Warrell Creek to Nambucca Heads Pacific Highway Upgrade

Commonwealth Approval EPBC 2013/7101
Annual Compliance Report
February 2023 – February 2024

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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 2023 to February 2024.

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 ninth reporting period (February 2023 – February 2024).

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

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
Detailed Design	Areas for STQ 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
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	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
	site the protocol shown in Table 4.1 is to be implemented.		
Construction	STQ Management Protocol (Table 4-1) to be implemented requiring all personnel to report STQs (including road kill). Assessment of future road kill risk including adaptive management actions to be provided by Project Ecologist where STQ road kill is detected.	No STQ roadkill has been identified on the Project.	Roadkill records and quarterly reports
Construction	Progressive rehabilitation of identified areas refer to Appendix C) during the construction stage using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation. Key rehabilitation measures would include: - Progressive revegetation/rehabilitation during the construction phase using collected topsoil and seed at specific sites and to develop different successional stages of rehabilitation. -Planting of locally occurring species, including plants representative of groundcover, understorey and canopy strata. - 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

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
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. soil and/or mulch over the concrete floor and apron. Advice will be provided by the project ecologist on fauna furniture to be installed within fauna crossing structures.	The EPA/Fisheries has been consulted with and have provided input into the detailed design of the fauna crossing structures including the fauna furniture design. The fauna furniture design has been demonstrated on site using a prototype and shown to the EPA. The EPA are satisfied with the general arrangement. The fauna drop down design has been demonstrated on site using a prototype and shown to the EPA. The EPA are satisfied with the general arrangement.	Detailed design drawings

Table 3.4 Compliance with the Giant Barred Frog Management Plan

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

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	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) 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	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 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.	Pre-clearing and Ground Disturbance Permit Site Inspection Record Urban Design and Landscape Plan
Construction	Giant Barred Frog road kill to be reported to the Project Ecologist 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	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	Urban Design and Landscape Plan Giant Barred Frog

Timing	Mitigation Measure	Implementation Comment	Compliance Evidence
	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 Monitoring and maintenance of plantings Managing and controlling weeds	rehabilitation of Upper Warrell Creek.	Monitoring Reports.

The Ecological Monitoring Annual Report 2023 - 2024 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. 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 final Bellingen Island Camp Management Plan has been provided to the Commonwealth Post Approvals on 4th March 2024 for Delegate Approval. The BSA for the Ainsworth Foraging Site is on track to be submitted to the BCT in June 2024.

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.
24.9	Prepare compliance report and upload to project website	By 9 May 2024	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/document-library?keyword=Warrell%20Creek%20to%20Nambucca%20Heads&date_from=&date_to=

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 - 2024

Transport for New South Wales

Warrell Creek to Nambucca Heads Pacific Highway Upgrade

Koala Monitoring Annual Report- Operational Phase, Year Five (2022-2023)

Transport for New South Wales | March 2024

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

Koala Monitoring Annual Report – Operational Phase, Year Five (2022-2023)

Sandpiper Ecological Surveys

Final Report

March 2024

Document Distribution

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
20/2/2024	A	Draft	L. Andrews & D. Rohweder	Sandpiper	MSW	N. Steel
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1/3/2024	2	Final	J. Sheehan	TfNSW	MSW	L. Andrews

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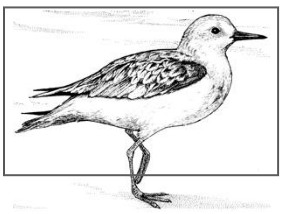

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Cover Photo: Koala recorded on the western side of the alignment during nest box monitoring in spring 2022.

Table of contents

List of tables

List of figures

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 report details the results pertaining to koala in year four and five of operational monitoring, which extends from August 2021 to August 2023. The report summarises results obtained from three monitoring tasks: koala population surveys; monitoring of underpasses and adjacent habitats and opportunistic records obtained during yellow-bellied glider population monitoring in Nambucca State Forest. The aim of koala monitoring is to identify changes in resident koala activity (abundance, home range and movements) in response to construction of the WC2NH upgrade and assess the effectiveness of koala habitat connectivity mitigation measures (i.e. fauna underpasses and exclusion fencing).

1.1 Background

The impact of the upgrade on koala (*Phascolarctos cinereus*) was assessed in the Project Environmental Assessment (Sinclair Knight Merz [SKM] 2010a, SKM 2010b), and following 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 project 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) it 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 koala monitoring methodology was developed to establish a pre-construction baseline. This involved conducting initial surveys during the autumn and spring of 2014 to assess the koala population and habitat conditions (SKM 2014). Subsequent monitoring efforts were carried out during the construction phase, with surveys conducted in the spring of 2015 (year 1 of construction) and 2017 (year 3 of construction) (Geolink 2017). As per the operational phase monitoring requirements, surveys were also conducted in the spring of 2018 (year 1 of operation) and 2020 (year 3 of operation), by Sandpiper Ecological (2018, 2021).

The following report describes the methods and results of the final year (Year 5) of koala population monitoring during the operational phase of the WC2NH project. It also evaluates the effectiveness of habitat connectivity measures, such as underpasses and exclusion fencing, in enabling koala movement and preserving habitat integrity. The report covers the targeted koala surveys conducted in spring 2022 and compiles all recorded koala data from baseline, construction, and operational monitoring phases. It examines koala movement patterns and underpass use, and assesses any changes in habitat use and the success of the mitigation strategies based on the following outcomes:

- The koala population near Nambucca State Forest/Old Coast Road has remained stable in abundance and distribution.
- The underpasses are used by koalas at a sufficient frequency to sustain the population.
- There have been no or few koala vehicle collisions in the area, indicating effective road risk mitigation.
- The fauna exclusion fencing has remained intact, with no breaches found, and the vegetation management has maintained a clear buffer zone to ensure the fencing effectiveness.

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.

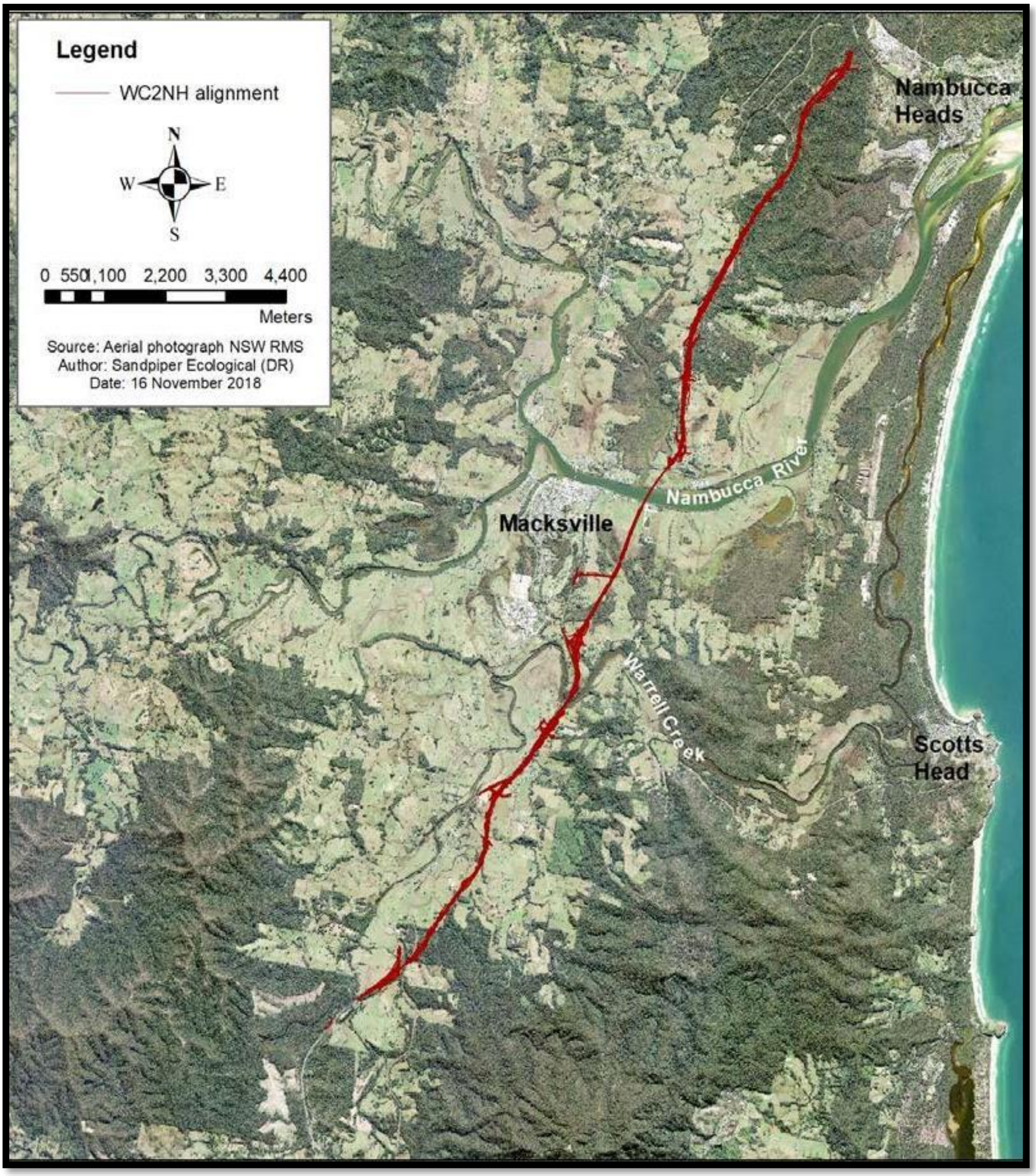

Figure 1: Footprint of the WC2NH pacific highway upgrade.

2 Methods

Methods used to sample koalas are summarised in the year five operational phase interim koala population monitoring report (Sandpiper 2022a), year five operational phase interim underpass monitoring report (Sandpiper 2023a) and year four operational phase yellow-bellied glider population monitoring report (Sandpiper 2023b). In this biennial report, data includes koala observations from year four and five underpass monitoring and spotlighting efforts, along with song meter recordings from yellow-bellied glider population surveys conducted during year four and six of operation.

3 Results

3.1 Spring 2022 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 (*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 (*Eucalyptus microcorys*) on transect E14, and beneath a small-fruited grey gum (*Eucalyptus propinqua*) on transect W10 (Table 2).

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 the species presence 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 in *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

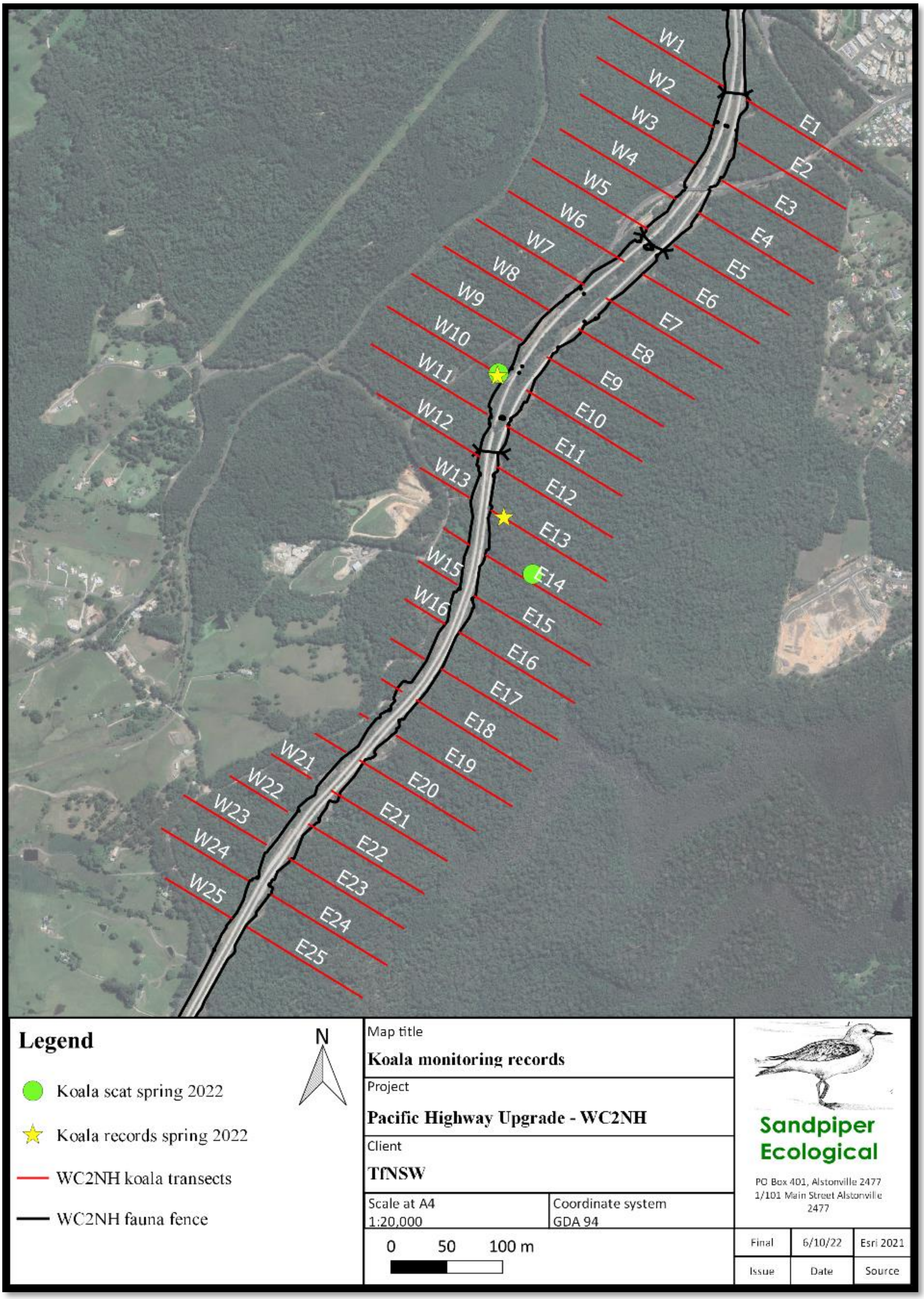

Figure 2: Location of koala records during spring 2022 monitoring at WC2NH.

3.2 Underpass monitoring

Koalas were recorded using underpasses to make complete crossings beneath the highway in both years four and five. In year four spring/summer, a koala was recorded via infra-red camera at site 4, and scat was recorded during adjacent habitat diurnal surveys at sites 7 and 8 (Table 3, Fig 3). During winter 2022, four underpasses were used by koalas to make complete crossings, including sites 2 (one occasion), 4 (one occasion) and 11/12 (two occasions) (Table 3, Figures 3 & 4). Scat was also detected in adjacent habitat diurnal surveys during winter 2022 at site 4 (Table 3). In spring year five, one koala was photographed at site 4, and in winter, koalas were detected making complete crossings at sites 9/10 and 11/12 (Plate 1) (Table 3, Figure 3). Adjacent habitat nocturnal surveys in year five spring/summer detected one healthy female on the east side of the alignment at site 9/10, and in winter, one individual was recorded on the west side of the alignment approximately 30 m from the entrance to site 7 (Table 3, Figure 3). Scat was detected in winter during adjacent habitat diurnal surveys underneath a tallowwood (*Eucalyptus microcorys*) on the east side of the alignment at site 11/12 (Table 3, Figure 3).

Plate 1: Koala recorded moving east through site 12 (L) and 11 (R) on 25 August during winter 2023 monitoring.

Table 3: Koalas recorded during underpass monitoring in year four and five operational phase monitoring for the WC2NH upgrade. * = scat, spr = spring, sum = summer, win = winter.

Survey type	Site			
	Spr/sum 21/22	Win 2022	Spr/sum 22/23	Win 2023
Infra-red camera	4	2, 4, 11/12	4	9/10, 11/12
Adjacent habitat diurnal surveys	7*, 8*	4*		11/12*
Adjacent habitat nocturnal surveys			9/10	7

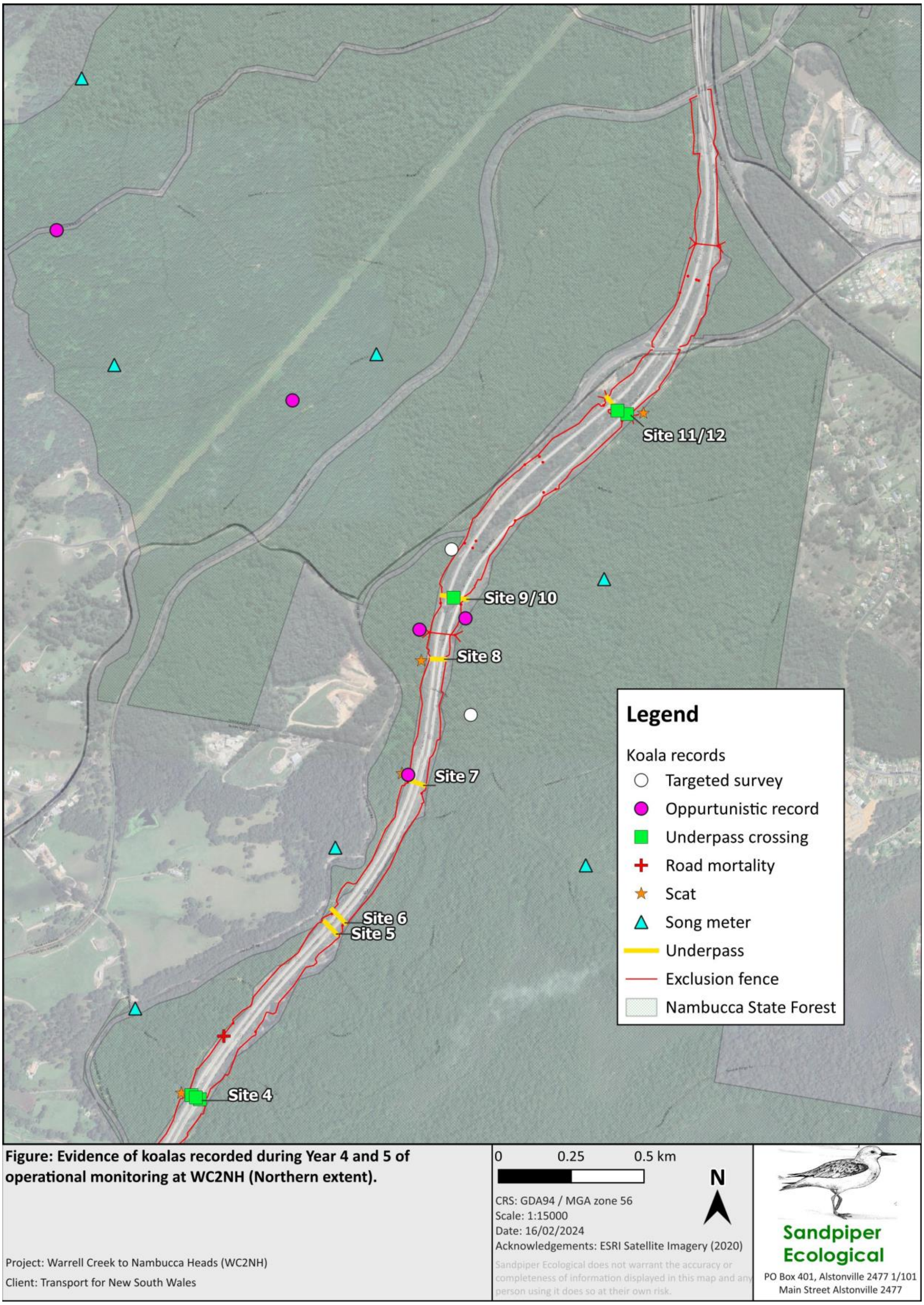

Figure 3: Location of koala records during year four and five monitoring at WC2NH (northern extent).

