Year Four (2022)

Transport for New South Wales | April 2023

Pacific Highway upgrade: Warrell Creek to Nambucca Heads (WC2NH)

Road-kill monitoring – operational phase

Year four (2022)

Sandpiper Ecological Surveys

Final Report
19 April 2023

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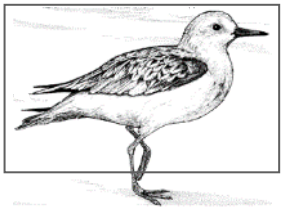

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1. Introduction

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. The Upgrade included several road-kill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate road-kill included:

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including culverts, bridges, rope bridges and glide poles.

Several fauna fence designs were installed to target threatened species including:

- **Type 1** - Chainmesh fence 1.8 m tall with floppy top feature, which is designed to exclude a range of native mammal species such as macropods, possums, spotted-tail Quoll (*Dasyurus maculatus*) and koala (*Phascolarctos cinereus*). 18.03 km of this fence type occurs at the site.
- **Type 3** - Small gauge mesh fence with sheet metal return angled away from the highway (combined with fauna floppy top fence), which is designed to exclude green-thighed frog (*Litoria brevipalmata*) from the road corridor. 1.32 km of type 3 fauna fence occurs at the site, overlapping with the type 1 fencing.
- **Type 4** - Chainmesh fence 4 m tall through the Macksville Flying-fox camp Paperbark Swamp Forest community designed to discourage grey-headed flying-fox (*Pteropus poliocephalus*) from flying within range of passing traffic when exiting or entering the roost. 1km of type 4 fence occurs at the site.

Sandpiper Ecological Surveys (SES) has been engaged by Transport for NSW (TfNSW) to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal road-kill surveys over the entire upgrade length. Monitoring of road-kill is a requirement of the approved WC2NH koala, spotted-tailed quoll and grey-headed flying-fox management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for road-kill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog (*Mixophyes iteratus*). Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Seasonal surveys are scheduled for January (summer), April (autumn), July (winter) and October (spring). 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.

The aim of road-kill monitoring is to:

- report on any vertebrate road-kill following opening to traffic.
- assess the effectiveness of fauna fencing to prevent fauna from being killed by vehicles while attempting to cross the WC2NH Upgrade.

The annual results of monitoring in 2018, 2019, 2020 and 2021 have previously been reported on (Sandpiper Ecological 2018, 2019a, 2020, 2021). The following report details the findings of the recent October 2022 sample, summarises findings from year four (2022) operational monitoring, and discusses the results in light of the monitoring aims and previous reports.

2. Methods

2.1 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the North (Figure 1).

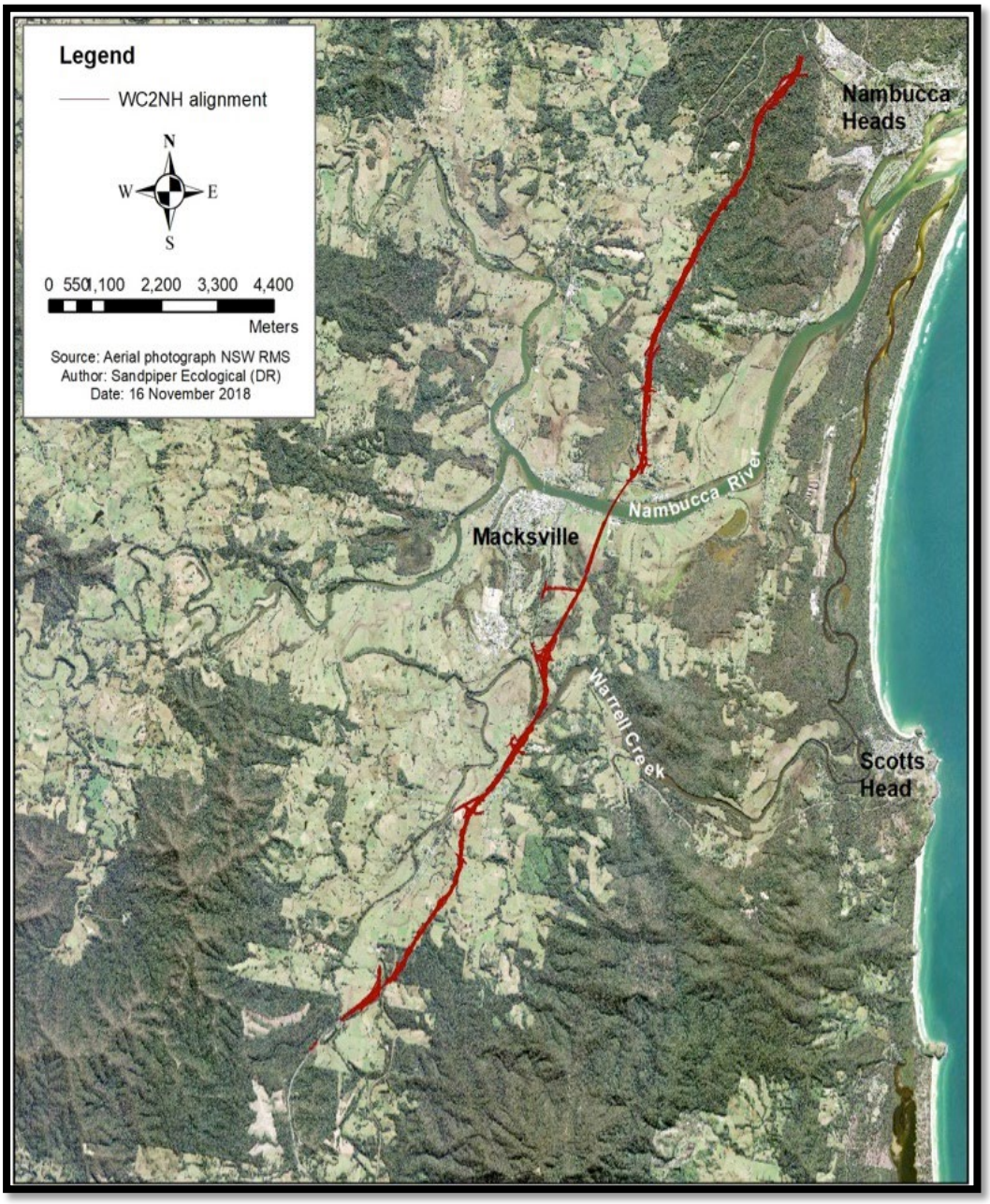

Figure 1: Location of the WC2NH alignment.

2.2 Road-kill surveys

The road mortality survey method was revised to ensure compliance with the updated TfNSW Traffic Control at Worksites Manual. The updated guidelines require vehicles to be parked 3m from (& behind) the wire rope, 11m from the fog line if there is no wire rope, and pedestrians to walk 3m behind the wire rope. These distance restrictions could not be achieved using the former method, which was revised during the autumn 2021 monitoring.

Surveys were conducted by a two-person team from a constantly moving vehicle driven at 80-90km/hr in the left lane. The vehicle was equipped with an amber (flashing) light and warning sign (Plate 1). The team consisted of a driver and an ecologist passenger with experience identifying road-killed fauna. During each monitoring month, surveys were undertaken weekly and commenced within three-four hours of sunrise. The ecologist scanned the road surface and road shoulder for fauna during each survey. When road-killed fauna was detected, the species or fauna group was recorded using a hand-held tape recorder, and a "drop pin" showing the site location was placed on an iPad running Motion-X. Fauna records considered likely to be an unidentified target species (i.e., spotted-tailed quoll, koala, grey-headed flying-fox, giant barred frog) were inspected more closely from a safe location. At the completion of each survey, the audio recordings were played back, and data were uploaded to Microsoft Excel on a desktop computer, with GPS coordinates downloaded from the iPad.

Plate 1: Work vehicle with signage, flashing amber light and indicators.

Data collected on each road-kill included:

- Geographic coordinate
- Presence/absence of fauna exclusion fence adjacent the record (recorded from GIS)
- Species/fauna group
- Date of survey
- Road-kill location – north or southbound carriageway

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and/or the *Biodiversity Conservation (BC) Act 2016*, included, where possible: sex and age (juvenile/adult); the presence of pouch young if applicable; the 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 the nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or road-side vegetation.

Broad size classes used to group fauna recorded at WC2NH included:

- Small mammal – rodent, juvenile bandicoot
- Medium mammal – bandicoot, brushtail possum, ringtail possum, cat
- Large mammal – wallabies and kangaroos
- Small bird – noisy miner, honeyeaters
- Medium bird – magpies, pigeons, frogmouth, swamp hen, ducks, kookaburra
- Large bird – Ibis, large forest owl, egret

All road-kills were cross-referenced with the previous week and season (i.e., winter 2022) survey data to identify possible duplicates. The consistent use of at least one team member across all surveys, GPS coordinates of each specimen, and carcass descriptions assisted with identifying duplicates. Distance to connectivity structure and distance to escape structure was determined via GIS.

2.3 Data summary and analysis

For temporal (i.e., years and seasons) and spatial (i.e., fenced vs unfenced) comparisons of road-kill during operational monitoring (2019-2022), road-kill totals were pooled across years and taxonomic groups (i.e., bandicoots, macropods) and converted to a rate of road-kill/km/week to enable comparisons to other highway projects of varying alignment lengths. The 2018 survey data was excluded from the pooled comparison due to the staged opening of the project occurring between 2017-2018.

A hot spot analysis was conducted using QGIS (2022) to identify sections of the alignment with high road-kill densities during operational monitoring (2019-2022). Two versions of the heat map were prepared: one showing the location of all road-killed fauna to identify general hot-spots and one showing the location of fauna that the exclusion fence should block. The extent of the exclusion fence was shown on both maps.

2.3.1 Statistical analysis

The primary aim of statistical analysis was to determine if there is a statistical difference in the frequency of road-kill between fenced and unfenced sections of the alignment. Road-kill data were summarised by removing species/groups that would not (under normal circumstances) be stopped by exclusion fence from accessing the road alignment e.g. birds, small reptiles, frogs, small mammals and flying-foxes. Species/groups of fauna likely to be stopped by exclusion fence and therefore included in the analysis are listed in Table 1. Introduced species were included in the analysis. Freshwater turtles were included, as an exclusion fence with a ground return should stop this group. Small lace monitors could move through exclusion fence; however, individuals of that size are rarely recorded in open habitats, and that species has been included.

The location of each road-kill in relation to the exclusion fence was determined by overlaying road-kill records on a plan of exclusion fence extent using QGIS. If exclusion fence occurred on one side only the record was classified as “No fence”. Further, road-kill records on bridges were considered unfenced unless exclusion fence extended 100 m beyond both ends of the bridge.

Data was pooled across all samples and divided into “fenced” and “unfenced.” Expected proportions were based on the proportion of the 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).

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

2.4 Exclusion fence inspection

Two to three persons traversed the entire length of the fauna exclusion fence on foot between 30 and 31 August 2022. Sections of exclusion fence inspected included: type 1 chain mesh fence with floppy top feature (18.03km), Type 3 frog fence combined with floppy top (1.32 km) and Type 4 flying-fox fence (1km) fence. The exclusion fence was assessed in relation to condition, structural integrity, overhanging vegetation and vine growth. Any issues were recorded on a datasheet, and the location logged using a hand-held GPS along with a written description of the issue and location.

3. Results

3.1 October 2022 sample

3.1.1 Weather condition

Weather conditions during the spring 2022 surveys were mostly fine, with good visibility during three of the four surveys (Table 2). Rainfall occurred in the 24 hours prior to and during the third survey, resulting in poor visibility (Table 2).

Table 2: Weather conditions were recorded at 9am on each sample day in October 2022. Relative humidity and temperature data were obtained from the Bureau of Meteorology Coffs Harbour Airport (station 059151) with rainfall data from the Bellwood station (059150).

Date	Rain during survey	Rainfall to 9am (mm)	Relative humidity (%)	Temperature (^{0}C)	Visibility
7/10/2022	Nil	0	76	20.9	Good
13/10/2022	Nil	0	75	18.5	Good
21/10/2022	Moderate rainfall	2	88	19.7	Poor
30/10/2022	Nil	0	38	23.2	Good

3.1.2 Road-kill survey

A total of 22 road-killed fauna were recorded during the October 2022 spring sample period (Table 3). Mammals were the most diverse group represented with three species and two groups recorded, reptiles with one species and two groups, and birds with two records of unidentified bird. (Table 3). Mammals were also the most frequently detected fauna group, with 16 individuals, followed by reptiles (4 individuals) and birds (2 individuals) (Table 3). Bandicoot spp. recorded the highest frequency of road-kill records with nine, followed by red-necked wallaby (3), wallaby spp. (2), *Chelidae spp.* (2) and bird spp. (2) (Table 3). The remaining road-kill records were of single individual species or groups (Table 3). No frogs or threatened species were recorded during the spring 2022 surveys. The full summary of fauna recorded to date is included in Appendix A, Table A2.

Road-kill during the spring sample period was recorded at an overall rate of 0.28 rk/km/week (number of road-killed individuals per kilometer per week), which represents the lowest road-kill rate recorded for the year four operational monitoring (Table 3). In year four, road-kill rates peaked during autumn monitoring (0.37 rk/km/week) and were similar in summer (0.30 rk/km/week), winter (0.29 rk/km/week) and spring (0.28 rk/km/week) (Table 3).

Table 3: Species of vertebrate fauna recorded during year four (2022) road-kill surveys along the WC2NH alignment. For a full road-kill summary of all surveys to date, see Appendix A, Table A2. RK=Roadkill. *Chelidae spp.* = Freshwater turtles.

Species	Sum 22	Aut 22	Win 22	Spr 22	Total
Birds					
Pied butcherbird	0	1	0	0	1
Magpie-lark	1	3	0	0	4
Little pied cormorant	0	0	1	0	1
Crested pigeon	0	1	0	0	1
Tawny frogmouth	0	0	1	0	1
Laughing kookaburra	2	0	0	0	2
Small bird spp.	1	2	2	0	5
Unidentifiable bird spp.	2	7	0	2	11
Total birds	**6**	**14**	**4**	**2**	**26**
Mammals					
Short-beaked echidna	0	1	0	1	2
Black flying-fox	1	1	0	0	2
Red-necked wallaby	1	0	3	3	7
Swamp wallaby	1	0	4	0	5
Wallaby spp.	2	1	0	2	5

Species	Sum 22	Aut 22	Win 22	Spr 22	Total
Northern brown bandicoot	0	0	2	1	3
Bandicoot spp.	4	3	4	9	20
Microbat spp.	0	0	1	0	1
Rodent spp.	1	1	2	0	4
Small mammal spp.	0	1	0	0	1
Medium mammal spp.	2	3	1	0	6
Total mammals	**12**	**11**	**17**	**16**	**56**
Reptiles					
Red-bellied black snake	0	0	0	1	1
***Chelidae* spp.**	0	1	1	2	4
Reptile spp.	2	3	0	0	5
Lizard spp.	0	0	0	1	1
Total reptiles	**2**	**4**	**1**	**4**	**11**
Introduced species					
Cat	1	0	0	0	1
European hare	1	0	1	0	2
Black rat	2	0	0	0	2
Total introduced species	**4**	**0**	**1**	**0**	**5**
Grand total	**24**	**29**	**23**	**22**	**98**
Rk/km/week	**0.30**	**0.37**	**0.29**	**0.28**	**0.31**

3.1.3 Distribution of road-kill

In October 2022, road-killed fauna was recorded in various sections of the WC2NH alignment (Figures 2 and 3). More road-kill was recorded in the fenced section of the alignment (13 records) compared to the unfenced (9 records) sections (Figure 2 and 3). Of the thirteen records in fenced areas, ten were individuals that should be blockeded by the fauna fence under normal circumstances, including seven bandicoots, two *Chelidae* spp. and one wallaby which was recorded 100m from a fence end (Figure 2 and 3). The remaining three individuals were fauna that readily move through (lizard spp. and red-bellied black snake) or over (bird spp.) exclusion fencing (Table 4).