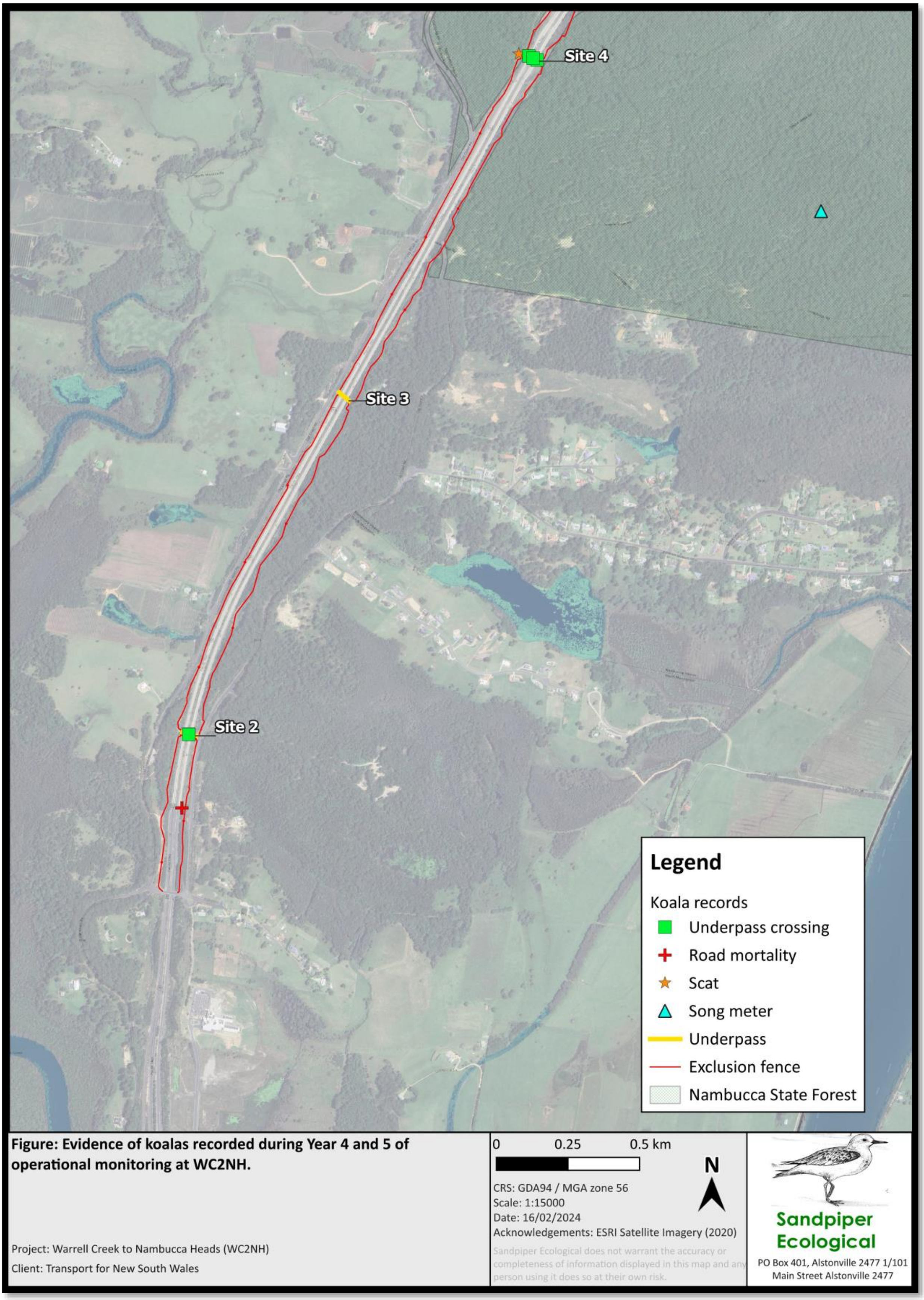

Figure 4: Location of koala records during year four and five monitoring at WC2NH (southern extent).

3.3 Roadkill records

Two road-killed koalas were recorded along the WC2NH alignment during year four and five monitoring. This included an incidental record on the northbound carriageway at 495821, 6607892 on 9 November 2022, approximately 2.8 km south of the Old Coast Road overpass, and one male during the winter road-kill survey at 494499, 6605063 on 3 July 2023, 290 meters north of the Mattick Road overpass on the southbound roadside verge (Figures 3 & 4).

In response to the koala record on 9 November 2022, an initial fence inspection was undertaken by Sandpiper 200m north and south of the record. A follow up fauna fence inspection was conducted 500m either side of the road-kill location on 10 November 2022 by TfNSW maintenance team to identify any obvious breech locations. Multiple potential points of entry were identified during both inspections, including vegetation against fauna fencing, gap in access gate and two missing panels in fauna fence. Repair work commenced in the week of 21 November 2022 to rectify and eliminate these possible breach causes.

Immediately following the koala road-kill on 3 July 2023, a search was conducted 200 m either side of the incident. The search identified a eucalyptus tree with a diameter of approximately 150mm growing through the fence on the west side, just south of the Site 2 underpass. A follow up inspection was carried out by the TfNSW maintenance team on 7 July 2023 and a small tree with possible koala claw markings over 500 metres north of the incident site was identified and removed. Additionally, heavy vegetation growth was noted and scheduled for mulching, including the tree identified as part of the fence inspection immediately following the koala road-kill.

3.4 Opportunistic records

Opportunistic records of koalas were collected whilst conducting spotlight and song meter surveys for yellow-bellied glider and nest-box surveys. Song-meters detected koala at eight sites (S1, 5-7, 9-12) during spring/summer 2021/2022. Calls were recorded on both sides of the highway and extended from song meter #5 near Jacks Ridge Mountain Bike Park in the south to song meter #9 near Gordons Knob Road in the north (Figures 3 & 4). One koala was recorded during yellow-bellied glider spotlight surveys on the west side of the highway on 21/8/2023 along Rosegum Trail (496057, 6610077) (Figure 3). Additionally, during nest-box surveys on 27 July 2022, a koala was recorded approximately 100 metres north-west of underpass 8 (496493, 6609289) (Figure 3).

3.5 Habitat use and distribution

Throughout monitoring, koalas have been recorded using both Open Blackbutt Forest on ridges and mid slope, and Flooded Gum Moist Open Forest in gullies. Occupied tree species during spring 2022 transect surveys included small fruited grey gum (*Eucalyptus propinqua*) and black sheoak (*Allocasuarina littoralis*), with scats recorded beneath tallowwood (*Eucalyptus microcorys*) and *E. propinqua*.

In 2022, targeted koala records occurred towards the centre of the study area (Figure 5). Year five koala and scat records were in a similar area to the records near sites 7, 8 and 9/10 in baseline, construction year three and operational years one and three (Figure 5).

Koala records show that the species continues to use habitat on both sides of the carriageway and records obtained from underpass monitoring show that individuals have utilised dedicated underpasses to move across the carriageway. Throughout operational monitoring, koalas have been recorded using site 4 during all years, sites 9/10 during years 1, 2 and 5, site 11/12 during years 1, 4 and 5, site 8 during year 3 and site 2 during year 4 (Figures 5 & 6).

Opportunistic records including song meter records show that koalas continue to be widely distributed in Nambucca State Forest, with records at song meter 1, 7 and 9-12 throughout both 2020/21 and 2022/23, S2, 3 and 8 during 2020/21 and S5 and 6 during 2022/23. Importantly, the song meter records are opportunistic and a more targeted monitoring program would likely result in additional records.

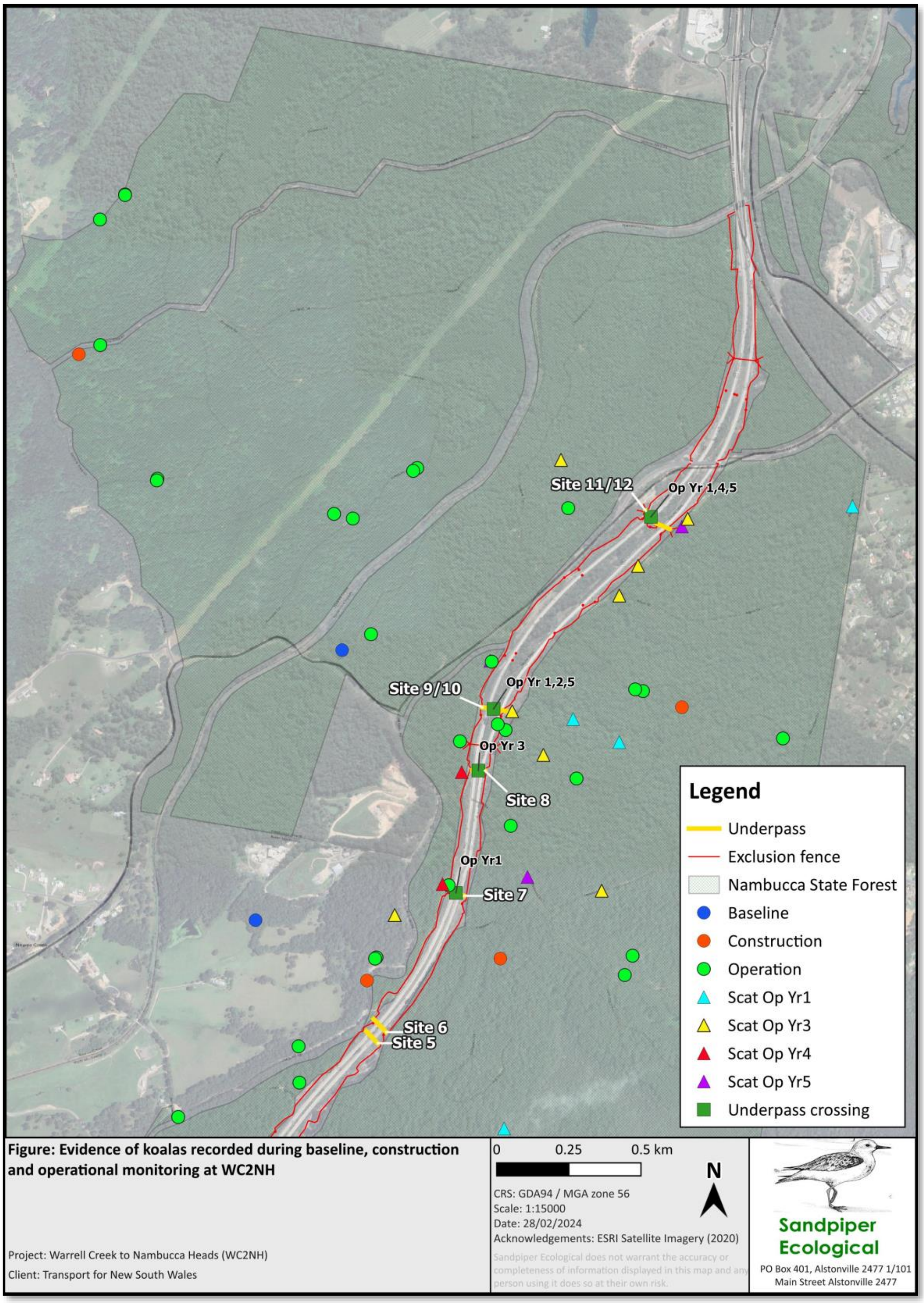

Figure 5: Evidence of koalas recorded during baseline, construction and operational monitoring at WC2NH (northern extent). Dots indicate koalas recorded during targeted surveys, spotlight surveys, song meters and opportunistically.

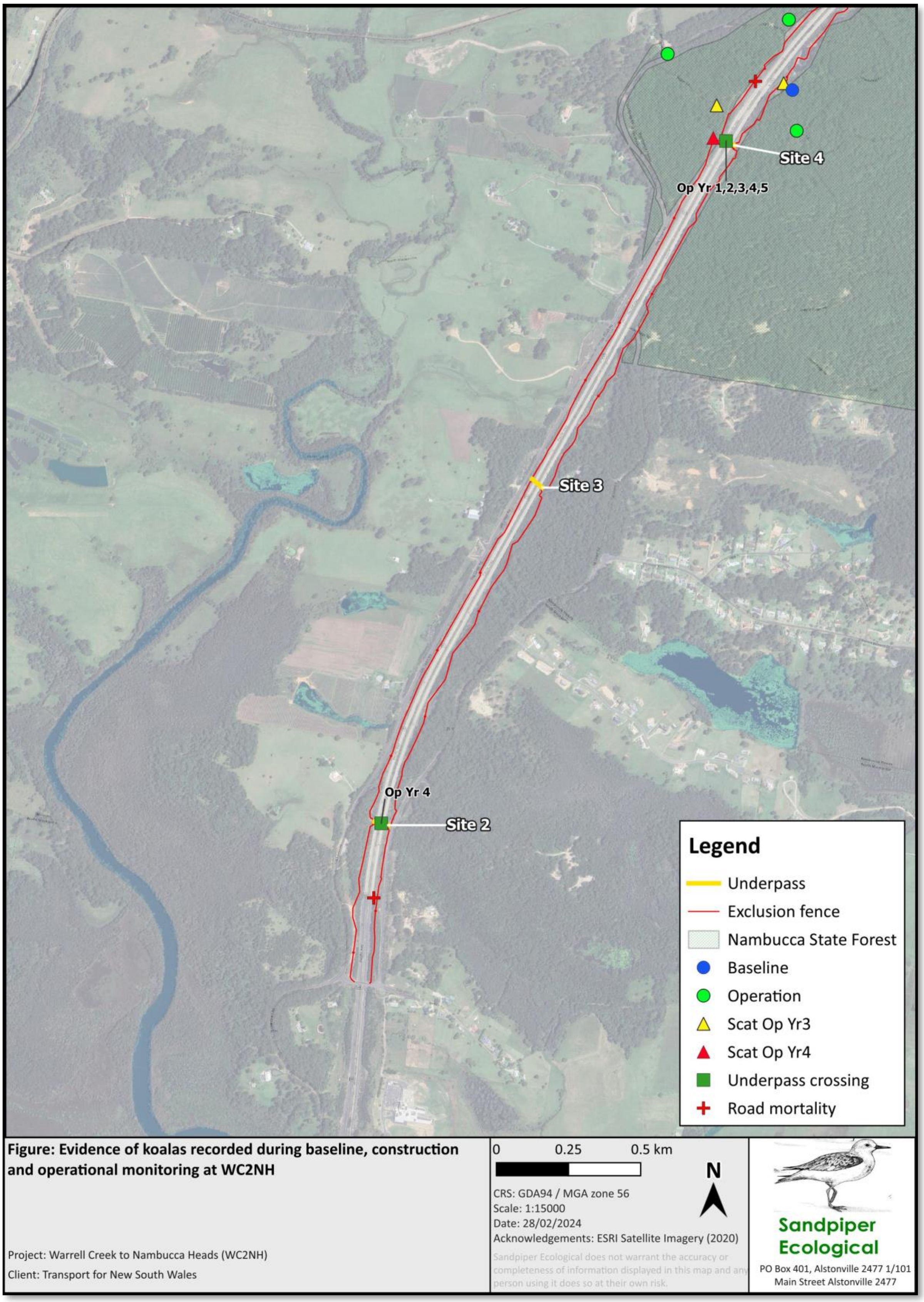

Figure 6: Evidence of koalas recorded during baseline, construction and operational monitoring at WC2NH (southern extent).

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 tracks and easements where most koalas have been recorded previously (Table 3 refer to previous reports). 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.

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 transect survey area, estimated to be approximately 104 ha (Sandpiper Ecological 2021). Home range areas of koalas residing in moderate to high quality habitat on the north coast is reportedly in the range of 23-37 ha (see Lassau *et al.* 2008; Goldingay & Dobner 2014). Koala density in the lower Richmond River range from 0.047 to 0.084 individuals/ha^{-1} (Sandpiper Ecological 2024). 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 resident individuals.

Despite fewer koala observations during 2022 targeted surveys compared to 2017 and 2018, the presence of several other records suggests that there are most likely more than two koalas residing in the study area. Additional koala records obtained during the year 5 survey period included opportunistic detection of two individuals, scats at six spatially separated locations, detection of koala calls at eight sites, camera records in six underpasses and detection of two individuals during adjacent habitat nocturnal surveys. The presence of calling males at eight sites and the broad distribution of records (see Figures 5 & 6) indicates that the area of NSF east and west of the highway supports a viable koala population.

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 koala calls and scats across the study area, especially adjacent to the upgrade corridor.

Two road-kill koalas were observed along the WC2NH alignment during year four and five monitoring, including one adjoining NSF near underpass 4. Due to the small population of koalas, these records are significant, and highlight the importance of ongoing fence maintenance to reduce the likelihood of koalas accessing the road corridor.

4.2 Habitat use and distribution

Individuals recorded in the recent 2022 surveys were located near underpasses 8 and 9/10 amongst open blackbutt forest on ridgelines, which has previously been noted as a preferred habitat type for koalas at WC2NH, particularly when tallowwood is also present (Sandpiper Ecological 2021).

Koala sightings, call records and scats east and west of the highway corridor combined with numerous complete crossings of six underpasses shows that the WC2NH Pacific Highway Upgrade is not a barrier to movement. The frequency of underpass records strongly suggests that the upgrade has been successful in maintaining habitat connectivity for koalas and the patterns of underpass use indicates use by resident, dispersing and breeding individuals. For example, a (likely) resident koala has used the site 4 underpass to cross the highway 30 times over the five-year survey period. This contrasts with the occasional winter dispersal or spring/summer breeding movements recorded at other underpasses. The ability to move beneath the highway is particularly important to ensure viability of the local population and enable koalas to cope with stochastic events such as drought and bushfires.

Since underpass monitoring commenced in 2018/19, koalas have been recorded using seven of the 12 structures monitored. Operational monitoring during years three and four suggested evidence of a slight temporal decline, however, monitoring in years four and five do not support this.

5 Conclusion and recommendations

The WC2NH upgrade has complied with all goals of the Koala Management Plan (KMP; Table 4). Monitoring has shown that connectivity has been maintained with koalas making complete crossings at six underpasses and moving both east and west during operational phase monitoring. Limitations of the koala monitoring method means that a robust temporal comparison of koala abundance is not possible and the only conclusion that can be drawn from the targeted survey data is that numbers recorded in year 5 were slightly higher than baseline. Importantly, results show that koalas continue to occur at a low-moderate density throughout NSF. The two road-kill koalas recorded in years 4 and 5 monitoring are significant and ongoing fence inspections and maintenance is essential to reduce the likelihood of koalas accessing the road corridor (Table 5). Landscape plantings are slowly becoming established and are supporting movement of koalas beneath the highway.

Table 4: Compliance with Table 6.1 from the Koala Management Plan.

Main goal	Performance criteria	Has performance criteria been satisfied	Corrective action required
Maintain connectivity for koalas potentially occurring either side of the upgrade.	No change to densities, distribution, habitat use and movement patterns compared to baseline Koala population data.	**Yes.** Koala abundance in year five is greater than baseline. Koalas continue to occur on both sides of the highway and regular movement beneath the highway has been confirmed.	No corrective action required.
Minimise road-kill of koala during operation of the WC2NH Project.	All fauna fencing is installed at the minimum number of locations identified in the	**Yes.** However, two road-kill koalas were recorded in years four and five monitoring and breaches were found	No corrective action is required.