Road-kill records during spring monitoring tended to be more frequent between the Old Coast Road overpass and 2km north of the Mattick Road overpass (9 records), the Gumma Floodplain (5 records), and around the Cockburns Lane overpass (3 records) (Figure 2 and 3). Other records were distributed between the southern end of the Gumma Floodplain and the Rosewood Road overpass (Figure 3). Only one bandicoot was recorded in the northern extent of the alignment where the Nambucca State Forest is situated to the east and west (Figure 3).

Table 4: The number of road-killed fauna recorded in fenced and unfenced sections of the WC2NH alignment during the October (spring) 2022 sample period. Includes sub-totals for fauna that the fauna fence should stop under normal circumstances (excluded) and fauna that would not be stopped by the fauna fence (not excluded).

Species	Fenced	Unfenced
Excluded		
Bandicoot spp.	6	3
Chelidae spp.	2	0
Northern brown bandicoot	1	0
Red-necked wallaby	0	3
Short-beaked echidna	0	1
Wallaby spp.	1	1

Subtotal (excluded)	10	8
Not excluded		
Bird spp.	1	0
Lizard spp.	1	0
Medium bird spp.	0	1
Red-bellied black snake	1	0
Subtotal (not excluded)	3	1
Grand total	**13**	**9**

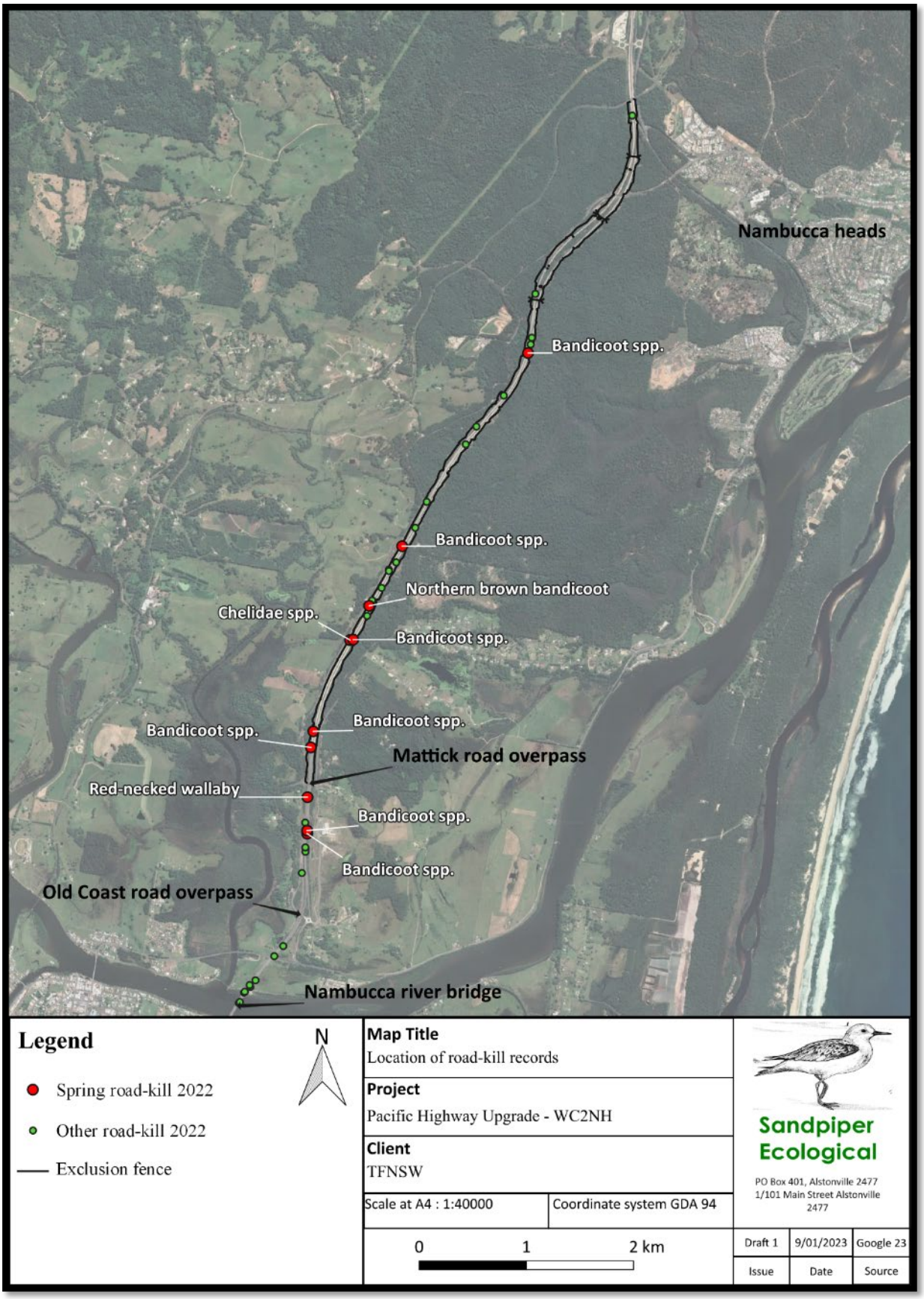

Figure 2: Location of road-killed fauna recorded in 2022 along the WC2NH alignment (northern extent). Note: only October (spring) 2022 records are labeled. Other road-kill fauna include summer, autumn, and winter records from year four surveys at WC2NH, 2022.

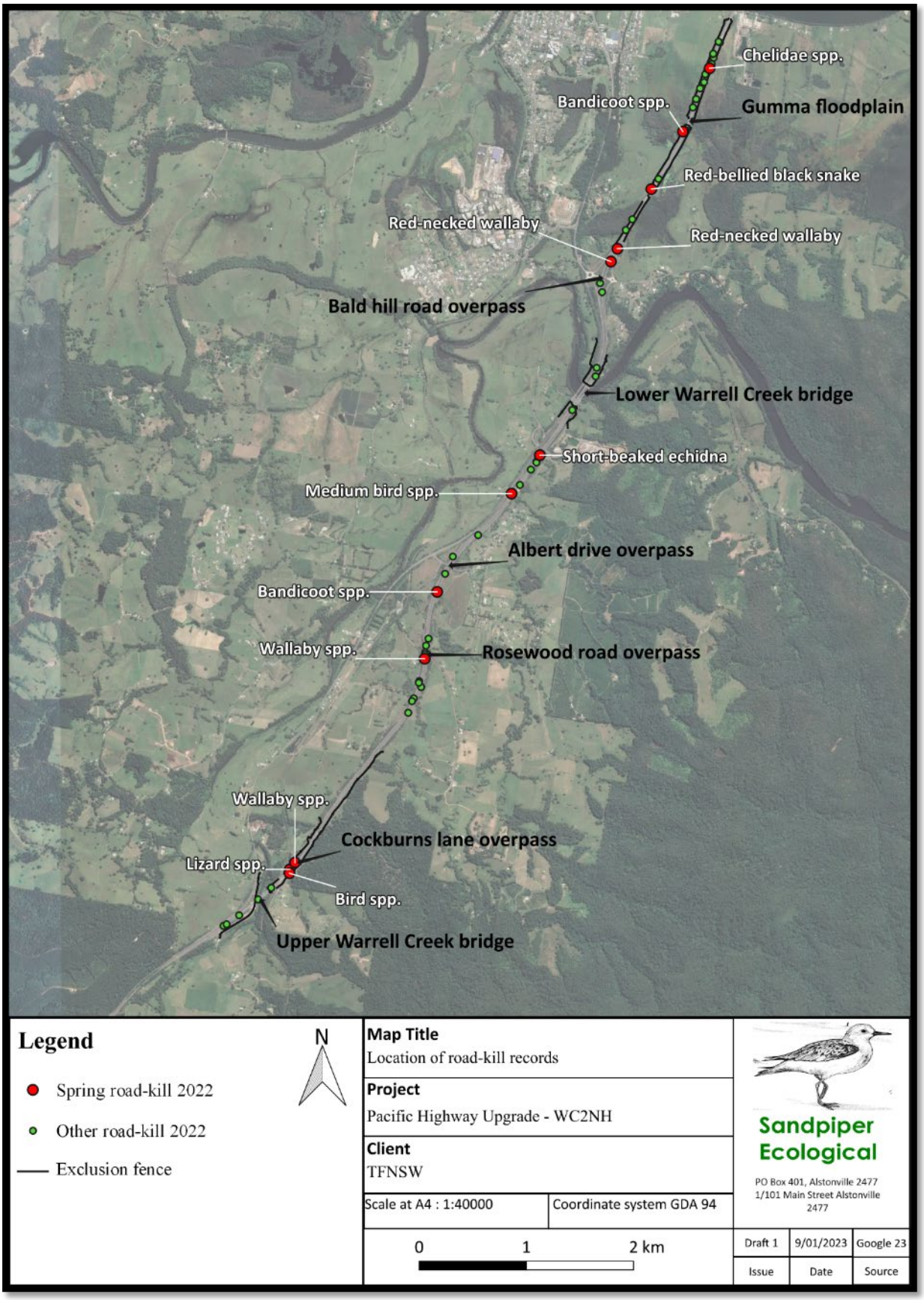

Figure 3: Location of road-killed fauna recorded in 2022 along the WC2NH alignment (southern extent). Note: only October (spring) 2022 records are labeled. Other road-kill fauna includes summer, autumn, and winter records from year four surveys at WC2NH, 2022.

3.2 Annual results and operational monitoring

3.2.1 Annual species richness and abundance

A total of 98 road-killed fauna (0.31 road-kill/km/week) were recorded during 2022 road-kill surveys (Table 3). This included 15 species and a further 11 fauna groups (Table 3). Birds were the most diverse group represented by six confirmed species, followed by mammals with five (including introduced species) and reptiles with one (Table 3). Six of the species recorded were single records, with the most recorded species being the red-necked wallaby (7 records), swamp wallaby (5 records), and magpie lark (4) (Table 3). Of the fauna groups, mammals were the most frequently recorded group, with 56 records, followed by birds (26 records), reptiles (11 records), and introduced species (5 records) (Table 3). Six species were represented by single records only, with the majority of road-kills being bandicoots (23), macropods (17), and unidentified bird spp. (11) (Table 3). No frogs or threatened species were recorded during the year four road-kill surveys.

3.2.2 Temporal comparisons

Operational monitoring (2019-2022) has shown a general decline in the number of road-kill recorded annually (Figure 4). Road-kill has decreased from 0.57 (± 0.40) rk/km/week in 2019 to 0.39 (± 0.19) rk/km/week in 2020, 0.34 (± 0.22) rk/km/week in 2021 and 0.31 (± 0.20) rk/km/week in 2022 (Figure 4). By comparison, the road-kill rate in 2022 was 47% lower than 2019, 15% lower than 2020 and 10% lower than 2021 (Figure 4). No distinct seasonal trends in total road-kill were evident over the monitoring period.

Road-kill rates have varied between and within fauna groups across operational monitoring (Figure 5). Since the commencement of operational monitoring and in order of detection, birds, macropods, bandicoots, flying foxes, and medium mammals have recorded the highest road-kill rates (Figure 5). Road-kill rates for birds, flying foxes, and medium mammals have consistently declined since 2019 (Figure 5). A substantial decline (87%) in flying fox records was experienced between 2019 (0.09 ± 0.11 rk/km/week) and 2020 (0.013 ± 0.02 rk/km/week), with lower rates (0.013 ± 0.3 rk/km/week) maintained in 2021 and only two records of black flying fox (0.006 ± 0.02 rk/km/week) in 2022 (Figure 5). Macropod records peaked during 2020 (0.1 ± 0.09 rk/km/week) and have since declined by approximately 45% (0.05 ± 0.09 rk/km/week) (Figure 5). In contrast, road-kill rates for bandicoots have consistently increased from 2019 monitoring, with the highest rate recorded in 2022 (0.07 ± 0.09 rk/km/week) (Figure 5). Other fauna groups, including feral predators, possums, echidnas and microbats, have recorded consistently low (<0.025 rk/km/week) or nil road-kill rates (Figure 5).

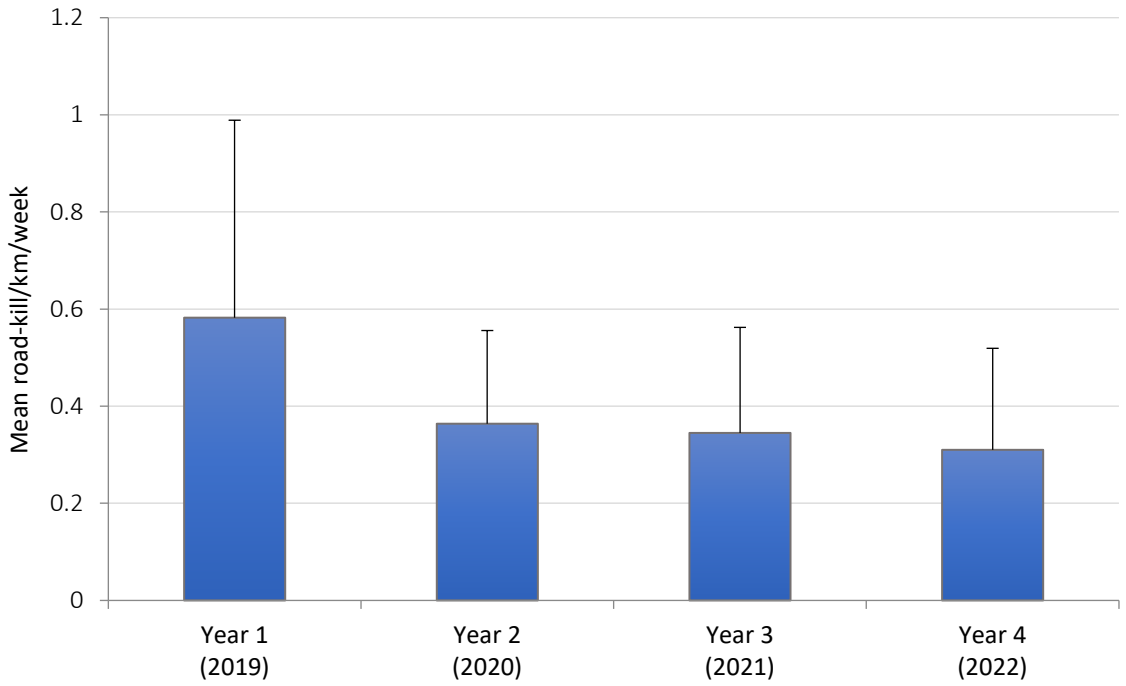

Figure 4: Mean (+SD) number of road-kill per kilometer per week (n=16) recorded during operational phase monitoring (2019-2022).

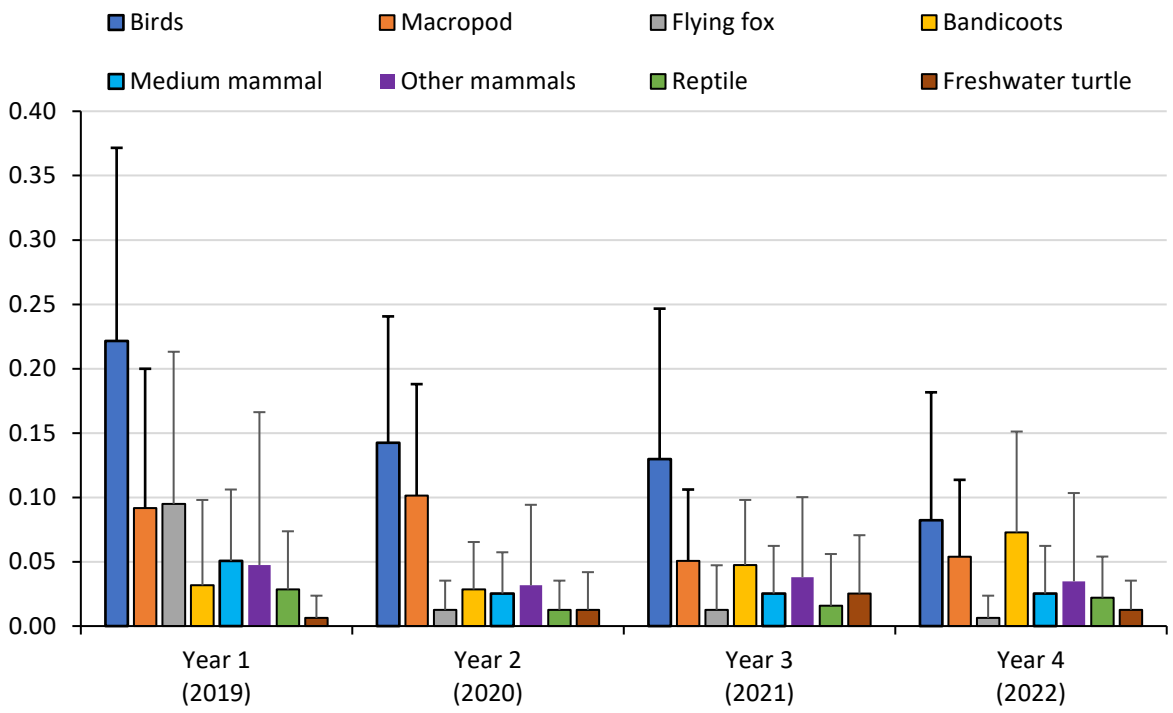

Figure 5: Mean (+SD) number of road-kill per kilometer per week (n=16) recorded for fauna groups during operational phase monitoring (2019-2022). Other mammals = combined microbat spp., echidna, feral predators, and small mammal spp.

3.2.2 Spatial comparison – fenced vs. unfenced

Road-kill rates have varied across the WC2NH alignment, with the primary determinant of variation being the presence or absence of fauna exclusion fence (Figure 6). During 2019 and 2020, fauna that should be blocked by fauna fence (see Table 1) recorded significantly higher road-kill rates in unfenced compared to fenced sections of the alignment (Figure 6, Table 5). During 2021, fenced and unfenced sections of the alignment recorded no statistically significant difference with similar road-kill rates of 0.15 (± 0.13) rk/km/week and 0.19 (± 0.19) rk/km/week, respectively (Figure 6, Table 5). This result continued in 2022, with no statistically significant difference (P=0.735; DF 1; Table 5) between fenced and unfenced sections of the alignment (Figure 6). Road-kill rates in fenced areas of the alignment have marginally increased between 2021 and 2022, whereas in unfenced areas, rates have slightly decreased during the same period (Figure 6).

Road-kill rates have differed between fauna groups in relation to the presence (fenced) and absence (unfenced) of fauna exclusion fencing, particularly for fauna groups that, under normal circumstances, would be blocked by fencing (Table 2, Figure 7). Throughout operational monitoring, macropods have consistently recorded higher road-kill rates in unfenced alignment sections (Figure 7). During 2022 monitoring, road-kill rates for macropods were approximately three times higher in unfenced sections of the alignment (0.16 ± 0.10 rk/km/week) compared to fenced sections (0.05 ± 0.01 rk/km/week) (Figure 7). Most macropod records within fenced sections of the alignment during 2022 monitoring were in close proximity to fence ends or interchanges (Figures 10 and 11)

Bandicoot records continued to increase during operational road-kill monitoring and were the second most frequently detected fauna group during 2022 (Figure 5). Bandicoots have been recorded in both unfenced and fenced sections of the alignment, with road-kill rates being almost twice as high in fenced (0.09 ± 0.07 rk/km/week) versus unfenced (0.05 ± 0.03 rk/km/week) sections in 2022 (Figure 7). Medium mammal, feral predators and possum records have been recorded at relatively low rates in the alignment's fenced and unfenced sections (Figure 7). Freshwater turtles have tended to be recorded in fenced sections of the alignment, particularly around the Gumma floodplain (Figure 11), whereas echidnas have exclusively been recorded in unfenced sections of the alignment (Figure 7).

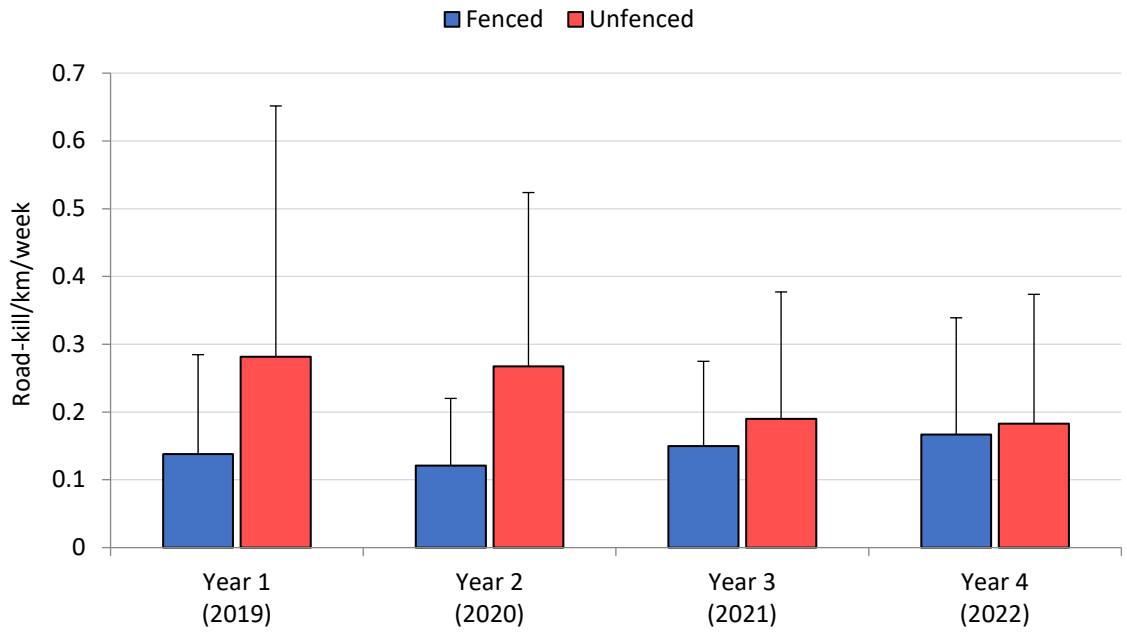

Figure 6: Annual comparison in the mean (+SD) number of road-kill per kilometer per week (n=16) recorded in fenced (10.86km) versus unfenced (8.89km) sections of the WC2NH alignment during operational monitoring. Only includes fauna that, under normal circumstances, would be blocked by the exclusion fence (see Table 1).

Table 5: G-test summary statistics on the number of road-kill in fenced versus unfenced sections of the WC2NH alignment during operational monitoring (years 1-4). Note, only fauna that should be blocked by exclusion fence under normal circumstances has been included.

Group	Category	Nº. road-kill	Expected proportion	Expected Nº.	Df	G statistic	P (2-tail)
2019	Fence	24	0.55	35.2	1	7.897	**0.005**
	No fence	40	0.45	28.8			
2020	Fence	21	0.55	32.45	1	8.973	**0.003**
	No fence	38	0.45	26.55			
2021	Fence	26	0.55	29.15	1	0.752	0.386
	No fence	27	0.45	23.85			
2022	Fence	29	0.55	30.25	1	0.114	0.735
	No fence	26	0.45	24.75			

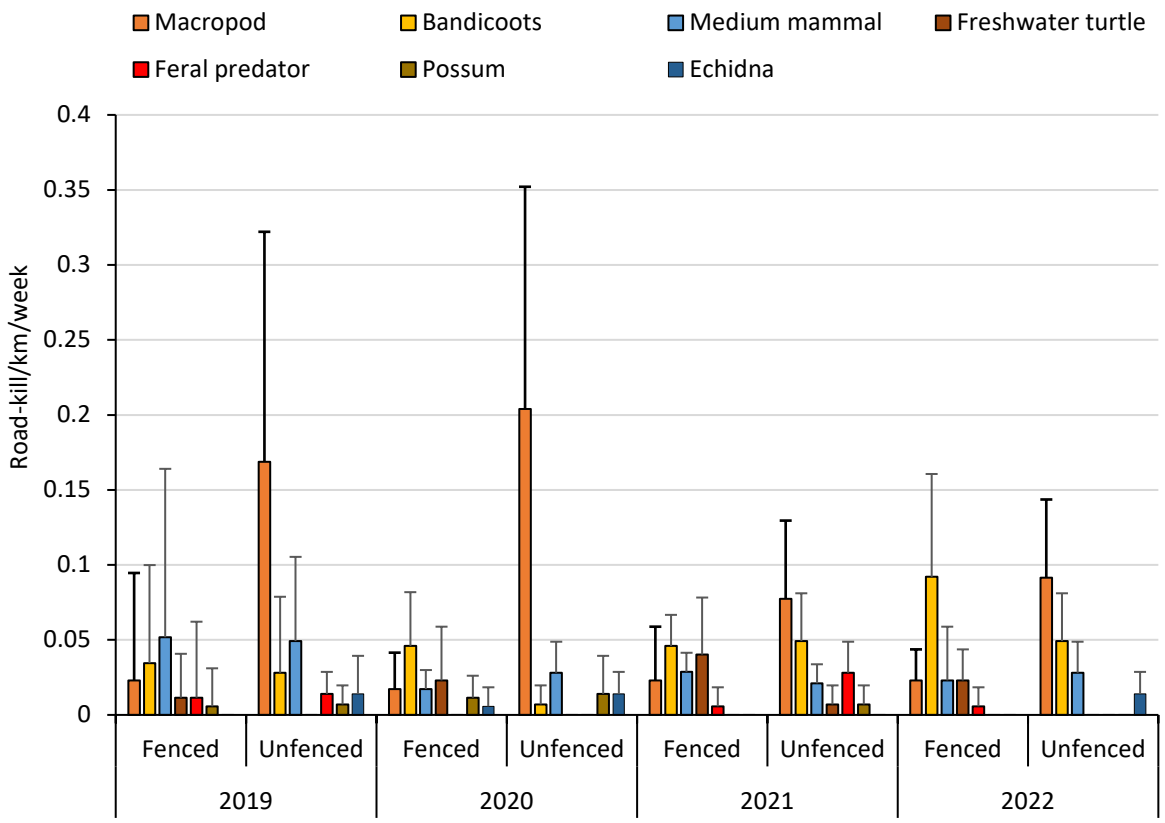

Figure 7: Annual comparison in the mean (+SD) number of road-kill per kilometer per week (n=16) along the WC2NH alignment in fenced (10.86km) and unfenced (8.89km) sections. Only includes fauna groups that, under normal circumstances, would be blocked by the exclusion fence (see Table 1).

3.2.3 Spatial comparison – Distribution of road-kill

Heat map analysis incorporating all road-kills from operational phase monitoring (2019-2022) identified several areas of increased road-kill density (Figure 8). A broad hot-spot was identified across the Gumma floodplain extending from the Nambucca River Bridge down to the Lower Warrell Creek Bridge (Figure 8). Hot-spots were also identified in unfenced sections of the alignment around the Rosewood Road Overpass, Quarry Road Overpass, south of Upper Warrell Creek Bridge, and to the south of the Mattick Road overpass (Figure 8). Less prominent hot-spots were recorded on fenced sections of the alignment, including 2km north of Mattick Road and to the north of Upper Warrell Creek Bridge (Figure 8).

Heat map analysis of road-killed fauna (2019-2022) that should, under normal circumstances, be blocked by exclusion fence (see table 1) were typically smaller in extent but largely consistent with hot-spots for all fauna (Figures 8 and 9). Hot-spots were identified in unfenced sections of the alignment, including to the south of Mattick Road overpass, the Bald hill road overpass, the Quarry access overpass, the Rosewood road overpass, and the Upper Warrell Creek bridge (Figure 9). Hot-spots were most prominent around the Bald Hill road and Rosewood road areas (Figure 9). Less prominent hot-spots were recorded on fenced sections of the alignment, including 2km north of Mattick Road, the Gumma floodplain and immediately north of the Lower Warrell Creek Bridge (Figure 9). Hot-spot analysis and the road-kill overlay (2019-2022) show that the fauna fence appears effective in the northern extent of the project to the east of Nambucca Heads, where substantially fewer road-kill records occur (Figure 9).