	EPBC approval prior to the operational phase of the WC2NH Upgrade.	in the fencing, highlighting the importance of ongoing fence inspections and maintenance to reduce access to the road corridor.	
Maintain habitat rehabilitation areas.	Self-sufficient areas of rehabilitated habitat for Koalas within all nominated areas.	**Yes.** Plantings are more established and seem to be supporting underpass use by koalas.	No corrective action is required.

Table 5: Recommendations based on findings of the year five koala monitoring.

Number	Recommendation	Transport for NSW Response
1.	Vegetation management and ongoing maintenance around the exclusion fence is warranted to minimise the risk of koalas accessing the alignment	Agree.

6 References

DoE (2013a). *EPBC Act Policy Statement 1.1 Significant Impact Guidelines.* Department of Environment and Heritage, Canberra.

GeoLINK (2016). *Koala Management Plan. Warrell Creek to Nambucca Heads Upgrade of the Pacific Highway*. Unpublished report prepared for Acciona and Ferrovial Joint Venture and Roads and Maritime Services.

GeoLINK (2017). *Construction stage (year 3) koala monitoring. Warrell Creek to Nambucca Heads Pacific Highway Upgrade*. Report prepared for Roads and Maritime Services.

Goldingay, R. L. & Dobner, B. (2014). Home range areas of koalas in an urban area of northeast New South Wales. *Australian Mammalogy:* **36,** 74-80.

Lassau, S. A., Close, R., Ryan, B. & Pile, J. (2008). Home ranges and mortality of a roadside koala *Phascolarctos cinereus* population at Bonville, New South Wales. *Australian Zoologist:* **34,** 127-136.

Sandpiper Ecological (2018). *Warrell Creek to Nambucca Heads Koala Monitoring Report – Year One Operational Phase – Final Report.* Report prepared for Roads & Maritime Services NSW.

Sandpiper Ecological (2021). *Warrell Creek to Nambucca Heads Underpass Monitoring Report – Year three Operational Phase.* Report prepared for Transport for New South Wales.

Sandpiper Ecological (2022a). *Warrell Creek to Nambucca Heads Koala Monitoring Interim Report- Operational Phase, Year five*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2022b). Warrell Creek to Nambucca Heads: underpass monitoring report, year four operational phase. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2023a). Warrell Creek to Nambucca Heads: underpass monitoring report, interim year five operational phase. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2023b). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads: yellow-bellied glider (Petaurus australis) population monitoring: year four operational phase.* Report prepared for Transport for New South Wales.

Sandpiper Ecological (2024). *Woolgoolga to Ballina Pacific Highway Upgrade: koala population monitoring program, annual report: year 6 2022/23*. Draft report prepared for Transport for New South Wales.

SEWPAC (2012). *Interim koala referral advice for proponents*. Department of Sustainability, Environment, Water, Population and Communities, Canberra.

SKM (2014). *Draft Pre-clearance Baseline Koala Monitoring Methodology*. Unpublished report prepared for Acciona and Ferrovial Joint Venture and Roads and Maritime Services.

Transport for New South Wales

Warrell Creek to Nambucca Heads

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

Transport for New South Wales | September 2023 | Final Report

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

Giant Barred Frog – operational phase year five summer interim report (2022-2023)

Sandpiper Ecological Surveys

Final Report

9 September 2023

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Table of contents

List of tables

List of figures

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 summer 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 pre-construction, 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, de-watering 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 with the absence of giant barred frog records during construction and operational surveys. As such, monitoring in year 5 focused on a 1km transect at Upper Warrell Creek. The transect extended either side of the upgrade alignment and was divided into 21 zones per baseline monitoring (Figure 2).

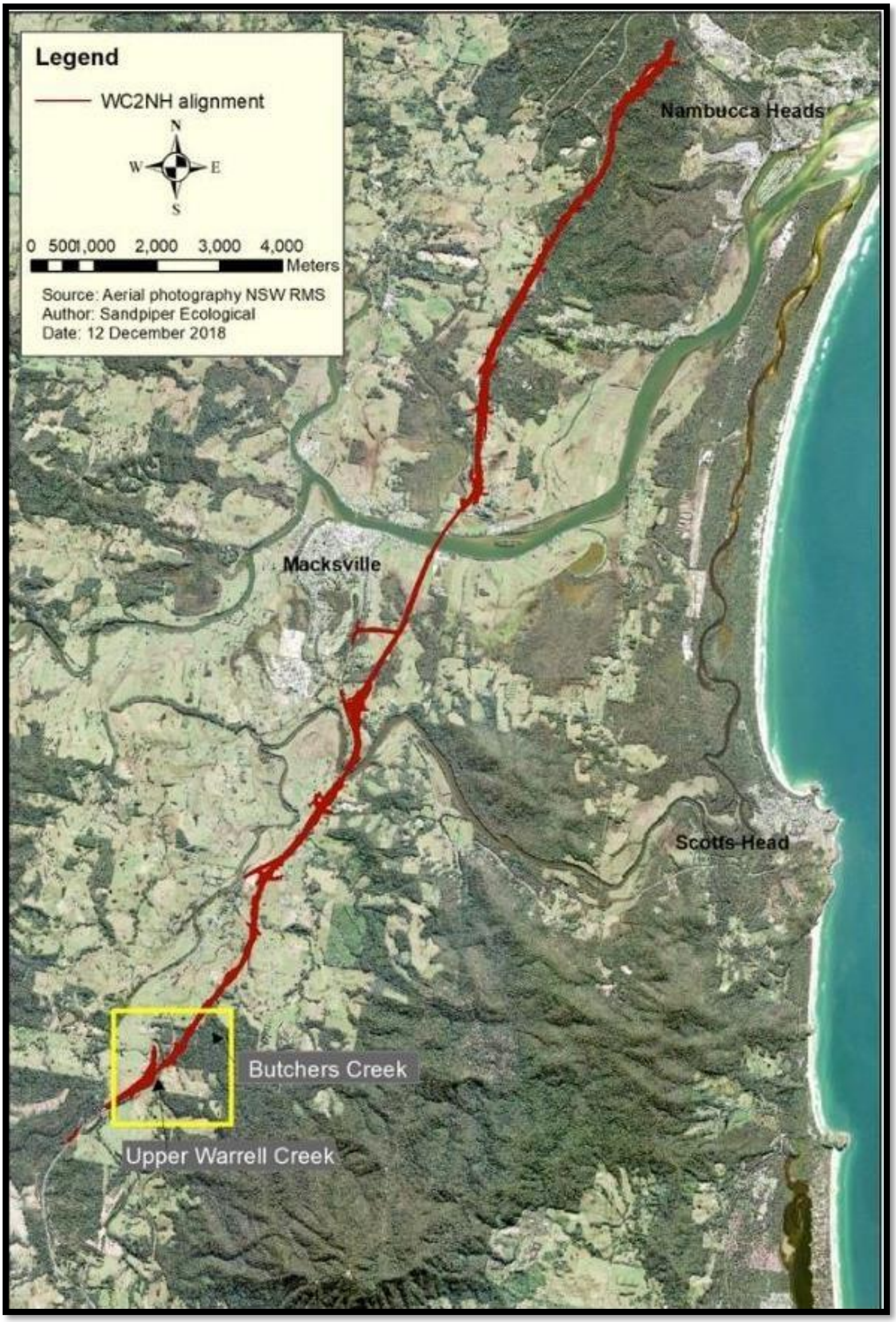

Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment.

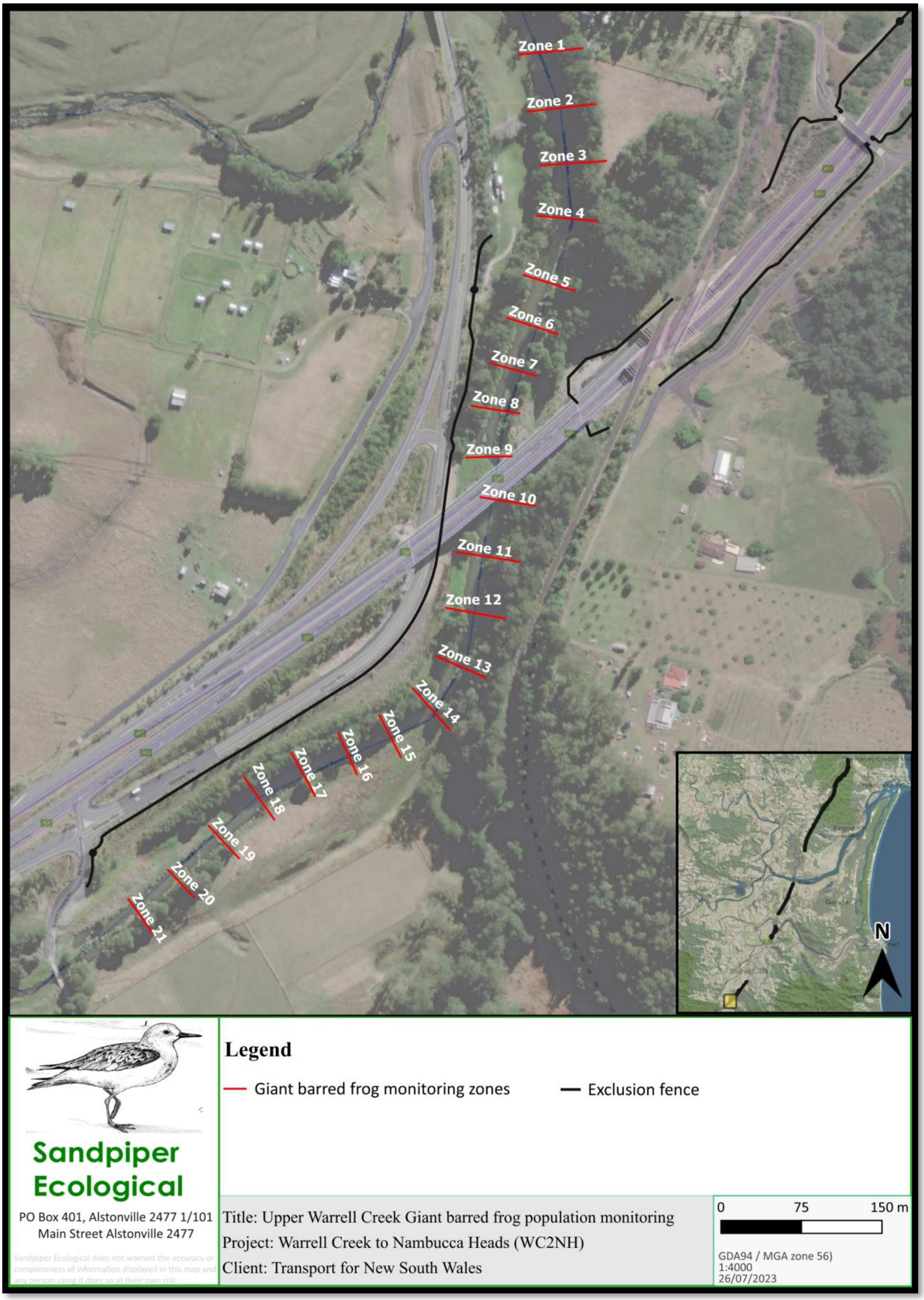

Figure 2: Survey monitoring zones at Upper Warrell Creek.

2.2 Frog surveys

Frog surveys followed the method specified in the Brief and baseline population survey (Lewis 2014). Surveys were conducted on 6, 7 and 24 March 2023. The method involved:

1. Two to three ecologists carried out nocturnal, foot-based surveys across 21 designated sample zones. These zones spanned a riparian area extending 25 meters on either side of Upper Warrell Creek (Figure 2).

2. 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.
3. All captured giant barred frogs were scanned with a Trovan Nanotransponder to determine if that frog had been previously pit-tagged. If the captured individual had not been pit-tagged and was deemed 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.
4. The dorsal pattern of all captured frogs was photographed. 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.
5. 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 were undertaken on 7 Feburary 2023 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, was installed within each zone for 2 -3 hours.
3. In the event of a tadpole capture the following information was recorded:
    a. Species
    b. Survey zone (20x50m).
    c. Sex (male, female, unknown).
    d. Weight (grams).

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

2.4 Habitat assessment

Habitat sampling was conducted on 7 Feburary 2023. Habitat data recorded in each zone included:

1. Land use: Description of existing land uses e.g. grazing, dairy, horticulture, conservation, private native forestry.

2. Broad vegetation type within the immediate riparian zone (primary stream bank): Riparian Rainforest, Dry Sclerophyll, Wet Sclerophyll, Sedgeland, Grassland or Cleared Land.

3. In stream physical characteristics including stream width and depth (metres), presence of pools and/or riffles, bed composition (sand, clay, rock, organic or other to be specified), and type of emergent vegetation, if present.

4. Stream bank characteristics including bank profile expressed as steep, benched or a gradual incline from the water's edge.

5. Foliage projective cover of overstorey, midstorey and ground layer vegetation on the stream bank.

6. Groundcover expressed as a percentage of vegetation, leaf litter, soil, and exposed rock.

7. Litter depth - Deep (>100 mm); Moderate (20-100 mm); Shallow (>0-20 mm); or Absent (0 mm).

2.5 Water quality sampling

Water samples and field measurements were taken within the sample transect at Upper Warrell Creek in zone 8 on the southern bank on 25 January 2023 (Figure 3). Due to a change in property ownership, the sample collection site was moved approximately 100m upstream during the summer sample. Field physicochemical measurements, including Conductivity, pH, Temperature, dissolved oxygen and turbidity, were measured using a Horiba U-52 multiparamter probe.

Water quality parameters analysed 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.

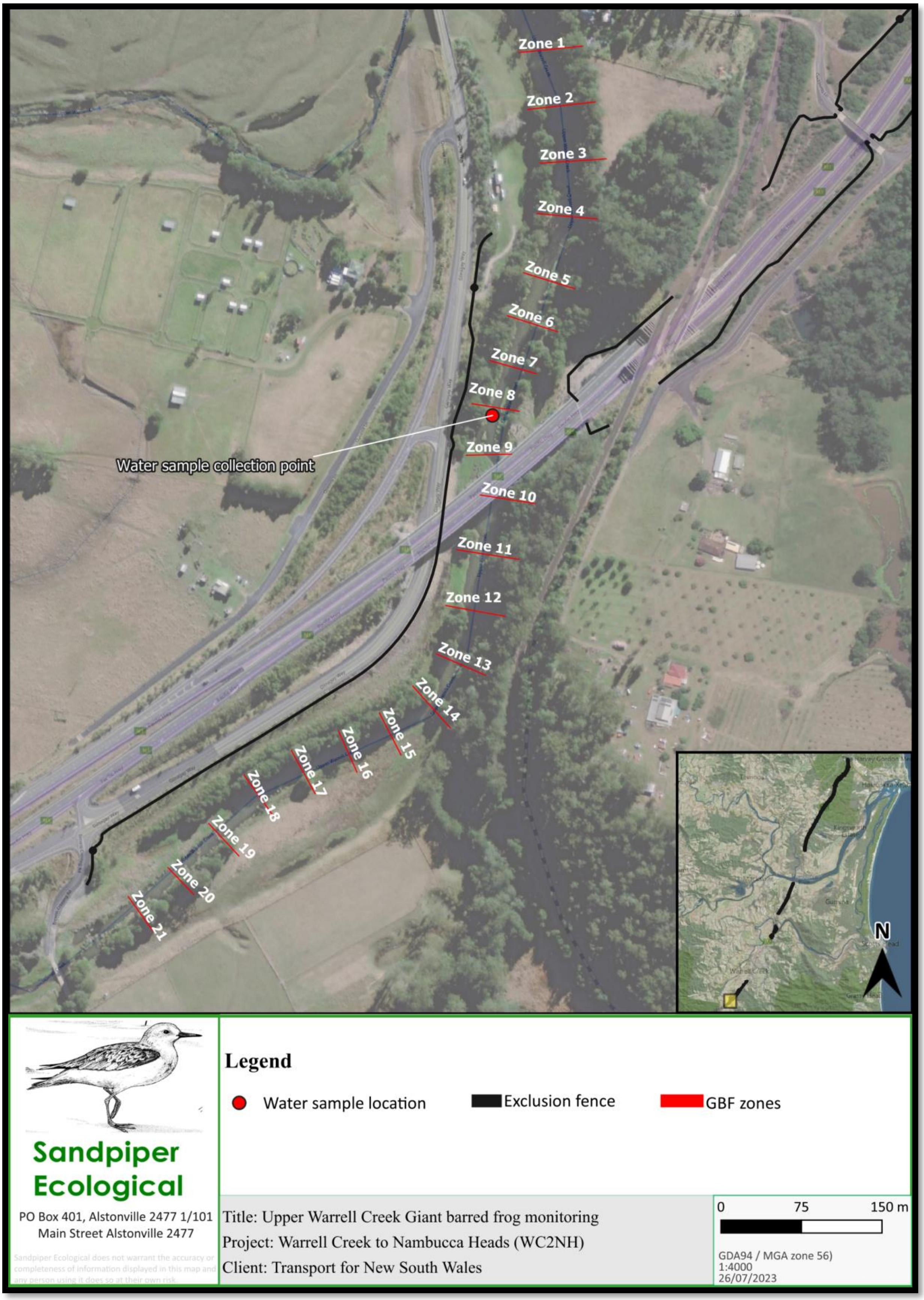

Figure 3: Location of water sampling site in relation to the survey zones at Upper Warrell Creek.

3. Results and discussion

3.1 Survey timing, effort and weather conditions

During the summer survey, the rainfall in the 30 days preceding the study was below average, with a total of 51 mm recorded (Table 1). Of this, 21 mm fell in the week prior the survey (Table 1 – rainfall prior). Moreover, rain occurred during the third summer survey, which may have influenced frog activity and detectability (Table 1).

The air temperature ranged between 20.7°C and 22.4°C across all surveys (Table 1), which was favorable for detecting giant barred frogs, particularly calling males (Koch & Hero 2009). The relative humidity was notably high, reaching 92% on 24 February (Table 1), and the dew point was consistently high during most nights (Table 1). Wind conditions remained calm, with no wind record across all surveys (Table 1).

Overall, the weather conditions were drier and warmer during the first two surveys, while the third survey took place under wet conditions (Table 1). The combined survey effort at Upper Warrell Creek during the summer sample amounted to 21.5 person-hours and exceeded the minimum requirement of 18 person-hours.

Table 1: Weather conditions and survey effort recorded during the year five summer 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 . Rainfall prior = rainfall totals (mm) recorded in 24hours/7 days/30 days prior to the survey recorded from the Bellwood weather station.

Date	Observers	Survey	PH	Effort	Rain	Rainfall prior	Temp	RH	Dew point	Wind
6/2/23	LA/AE	1	2	9.00	Nil	0/21/51	22.4	61	15.9	0
7/3/23	LA/AE	2	2	8.50	Nil	0/9/51	21.9	74	16.1	0
24/3/23	LA/AE	3	2	4.00	Showers	22/88/110	20.7	92	20.1	0

3.2 Tadpole surveys

No giant barred frog tadpoles were detected at Upper Warrell Creek during the year five summer dip-netting and bait trap surveys. The only vertebrate species captured were various freshwater fish. These included empire gudgeons (*Hypseleotris compressa*), striped gudgeons (*Gobiomorphus australis*), and australian smelt (*Retropinna semoni*). Notably, these species were recorded through both dip-netting and bait-trapping methods.

3.3 Habitat assessment

The Upper Warrell Creek study area included a diverse range of habitats, ranging from grassland to moderate quality riparian and wet sclerophyll forest with a dense litter layer. The riparian forest was fragmented and grazed in some parts, while the rest consisted of a narrow strip of vegetation along the creek, surrounded by agricultural land. The riparian vegetation width varied, but it was mostly confined to the bank and did not exceed 30m. Leaf litter cover was high (>75%) in intact riparian zones, but low (<40%) in cleared and grazed areas. The creek bank topography also varied, with steep banks on both sides downstream of the alignment (Zones 1-6), and on the north bank upstream of the alignment (Zones 11-13). A flatter bank profile occurred on the north bank near the alignment (Zones 7-11), and upstream (Zones 14-21).

During the 2021-2022 period, severe floods had a substantial impact on the microhabitat. Numerous trees in the riparian zone were uprooted, and areas of grass and regrowth were either eroded or flattened. The floods also washed away leaf litter, leaving the soil exposed. Consequently, there was a decrease in litter cover, and a drastic increase in woody debris and scoured ground cover.

However, the February 2023 survey revealed some changes in microhabitat. There was a noticeable improvement in leaf litter cover, and scouring was less prominent. Flood debris was still present, particularly around the southern banks of Zones 4-8 and Zones 13-11, creating potential refuge areas for giant barred frogs.

Weeds, predominantly pigeon grass (*Setaria geniculata*) and tall knotweed (*Persicaria orientalis*), dominated the vegetation on the northern and southern banks in Zones 8 and 9. Broad leaf paspalum (*Paspalum mandiocanum*) declined in areas where it was previously problematic (Zones 7-9). Remediation works, including the planting of weeping lilly pilly (*Waterhousia floribunda*) on the northern bank in Zones 7-9, remained in good condition. More time is required for the weeping lilly pilly to form a canopy with the existing vegetation and prevent further weed proliferation.

3.4 Water quality

The surface water sample collected from Upper Warrell Creek displayed a slightly low pH, reduced dissolved oxygen, and low levels of heavy metals (Table 5). Notably, there were no indications of hydrocarbon contamination (Table 5). Stagnation during low flow periods, as observed in the January sample (per obs), can significantly affect water quality during sampling. The stagnant conditions arise due to reduced flow, which may lead to lower levels of dissolved oxygen and pH. This could be attributed to increased water temperature and higher biochemical oxygen demand (BOD) resulting from the breakdown of organic material. However, it is essential to acknowledge the limitations of the water quality sampling approach. The approach involves taking isolated samples, sometimes months or even years apart, and only from a single location. Relying on sporadic and localised sampling might not fully represent the actual water quality conditions across the entire sample area at Upper Warrell Creek (Leigh *et al*., 2019).

Table 2: Results of water sample analysis for Upper Warrell creek. ID = insufficient data to derive a reliable trigger value (ANZECC 2000). N/A = not value provided/ not applicable.

Parameter	Units	Measurement	ANZECC/ARMCANZ Trigger value for freshwater (95% species level of protection)
General parameters			
Temperature	Celsius degrees	27.91	N/A
pH	pH units	6.23	6.5-8.0
ORP	mV	125	N/A
Conductivity	dS/m	0.247	125-2200
Turbidity	Nephelometric Turbidity Units (NTU)	8.3	N/A
Dissolved Oxygen	mg/L	0.9	9-10.5
DO% Saturation	percentage (%)	11.7	80-110
TDS	g/l	0.161	N/A
Salinity	parts per thousand (ppt)	0.1	N/A
Hydrocarbons			
Benzene	µg/L	<1	ID
Toluene	µg/L	<1	ID
Ethylbenzene	µg/L	<1	ID
m+p-xylene	µg/L	<2	ID
o-xylene	µg/L	<1	ID
Naphthalene	µg/L	<1	ID
TRH C6 - C9	µg/L	<10	ID
TRH C6 - C10	µg/L	<10	ID
TRH C6 - C10 less BTEX (F1)	µg/L	<10	ID
TRH C10 - C14	µg/L	<50	ID
TRH C15 - C28	µg/L	<100	ID
TRH C29 - C36	µg/L	<100	ID
TRH >C10 - C16	µg/L	<50	ID
TRH >C10 - C16 less Naphthalene (F2)	µg/L	<50	ID
TRH >C16 - C34	µg/L	<100	ID
TRH >C34 - C40	µg/L	<100	ID
Surrogates			
Surrogate Dibromofluoromethane	%	110	No guideline
Surrogate toluene-d8	%	104	No guideline
Surrogate 4-BFB	%	98	No guideline
Surrogate o-Terphenyl	%	61	No guideline
Heavy metals			
Silver-Total	µg/L	<1	0.012
Aluminium-Total	µg/L	50	552
Arsenic-Total	µg/L	2	132
Cadmium-Total	µg/L	<0.1	0.22
Chromium-Total	µg/L	<1	12
Copper-Total	µg/L	<1	1.42
Iron-Total	µg/L	1200	10002
Manganese-Total	µg/L	410	19002
Nickel-Total	µg/L	1	112
Lead-Total	µg/L	<1	3.42
Selenium-Total	µg/L	<1	112
Zinc-Total	µg/L	1	82
Mercury-Total	µg/L	<0.05	0.062
Nutrients			
Phosphorus - Total	mg/L	<0.05	0.05
Total Suspended Solids	mg/L	14	6
Phosphate	mg/L	<0.005	0.025
Nitrite	mg/L	<0.005	0.01
Nitrate	mg/L	0.006	1
Ammonia	mg/L	0.036	Dependent on ph
Total Nitrogen in water	mg/L	0.2	0.5

3.5 Giant barred frog records and distribution

Three giant barred frog individuals were recorded at Upper Warrell Creek during the year five summer survey (Table 3). This included two juveniles (Frog 5 and 6), neither of which were recaptures and were deemed too small for pit-tagging (snout-vent length <40mm) (Table 3; Plate 1). An additional male giant barred frog (Frog 7) was heard calling on the southern bank and was unable to be found following a thorough inspection of the area (Table 3). The record of a calling male and two juveniles is encouraging as it provides positive indication of breeding activity in the current population at Upper Warrell Creek.

Giant barred frogs were recorded both downstream (1 adult male) and upstream of the alignment (2 juveniles) (Figure 4). The detections were between zones 5 and 13 (Figure 4) 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, one was recorded on the south bank. All captured individuals were positioned within 10m of the stream sitting on leaf litter (Table 3). No recaptures were recorded; hence, no individuals were found to have crossed the alignment.

Table 3: Data recorded for giant barred frogs captured or heard calling during the year 5 summer operational phase monitoring survey at Upper Warrell Creek. SI = Saw individual HC = Heard call. UK= unknown. S/V = snort-vent length; g = grams; mm = millemetres. New = new individual recorded no previous matching tags or dorsal photos. Recapture = previously tagged individual or matching dorsal photos from previous sample. N/A = not applicable.

Frog ID	Date	Zone	Creek side	Easting	Northing	Sex*	Age*	S/V length (mm)	Weight (g)	Detection	New or recapture	Microchip ID
Frog 5	6/2/23	13	North	489245	6594087	UK	Juvenile	33.2	8	SI	New	N/A
Frog 6	6/2/23	13	North	489248	6594087	UK	Juvenile	26.9	6	SI	New	N/A
Frog 7	7/6/23	5	South	489320	6594421	M	Adult	UK	UK	HC	UK	UK

Plate 1: Dorsal comparison of the two juvenile giant barred frogs captured on the southern bank during the summer surveys at Upper Warrell Creek. Indivdual on left is frog 5 and individual on right is frog 6.

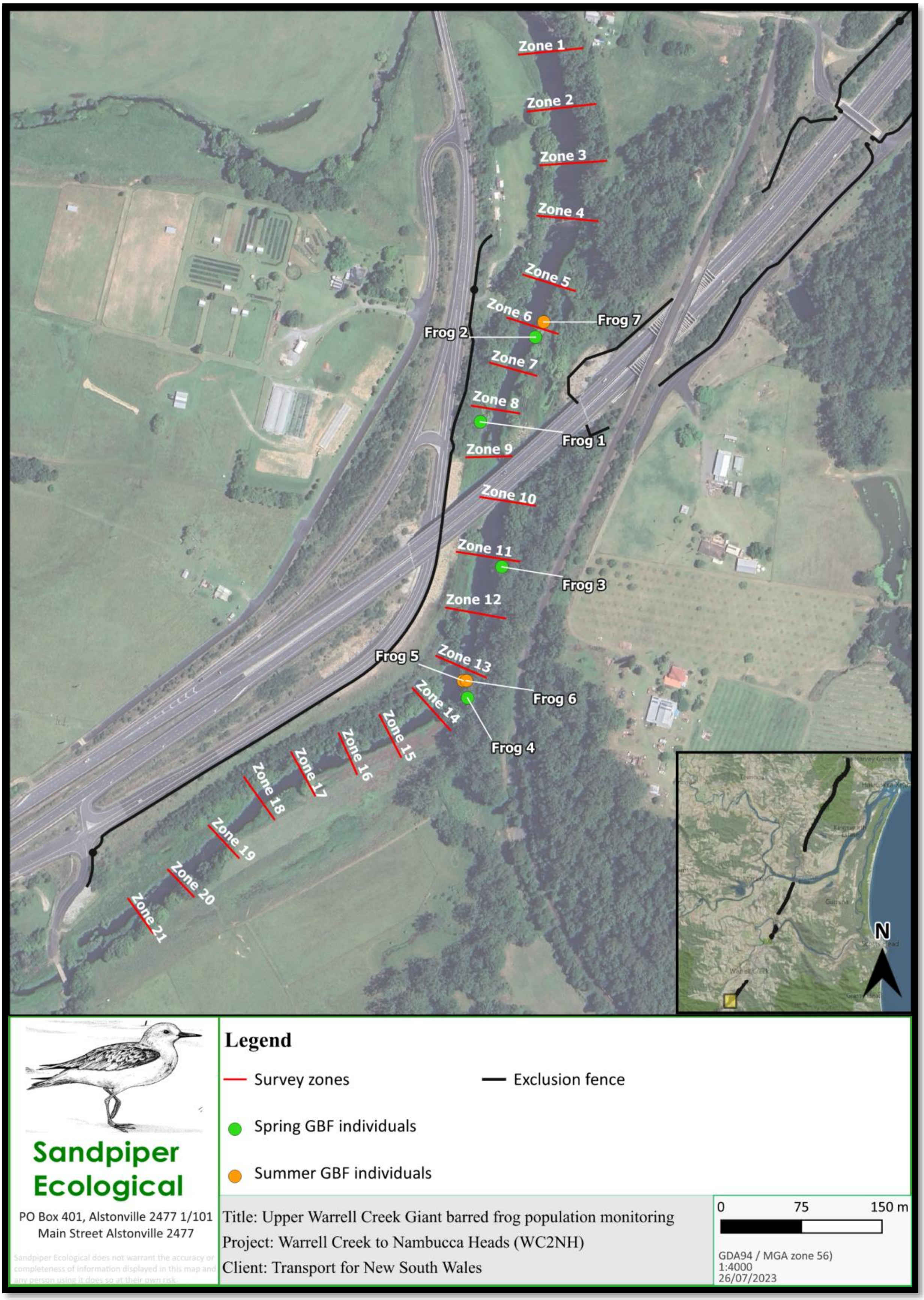

Figure 4: Location of GBF individuals recorded during spring and summer surveys at Upper Warrell Creek, WC2NH, 2023.

3.6 Giant barred frog abundance

Five years after the completion of construction, Upper Warrell Creek continues to support a population of giant barred frogs. A total of three frogs were recorded in summer of year 5, including two juveniles and one adult. The origin of the juvenile frogs remains unknown due to uncertainty about whether they are breeding locally or migrating from upstream. Notably, no recaptures were recorded in the recent summer survey, but the calling male (Frog 7) is likely to be the same individual as recorded in a similar location during the spring surveys (Frog 2).

The lack of recaptures in the fifth year cannot be solely attributed to the highway or other factors identified in the year 4 monitoring report. Therefore, it is crucial to consider other possible factors, including flood movements and threats like the amphibian chytrid fungus (*Batrachochytrium dendrobatidis*), noting that these factors are outside the requirements of the Ecological Monitoring Program. These could potentially impact the giant barred frog population and contribute to explaining the absence of recaptures. Nonetheless, the record of a calling male and two juveniles is encouraging as it provides a positive indication of breeding activity. Further monitoring in autumn will assist in determining the status of the adult frog population at Upper Warrell Creek.

4. Recommendations

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

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

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.

Geolink (2016). Annual report – WC2NH giant barred frog population monitoring. Report prepared for Pacifico.

Koch, A. J., & Hero, J.-M. (2009). The relationship between environmental conditions and activity of the giant barred frog (Mixophyes iteratus) on the Coomera River, south-east Queensland. Australian Journal of Zoology, 55(2), 89-95

Leigh, C., Kandanaarachchi, S., McGree, J. M., Hyndman, R. J., Alsibai, O., Mengersen, K., & Peterson, E. E. (2019). Predicting sediment and nutrient concentrations from high-frequency water-quality data. PLoS One, 14(8), e0215503.

Lewis, B. D. (2014a). Warrell Creek to Urunga: giant barred frog management strategy. Report prepared for the Roads and Maritime Services by Lewis Ecological Surveys.

Lewis, B. D. (2014b). Warrell Creek to Nambucca Heads: giant barred frog preconstruction baseline monitoring. Report prepared for the Roads and Maritime Services by Lewis Ecological Surveys.

Lewis, B. D. (2015). Giant barred frog (Mixophyes iteratus): design review at Butchers Creek following discovery of tadpoles. Letter report prepared for Pacifico by Lewis Ecological Surveys.

Sandpiper Ecological (2021). *Warrell Creek to Nambucca Heads giant barred frog monitoring report – year three operational phase*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2022). *Warrell Creek to Nambucca Heads giant barred frog monitoring report – year four operational phase*. Report prepared for Transport for New South Wales.

SKM (2010). Environmental Assessment Volume 2 - Working paper 1 Flora and Fauna. January 2010 for Roads and Traffic Authority.

Transport for New South Wales

Warrell Creek to Nambucca Heads

Giant Barred Frog Population Monitoring – Annual Report Year Five Operational Phase (2022-2023)

Transport for New South Wales | October 2023 | Draft Report

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

Giant Barred Frog – operational phase year five annual report (2022-2023)

Sandpiper Ecological Surveys

Draft Report

17 October 2023

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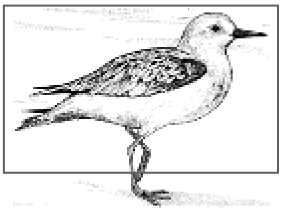

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Cover Photo: Giant barred frog (*Mixophyes iteratus*) found on leaf litter at Upper Warrell Creek.

Table of contents

List of tables

List of figures

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 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. TfNSW was responsible for managing and evaluating the effectiveness of these measures. Sandpiper Ecological Surveys (SES) was contracted by 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 giant barred frog was one threatened species identified as requiring mitigation and monitoring through the course of the project's construction and operational periods.The following annual report presents the findings of the year five operational phase giant barred frog population monitoring, and concludes the monitoring for the project as defined within the Giant Barred Frog Management Strategy (GBFMS). The objective of giant barred frog monitoring, is "to demonstrate through the life of the project that mitigation has maintained or improved population sizes and habitat of giant barred frog." (Lewis 2014b). This objective is discussed in light of findings from the baseline, construction and operational phase monitoring.

1.1 Background and monitoring framework

The giant barred frog is listed as 'Endangered' under both the NSW *Biodiversity Conservation Act 2016* (BC Act) and Commonwealth *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, de-watering 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 years 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. To track population trends more closely Sandpiper Ecological (2021) recommended that additional surveys be undertaken in year 4 (i.e. 2021/22). The recommendation was approved and an annual report was produced in 2022 (Sandpiper Ecological 2022).

Pre-construction baseline surveys for giant barred frog were conducted between 20 September 2013 and 2 April 2014. The baseline surveys recorded 47 giant barred frogs, including 22 adults (11 females & 11 males), eight sub-adults, and eight 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 the operational phase, the population was estimated to be seven with a 95% confidence interval (CI) of 4.8 in the first year (2018/2019), increasing to 19 with a 95% CI of 21.5 in the third year (2020/2021), and 21.5 with a 95% CI of 17.38 in the fourth year (2021/2022) (Sandpiper Ecological 2019, 2021, 2022). The increased population estimate in the third and fourth operational year was attributed to favorable breeding conditions between February 2020 and April 2022 (Sandpiper Ecological 2021).

1.2 Monitoring at Butchers Creek

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). After completing the Year 3 spring operational phase survey, it was agreed with TFNSW to discontinue future monitoring at Butchers Creek. This decision was influenced by the landowner's refusal to grant entry due to heightened tree-fall risks from severe flooding. Moreover, there were no records of the giant barred frog during both construction and operational surveys. Consequently, subsequent surveys in year four and five were exclusively conducted at the Upper Warrell Creek site.

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). Due to the removal of Butchers Creek as a survey site in year 3, monitoring in year 5 focused on the 1km transect at Upper Warrell Creek (Figure 2). The transect extended either side of the upgrade alignment and was divided into 21 zones as per baseline monitoring (Figure 2).

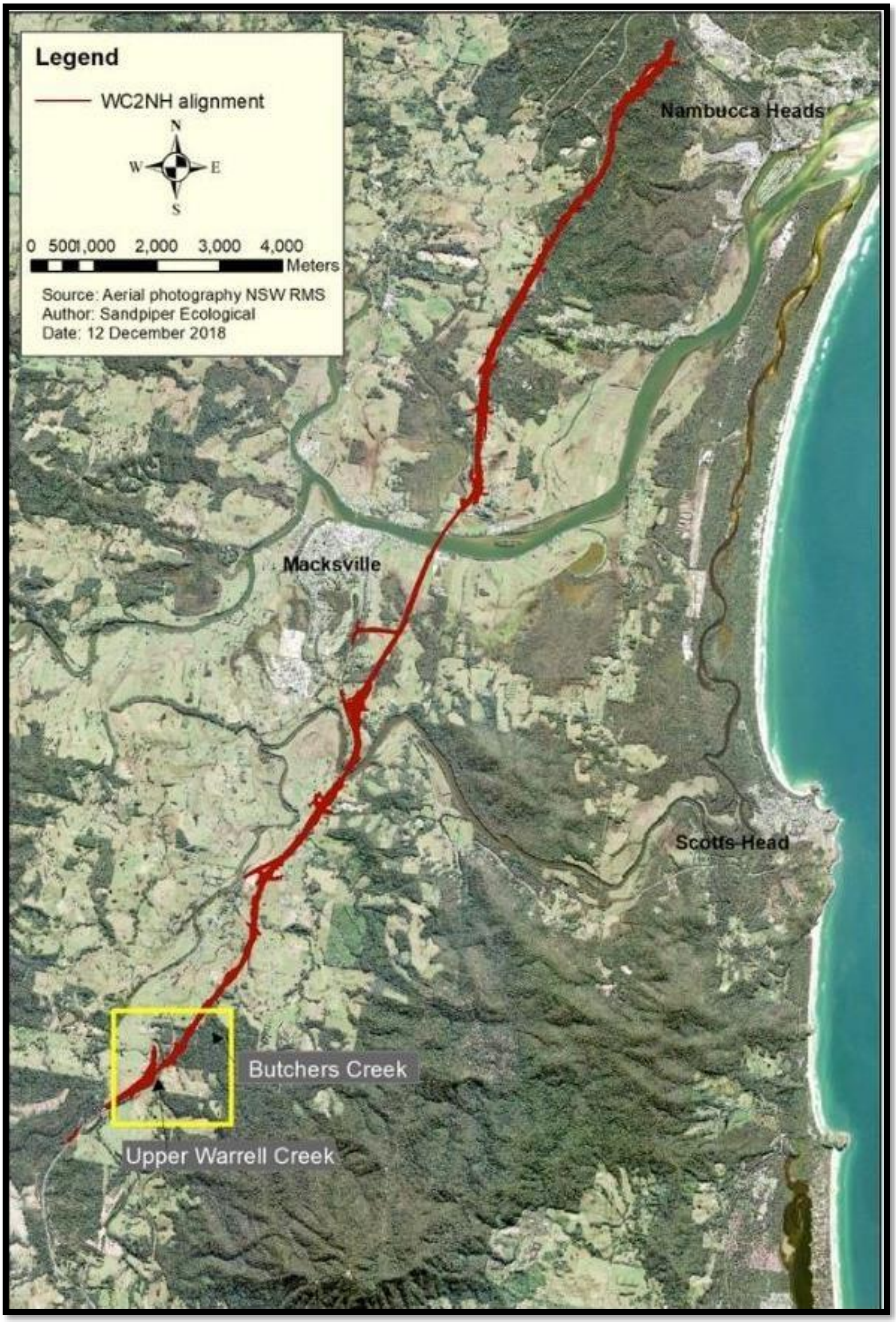

Figure 1: Location of giant barred frog sample sites in relation to the WC2NH alignment.