The distribution of road-killed fauna recorded in 2022 that should be blocked by fauna fence was largely consistent with the operational phase (2019-2022) heat-map analysis (Figures 10, 11, and 9). Records predominantly consisted of bandicoots (23 records = combined northern brown bandicoot and Bandicoot spp.) and macropods (17 records = combined swamp wallaby, wallaby spp., red-necked wallaby) with fewer records of medium mammal spp. (6 records), *Chelidae* spp. (4 records), short-beaked echidna (2 records), European hare (2 records) and cat (1 record) (Figures 10 and 11). Bandicoots were predominately recorded around the fenced area and the hot spot between the Mattick Road overpass and 2 km north (8 records), with other clusters located south of Mattick Road (unfenced) and along the Gumma flood plain (fenced) (Figure 10 and 11). Macropods were predominately recorded around the Bald Hill road overpass (unfenced) and southern fence end of the Gumma floodplain (5 records), Rosehill road (unfenced) overpass (5 records) and around Upper Warrell Creek Bridge (4 records) (Figure 11).

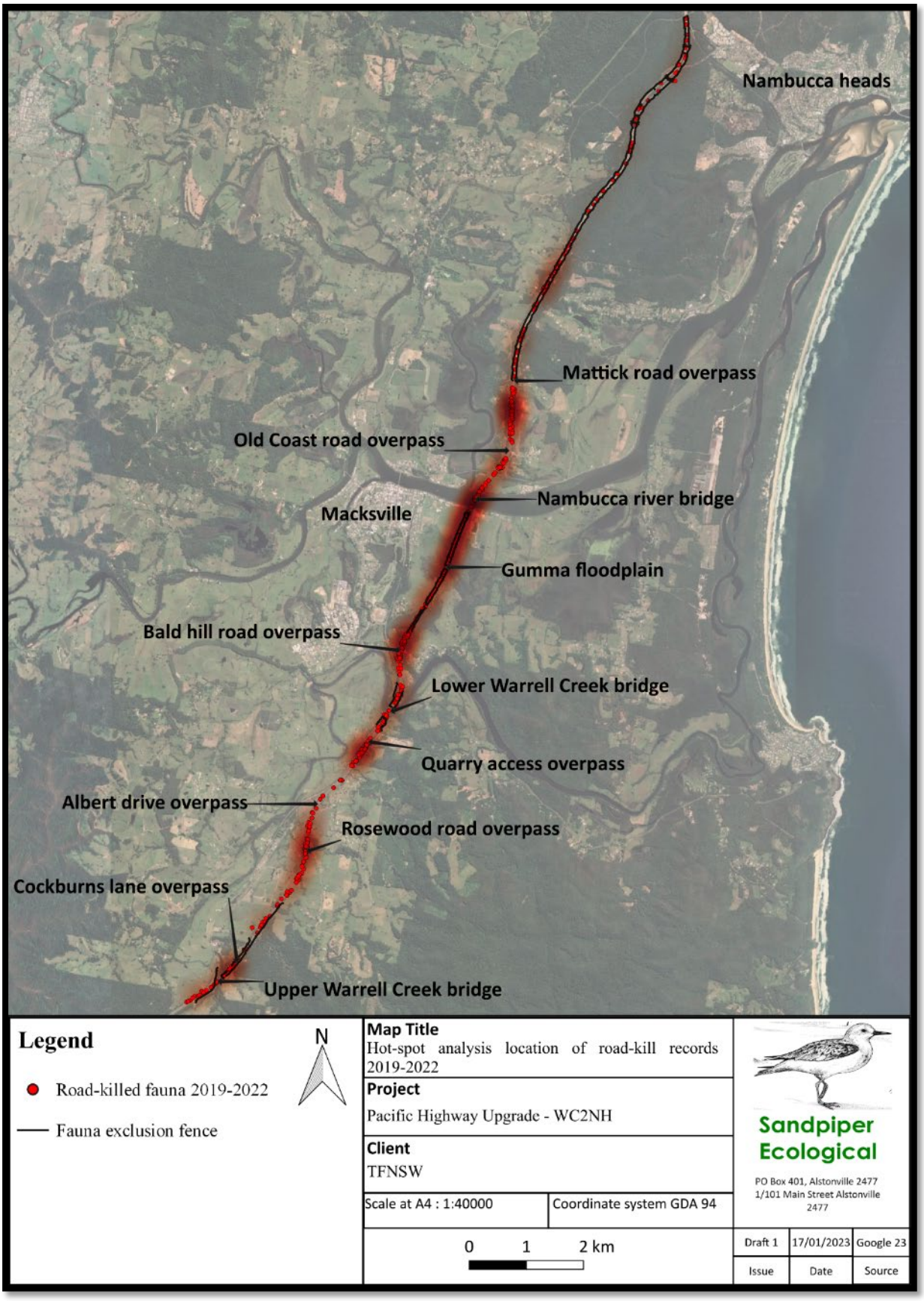

Figure 8: Heat map analysis of all road-killed fauna during operational monitoring surveys (2019-2022) at WC2NH.

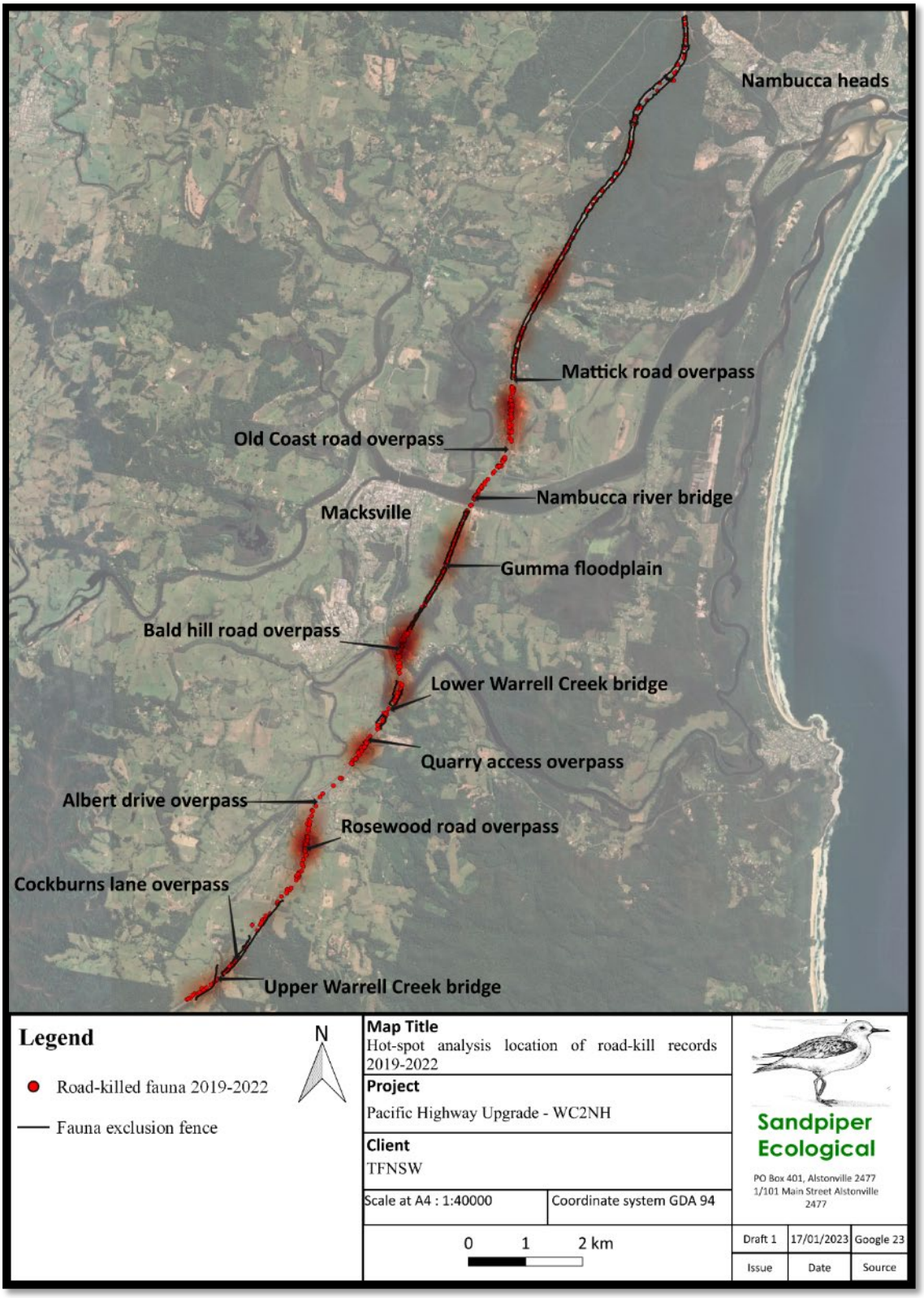

Figure 9: Heat map analysis of road-killed fauna that, under normal circumstances would be blocked by fauna fence (see Table 1) during operational monitoring surveys (2019-2022) at WC2NH. Overlaid red dots indicate the location of road-killed individuals recorded between 2019 and 2022.

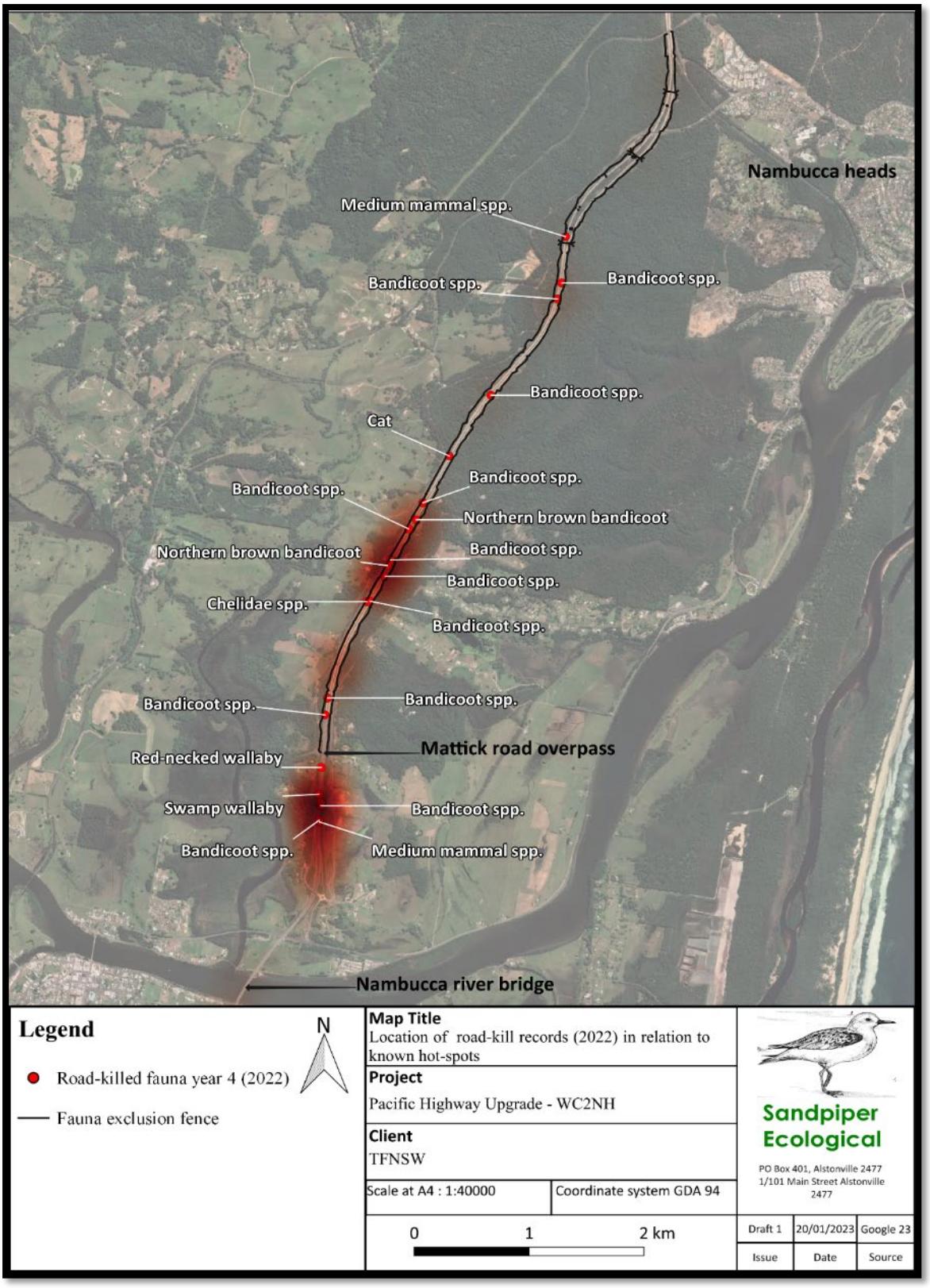

Figure 10: The location of road-killed fauna recorded during 2022 surveys in relation to known hot spots at WC2NH (northern extent). Hot spots have been determined by heat map analysis (2019-2022) of road-killed fauna, as seen in Figure 9. Note only include fauna which, under normal circumstances, are blocked by exclusion fence (see Table 1).

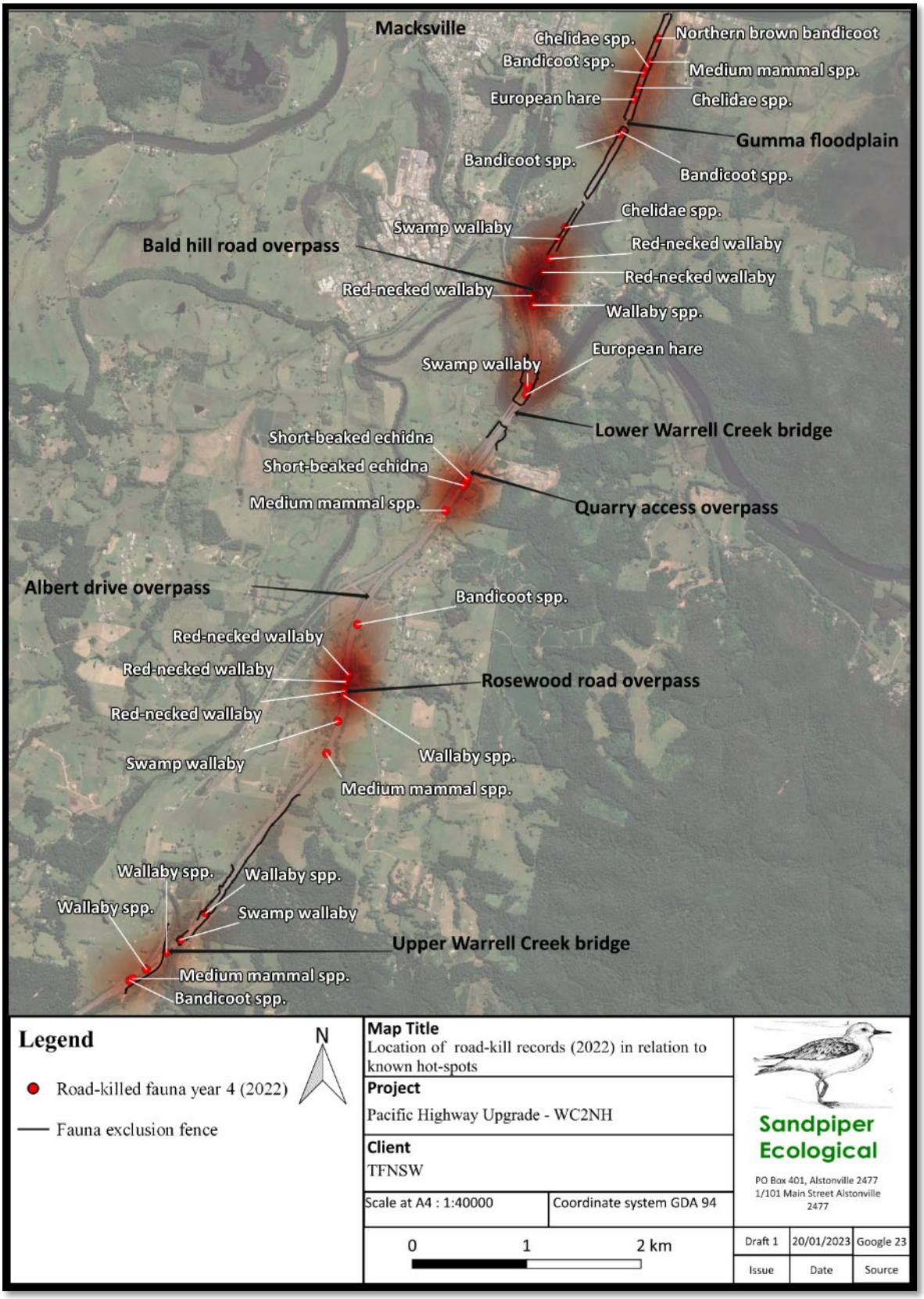

Figure 11: The location of road-killed fauna recorded during 2022 surveys in relation to known hot spots at WC2NH (southern extent). Hot spots have been determined by heat map analysis (2019-2022) of road-killed fauna, as seen in Figure 9. Note only include fauna which, under normal circumstances, are blocked by exclusion fence (see Table 1).