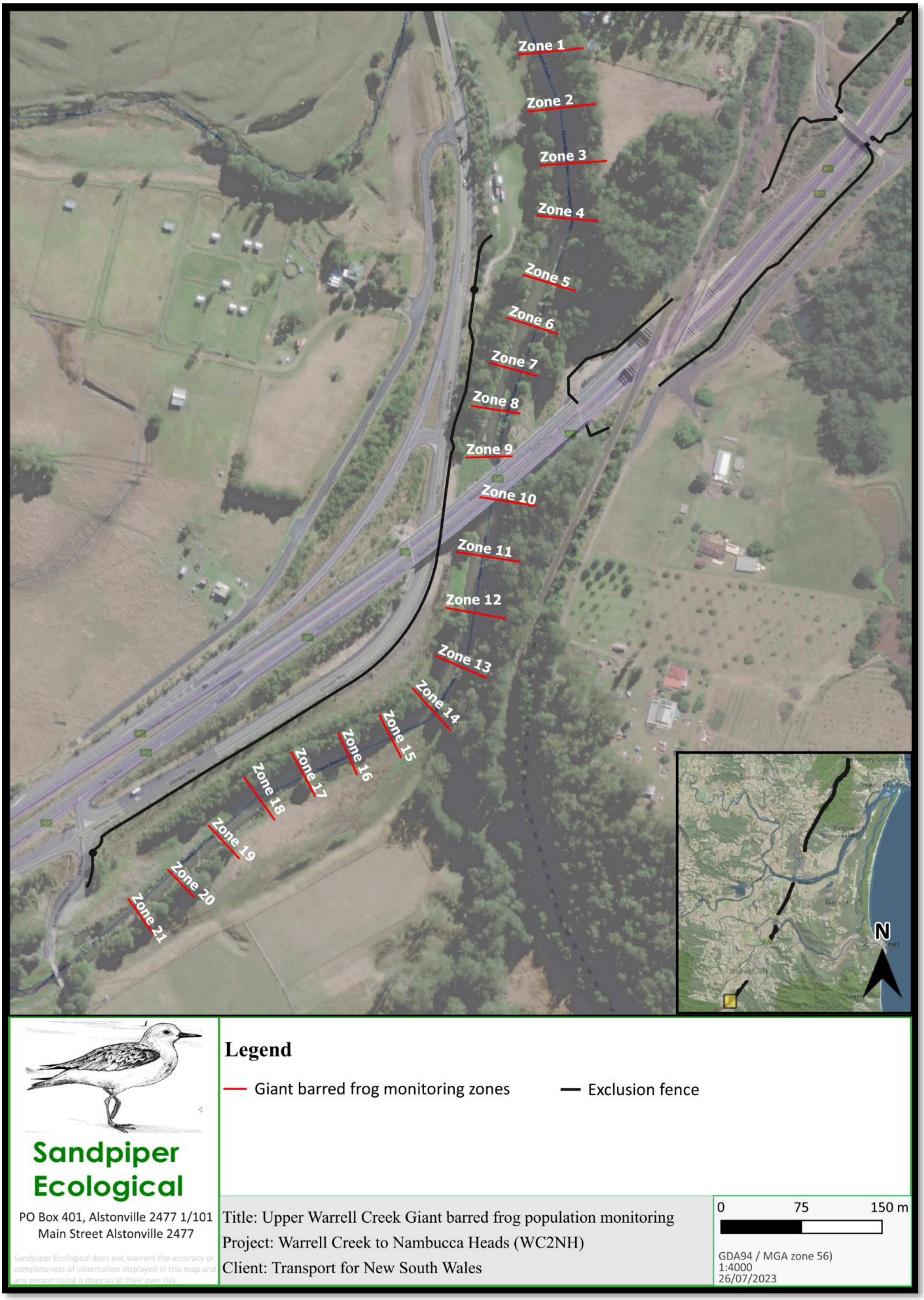

Figure 2: Survey monitoring zones at Upper Warrell Creek.

2.2 Frog surveys

Year five (2022-2023) giant barred frog surveys were undertaken across three seasons: spring 2022, summer 2023, and autumn 2023. Surveys took place within a seven-day period following rainfall events that registered more than 10 mm in a 24-hour period, as recorded by the Bellwood weather station (BOM station: 05915). Surveys followed the method specified in the Brief and baseline population survey (Lewis 2014a &b). The method involved:

1. Two to three ecologists carried out nocturnal, foot-based surveys across 21 designated sample zones. These zones spanned the riparian area extending 25 meters on either side of Upper Warrell Creek (Figure 2).
2. Each ecologist carried a 200-700 lumen spotlight and methodically traversed the riparian zone to visually identify and audibly detect frogs. A 2-watt Bluetooth speaker was used to broadcast giant barred frog calls for five minutes in each zone. Both ecologists actively listened for call responses during and immediately after the broadcast.
3. All captured giant barred frogs were scanned with a Trovan Nanotransponder to determine if that frog had been previously pit-tagged. Un-tagged frogs measuring over 40mm in snout-vent length received a subdermal pit-tag on their left side. The incision was disinfected with Betadine and sealed with vet bond. The size criterion for pit-tagging was lowered from 60mm to 40mm in Autumn 2021 to align with baseline and construction phase surveys.
4. Dorsal pattern photographs were taken of all captured frogs for individual identification, aiding in the identification of untagged records captured during Autumn 2021 and March 2022.

Data collected for each captured frog included the following variables:

- Survey zone (20x50m)
- Distance from stream edge, accurate to 0.1m
- Microhabitat location (e.g., under or above litter, exposed, on rock/log)
- Sex (male, female, unknown)
- Age class (adult >60mm, sub-adult 40-60mm, juvenile <40mm)
- Snout-vent length in mm
- Weight in grams
- Breeding condition:
    - i. Males: nuptial pad coloration (none, light, moderate, dark) as per Lewis's (2014b) classification
    - ii. Females: gravidity status (egg-bearing, usually weighing over 100 grams, or not)
    - iii. Immature designation for frogs with snout-vent length <60mm

2.3 Tadpole survey

Tadpole surveys were undertaken during summer 2023 and autumn 2023 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, was installed within each zone for 2 -3 hours.
3. In the event of a tadpole capture the following information was recorded:
    i. Species
    ii. Survey zone (20x50m).
    iii. Sex (male, female, unknown).
    iv. Weight (grams).

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

2.4 Habitat assessment

A habitat assessment was conducted during the summer survey on 7 Feburary 2023. Habitat data recorded in each zone included:

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

2.5 Water quality sampling

Water samples and field measurements were taken at Upper Warrell Creek in zone 8 during summer and autumn of 2023 (Figure 3). Due to a change in property ownership, the sample collection site was moved approximately 100m upstream. Field physicochemical measurements, including Conductivity, pH, Temperature, dissolved oxygen and turbidity, were measured using a Horiba U-52 multiparamter probe.

Water quality parameters analysed 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:
    i. 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).
    ii. BTEX group including Benzene, Ethylbenzene, m&p-Xylenes, o-Xylene, Toluene and Xylenes – total.

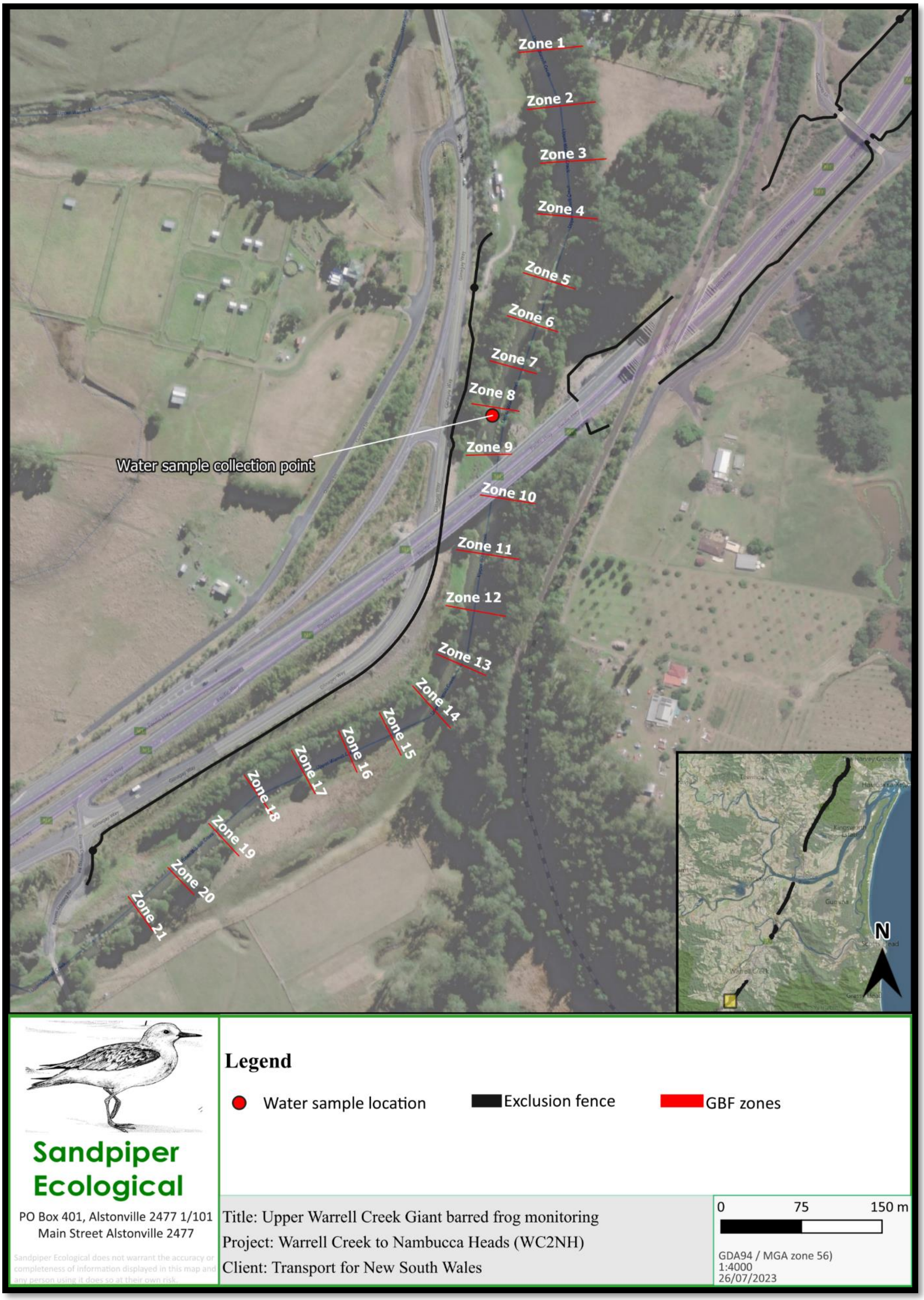

Figure 3: Location of water sampling site in relation to the survey zones at Upper Warrell Creek.

2.6 Population estimate calculation

The modified Petersen-Lincoln index method (that is the Petersen-Lincoln method with the Chapman estimator) was used to calculate a population estimate for each operational phase monitoring year. The method follows that applied during previous surveys (Lewis 2014b; Geolink 2018; Sandpiper Ecological 2019, 2021, 2022). Juveniles, sub-adult, and non-captured records (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 spring and summer 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) }

2.7 Chytrid sampling

Chytrid sampling was undertaken during summer of year 4 operational phase monitoring. 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 4 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.

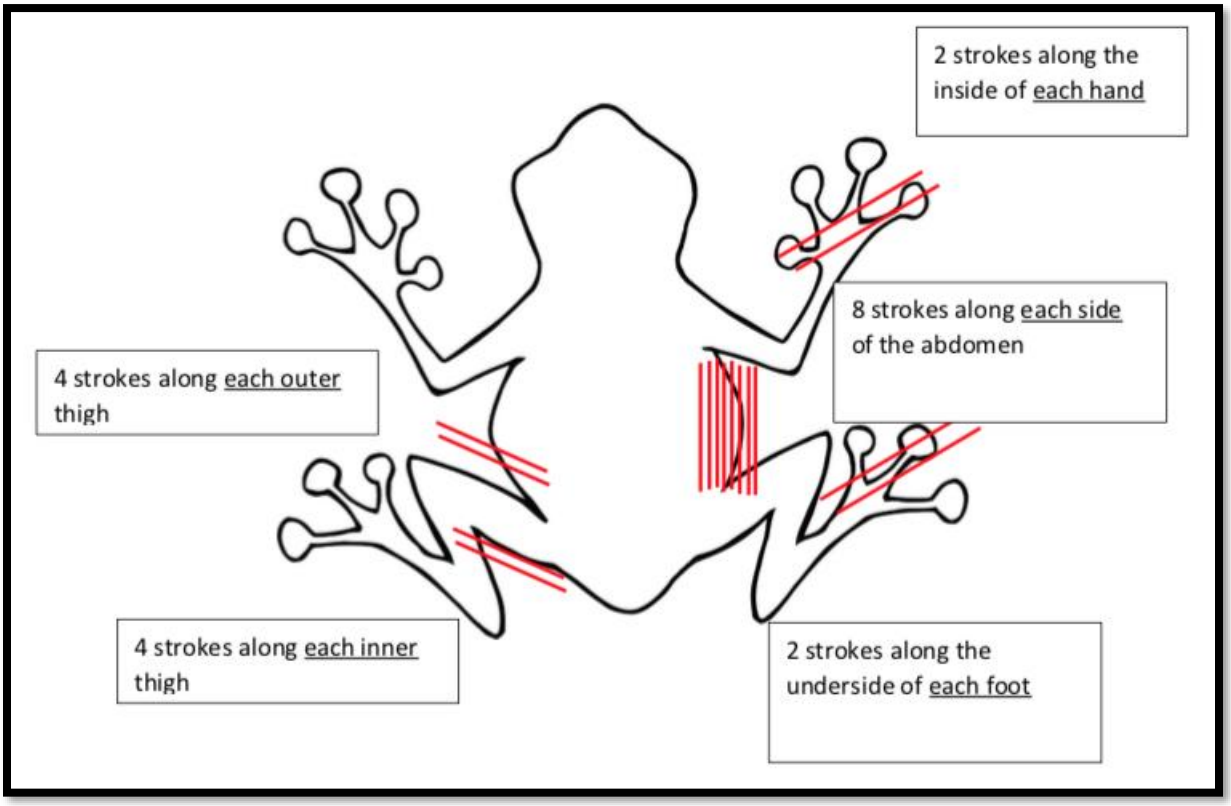

Figure 4: Chytrid swabbing protocol.

2.8 Data summary and statistical analysis

Individual frogs were identified using PIT tag numbers and comparing them with those reported by Sandpiper Ecological (2019, 2021, 2022), Geolink (2018), and Lewis (2014b). Additionally, dorsal photographs from year 4 monitoring and the surveys conducted in spring 2022 and summer 2023 were used as a secondary method of identifying potential recaptures. Confirming the sex of non-calling adult frogs is challenging. In the absence of calls, the sex of adult frogs was determined based on snout-vent length and weight.

To provide a temporal comparison of frog abundance, data collected during the year five operational phase were compared to previous operational surveys, the construction phase, and baseline surveys. The number of giant barred frogs detected (i.e., captured and heard calling) for each time period is presented using histograms. Population estimates derived during each survey are also compared. The number of records calculated for the year one construction phase might be an underestimate as it does not include records obtained during the first autumn sample (GeoLink 2018).

Rainfall data for the year five survey and historical records were sourced from the Bellwood weather station (BOM station: 05915). Rainfall events exceeding 75mm were considered to trigger potential flood events for Upper Warrell Creek following reference to the Green thighed frog management plan for WC2NH (Lewis 2013).

A linear regression analysis was performed in Excel using the Data Analysis ToolPak add-in to explore the relationship between seasonal rainfall and the number of giant barred frog records. Data on the total number of giant barred frog records, including both calling and captured individuals, were collected for each season in years 1-5 of operational montiroing. Seasonal rainfall totals for the same seasons were obtained from the

Bellwood weather station. It is imperative to note that the analysis was based on a limited dataset comprising only 12 data points, and the results should be cautiously interpreted as indicative rather than conclusive.

3 Results

3.1 Survey timing, effort and weather conditions

Rainfall varied noticeably across the surveys during the year 5 monitoring period. Although rainfall occurred before the first spring 2022 survey, it was not recorded until 9am the next day, resulting in only 7mm in the 30 days leading up to the survey. A further 19mm fell 24 hours prior to the second survey (Table 1). The summer period also experienced below-average rainfall, with only 51mm falling in the 30 days prior to the surveys (Table 1). In comparison, the first autumn survey in March 2023 was preceded by a notably higher 174mm of rainfall within the same time frame (30 days).

In terms of atmospheric conditions, relative humidity and dew point remained relatively high across the surveys, while temperatures ranged from 15.6°C to 22.4°C. Temperatures were conducive for detecting calling males on five out of seven occasions, based on the criterion of Koch & Hero (2007) that the temperature should be above 18°C. Wind conditions were also generally calm and showers did occur once during the third summer survey.

Survey effort varied slightly. The summer period recorded the highest survey effort, accumulating a total of 21.5 person-hours, followed by the autumn period with 16.75 hours and the spring 2022 period with 15.75 person-hours. Overall a total of 54 person-hours were spent conducting frog surveys at Upper Warrell Creek during year 5 population monitoring.

Table 1: Weather conditions and survey effort recorded during the year five giant barred frog surveys at Upper Warrell Creek. Rainfall data were sourced from the Bellwood weather station (BOM station: 05915). 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 . Rainfall prior = rainfall recorded at the Bellwood weather station 24hours/7 days/30 days prior to the specific survey.