3.4 Exclusion fence inspection

Fifty-three fence issues were recorded during the 2022 winter inspection (Table 6, see Appendix A, Table A2). The most frequently encountered issue was sections of vegetation overgrowth (28) followed by a tree/branch growing through or over the fence (8), tree/branch fallen on the fence (5), gaps around drains (4), gaps around gates (3), return wire uplift (3), unlocked gate (1) and fence top collapse (1) (Table 6). Overall, the structural integrity of the exclusion fence was sound, with the prominent issue being vegetation overgrowing, overhanging, or protruding through the fence (Table 6).

Results from the exclusion fence inspection show 12 issues are considered a high priority (potential for threatened fauna including koala or quoll to access alignment), 13 moderate (potential to facilitate small common fauna movement onto the alignment), and 23 low (likely to become an issue over time) (Table 6). Priority issues include moderate-sized (>100mm diameter) trees or branches that are growing through or over the exclusion fence (5), trees or branches fallen on the fence (5), gaps around drains (1), and a gate unlocked (1) (for full details see Appendix A, Table A2). Most issues of vegetation overgrowth and trees/branches on the fence are attributed to *Acacia* spp. regrowth on and around the batters north of Mattick Road (Plate 2, Appendix A, Table A2). Also, dense grasses growing through and over the fauna fence were a feature of fence inspections along the alignment (Plate 2, Appendix A, Table A2).

Plate 2: Thick grass protruding through and over the fauna fence north of Mattick Road (Top). *Acacia* spp. overhanging fauna fence adjacent to old coast road (Bottom).

Table 6: Issues identified and their priority for action from the exclusion fence inspection at WC2NH, 2022. *Trees or branches recorded on the fence were between 100mm to 200mm.

Issues identified	High	Moderate	Low	Grand Total
Vegetation overgrowth	0	4	24	28
Tree/branch growing through or over fence*	5	3	0	8
Tree/branch fallen on fence*	5	0	0	5
Gap around gate	0	1	2	3
Return wire uplift	0	2	1	3
Gap around drains	1	2	1	4
Unclocked gate	1	0	0	1
Fence top collapsed	0	0	1	1
Grand Total	**12**	**13**	**28**	**53**

4. Discussion

4.1 October 2022

Road-kill monitoring over the entire WC2NH alignment in October 2022 indicated that fauna continued to be killed by vehicles four years after the entire alignment was open to traffic. Road-kill was recorded at an overall rate of 0.28 road-killed individuals/km/week, which was the lowest road-kill rate recorded in year four operational monitoring. One limitation of the October 2022 survey was the occurrence of moderate rainfall during the third survey which may have obscured visibility and reduced carcass retention. Birds and mammals have continued to comprise the majority of road kills in all surveys to date. Notably, the survey method is biased towards larger and long-lasting carcasses, which tend to be birds and mammals. The method also reduces the ability to identify all carcasses confidently, resulting in some individuals being assigned to a size class and fauna group (Ogletree and Mead 2020). The absence of amphibians in October 2022 is consistent with previous surveys and further emphasises the difficulty of identifying road-killed amphibians during vehicle-based surveys.

4.2 Temporal variation

Results of the 2022 road-kill monitoring provide further evidence of a temporal decline in the overall road-kill abundance since the WC2NH highway upgrade was opened to traffic. By comparison, the road-kill rate in 2022 was 47% lower than 2019, 15% lower than 2020, and 10% lower than 2021. Furthermore, the 2022 road-kill rate was similar to the road-kill rate (0.3 rk/km/week) recorded on three major roads in north-eastern New South Wales (Talor and Goldingay 2004).

While overall road-kill rates continued to decline from 2021 to 2022, there have been notable changes in the frequency of detection for some fauna groups. For example, road-kill rates for bandicoots have consistently increased, with the highest recorded in 2022. Better climatic conditions in 2021 and 2022 have likely contributed to an increase in the abundance and movement of bandicoots (Vernes and Pope 2009). Numerous bandicoot diggings have been observed on mulch bunds situated on the road side of exclusion fence (L. Andrews pers obs). This suggests that with an increase in the abundance of bandicoots, more individuals are accessing the road corridor to forage on mulch bunds, leading to a higher incidence of vehicle strike.

The abundance of macropod records remained relatively stable between 2021 (15 road-kills) and 2022 (17 road-kills), following a substantial decline in records from 2020 (27 road-kills). The lower abundance of

macropods in 2022 on the back of favourable climatic conditions further supports the hypothesis that the higher road-kill rates recorded in 2019 and 2020 were likely due to drought (Klocker *et al.* 2006). Reduced grass quality and quantity in drought conditions means individuals may move larger distances in search of new growth, which may occur along road-sides, or cause individuals to cross roads. Nonetheless, it is difficult to confirm whether the decrease in vehicle strike may be due to a decline in local abundance caused by high road-kills numbers in 2020 (27 individuals), particularly for red-necked wallaby (Bond and Jones 2013). The observed decrease in vehicle strike is likely due to the combined effect of improved climatic conditions and reduced local abundance.

Sandpiper Ecological (2018) suggested that the occurrence of birds in road-kill might decline as individuals habituate to the highway. This suggestion is supported by a 40% decline from 2019 to 2020, 9% decline in 2021 and a further 35% decline in 2022. It is difficult to determine if the decline in bird abundance is due to population decline or avoidance of the highway. Whilst the highway may represent a population sink for resident territorial species, such as frogmouths, owls, and kookaburras (see Loss *et al.* 2014), habituation to the highway and changes in habitat are likely to be contributing factors.

The spring and summer peaks in road-kill numbers recorded in 2018 and 2019 were not recorded in 2022, which is consistent with the 2021 result. In 2022, road-kill peaked in autumn (29 individuals) with lower records in winter (23) and summer (22). The previously recorded spring/summer peak was attributed to seasonal changes in breeding cycles and foraging demands (Sandpiper Ecological 2019a). The pattern recorded in 2021 and 2022 may be influenced by better climatic conditions, reducing the need for herbivores to forage along the road edge and/or to move greater distances across road alignments.

4.3 Distribution and fenced vs unfenced

Similar to 2021 monitoring, the G-test identified no significant difference ($P>0.05$) in road-kill abundance between fenced and unfenced sections of the alignment in 2022. This result suggests that fauna that should be blocked by exclusion fence were killed at an equivalent rate between fenced and unfenced sections of the alignment in 2022. The result is contrary to findings in years one and two (Sandpiper Ecological 2019, 2020) and inconsistent with the hypothesis that exclusion fence reduces road mortality.

Despite the higher incidence of road-kill in fenced areas in 2021 and 2022, the results do not show how many individuals are blocked from entering the carriageway by exclusion fence. At WC2NH, exclusion fence corresponds with vegetated areas were a higher abundance of fauna is expected; without exclusion fence road-kill would be substantially higher in these areas (de Carvalho *et al.* 2014). The results of the hot-spot analysis and the road-kill overlay from 2019 to 2022 indicate that the fauna fence is particularly effective in the northern extent of the project, around the Nambucca State Forest, where substantially fewer road-kill records were found. This can be attributed to the continuous nature of the fauna fence in this section, which has limited fence ends or interchanges and features underpasses that facilitate the movement of fauna across the alignment.

Bandicoots have predominantly contributed to the higher number of road-kill in fenced sections during 2021 and 2022. Clusters of bandicoot records occur around known hot-spots 2km north of Mattick Road and along the Gumma Floodplain. Access to the alignment via spill drains to the north of Mattick Road has continued to be associated with the high frequency of bandicoot road-kills in the area (Sandpiper 2021). The modification works undertaken in early 2021 appear to have been ineffective at preventing bandicoots from accessing the alignment. This is largely due to the behaviour of bandicoots and their ability to move through small gaps that occur around open drains. It is highly unlikely that any exclusion fence can be 100% effective at all times and a certain level of road mortality for these species needs to be accepted. However, obvious fence breaches which provide access for priority species such as spotted-tailed quoll, koala and giant barred frog should remain a focus.

Throughout operational monitoring, macropod road-kills are typically occurring around unfenced sections of the alignment such as Rosehill Road, Upper Warrell Creek and fence ends/interchanges at Bald Hill Road and south of Mattick Road. The 2022 exclusion fence inspection did not identify any gaps suitable for a macropod; hence no modification to fence design is recommended for that species. Hot-spot analysis has highlighted the increased wildlife vehicle-strike risk associated with interchanges and fence ends. Whilst changes to interchange design are beyond the scope of this assessment, and there is at present no pressing need to extend fauna fence the results provide useful information for future road projects.

Data suggest that species likely to be blocked by exclusion fence are killed regardless of whether a drop-down occurs nearby. Whilst the influence of drop-downs on road-kill rate requires further analysis this observation is consistent with drop-down monitoring which showed negligible use by native fauna (Sandpiper Ecological 2019b).

4.4 Threatened fauna

Since WC2NH became operational four threatened species have been recorded as road-kill (grey-headed flying-fox, masked owl, black bittern and eastern grass owl), with no additional threatened species recorded in 2022. Overall, the number of grey-headed flying fox mortalities has declined since 2019. This trend is likely a result of improved foraging conditions associated with higher summer and autumn rainfall between 2020 and 2022, and less visitation to roadside trees to forage. 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 Victoria clinics were due to a vehicle strike, and 84.6% of these were euthanised.

5. Conclusion and recommendations

The 2022 road-kill monitoring program for the WC2NH upgrade has yielded additional evidence of a temporal decline in the abundance of road-killed fauna since the highway was opened to traffic. Most of the road-killed fauna that the fauna fence should exclude were found around fence ends and interchanges, emphasising the importance of ensuring that fence extents are consistent on both sides of the alignment and minimizing the number of fence ends. While it is expected that some common small to medium-sized fauna, such as bandicoots, may still be road-killed in fenced areas, the overall annual road-kill rates (0.31rk/km/week) were the lowest to date since the project's opening and similar to rates on three major roads in north-eastern New South Wales (Taylor and Goldingay 2004). Therefore, no corrective action is proposed based on the year four findings (Table 7), but monitoring is recommended to continue into year five (Table 8).

Table 7: Potential problems outlined in the EMP and possible contingency measures.

Potential problem	Contingency/Corrective Action	Proposed action
High rates of fauna road mortality.	Modify exclusion fencing design, location or extent depending on the species and location of mortalities	No corrective action is warranted. Year four monitoring suggests that the road mortality rate is declining over time and is consistent with rates observed on three major roads in north-eastern NSW.

Table 8: Recommendations based on findings of the year 4 operational phase road-kill monitoring program.

Number	Recommendation	Transport for NSW Response
1.	Continue to undertake road-kill monitoring in accordance with the Ecological Monitoring Program and the operational phase methods	Noted.

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Appendix A – Field data

Table A1: Road-kill summary of all fauna recorded to date during operational phase monitoring at WC2NH (2018-2022). * denotes threatened species; ** = stage 2a only; Sum = summer; Aut = autumn; Win = winter; Spr = spring.

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Total
Birds																					
Australian magpie	6	1	0	1	0	0	0	2	2	1	0	0	1	0	0	2	0	0	0	0	16
Grey butcherbird	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pied butcherbird	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Magpie-lark	2	0	1	0	1	0	1	0	1	0	1	1	0	1	0	1	1	3	0	0	14
Australian white ibis	0	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	4
Cattle egret	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Little pied cormorant	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Buff-banded rail	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Purple swamphen	3	0	2	2	0	1	0	2	3	0	1	1	0	3	1	1	0	0	0	0	20
Wonga pigeon	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
White-headed pigeon	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Crested pigeon	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3
Galah	7	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	11
Rainbow lorikeet	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Eastern grass owl*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Australian boobook	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	4
Masked owl*	1	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	4
Eastern barn owl	0	0	11	3	0	1	5	2	1	0	0	0	0	0	0	1	0	0	0	0	24
Tawny frogmouth	1	3	1	2	0	6	0	4	0	1	0	1	1	1	1	0	0	0	1	0	23
Australian owlet-nightjar	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Laughing kookaburra	3	0	2	1	0	2	0	3	1	1	2	1	0	0	0	2	2	0	0	0	20
Forest kingfisher	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Australian wood duck	20	0	0	2	2	0	1	2	0	0	0	2	1	0	0	0	0	0	0	0	30
Pacific black duck	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Whistling kite	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Black-shouldered kite	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Torresian crow	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
Pied currawong	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	3
Black-faced cuckoo-shrike	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Noisy miner	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	4
Dollarbird	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Green catbird	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
Australasian figbird	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Total
Black bittern*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Eastern yellow robin	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pheasant coucal	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0	4
Masked lapwing	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Welcome swallow	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Red-browed finch	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Duck spp.	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Tyto spp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Small bird	0	0	0	0	0	0	0	2	0	0	0	0	0	1	1	0	1	2	2	0	9
Medium bird	0	0	0	1	2	2	2	2	6	1	1	0	0	2	0	2	0	0	0	0	21
Unidentifiable bird	5	4	1	0	3	0	0	0	0	0	2	2	1	0	2	2	2	7	0	2	33
Total birds	53	8	22	17	18	16	13	25	16	11	8	9	10	12	8	11	6	14	4	2	283
Mammals																					
Short-beaked echidna	0	0	0	3	0	0	0	2	0	1	2	1	0	0	0	0	0	1	0	1	11
Black flying-fox	2	1	0	0	7	1	1	0	0	0	0	0	0	1	0	0	1	1	0	0	15
Grey-headed flying-fox*	0	0	0	0	8	0	0	5	2	0	0	0	0	2	0	0	0	0	0	0	17
Pteropus spp.	0	0	0	0	3	8	1	0	1	1	0	0	0	1	0	0	0	0	0	0	15
Short-eared brushtail possum	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Common brushtail possum	0	0	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4
Trichosurus spp.	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	3
Common ringtail possum	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Eastern grey kangaroo	0	0	0	3	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	5
Red-necked wallaby	0	0	6	0	8	2	8	3	7	1	8	3	1	1	4	2	1	0	3	3	61
Swamp wallaby	2	1	0	1	0	1	1	0	0	1	1	2	1	0	2	1	1	0	4	0	19
Wallaby spp.	0	0	0	0	0	2	0	0	3	0	0	2	0	1	0	1	2	1	0	2	14
Macropod spp.	3	0	2	1	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	10
Northern brown bandicoot	1	0	1	0	1	1	1	2	2	3	3	0	1	2	2	1	0	0	2	1	24
Bandicoot spp.	0	0	0	0	0	1	0	4	0	0	0	1	0	2	4	2	4	3	4	9	34
Chalinolobus spp. (microbat)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Microbat spp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Swamp rat	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Rodent spp.	0	0	0	0	0	2	0	0	0	0	0	1	0	0	1	1	1	1	2	0	9
Small mammal	0	0	0	0	2	0	0	0	0	0	1	0	1	3	0	0	0	1	0	0	8
Medium mammal	0	0	0	2	4	2	4	5	2	2	2	0	0	2	4	2	2	3	1	0	37
Large mammal	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	4
Unidentified Mammal	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Total mammals	9	2	10	17	37	20	17	23	18	13	20	10	5	16	18	10	12	11	17	16	301
Reptiles																					
Common blue-tongued skink	1	0	0	2	1	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	7
Carpet python	1	0	0	2	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	7
Common tree snake	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4
Eastern long-neck turtle	1	0	0	6	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	10

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Total
Macquarie river turtle	5	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Unidentified *Chelidae* spp.	6	0	0	0	0	0	0	1	0	0	0	1	2	4	1	0	0	1	1	2	19
Red-bellied black snake	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Eastern water dragon	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Eastern bearded dragon	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	2
Blackish blind snake	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Yellow-faced whipsnake	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Unidentified reptile	0	0	0	0	0	0	0	2	0	1	0	0	0	2	0	0	2	3	0	0	10
Lizard spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Total reptiles	17	3	0	12	2	2	1	5	2	2	0	4	4	7	1	0	2	4	1	4	73
Frogs																					
Green tree frog	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Striped marsh frog	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Medium frog	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Large frog	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total frogs	5	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Introduced species																					
Cat	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	3
Dog	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
European fox	3	1	1	2	1	1	2	0	0	0	0	0	0	1	2	0	0	0	0	0	14
European hare	2	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	1	0	8
Rabbit	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Black rat	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4
House mouse	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rock pigeon	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Domestic goose	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Total introduced species	8	1	2	5	2	2	2	0	0	1	0	2	1	2	2	1	4	0	1	0	36
Grand total	**92**	**14**	**34**	**55**	**59**	**40**	**33**	**53**	**36**	**27**	**28**	**25**	**20**	**37**	**29**	**22**	**24**	**29**	**23**	**22**	**702**
Road-kill/week/km	**1.16**	**0.18**	**0.43**	**0.70**	**0.75**	**0.51**	**0.42**	**0.67**	**0.46**	**0.34**	**0.35**	**0.32**	**0.25**	**0.47**	**0.37**	**0.28**	**0.30**	**0.37**	**0.29**	**0.28**	**0.44**

Table A2: Exclusion fence inspection notes, WC2NH (winter 2022).

Date	Issue number	Side	Issue identified	Easting	Northing	Type	Priority	Comments
30/08/2022	1	West	Moderate acacia overhanging/growing through fence 100m north	497433	6610994	Overgrowth	Moderate	
30/08/2022	2	East	Thick, overgrown acacia - 150 m north	497506	6610977	Overgrowth	Moderate	
30/08/2022	3	East	Overgrown till approx. 300m south	497512	6610512	Overgrowth	Low	
30/08/2022	4	East	Overgrown - vine and acacia overhanging fence for 250m north	497417	6610269	Overgrowth	Low	
30/08/2022	5	East	Overgrown start continues 80 meters south	497372	6610228	Overgrowth	Low	
30/08/2022	6	West	Overgrown start, continues for 50m south along fence	497050	6610002	Overgrowth	Low	
30/08/2022	7	East	Minor- tree growing on slant over fence	497028	6609835	Overgrowth	Low	
30/08/2022	8	East	Minor base uplift	497009	6609812	Return wire uplift	Low	
30/08/2022	9	East	Thin tree growing through fence	497005	6609811	Tree/branch growing through or over fence	Moderate	
30/08/2022	10	West	Netting on floor not set down properly	496809	6609810	Return wire uplift	Moderate	
30/08/2022	11	East	Thick tree branch growing over fence	496982	6609797	Tree/branch growing through or over fence	High	
30/08/2022	12	East	Dig out under gate about 10cm	496642	6609370	Gate gap	Low	
30/08/2022	13	West	Trees/branches over fence	496492	6609073	Tree/branch growing through or over fence	Moderate	
30/08/2022	14	East	Overgrown start, continues for 30m south of point	496570	6608984	Overgrowth	Low	
30/08/2022	15	East	Base of gutter guard flap broken	496550	6608953	Drain gaps	Moderate	Screws missing
30/08/2022	16	West	Branch over fence	496481	6608892	Branch/tree fallen on fence	High	Too heavy for manual removal
30/08/2022	17	East	Digs in dirt near base of gutter guard	496514	6608753	Drain gaps	Low	
30/08/2022	18	East	Tree growing over fence	496483	6608643	Tree/branch growing through or over fence	High	
30/08/2022	19	West	Branch over fence	496371	6608611	Branch/tree fallen on fence	High	
30/08/2022	20	West	Overgrown start continues for 400 m south	496117	6608268	Overgrowth	Low	

Date	Issue number	Side	Issue identified	Easting	Northing	Type	Priority	Comments
30/08/2022	21	East	Tree growing through fence	496194	6608219	Tree/branch growing through or over fence	High	
30/08/2022	22	East	Gate opening about 20cm at base	496153	6608147	Gate gap	Moderate	
30/08/2022	23	East	Overgrown start, continues for 10/15m along fence South	496115	6608125	Overgrowth	Low	
30/08/2022	24	East	Overgrown start - ends 150m along fence	496015	6607976	Overgrowth	Low	
30/08/2022	25	West	fence gap in return wires abutting the northern side of culvert 4	495702	6607701	Return wire uplift	Moderate	
30/08/2022	26	West	overhanging moderate overgrowth for 20 m north	495332	6607016	Overgrowth	Low	
30/08/2022	27	East	moderate grassy and acacia overgrowth 300m s	495318	6606887	Overgrowth	Low	
30/08/2022	28	West	Minor over hanging acacia vegetation and long grass grown through fence for 1.5 km south	495238	6606871	Overgrowth	Low	Grass forms thick matt that overtops fence in most locations
30/08/2022	29	East	100mm gap - in drain below metal sheath	495234	6606738	Drain gaps	Moderate	
30/08/2022	30	East	metal sheath drains uplifted 200mm gaps	495082	6606464	Drain gaps	High	
30/08/2022	31	East	overhanging acacia and thick infestation of gahnia spp. growing sporadically for next 500 meters south	495053	6606376	Overgrowth	Low	
30/08/2022	32	West	two medium sized acacia 100mm dbh down on fence	494957	6606335	Branch/tree fallen on fence	High	Possibly accessible by koala
30/08/2022	33	West	larger 100mm dbh acacia tree fallen on fence	494975	6606276	Branch/tree fallen on fence	High	Possible access to highway for koala and possum
30/08/2022	34	East	moderate overhanging acacia for 15 meters south	494614	6605539	Overgrowth	Low	
30/08/2022	35	West	Eucalyptus 150mm dbh growing through fence	494488	6605316	Tree/branch growing through or over fence	High	Possible access to highway for koala and possum
30/08/2022	36	West	overhanging acacia and thick grass/ gahnia spp. growing through and over	494484	6605288	Overgrowth	Moderate	

Date	Issue number	Side	Issue identified	Easting	Northing	Type	Priority	Comments
			fence 500m south to Mattick Road					
31/08/2022	37	East	overhanging acacia and thick grass growing through and over fence 300m south to Mattick Road	494517	6605077	Overgrowth	Moderate	
31/08/2022	38	West	over grown 2m grass through fence all the way north to Nambucca bridge	493268	6601545	Overgrowth	Low	Unable to view fence
31/08/2022	39	East	over grown 2m grass through fence all the way north to Nambucca bridge	493299	6601534	Overgrowth	Low	Unable to view fence
31/08/2022	40	West	Trees overgrown over fence for 10m south starting from Lat, long	492950	6600973	Overgrowth	Low	
31/08/2022	41	West	Tree fallen over fence	492944	6600963	Branch/tree fallen on fence	High	
31/08/2022	42	East	Tree growing through fence	492895	6600791	Tree/branch growing through or over fence	High	
31/08/2022	43	East	drop down over grown	492886	6600770	Overgrowth	Low	
31/08/2022	44	West	grass 1m overgrown fence 250 m north	492734	6600586	Overgrowth	Low	
31/08/2022	45	West	Collapsed fence top start	492702	6600535	Fence top collapsed	Low	
31/08/2022	46	East	Thick long grass smothered fence	492501	6599267	Overgrowth	Low	Unable to view fence
31/08/2022	47	East	Vine an thick grass smothering fence under Upper Warrell Creek bridge	492194	6598856	Overgrowth	Low	
31/08/2022	48	West	Minor 100mm gap in access gate	489840	6594980	Gate gap	Low	
31/08/2022	49	West	acacia and long grass growing through western side	489712	6594813	Overgrowth	Low	
31/08/2022	50	West	Thick Lantana overgrowth 200 south back towards Upper Warrell Creek bridge	489261	6594500	Overgrowth	Low	
31/08/2022	51	West	tree dbh of 120mm immediately adjacent to fence	489363	6594363	Tree/branch growing through or over fence	Moderate	Possible to be climbed

Date	Issue number	Side	Issue identified	Easting	Northing	Type	Priority	Comments
31/08/2022	52	West	fence gate with no pad lock - parking spot Upper Warrell Creek	489361	6594355	Fence gate no lock	High	Locks have been cut off
31/08/2022	53	East	Thick acacia and long grass overgrowth 300m north			Overgrowth	Low	

Transport for
New South Wales

Warrell Creek to Nambucca Heads

Operational Phase – Year five (2023) summer interim road-kill monitoring report

Transport for New South Wales | February 2023

Pacific Highway upgrade: Warrell Creek to Nambucca Heads (WC2NH)

Road-kill monitoring – summer interim report year five (2023)

Sandpiper Ecological Surveys

Final Report
15 March 2023

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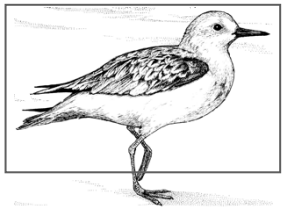

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1. Introduction

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. The Upgrade included several road-kill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate road-kill included:

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including culverts, bridges, rope bridges and glide poles.

Several fauna fence designs were installed to target threatened species including:

- **Type 1** - Chainmesh fence 1.8 m tall with floppy top feature, which is designed to exclude a range of native mammal species such as macropods, possums, spotted-tail Quoll (*Dasyurus maculatus*) and koala (*Phascolarctos cinereus*). 18.03 km of this fence type occurs at the site.
- **Type 3** - Small gauge mesh fence with sheet metal return angled away from the highway (combined with fauna floppy top fence), which is designed to exclude green-thighed frog (*Litoria brevipalmata*) from the road corridor. 1.32 km of type 3 fauna fence occurs at the site, overlapping with the type 1 fencing.
- **Type 4** - Chainmesh fence 4 m tall through the Macksville Flying-fox camp Paperbark Swamp Forest community designed to discourage grey-headed flying-fox (*Pteropus poliocephalus*) from flying within range of passing traffic when exiting or entering the roost. 1km of type 4 fence occurs at the site.

Sandpiper Ecological Surveys (SES) has been engaged by Transport for NSW (TfNSW) to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal road-kill surveys over the entire upgrade length. Monitoring of road-kill is a requirement of the approved WC2NH koala, spotted-tailed quoll and grey-headed flying-fox management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for road-kill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog (*Mixophyes iteratus*). Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Seasonal surveys are scheduled for January (summer), April (autumn), July (winter) and October (spring). 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.

The aim of road-kill monitoring is to:

- report on any vertebrate road-kill following opening to traffic.
- assess the effectiveness of fauna fencing to prevent fauna from being killed by vehicles while attempting to cross the WC2NH Upgrade.

The following report details the findings of the January 2023 sample and discusses the results in light of the monitoring aims and previous reports.

2. Methods

2.1 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the North (Figure 1).