Season	Date	Observers	Survey	Effort (PH)	Rain (during)	Rainfall prior	Temp	RH	Dew point	Wind
Spring 22	1/12/22	LA/AE	1	7.75	Nil	0/0/7	16.8	86	14.9	2
	2/12/22	LA/AE	2	8	Nil	19/19/26	18.2	69	14.2	1
Summer 23	6/2/23	LA/AE	1	9	Nil	0/21/51	22.4	61	15.9	0
	7/3/23	LA/AE	2	8.5	Nil	0/9/51	21.9	74	16.1	0
	24/3/23	LA/AE	3	4	Showers	22/88/110	20.7	92	20.1	0
Autumn 23	29/3/23	LA/AE	1	8.5	Nil	27/105/174	19.9	73	13.8	0
	2/5/23	LA/AE/EL	2	8.25	Nil	0/14/92	15.6	54	8.2	0

3.2 Rainfall patterns

The annual rainfall in the Upper Warrell Creek area (Bellwood) has exhibited considerable variation over the years, particularly before, during, and after the upgrade construction (Figure 5). Above and below average annual rainfall was recorded from 2012-2014 during the baseline surveys (Figure 5). Among these, 2014 was the driest year, with a recorded rainfall of 978 mm. The construction phase (2015-2018) also experienced some dry years, especially in 2016 (902mm). Subsequently, during the operational phase monitoring (2018-2023) the driest rainfall on record was recorded during 2019 (637mm) which was followed by two exceptionally wet years (2021 and 2022). Of these, 2022 emerged as the wettest year on record, with a total rainfall of 2889 mm. In 2023, the months from January to April experienced dry conditions, with each month recording below-average rainfall.

The number of heavy rainfall days (>75 mm) followed a similar pattern to that of annual rainfall. Between 2012 and 2019, there were only a few or a single heavy rainfall day(s), which generally corresponded to below (2012, 2014, 2016, 2018, 2019) or slightly above average (2013, 2015, 2017) annual rainfall. In contrast, in 2021 there were five heavy rainfall days that contributed to the potential for flooding at Upper Warrell Creek. In 2022, there were ten days with more than 75 mm of rain. This increased the frequency and intensity of flooding events at Upper Warrell Creek. No rainfall events exceeding 75mm have been recorded in 2023.

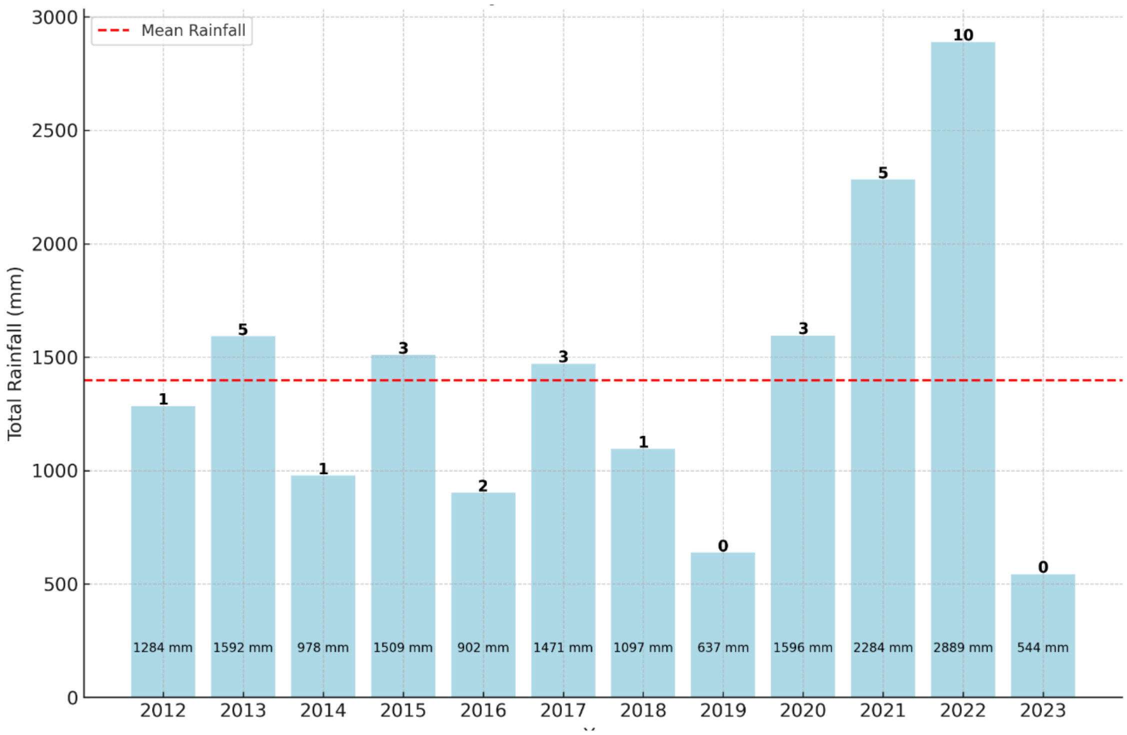

Figure 5: Total annual rainfall at the Bellwood weather station from 2012 to 2023. Numbers above bars represent number of likely flood events (i.e. >75mm in 24 hours). Red line = average annual rainfall (1399mm). Note 2023 = to date only as of 30 August 2023.

3.3 Tadpole surveys

No giant barred frog tadpoles or any tadpoles were detected at Upper Warrell Creek during any of the operational monitoring (Years 1, 3 and 5) dip-netting and bait trap surveys. The only vertebrate species captured were various freshwater fish. These included empire gudgeons (*Hypseleotris compressa*), striped gudgeons (*Gobiomorphus australis*), and australian smelt (*Retropinna semoni*). These species were recorded through both dip-netting and bait-trapping methods. Other records included various species of invertebrate fauna including freshwater shrimp.

3.4 Habitat assessment

The Upper Warrell Creek study area included a diverse range of habitats, ranging from grassland to moderate quality riparian and wet sclerophyll forest with a dense litter layer. The riparian forest was fragmented and grazed in some parts, while the remainder consisted of a narrow strip of vegetation along the creek, surrounded by agricultural land. The riparian vegetation width varied, but it was mostly confined to the bank and did not exceed 30m. Leaf litter cover was high (>75%) in intact riparian zones, but low (<40%) in cleared and grazed areas. The creek bank topography also varied, with steep banks on both sides downstream of the alignment (Zones 1-6), and on the north bank upstream of the alignment (Zones 11-13). A flatter bank profile occurred on the north bank near the alignment (Zones 7-11), and upstream (Zones 14-21).

3.5 Water quality

The surface water samples collected from Upper Warrell Creek during summer and autumn 2023 showed that the pH of both samples was below the ANZECC guidelines, indicating slightly acidic conditions (Table 2). The dissolved oxygen levels were also below the ANZECC guidelines (Table 2). Heavy metal concentrations were low, and nutrient levels were below the ANZECC guidelines for 95% protection level for lowland streams in south-eastern Australia (Table 2). Notably, there were no indications of hydrocarbon contamination (Table 2).

Comparing the two samples, the autumn sample had a lower temperature and slightly lower pH than the summer sample. Additionally, the autumn sample exhibited increased turbidity and higher levels of dissolved oxygen compared to the summer sample.

Table 2: Water quality parameters for the summer and autumn samples in 2023 at Upper Warrell Creek in comparison to the ANZECC guidelines (95% protection) for lowland streams in south-east Australia (ANZECC 2000). ORP = oxidation-reduction potential. NTU = Nephelometric turbidity units. TDS = Total dissolved solids. DO = Dissolved oxygen. ID = insufficient data to derive a reliable trigger value.

Parameter (unit)	Summer 2023 sample	Autumn 2023 sample	ANZECC Trigger (95% species level protection)
General parameters			
Temperature (°C)	27.91	15.02	N/A
pH (pH units)	6.23	6.12	6.5-8.0
ORP (mV)	125	265	N/A
Conductivity (dS/m)	0.247	0.262	125-2200
Turbidity (NTU)	8.3	7.1	2
Dissolved Oxygen (mg/L)	0.9	4.49	9-10.5
DO% Saturation (%)	11.7	46	80-110
TDS (g/l)	0.161	0.17	N/A
Salinity (parts per thousand (ppt)	0.1	0.1	N/A
Hydrocarbons			
Benzene (µg/L)	<1	<1	ID
Toluene (µg/L)	<1	<1	ID
Ethylbenzene (µg/L)	<1	<1	ID
m+p-xylene (µg/L)	<2	<2	ID
o-xylene (µg/L)	<1	<1	ID
Naphthalene (µg/L)	<1	<1	ID
TRH C6 - C9 (µg/L)	<10	<10	ID
TRH C6 - C10 (µg/L)	<10	<10	ID
TRH C6 - C10 less BTEX (F1) (µg/L)	<10	<10	ID
TRH C10 - C14 (µg/L)	<50	<50	ID
TRH C15 - C28 (µg/L)	<100	<100	ID
TRH C29 - C36 (µg/L)	<100	<100	ID
TRH >C10 - C16 (µg/L)	<50	<50	ID
TRH >C10 - C16 less Naphthalene (F2) (µg/L)	<50	<50	ID
TRH >C16 - C34 (µg/L)	<100	<100	ID
TRH >C34 - C40 (µg/L)	<100	<101	ID
Surrogates			

Parameter (unit)	Summer 2023 sample	Autumn 2023 sample	ANZECC Trigger (95% species level protection)
Surrogate Dibromofluoromethane (%)	110	96	No guideline
Surrogate toluene-d8 (%)	104	91	No guideline
Surrogate 4-BFB (%)	98	97	No guideline
Surrogate o-Terphenyl (%)	61	74	No guideline
Heavy metals			
Silver-Total (µg/L)	<1	<1	0.012
Aluminium-Total (µg/L)	50	<10	552
Arsenic-Total (µg/L)	2	<1	13.2
Cadmium-Total (µg/L)	<0.1	<0.1	0.22
Chromium-Total (µg/L)	<1	<1	1.2
Copper-Total (µg/L)	<1	<1	1.42
Iron-Total (µg/L)	1200	700	1000
Manganese-Total (µg/L)	410	61	1900
Nickel-Total (µg/L)	1	<1	11.2
Lead-Total (µg/L)	<1	<1	3.4
Selenium-Total (µg/L)	<1	<1	11.2
Zinc-Total (µg/L)	1	<1	8
Mercury-Total (µg/L)	<0.05	<0.05	0.06
Nutrients			
Phosphorus - Total (mg/L)	<0.05	<0.05	0.05
Total Suspended Solids (mg/L)	14	15	25
Phosphate (mg/L)	<0.005	<0.005	0.025
Nitrite (mg/L)	<0.005	0.03	0.9
Nitrate (mg/L)	0.006	<0.005	1
Ammonia (mg/L)	0.036	0.046	Dependent on pH
Total Nitrogen in water (mg/L)	0.2	0.2	0.5

3.6 Giant barred frog surveys

3.6.1 Age classes and abundance

During operational phase monitoring at Upper Warrell Creek (Years 1, 3, 4, and 5), a total of 66 giant barred frogs were captured or audibly detected (see Appendix A, Table A1; Table 3). Of these, 55 were considered distinct individuals: 52 recorded during the operational phase and three initially tagged during the construction phase (See section 3.5.2). Among these, 48 were verified through physical capture, while the remaining seven were identified as calling males but were included in the total individual count (see Appendix A, Table A1).

Adults made up the majority of records, accounting for 64% (42 out of 66, Table 3). The adult population was divided into 16 females and 26 males, representing approximately 24% and 39% of the overall count, respectively. Sub-adults, characterised by snout-vent (S-V) lengths between 40 and 60mm, constituted 24% of the records (16 out of 66). The remaining 12% were juveniles with S-V lengths under 40mm. Female adults had S-V lengths ranging from 79.5 to 119mm, while males ranged from 63 to 83mm (Table 3).

During operational monitoring variations were observed in the composition of age classes (Table 3). Year 1 recorded 12 records, primarily adults, including 7 males and 4 females, along with a single sub-adult. In Year 3, the count increased to 21 and featured a more diversified age distribution: 7 adult males, 2 adult females, 3 juveniles, and 9 sub-adults. Year 4 saw a peak of 25 records, with numbers distributed equally between age classes and sexes, while Year 5 experienced a decline to just 8 records, five adults and one juvenile (Table 3).

Seasonal fluctuations were also evident (Table 3). Spring had the fewest records, totaling 17, and was mainly dominated by adults. Summer, with 24 records, showed a balanced age distribution, particularly in Year 4. This contrasted with Year 1 and Year 3, where only adults were recorded in Year 1, and juveniles and sub-adults were more prevalent in Year 3. Autumn had the highest count with 25 records, and was notable for a larger number of sub-adults, especially in Years 3 (6 records) and 4 (4 records).

Shifting from the baseline to the Year 1 construction phase led to a sharp decline in the number of recorded frogs (Figure 6). Specifically, 47 detections in the baseline year fell to just 16 in the first year of construction. This decline occurred for both new individuals, which decreased from 38 to 14, and recaptures, which dropped from 9 to 2 (Figure 6). No indiviuals from the baseline sample were recaptured during construction.

In contrast, the operational phase initially started to reverse this downward trend (Figure 6). The number of total captures rose from 12 in the first year to 21 in the third year. This increase was largely driven by new individuals, which reached 18 in year 3, while recaptures decreased to only 3 (Figure 6).

Subsequently, the increase in total detections peaked in the fourth operational year when 25 giant barred frogs were recorded (Figure 6). New individuals accounted for 20 of these, and recaptures contributed 5. However, this positive trend was not sustained in Year 5, which saw a drop to just 8 new individuals and, notably, no recaptures.

Table 3: Temporal comparison in the age classes of giant barred frogs recorded at Upper Warrell Creek during operational phase monitoring. Records include individual captured and audibly detected (Males only).

Year	Season	Adult		Immature		Seasonal total
		Female (79.5-119mm)	Male (63-83mm)	Juvenile (<40mm)	Sub-adult (40-60mm)	
Year 1	Spring	1	1			2
	Summer	1	3			4
	Autumn	2	3		1	6
Year 3	Spring	1	2			3
	Summer		1	2	3	6
	Autumn	1	4	1	6	12
Year 4	Spring	4	4			8
	Summer	4	3	2	2	11
	Autumn	1	1		4	6
Year 5	Spring	1	3			4
	Summer		1	2		3
	Autumn			1		1
Total		16	26	8	16	66

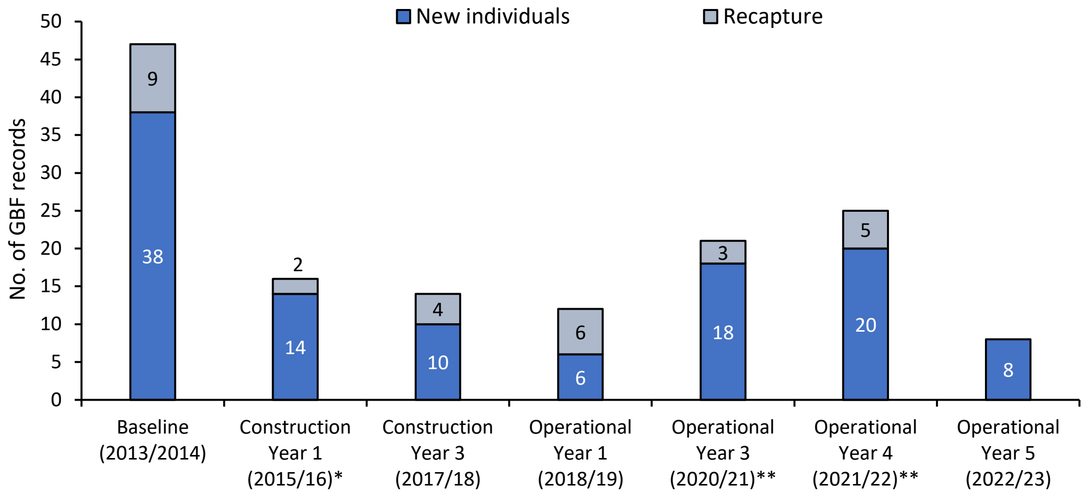

Figure 6: Total count of giant barred frog records, including new individuals and recaptures, throughout the baseline, construction, and operational phase monitoring at Upper Warrell Creek, WC2NH 2023. * Year one construction phase number may be an underestimate as it does not include frogs recorded in autumn 2015 (GeoLink 2018). **could include recapture of unmarked sub-adults.

3.6.2 Recaptures

During operational monitoring, a total of eight giant barred frogs were identified as recaptured individuals (**Error! Reference source not found.**). These recaptured individuals were verified using pit tags (6 individuals) and dorsal photos (2) (**Error! Reference source not found.**). Three of the individuals were originally tagged during the construction phase (GBF#2,3,4), with the remaining captured during operational monitoring.

Most of the recaptured frogs (5 out of 8) were only captured once. GBF#3 was captured four times, GBF#4 was captured three times, and GBF#2 was captured twice. GBF#3 was the only frog that was tagged before spring 2020 and recaptured afterwards (**Error! Reference source not found.**).

The locations of the PIT-tagged frogs along the transect were mapped to see if they crossed the alignment (Figure 7). The frogs usually stayed within a range of less than 100m from their initial capture location (Figure 7). Five frogs remained in the same zone, while three frogs moved to different zones. Two of these frogs (GBF#4 and GBF#3) moved to adjacent zones (Zones 4-5 and Zones 5-6, respectively, Table 4). One frog (GBF#2) crossed the alignment and travelled about 800m upstream from Zone 2 to Zone 20 (Table 4 and Figure 7).

Table 4: Recapture data of giant barred frog individuals during operational phase monitoring at Upper Warrell Creek. Phases: Con = construction, Op = Operational. ID = pit tag number.