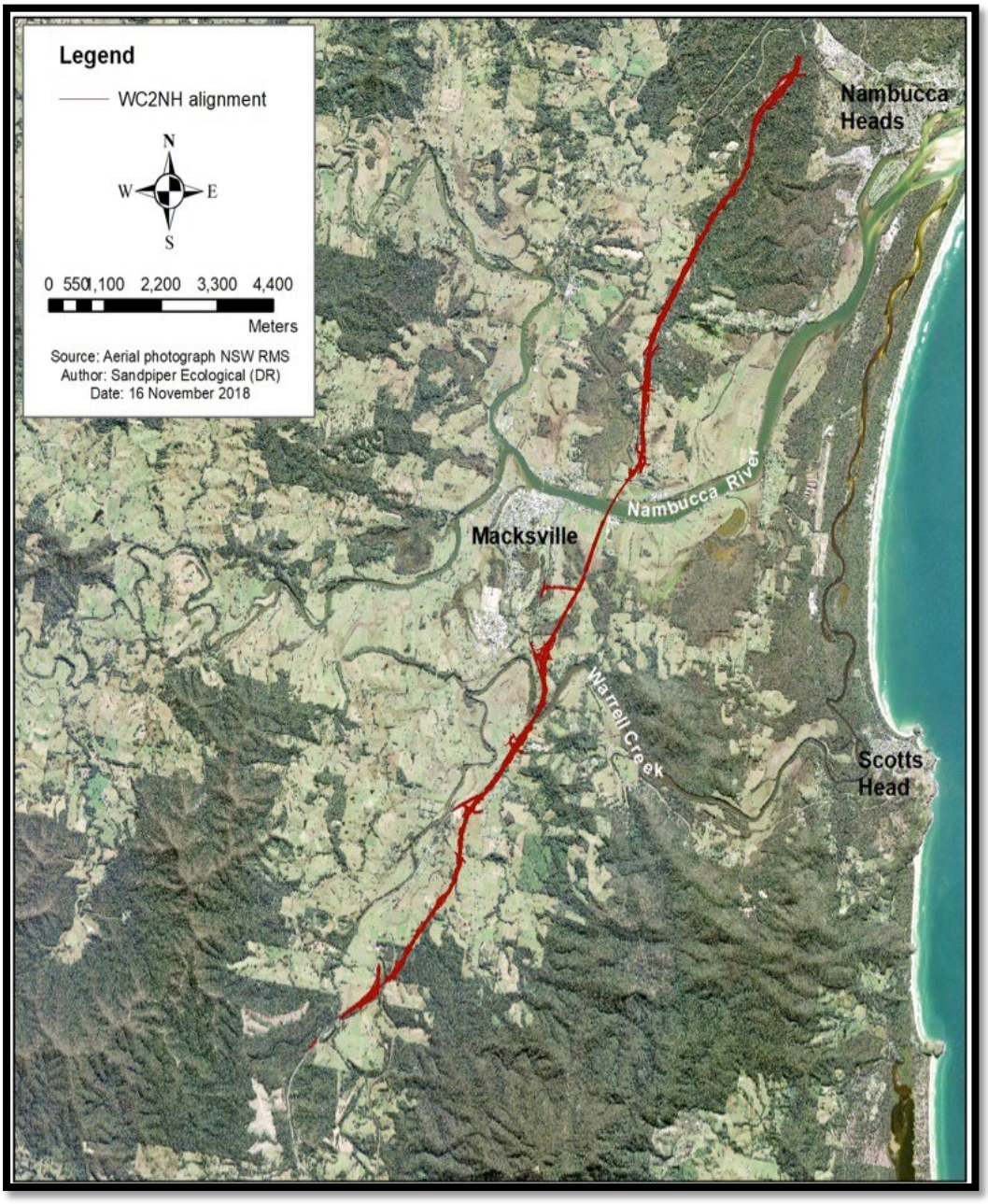

Figure 1: Location of the WC2NH alignment.

2.2 Road-kill surveys

The road mortality survey method was revised to ensure compliance with the updated TfNSW Traffic Control at Worksites Manual. The updated guidelines require vehicles to be parked 3 m from (& behind) the wire rope, 11 m from the fog line if there is no wire rope, and pedestrians to walk 3 m behind the wire rope. These distance restrictions could not be achieved using the former method, which was revised during the autumn 2021 monitoring event.

Road-kill surveys were conducted by a team consisting of a driver and an ecologist passenger who had experience identifying road-killed fauna. The surveys were conducted from a moving vehicle driven at a speed of 80-90km/hr in the left lane. The vehicle was equipped with an amber light (flashing) and a warning sign (Plate 1) to alert other drivers.

Surveys were conducted weekly during each monitoring month and began within three to four hours after sunrise. During each survey, the ecologist scanned the road surface and road shoulder for any road-killed fauna. If any fauna was detected, the species or fauna group was recorded using the internal GPS of a smart device, and the waypoint was recorded in Australia topo maps.

In cases where the fauna records were likely to be a potential target species, such as spotted-tailed quoll, koala, grey-headed flying-fox, and giant barred frog, the team inspected them more closely from a safe location.

At the end of each survey, the data were uploaded as a CSV file from Australia Topo maps and recorded into Microsoft Excel on a desktop computer for further analysis.

Plate 1: Work vehicle with signage, flashing amber light and indicators.

Data collected on each road-kill included:

- Geographic coordinate
- Presence/absence of fauna exclusion fence adjacent the record (recorded from GIS)
- Species/fauna group
- Date of survey
- Road-kill location – north or southbound carriageway

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and/or the *Biodiversity Conservation (BC) Act 2016*, included, where possible: sex and age (juvenile/adult); the presence of pouch young if applicable; the 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 the nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or road-side vegetation.

Broad size classes used to group fauna recorded at WC2NH included:

- Small mammal – rodent, juvenile bandicoot
- Medium mammal – bandicoot, brushtail possum, ringtail possum, cat
- Large mammal – wallabies and kangaroos
- Small bird – noisy miner, honeyeaters
- Medium bird – magpies, pigeons, frogmouth, swamp hen, ducks, kookaburra
- Large bird – Ibis, large forest owl, egret

2.3 Data summary and analysis

QGIS was used to identify possible duplicates in the road-kill data. This was achieved by uploading all road-kill data to QGIS and cross-referencing it with the data from the previous week and/or season (i.e., spring 2022). The consistent use of at least one team member, GPS coordinates, and carcass descriptions helped in identifying duplicates.

For temporal (i.e., years, seasons and weeks) and spatial (i.e., fenced vs unfenced) comparisons of road-kill during operational monitoring (2019-2023), road-kill totals were pooled across years and taxonomic groups (i.e., bandicoots, macropods) and converted to a rate of road-kill/km/week to enable comparisons to other highway projects of varying alignment lengths. The 2018 survey data was excluded from the pooled comparison due to the staged opening of the project occurring between 2017-2018.

2.4 Statistical analysis

Statistical analysis is to be undertaken as part of the year five annual report and was not performed on the summer 2023 dataset.

3. Results

3.1 Summer 2023 sample

3.1.1 Weather condition

Weather conditions during the road-kill surveys were generally good, with no rain during each survey and low to moderate cloud cover (Table 2). The relative humidity was moderate to high, ranging from 60% to 79%, and the temperature ranged from 24.1°C to 25.8°C (Table 2). Rainfall to 9 am varied across the surveys, with no rainfall on most survey days, except on 23/1/23, when 7 mm of rainfall was recorded. Visibility was good during all surveys and favorable for detecting road-kill.

Table 1: Weather conditions were recorded at 9 am on each sample day in October 2022. Relative humidity and temperature data were obtained from the Bureau of Meteorology Coffs Harbour Airport (station 059151) with rainfall data from the Bellwood station (059150).

Date	Rain present	Rainfall to 9am (mm)	Relative humidity (%)	Temperature (^{0}C)	Cloud cover (Oktas)	Visibility
9/1/23	Nil	0	60	22.2	0	Good
15/1/23	Nil	0	61	24.4	0	Good
23/1/23	Nil	7	68	24.1	2	Good
30/1/23	Nil	0	79	25.8	0	Good

3.1.2 Road-kill survey

A total of 32 road-killed fauna were recorded during the January 2023 sample at an overall rate of 0.41 rk/km/week (number of road-killed individuals per kilometer per week) (Table 3). Mammals were the most diverse group, with four species and five groups recorded, birds with two species and four groups, and reptile species with two groups (Table 3). Mammals were also the most frequently detected fauna group, with 18 individuals, followed by birds (11 individuals) and reptiles (3 individuals) (Table 3). Bandicoot spp. had the highest frequency of road-kill with eight records, followed by unidentifiable bird spp. (4) rodent species (3), tawny frogmouth (2), and small bird secies (2) (Table 3). The remaining road-kill records were of single individual species or groups (Table 3). No frogs or threatened species were recorded during the summer 2023 surveys. A single raptor species was recorded on the Nambucca Bridge and was identified as a probable whistling kite. The full summary of fauna recorded to date is included in Appendix A, Table A2.

Table 2: Species of vertebrate fauna recorded during year five (2023) summer (January) road-kill surveys along the WC2NH alignment. For a full road-kill summary of all surveys to date, see Appendix A, Table A2. RK=Roadkill. Pr. = probable

Species	Sum 23	Aut 23	Win 23	Spr 23	Total
Birds					
Little pied cormorant	1				
Tawny frogmouth	2				
Laughing kookaburra					
Corvus spp.	1				
Raptor spp. (pr. Whistling kite)	1				
Small bird spp.	2				
Unidentifiable bird spp.	4				
Total birds	11	0	0	0	0
Mammals					
Short-beaked echidna	1				
Red-necked wallaby	1				
Northern brown bandicoot	1				
Long-nosed bandicoot	1				
Bandicoot spp.	8				
Microbat spp.	1				
Rodent spp.	3				
Small mammal spp.	1				
Medium mammal spp.	1				
Total mammals	18	0	0	0	0
Reptiles					
Eastern blue-tongued lizard	1				
Unidentified reptile spp.	1				
Lizard spp.	1				
Total reptiles	3	0	0	0	0
Grand total	**32**	**0**	**0**	**0**	**0**
Rk/week/km	**0.41**	**0.00**	**0.00**	**0.00**	**0.00**

3.1.3 Distribution of road-kill

In summer of 2023, road-killed fauna was recorded in various sections of the WC2NH alignment (Figures 2 and 3). Road-kill records during summer year five monitoring tended to be more frequent in the northern section of the alignment to the west of Nambucca Heads (7 records), between the unfenced section south of the Mattick Road overpass to Old Coast Road (6 records), and along the Gumma floodplain including Nambucca Bridge (4 records) (Figures 2 and 3). Other records were distributed between the Bald Hill Road overpass and the project's southern extent at Upper Warrell Creek Bridge (Figure 3).

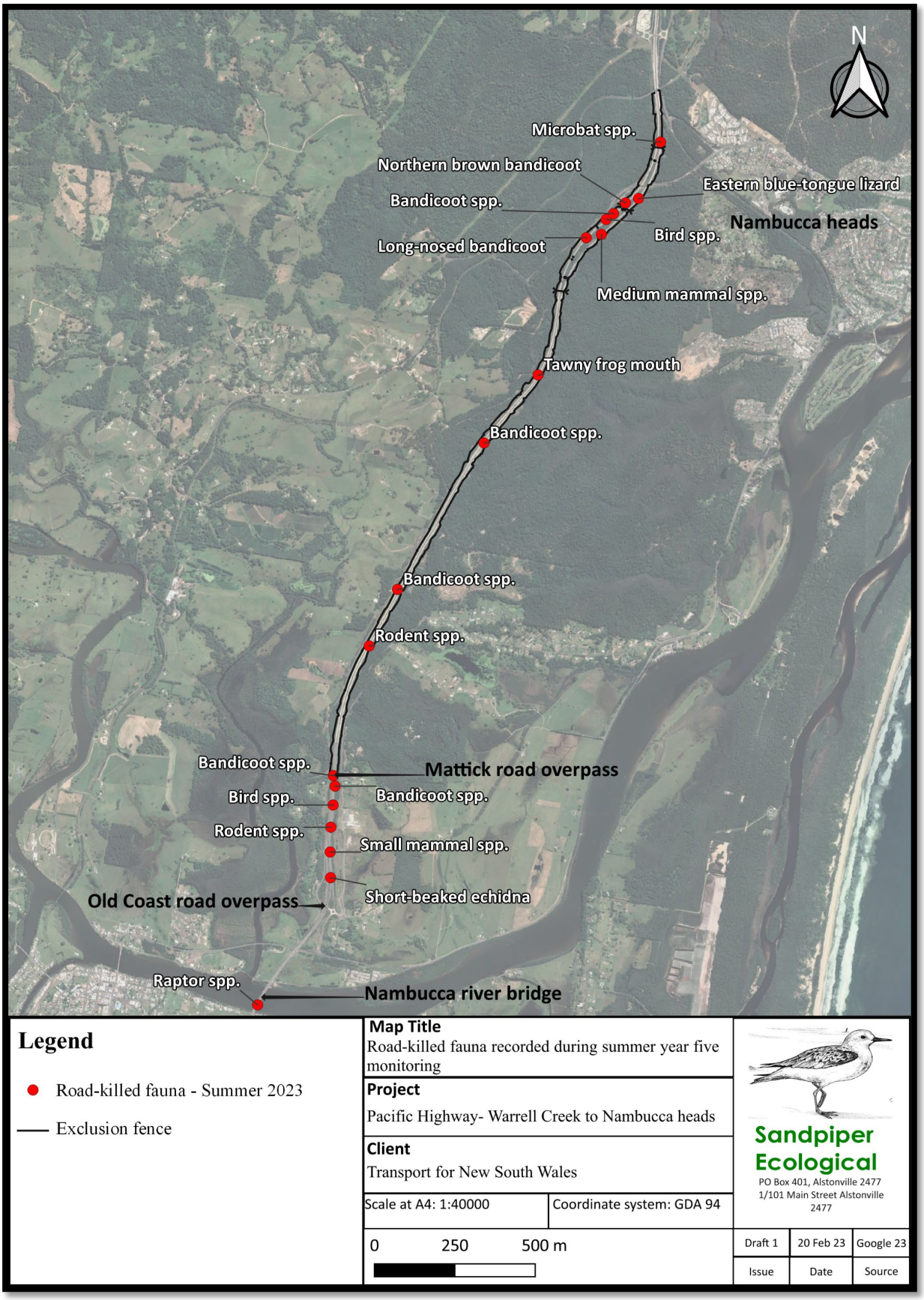

Figure 2: Location of road-killed fauna recorded in summer 2023 along the WC2NH alignment (northern extent).

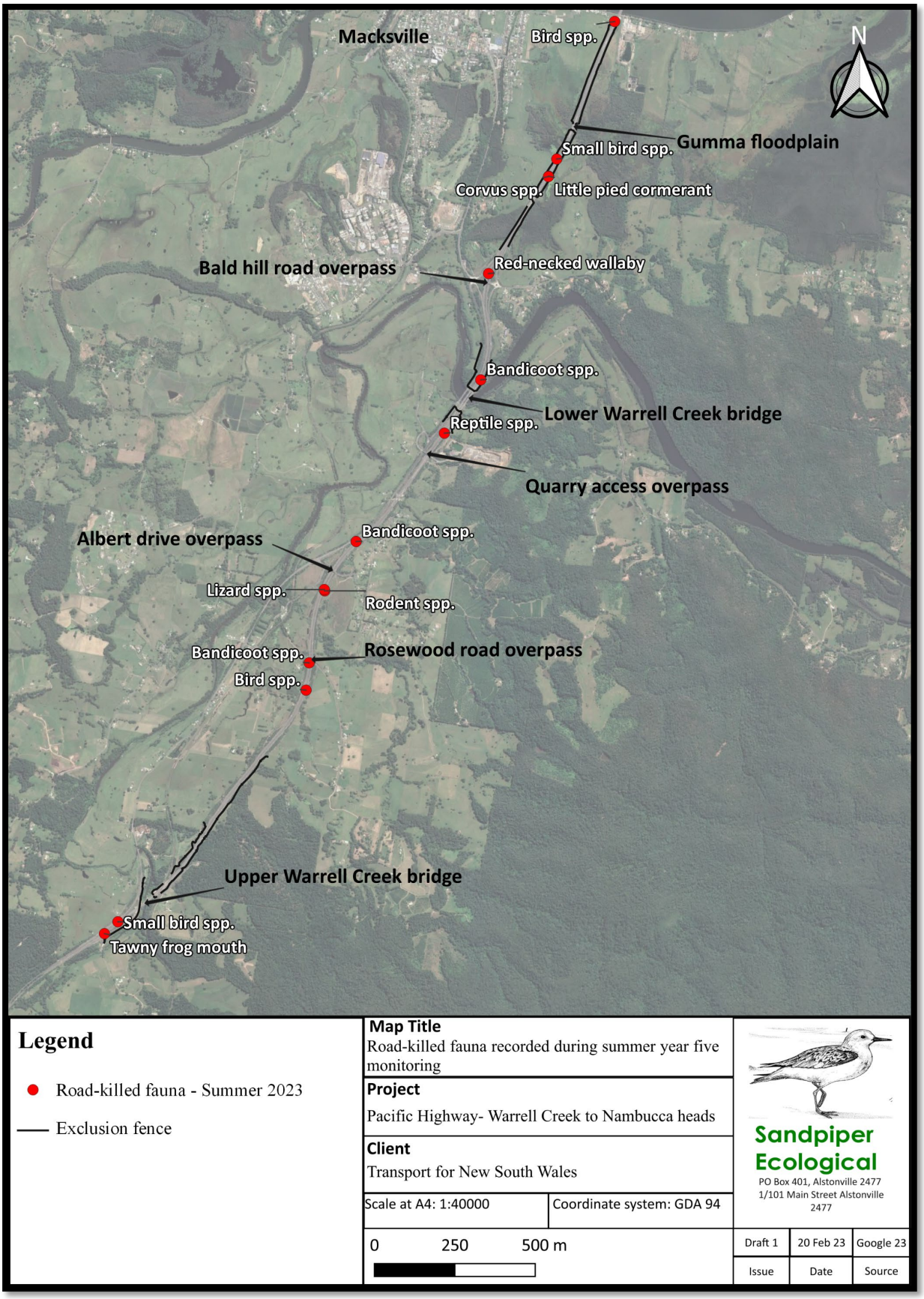

Figure 3: Location of road-killed fauna recorded in summer 2023 along the WC2NH alignment (southern extent).

More road-kill was recorded in the unfenced section of the alignment (17 records) compared to the fenced (15 records) sections (Figures 2, 3, and Table 4). Seven of the fifteen records in fenced areas were individuals that the fauna fence should block under normal circumstances, including six bandicoots and one medium mammal (Table 4). The remaining six individuals were fauna that readily move through (eastern blue-tongue lizard, rodent spp.) or over (birds and microbats) exclusion fencing (Table 4).

Bandicoots tended to be recorded along the fenced section of the alignment to the north of the Mattick Road overpass (Figure 2, 5 records), with one other record in a short fenced section to the north of Lower Warrell Creek Bridge (Figure 3). Birds were recorded on and to the south of the Nambucca River bridge, with one record of a tawny frogmouth in the northern extent of the project west of Nambucca Heads (Figure 2). One red-necked wallaby was recorded in an unfenced section of alignment near the Bald Hill Road Overpass. This was the only macropod recorded during the summer 2023 surveys (Figure 3).

Table 3: The number of road-killed fauna recorded in fenced and unfenced sections of the WC2NH alignment during the January (summer) 2023 sample period. Includes sub-totals for fauna that the fauna fence should block under normal circumstances (excluded) and fauna that would not be stopped by the fauna fence (not excluded).

Species and fauna groups	Excluded vs not excluded	Fenced	Unfenced
Long-nosed bandicoot	Excluded	1	
Northern brown bandicoot	Excluded	1	
Bandicoot spp.	Excluded	4	4
Medium mammal spp.	Excluded	1	
Red-necked wallaby	Excluded		1
Short-beaked echidna	Excluded		1
Sub-total (excluded)		**7**	**6**
Bird spp.	Not excluded	1	3
Lizard spp.	Not excluded		1
Reptile spp.	Not excluded		1
Rodent spp.	Not excluded	1	2
Small bird spp.	Not excluded	1	1
Small mammal spp.	Not excluded		1
Microbat spp.	Not excluded	1	
Tawny frog mouth	Not excluded	1	1
Little pied cormorant	Not excluded	1	
Raptor spp.	Not excluded		1
Corvus spp.	Not excluded	1	
Eastern blue-tongue lizard	Not excluded	1	
Sub-total (not excluded)		**8**	**11**
Grand Total		**15**	**17**

4. Discussion

4.1 Summer 2023

In January 2023, road-kill monitoring conducted along the entire WC2NH alignment indicated that fauna continued to be struck by vehicles more than four years after the highway upgrade opened. The summer sample recorded 32 individuals, resulting in a road-kill rate of 0.41 individuals/km/week, which is slightly below the average rate at WC2NH of 0.44 road-killed individuals/km/week (see Appendix A, Table A1). Notably it is the highest recorded summer rate since 2020 and the highest rate since autumn 2021, representing a 35% increase from the most recent spring 2022 survey (0.3 rk/km/week). Importantly, previous annual reports (Sandpiper 2019, 2020, 2021, 2022) have consistently identified temporal variation as a feature of road-kill monitoring, potentially due to seasonal changes in breeding cycles and foraging demands, as well as survey conditions, with some survey periods favoring increased carcass retention and detection such as during the dry recent summer 2023 survey. Interestingly, the observed summer road-kill rate was higher than the rate (0.3 rk/km/week) reported by Talor and Goldingay (2004) on three major roads located which were unfenced in north-eastern New South Wales.

Mammals and birds continue to comprise the majority of road kills in all surveys to date. Notably, the survey method is biased towards larger and long-lasting carcasses, which tend to be birds and mammals (Ogletree and Mead 2020). The method also reduces the ability to identify all carcasses confidently, resulting in some individuals being assigned to a size class and fauna group. The absence of amphibians in January 2023 is consistent with previous surveys and further emphasises the difficulty of identifying road-killed amphibians during vehicle-based surveys (Sandpiper 2022).

Despite exclusion fences, fauna that would normally be prevented from entering the carriageway continue to be recorded within fenced sections of the alignment similar to results in 2021 and 2022. Bandicoots, in particular, make up the majority of road-kill records within fenced areas, especially north of Mattick road, likely due to their behavior and ability to navigate through small gaps near open drains. It is unlikely that any exclusion fence can be completely effective at all times, and some level of road mortality for these species may be unavoidable. Nevertheless, it is crucial to prioritise the prevention of obvious fence breaches that allow access for priority species like spotted-tailed quoll, koala, and giant barred frog.

Only one macropod road-kill was recorded during summer 2023 monitoring which is equivalent to autumn 2022 and the lowest on record (See appendix Table A1). The record was around the known hot-spot at the Bald Hill Road overpass and continues the trend of increased risk of macropod vehicle strikes around unfenced sections of the alignment and at interchanges (Sandpiper 2022). With the data available it is difficult to confirm whether the decrease in macropods is due to a decline in local abundance caused by high road-kills in 2020 (27 individuals), particularly for red-necked wallaby (Bond and Jones 2013). A more comprehensive analysis in the annual year five report is likely to assist in determining the reason for the decline in macropod road-kills.

Data suggest that species likely to be blocked by exclusion fence are killed regardless of whether a drop-down occurs nearby. Whilst the influence of drop-downs on road-kill rate requires further analysis this observation is consistent with drop-down monitoring which showed negligible use by native fauna (Sandpiper Ecological 2019b).

4.2 Threatened fauna

Since WC2NH became operational four threatened species have been recorded as road-kill (grey-headed flying-fox, masked owl, black bittern and eastern grass owl), with no additional threatened species recorded in summer

2023. Importantly, priority threatened species including koala, spotted-tailed quoll or giant barred frog have not been recorded in road-kill surveys to date.

5. Conclusion and recommendations

Despite a slight increase in the road-kill rate during the summer of 2023 compared to previous seasons, the rate remained below the overall operational monitoring average of 0.44 road-killed individuals/km/week. However, in order to confirm any temporal trends and accurately assess road-kill rates in known hot spots, continued monitoring is necessary (Table 5).

Table 5: Recommendations based on findings of the summer year five operational phase road-kill monitoring program.

Number	Recommendation	Transport for NSW Response
1.	Continue to undertake road-kill monitoring in accordance with the Ecological Monitoring Program and the operational phase methods	Noted.

6. References

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Appendix A – Field data

Table A1: Road-kill summary of all fauna recorded to date during operational phase monitoring at WC2NH (2018-2022). * denotes threatened species; ** = stage 2a only; Sum = summer; Aut = autumn; Win = winter; Spr = spring.

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Sum 23	Total
Birds																						
Australian magpie	6	1	0	1	0	0	0	2	2	1	0	0	1	0	0	2	0	0	0	0	0	16
Grey butcherbird	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pied butcherbird	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Magpie-lark	2	0	1	0	1	0	1	0	1	0	1	1	0	1	0	1	1	3	0	0	0	14
Australian white ibis	0	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	4
Cattle egret	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Little pied cormorant	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3
Buff-banded rail	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Purple swamphen	3	0	2	2	0	1	0	2	3	0	1	1	0	3	1	1	0	0	0	0	0	20
Wonga pigeon	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
White-headed pigeon	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Crested pigeon	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3
Galah	7	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Rainbow lorikeet	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Eastern grass owl*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Australian boobook	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4
Masked owl*	1	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4
Eastern barn owl	0	0	11	3	0	1	5	2	1	0	0	0	0	0	0	1	0	0	0	0	0	24
Tawny frogmouth	1	3	1	2	0	6	0	4	0	1	0	1	1	1	1	0	0	0	1	0	1	24

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Sum 23	Total
Australian owlet-nightjar	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Laughing kookaburra	3	0	2	1	0	2	0	3	1	1	2	1	0	0	0	2	2	0	0	0	1	21
Forest kingfisher	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Australian wood duck	20	0	0	2	2	0	1	2	0	0	0	2	1	0	0	0	0	0	0	0	0	30
Pacific black duck	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Whistling kite	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Black-shouldered kite	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Torresian crow	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Pied currawong	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	3
Black-faced cuckoo-shrike	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Noisy miner	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	4
Dollarbird	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Green catbird	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Australasian figbird	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Black bittern*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Eastern yellow robin	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pheasant coucal	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0	4
Masked lapwing	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Welcome swallow	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Red-browed finch	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Raptor spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Duck spp.	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Corvus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Tyto spp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Small bird	0	0	0	0	0	0	0	2	0	0	0	0	0	1	1	0	1	2	2	0	2	11

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Sum 23	Total
Medium bird	0	0	0	1	2	2	2	2	6	1	1	0	0	2	0	2	0	0	0	0	0	21
Unidentifiable bird	5	4	1	0	3	0	0	0	0	0	2	2	1	0	2	2	2	7	0	2	4	37
Total birds	53	8	22	17	18	16	13	25	16	11	8	9	10	12	8	11	6	14	4	2	11	294
Mammals																						
Short-beaked echidna	0	0	0	3	0	0	0	2	0	1	2	1	0	0	0	0	0	1	0	1	1	12
Black flying-fox	2	1	0	0	7	1	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	15
Grey-headed flying-fox*	0	0	0	0	8	0	0	5	2	0	0	0	0	2	0	0	0	0	0	0	0	17
Pteropus spp.	0	0	0	0	3	8	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	15
Short-eared brushtail possum	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Common brushtail possum	0	0	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4
Trichosurus spp.	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	3
Common ringtail possum	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Eastern grey kangaroo	0	0	0	3	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	5
Red-necked wallaby	0	0	6	0	8	2	8	3	7	1	8	3	1	1	4	2	1	0	3	3	1	62
Swamp wallaby	2	1	0	1	0	1	1	0	0	1	1	2	1	0	2	1	1	0	4	0	0	19
Wallaby spp.	0	0	0	0	0	2	0	0	3	0	0	2	0	1	0	1	2	1	0	2	0	14
Macropod spp.	3	0	2	1	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	10
Northern brown bandicoot	1	0	1	0	1	1	1	2	2	3	3	0	1	2	2	1	0	0	2	1	1	25
Long-nosed bandicoot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Bandicoot spp.	0	0	0	0	0	1	0	4	0	0	0	1	0	2	4	2	4	3	4	9	8	42
Chalinolobus spp. (microbat)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Microbat spp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3
Swamp rat	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Rodent spp.	0	0	0	0	0	2	0	0	0	0	0	1	0	0	1	1	1	1	2	0	3	12
Small mammal	0	0	0	0	2	0	0	0	0	0	1	0	1	3	0	0	0	1	0	0	1	9

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Sum 23	Total
Medium mammal	0	0	0	2	4	2	4	5	2	2	2	0	0	2	4	2	2	3	1	0	1	38
Large mammal	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	4
Unidentified Mammal	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Total mammals	9	2	10	17	37	20	17	23	18	13	20	10	5	16	18	10	12	11	17	16	18	319
Reptiles																						
Common blue-tongued skink	1	0	0	2	1	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	1	8
Carpet python	1	0	0	2	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	7
Common tree snake	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Eastern long-neck turtle	1	0	0	6	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	10
Macquarie river turtle	5	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Unidentified *Chelidae* spp.	6	0	0	0	0	0	0	1	0	0	0	1	2	4	1	0	0	1	1	2	0	19
Red-bellied black snake	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Eastern water dragon	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Eastern bearded dragon	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	2
Blackish blind snake	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Yellow-faced whipsnake	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Unidentified reptile	0	0	0	0	0	0	0	2	0	1	0	0	0	2	0	0	2	3	0	0	1	11
Lizard spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Total reptiles	17	3	0	12	2	2	1	5	2	2	0	4	4	7	1	0	2	4	1	4	3	76
Frogs																						
Green tree frog	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Striped marsh frog	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Medium frog	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Large frog	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total frogs	5	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Sum 23	Total
Introduced species																						
Cat	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	3
Dog	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
European fox	3	1	1	2	1	1	2	0	0	0	0	0	0	1	2	0	0	0	0	0	0	14
European hare	2	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	1	0	0	8
Rabbit	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Black rat	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	4
House mouse	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rock pigeon	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Domestic goose	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
Total introduced species	8	1	2	5	2	2	2	0	0	1	0	2	1	2	2	1	4	0	1	0	0	36
Grand total	**92**	**14**	**34**	**55**	**59**	**40**	**33**	**53**	**36**	**27**	**28**	**25**	**20**	**37**	**29**	**22**	**24**	**29**	**23**	**22**	**32**	**734**
Rk/week/km	**1.16**	**0.18**	**0.43**	**0.70**	**0.75**	**0.51**	**0.42**	**0.67**	**0.46**	**0.34**	**0.35**	**0.32**	**0.25**	**0.47**	**0.37**	**0.28**	**0.30**	**0.37**	**0.29**	**0.28**	**0.41**	**0.44**