Frog ID (GBF#)	Count	Verification technique	Initial capture date & phase	Recapture dates	Capture zones
GBF#2	2	Pit tag (ID: 00078ABB9B)	02/07/18 (con)	07/02/18, 17/10/18	3
GBF#3	4	Pit tag (ID: 00077E8FEF)	11/06/17 (con)	26/02/19, 20/03/19, 27/10/20, 17/11/2021	5 and 6
GBF#4	3	Pit tag (ID: (00078ABBF2)	07/05/18 (con)	05/02/18, 26/02/19, 27/10/20	4 and 5
GBF#6	1	Pit tag (ID: 991001000620121)	19/03/19 (Op)	28/10/2020	2 and 20
GBF#23	1	Pit tag (ID:956000010433901)	15/04/21 (Op)	17/11/2021	5 and 6
GBF#25	1	Dorsal photo	15/04/21 (Op)	18/11/2021	4 and 7
GBF#26	1	Dorsal photo	15/04/21 (Op)	18/11/2021	4 and 5
GBF#29	1	Pit tag (ID:960000011459761)	18/11/21 (Op)	9/02/2022	4

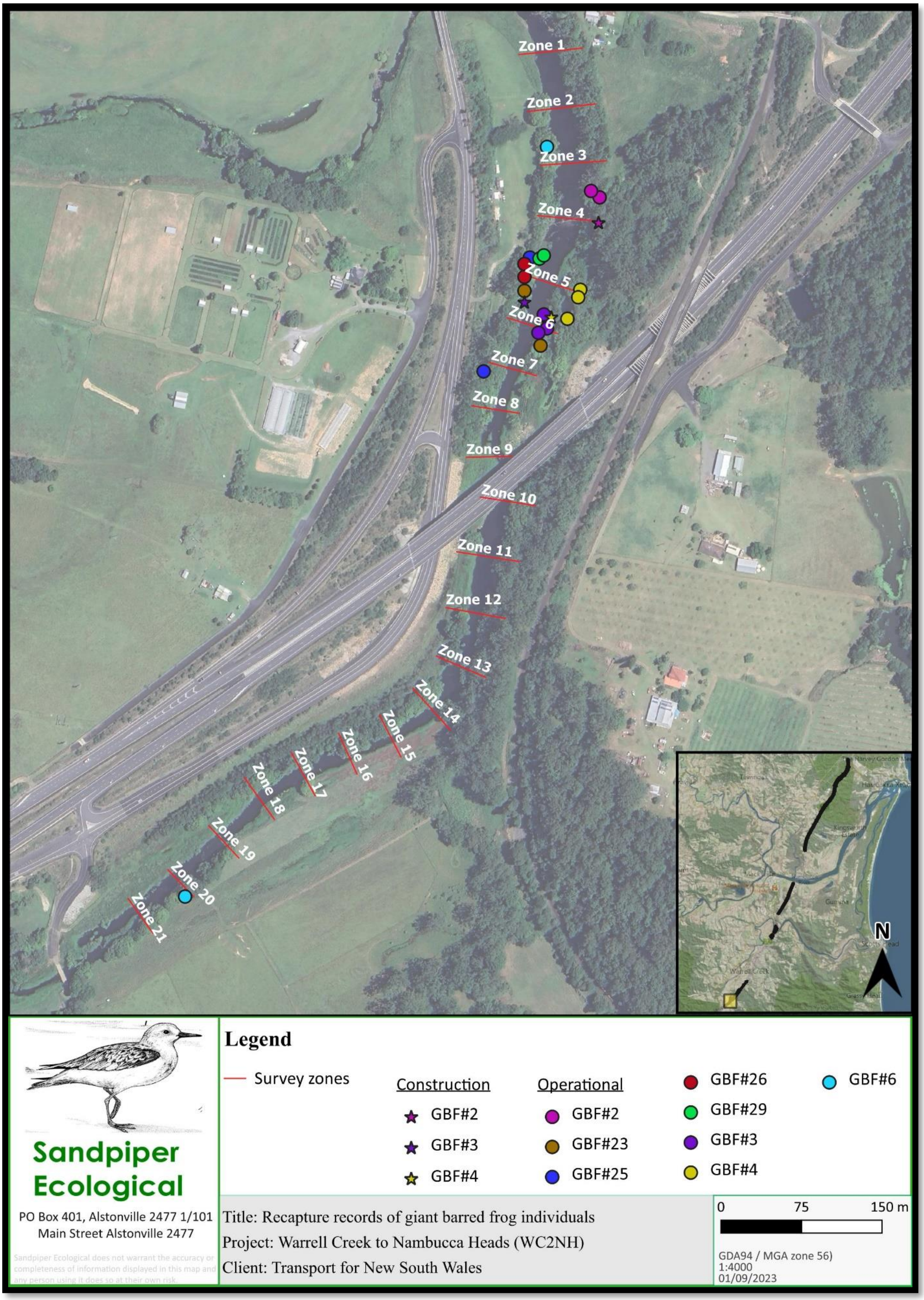

Figure 7: Location and movement patterns of recaptured giant barred frogs (individuals) recorded during the operational phase monitoring at WC2NH. The map includes both initial capture locations including three individuals that were originally tagged during the construction phase. Unique colours represent individuals.

3.6.3 Spatial distribution

At Upper Warrell Creek, all of the 66 giant barred frog detections occurred within 10 meters of the creek's edge, with 71.2% (47 records) found within 6 meters of the waters edge (Appendix A, Table A1). The primary bank within the riparian forest was the preferred habitat. Within this area 27 frogs were located on exposed leaf litter, while 17 were found in leaf litter with cover, such as beneath a lomandra or at the base of a tree. Leaf litter microhabitats accounted for two-thirds (66.6%) of all records (see Appendix A, Table A1). Notably, in the aftermath of flooding events during years 3 and 4, frogs were captured on bare earth (6 records) or on bare earth with partial vegetation cover (7 records).

During the operational monitoring in years 1, 3, 4, and 5 at Upper Warrell Creek, specific survey zones showed clustering of giant barred frog detections (Figure 8 and Figure 9). Zones 3 through 8 were particularly noteworthy for the clustering of records throughout operational monitoring (Figure 8 and Figure 9). Among the downstream zones, zone 5 recorded the highest number of decteions with 14 following by zone 4 (13) and zone 8 (6) (Figure 8). In total, the downstream areas contributed 49 records, comprising approximately 74.2% of all detections. Upstream, zone 13 was most active with 5 detections, while zones 12, 16, and 20 each recording one frog. Seventeen records (25.8%) were recorded upstream of the highway. Interestingly, zone 9, intersected by the alignment, and zones 1 (downstream), 14, 15, and 21 upstream did not record any giant barred frogs (Figure 8 and Figure 9).

During the operational phase monitoring, spatial and temporal data showed distinct trends in frog distribution. In year one, most frog detections occurred on the northern bank downstream of the highway (Figure 9). In years three and four, frog numbers increased in two areas: first, on the southern bank between hydrological zones 4-9 (downstream); second, in the riparian forest between zones 11 and 13 (upstream). By the end of the monitoring period, eight frogs were evenly distributed across both upstream/downstream and northern/southern banks.

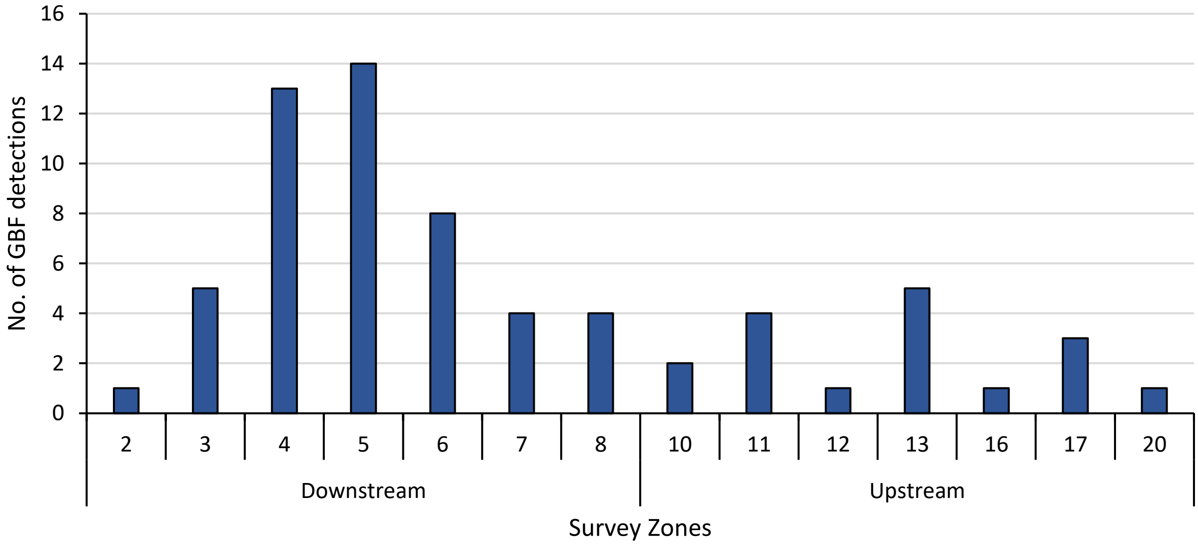

Figure 8. Number of giant barred frog records in relation to the survey zones downstream and upstream of the alignment. Note the alignment passed directly through zone 9. No individuals were recorded in zones 1, 9, 14, 15 and 21 upstream and were removed.

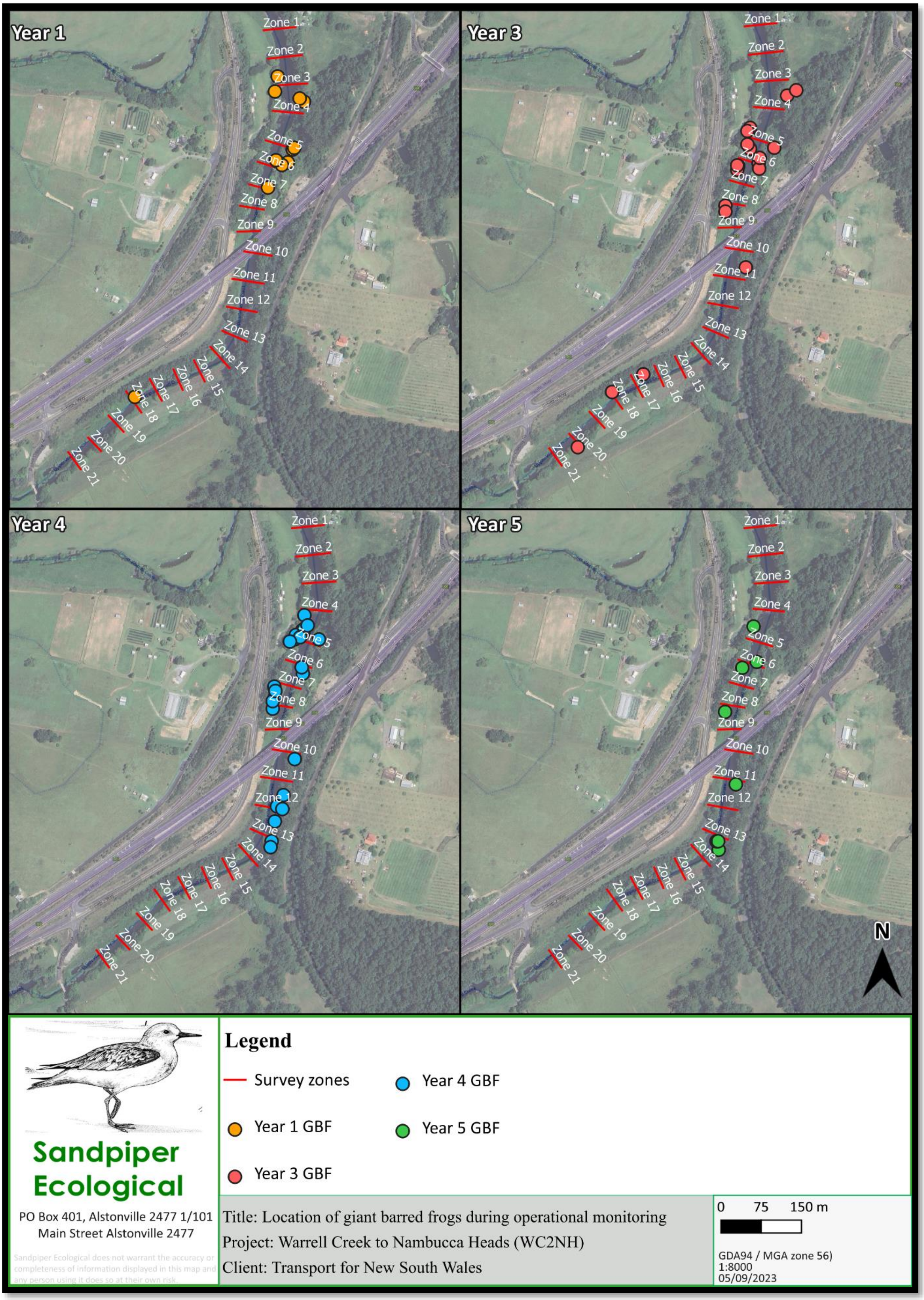

Figure 9: Location of giant barred frog records during year 1,3,4 and 5 of operational phase monitoring at Upper Warrell Creek.

3.6.4 Population estimates and trends

A comparison of adult population estimates across the seven 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 5 and Figure 10). The population estimate of 43 adult frogs (CI 26.6) in 2013/14 declined to seven (CI 9.77) in year one of the construction phase with estimates of eight (CI 10.46) and seven (CI 4.8) recorded in year 3 construction phase and year one operation phase respectively (Table 5 and Figure 10). The population increased substantially in years three and four of the operational phase with population estimates of 19 (CI 21.46) and 21.5 (17.38) adult frogs respectively. This was followed by a decline to only 3 individuals in year 5 monitoring (Table 5). Notably, a precise population estimate and confidence interval could not be determined for the year 5 data due to the absence of recaptures.

Table 5: Population estimates of adult giant barred frog at Upper Warrell Creek prior to construction (Lewis 2014), during construction (GeoLink 2018) and operational phase (Sandpiper 2019-2023).

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)	Year 5 OP (2022/2023)
GBF population estimate	43	7	8	7	19	21.5	3
95% confidence interval	26.6	9.77	10.46	4.8	21.46	17.38	N/A

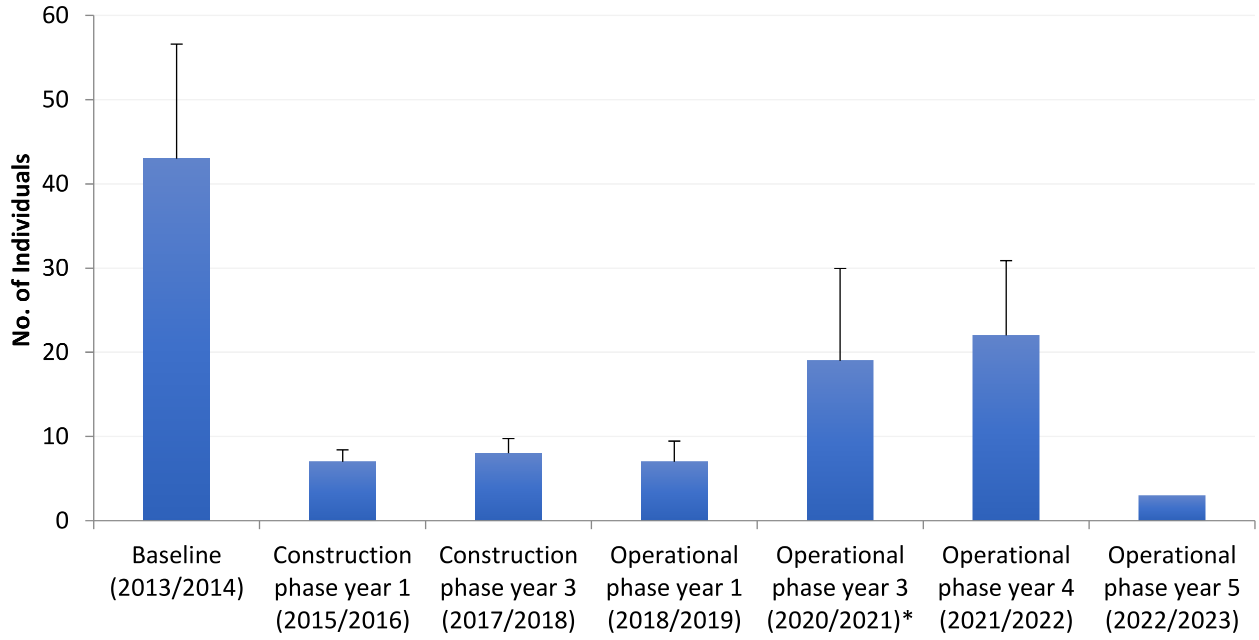

Figure 10: Adult population estimates (+ standard error) at Upper Warrell Creek during baseline (Lewis 2014b), construction phase (GeoLink 2018), year one operational phase (Sandpiper Ecological 2019), year three operational phase monitoring (Sandpiper Ecological 2021) and year four operational phase (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. Note an accurate population estimate and SE could not be derived for year five as no recaptures were recorded.

3.6.5 Chytrid sampling

Analysis of swabs from year four monitoring 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) 2022. 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).

3.7 Rainfall and giant barred frog abundance

Giant barred frog records at Upper Warrell Creek tended to increase as rainfall increased. The linear regression analysis revealed a significant positive relationship ($n=12, F=6.48$, $p\text{-value} = 0.029$) between seasonal rainfall and the number of giant barred frog captures (Figure 11 and Appendix B, Table B1). An R-squared value 0.393 suggests that 39.3% of the variation in the number of frog captures can be explained by the seasonal rainfall (Appendix B, Table B1). The scatter plot substantiates these findings, showing a trend where seasons with higher rainfall generally corresponded to a higher number of frog captures (Figure 11).

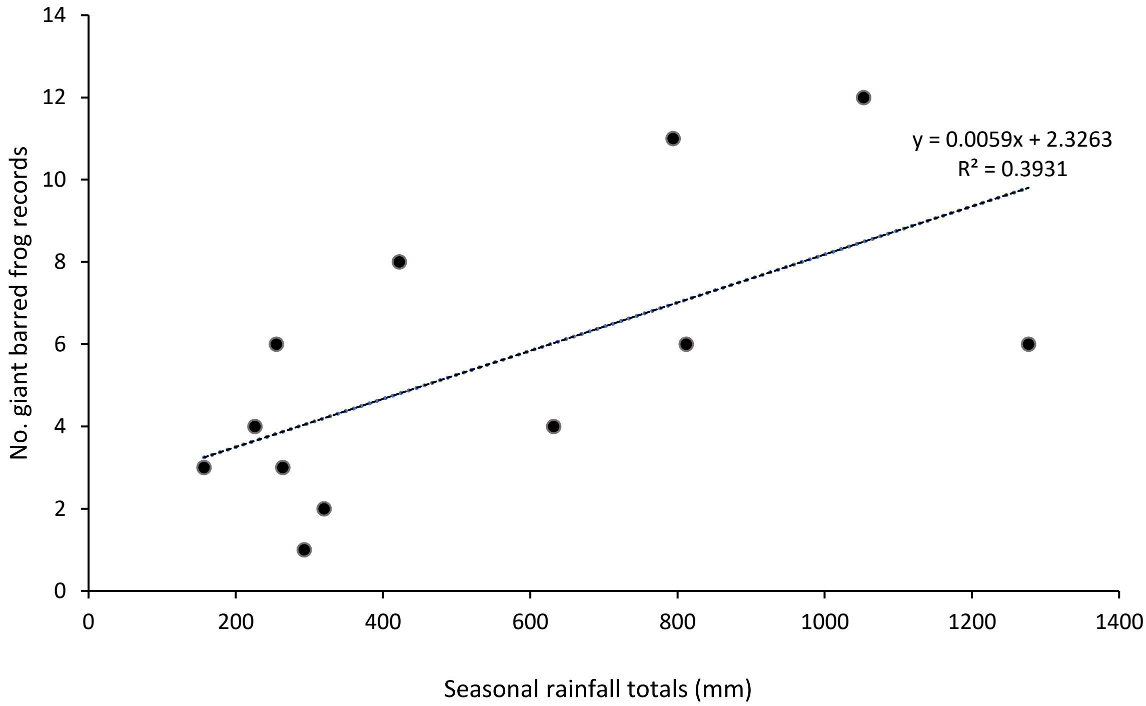

Figure 11. Linear regression between the number of giant barred frog recorded and seasonal rainfall at Upper Warrell Creek. Note that the R squared value of 0.393 indicates that rainfall explains approximately 39.3% of the variation in frog captures (Appendix B, Table B1).

4 Discussion

As outlined in the GBFMS, the primary aim of population monitoring is to assess if mitigation measures have preserved or enhanced the population size and habitat of the giant barred frog at Upper Warrell Creek. To determine this, the baseline, construction, and operational data will be compared and the key findings of operational monitoring will be discussed in relation to relevant literature. The main outcomes will then be summarised and evaluated based on the potential indicators of success specified in the GBFMS. From this, an evaluation on the effectiveness of the mitigation measures and whether the aim has been achieved will be determined with recommendations included.

The giant barred frog population at Upper Warrell Creek has fluctuated between 2013 and 2023. Starting with an estimated 43 individuals in 2013/14 (Baseline survey), the population experienced a sharp decline during the construction phase, reaching estimates of seven and eight individuals in the first (2015/16) and third years (2017/18), respectively. Notably, the third (2020/21) and fourth years (2021/22) of the operational phase monitoring saw a recovery, with the estimated population size increasing to 19 and 21.5 individuals. However, this recovery was short-lived, as year five (2022/23) recorded a substantial decline to an estimated three individuals. Population fluctuations appear characteristic of giant barred frogs, as similar patterns have been observed at other monitoring sites along the Pacific Highway (Sandpiper Ecological 2022a, Niche 2023 and Lewis 2018). Population fluctuations have been consistent at both impacted sites, where the highway passes through giant barred frog habitat, and reference sites, where the highway has no direct impact. Comparable variation was observed at Greys Dam (impact), and Arrawarra Creek (reference) at Sapphire to Woolgoolga (S2W; Sandpiper Ecological 2022a), Cooperbung Creek (impact and reference), Pipers Creek (impact and reference), Maria River (impact) and Smiths Creek (impact) at Oxley Highway to Kempsey (OH2K; Niche 2023) and four impact and four reference sites at Woolgoolga to Ballina sections 1 and 2 (W2B S1&2; Lewis 2018).

To understand these fluctuations, examining the concept of meta-populations is useful. Frogs, particularly along Australia's east coast, often exist in meta-populations created by habitat fragmentation and environmental conditions (Alford & Richards 1999). Sites along the Pacific Highway, such as Upper Warrell Creek, occur within a landscape mosaic with agricultural areas interspersed by patches of favourable riparian habitat, making it a prime example where frog meta-populations are likely to exist. These populations experience periods of decline, followed by times of high recruitment when environmental conditions are favourable. The recruitment success and population size depend on factors such as climate, floods, population age, habitat connectivity, and levels of disease (Green 2003; Newell 2018). Given the inherent variability of a meta-population, a number of factors can be expected to influence population numbers at sites like Upper Warrell Creek, irrespective of the highway construction.

4.1 Climate and hydrological conditions

Climate conditions, particularly rainfall, is one key factor influencing barred frog abundance through breeding and recruitment success (Knowles *et al*. 2015). Population estimates at Upper Warrell Creek largely mirrored rainfall trends during the construction and operational phase monitoring. The linear regression analysis revealed a significant positive relationship ($n=12, F=6.48$, p-value = 0.029) between seasonal rainfall and the number of giant barred frog captures. The first two years of construction and the initial year of operation (2015-2019) experienced average to below-average rainfall, and the population was estimated to be between seven and eight individuals during this period. These drier conditions were characterised by a higher proportion of adult frogs, suggesting low recruitment due to limited breeding opportunities. Interestingly, the number of giant barred frogs also declined at OH2K during this period, with as much as a 100% decline seen at the Cooperbung reference and impact sites (Niche 2023). Above-average rainfall in 2020-2021 led to a noticeable population recovery at Upper Warrell Creek, with the population increasing from eight individuals in year one to 19 in year three (2020-21) and peaked at 21.5 in year four (2022-23). Notably, sub-adult frogs and juveniles comprised up to 63% of the population in year three. Wet years typically increase the number of breeding opportunities and, consequently, the recruitment success of barred frog species (Newell *et al*. 2013; Knowles *et al.* 2015).

Furthermore, a noticeable rise in invertebrate abundance, the primary food source for the giant barred frog (Lemckert & Shoulder 2007), was observed in 2022 (Sandpiper Ecological 2022), likely due to the favourable climatic conditions. Together, these factors created suitable conditions for the breeding and growth of the giant barred frog population at Upper Warrell Creek. The presence of gravid females, calling males, and males with dark nuptial pads, especially in year four, are indicative of active breeding in response to good conditions.

Flooding presents another factor contributing to the movement of frogs in and out of the study area, as discussed in the year three and four monitoring reports (Sandpiper Ecological, 2021 and 2022). Confirming the influence of flooding requires repeated sampling over consecutive years both downstream and upstream of study area, which is beyond the scope of the monitoring program. However, several lines of evidence suggest a tangible effect of floods on the giant barred frog population:

1. Change in the spatial distribution of frogs: Prior to the December 2020 flood events, zones 4-7 on the northern creek bank recorded the highest number of giant barred frog captures during both the construction and year one operational phase. Distinguished by low elevation, these areas were prone to flood-induced alterations to habitat quality. Post-flooding habitat assessment in year three monitoring showed accumulation of flood debris, creek bank erosion, and depletion in leaf litter and ground-level vegetation. Data collected from the third and fourth years of monitoring identified a discernible shift in the spatial distribution of giant barred frogs. The newly observed concentrations occurred in zones 4-8 along the southern creek bank and zones 11-13 on the northern creek bank—areas characterised by steeper bank profiles likely acting as a refuge from flood waters (Lewis 2014b).

2. Variation in recapture rates: The recapture rates were high during the initial construction and operation phase between 2015-19, which had moderate to below-average rainfall and infrequent flood events. The average recapture rate between seasons in the first operational year was 52.7% (Sandpiper Ecological, 2019). However, recapture rate decreased in the following years (2020-23), along with increased rainfall and flooding frequency and severity. Notably, the recapture rates during the year three and year four monitoring events dropped below 10%, starkly contrasting the rates observed in the first year of operational monitoring (Sandpiper Ecological 2019). After multiple flood events from 2020 through spring 2022, no recaptures were observed during year five of monitoring with several new individuals arriving. This sharp decline in recaptures and increase in new individuals, particularly following flood events, suggests that flooding may influence frog movement into and out of the study area.

3. Flood severity and new observations: The catchment area experienced increasing rainfall totals from 2020 to 2022, with well-above-average rainfall recorded in 2022. This likely led to the saturation of the catchment area, which, combined with several heavy rainfall days (10 days >75mm in 2022), increased the intensity and frequency of floods. The floods changed the Upper Warrell Creek habitat, by scouring the ground, depositing flood debris, and causing bank erosion resulting in tree fall. Previous studies have shown that juvenile frogs are naturally vulnerable to flood-mediated displacement because of their size (Koch & Hero 2007). However, the third-year post-flood monitoring in 2021 also noted the presence of several large gravid adult frogs that had not been recorded before, in addition to juveniles and sub-adults. Considering the high recapture rates recorded in year one operation monitoring (around 50% on average) and the estimated detection rates of 0.54-0.65 across three surveys for giant barred frogs (Lollback 2021), coupled with their known lifespan of 5-6 years (Lewis 2014b), it is unlikely that all of these new gravid females (N=five) went undetected in previous surveys. This suggests that some adult frogs were

transported to the area during floods and equally, some adult frogs would have been washed out of the study area during this period.

The possibility that frogs moved into or out of the sample population during the sample period raises concerns about the validity of the population estimate. A key assumption of the population estimate procedure is limited immigration, emigration, and mortality during the sample period (Fowler *et al*. 1999). This implies that the population estimate may be biased or inaccurate. For instance, net immigration due to flooding would inflate population estimates, whereas net emigration would result in deflation. Although flooding could theoretically balance immigration and emigration, data indicate a net loss of individuals in year five. This is substantiated by six heavy rainfall events (>75mm) between the conclusion of year four monitoring in April 2022 and the initiation of year five monitoring in December 2022.

The study area's riparian zone warrants further consideration. Characteried by its narrow, degraded, and fragmented condition, this environmental context likely intensifies flood impacts on the frog population. Specifically, the degraded riparian zone restricts refuge habitats and hampers along-bank movement upstream of the highway. Such limitations could skew the balance between immigration and emigration during flood events, adding another layer of complexity to population estimate interpretations.

4.2 Chytrid fungus

In addition to climatic variables, the year four monitoring report discussed another important variable affecting frog populations: chytrid fungus (Sandpiper Ecological 2022). Chytrid fungus (*Batrachochytrium dendrobatidis- bd*) has been confirmed in the Upper Warrell Creek frog population and poses a potential threat to its stability. Chytrid fungus causes a disease called Chytridiomycosis, which can have various outcomes for amphibians, ranging from rapid population decline to possible recovery and resistance after infection (Lips2016; Newell *et al*. 2013; Retallick *et al*. 2004). The presence of chytrid fungus in the Upper Warrell Creek frog population was confirmed during the baseline and construction surveys, with four out of 22 tested frogs showing positive results (Lewis 2014b; Geolink 2018). One of these frogs tested negative in a later sample, indicating recovery from the infection (Geolink 2018). However, the year four monitoring data showed a an increase in chytrid detections, with five confirmed and six possible cases, resulting in a potential prevalence rate of 44% among the sampled frogs (Sandpiper Ecological 2022). This could explain the observed declines in frog numbers during year five monitoring, as chytrid-related population crashes have been documented in other studies (Retallick *et al*. 2004; Penman *et al.* 2008).

No obvious symptoms of chytrid infection, such as lethargy or discoloration, have been reported at Upper Warrell Creek, however the pathogen's impact should not be overlooked. Moreover, previous research has found that juvenile giant barred frogs are more likely to be infected with chytrid fungus than adults, and that infection intensity is negatively correlated with snout-vent length (Kriger 2006). This suggests that the successful recruitment of juveniles and sub-adults recorded during year three and four monitoring may have been compromised by the high prevalence of chytrid fungus in year four. Furthermore, environmental conditions such as lower temperatures and increased rainfall can influence the infection dynamics of chytrid fungus, as they are associated with higher Bd prevalence, infection intensity, and rates of gaining infection (Holanders *et al*. 2022). These conditions were experienced during 2021-2022, particularly between the end of year four and the beginning of year five monitoring periods (i.e. April-October 2022), which may have increased the susceptibility of the younger cohort at Upper Warrell Creek. Interestingly, chytrid fungus was detected in the frog population even before any construction activities took place, indicating that it was likely introduced prior to the commencement of monitoring. However, understanding the complex interactions between frog population age structures, environmental conditions and chytrid fungus is challenging, and it is difficult to assess the severity of its impact on the Upper Warrell Creek population. Nevertheless, the elevated incidence of chytrid fungus observed in the fourth year, coupled with the subsequent decline in population and absence of recaptures in Year five, implicates the fungus as a potential contributory factor to population decline, particularly under cooler *La Nina* conditions.

4.3 Habitat modificiation – highway construction

The year three operational monitoring report detailed habitat changes as a result of highway construction activities at Upper Warrell Creek (Sandpiper Ecological 2021). Aerial photographs from 2010 and 2013 were used as historical benchmarks to compare stream morphology before and after construction. The photographs revealed that geomorphic features such as back channels, lateral bars, and fluvial islands existed in the pre-construction period. These features offered high-quality breeding habitats for giant barred frogs by providing refuge from predators and buffering against hydrological fluctuations (Lewis 2014a). However, the photographs were captured during high-rainfall events, which might have skewed the baseline hydrological conditions.

Lewis (2014b) identified Zones 8 and 9 as ecologically vital for giant barred frogs because they contained geomorphic features that supported their breeding behaviour. In the baseline sample 44% of frogs were found in Zones 8 and 9, indicating the ecological importance of these zones within the 1 km sample area. However, construction activities, especially bridge construction, altered the stream morphology of both zones. For instance, the back channel of Zone 8 was partially eliminated by the reshaping of the northern channel, reducing the availability of refuge habitats. Moreover, the upstream section of the back channel in Zone 8 was modified by the introduction of rock fill, which may have degraded its suitability as breeding habitat by changing its hydrological characteristics and removing the natural bank structure. A small back-channel on the north bank in zone 18 was also dominated by dense vegetation following removal of stock, likely rendering this area unsuitable for frogs.

Some potential breeding habitat remains within the study area, particularly the lateral bar on the north bank in zones 6 and 7. This area includes a shallower littoral zone with overhanging banks both on the main channel and back channel sides and is the only area where male frogs were consistently heard calling throughout the monitoring program. Lollback (2021) and Lewis and Rohweder (2005) studied the habitat requirements of giant barred frogs and suggested they prefer riparian forests with abundant leaf litter, sparse ground vegetation, and undercut banks in creeks with a pool/riffle sequence. Occupancy models revealed a higher probability of frog presence in habitat areas with ponds longer than 10m and undercut banks (Lollback 2021). Habitat at Upper Warrell Creeek differs to that studied by Lollback (2021) and Lewis and Rohweder (2005) as it lacked a pool/riffle sequence and contained a single riffle within the 1km study area. Interestingly, the highest abundance of frogs in the baseline was recorded just downstream of the riffle zone in an area that included a riffle, the start of a large pool and back-channel pools.

According to Knowles *et al.* (2015) giant barred frogs lay their eggs in the water and the female deposits the eggs on a near vertical or overhanging bank from a floating position. Whilst the subject site includes an abundance of vertical and overhanging banks, access to and from the water would be challenging and frogs floating in the water would be subject to predation from eels and predatory native fish. Predation risk on adult frogs at Upper Warrell Creek may be higher than at sites with smaller pools and riffles. Whilst there is approximately 400m of habitat with steep undercut banks the suitability of this habitat for breeding is uncertain. The restricted occurrence of calling males is indicative of suitable breeding habitat extent.

4.4 Distribution and Movement

During year five of operational monitoring at Upper Warrell Creek, several noteworthy patterns in giant barred frog distribution and habitat use were observed. While no individuals were found to have moved beneath the highway, the species was detected in five out of 21 survey zones. Continued occupation of several zones suggests that the population persists in the study area, albeit with reduced spatial distribution compared to baseline surveys (Lewis 2014b). Interestingly, the fifth-year data again recorded individuals on the north bank within zones 11-13, a location where frogs had not been previously recorded in the first three years of the operational phase. This sudden clustering in these zones is attributed to flood-induced movement as suggested in years three and four (Sandpiper Ecological 2021, 2022).

The majority (74.2%) of giant barred frog detections throughout operational monitoring were concentrated in downstream zones, specifically zones 3 through 8, with zone 5 exhibiting the highest activity. This downstream preference has been a consistent pattern throughout the monitoring period. However, upstream zones were not devoid of activity, contributing to 25.8% of total detections, mostly within zone 13.

In terms of microhabitat preference, leaf litter remains the dominant substrate where two-thirds of the individuals were found, while a small proportion were found on bare earth, potentially due to the removal of leaf litter by flood events. Notably, all detections occurred within a 10-meter radius from the creek's edge, this coincides with 71.2% of records found within a 6-meter radius from the water's edge. These observations reinforce the importance of riparin forest on the primary bank as the species' preferred habitat.

Movement of giant barred frogs beneath the highway was confirmed during year three monitoring. A male frog, initially tagged in autumn 2019, was recaptured 880m upstream in spring 2020. Whilst giant barred frogs have been recording moving up to 200m in a night, average nightly movement distance is typically less than 25m (Lemckert and Brassil 2000). Records of highway crosses appeared to be more frequent at impact sites at OH2K where a total of twelve individuals crossed the alignment (Niche 2023). Movement at Upper Warrell Creek is likely hampered by dense pigeon grass (S*etaria sphacelata*) on the northern bank. This is discussed further in the following section.

4.5 Potential indicators of success

Continued presence of giant barred frog along any part of the 1 km transect

This indicator of success has been met. Despite experiencing population fluctuations giant barred frogs have persisted in various zones within the study area through all years of operational monitoring. Frogs were recorded in five out of 21 survey zones during year five of operational monitoring.

The recapture of one or more giant barred frog following their relocation from the clearing footprint (if this occurs); or the presence of tadpoles, metamorphs or juveniles frogs during follow up surveys post construction (LES 2014a).

Although no giant barred frogs were recaptured from the baseline surveys, juvenile frogs have been regularly observed during the operational phase. This data provides evidence of successful breeding and recruitment in the post-construction phase. Furthermore, the consistent detection of juveniles implies the existence of viable breeding habitats either within the surveyed transects or upstream. Such habitats are likely critical for sustaining the population amid current threats.

A <30% decline in measured habitat parameters; or <15% increase in bare ground cover;

Habitat parameters have remained relatively consistent during operational monitoring with the main change occurring post construction within zones 8 and 9. Previous monitoring reports have touched on potential habitat concerns. One notable aspect of concern was growth of pigeon grass (S*etaria sphacelata*) and broad-leaved paspalum (*Paspalum mandiocanum*) on the north bank in zones 5, 7 and 8. Pigeon grass also dominated the south bank of zones 10, 11, 19, 20 and 21. Dense grass represents a barrier to movement. Geolink (2015, 2018) recorded paspalum and/or pigeon grass in zones 7, 8 and 10, and images presented by Geolink (2018) show pigeon grass in zones 8 and 10. Based on available information, it seems likely that pigeon grass was present at commencement of construction, however grazing by stock may have kept grass under control and the exclusion of stock, particularly on the south bank, has enabled grass to grow and form a barrier to movement.

Work to control pigeon grass and paspalum in zones 7, 8, 9 and 10 commenced in July 2021. The programmed works included targeted weed control aimed at reducing the extent / density of pigeon grass and paspalum followed by planting of 60 *Waterhousia floribunda* (on the northern bank in zones 7,8 & 9) to form a canopy and connect existing remnant canopy trees. Additional *Lamandra spp.* to bolster the plantings were also added into the area (Zone 9 on the northern bank under the bridge and as needed to repair flood damage). The scope of this work was developed in consultation with and endorsed by the EPA. Post-implementation, *Paspalum mandiocanum* was notably less prevalent in previously affected areas (Zones 7-9). Restoration efforts, which included planting *Waterhousia floribunda* in Zones 7-9 on the north bank, have been successful. However, for these plants to fully integrate with existing vegetation and counter weed spread, more time is necessary. Pigeon grass remains an issue in Zones 7 and 8 on the north bank.

During the 2021-2022 period, severe floods had a substantial impact on microhabitat. Numerous trees in the riparian zone were uprooted, and areas of grass and regrowth were either eroded or flattened. The floods also washed away leaf litter, leaving exposed earth in several areas of the riparian zone. Consequently, there was a decrease in litter cover, and a substantial increase in woody debris and scoured ground cover. However, the February 2023 habitat assessment revealed some positive improvements to microhabitat condition. There was a noticeable improvement in leaf litter cover, and scouring was less prominent. Flood debris were still present, particularly around the southern banks of Zones 4-8 and 11-13, creating potential refuge areas for giant barred frogs. The leaf litter and bare ground cover had returned to baseline levels and this indicator is considered to have been met.

No statistically significant changes in measured water quality parameters

Water quality analysis conducted during operational monitoring predominantly remained within the parameters established by ANZECC guidelines, thereby necessitating minimal concern. Results from year five monitoring showed a slightly low pH, reduced dissolved oxygen, and low levels of heavy metals, but no signs of hydrocarbon contamination (Table 2). These parameters could be influenced by low flow conditions. Stagnation can lower the dissolved oxygen and pH levels due to increased water temperature and higher biochemical oxygen demand (BOD) from the decomposition of organic matter (Lintern *et al.* 2018). However, the reliability of the water quality assessment is limited by the sampling approach, which only takes isolated samples from a single location at long intervals. This may not capture the spatial and temporal variations of water quality across Upper Warrell Creek (Leigh *et al*., 2019). As such, statistical analysis is not considered applicable and would require water sampling at a higher temporal and spatial resoluation to achieve valid comparisons (Leigh *et al*. 2019).

No road kill of Giant Barred Frog resulting from operation of highway.

This indicator has been met. No giant barred frogs have been recorded during construction or operational road kill monitoring.

5 Conclusion

Management of riparian habitat at Upper Warrell Creek aimed to either sustain or enhance the population and habitat of the giant barred frog. Monitoring of the giant barred frog population over the first five years of the operational phase indicates that most indicators of success have been achieved. Nonetheless, these indicators do not provide unequivocal evidence of a stabilised or improved population of the giant barred frog. This uncertainty arises from the inherent variability in the frog's population, which is likely to have been influenced by an interplay of external variables such as climate conditions, flood events, disease outbreaks, and changes in habitat structure. As a result, the established indicators of success, in isolation, are inadequate to conclusively determine the effectiveness of the project in terms of long-term population stability or enhancement for the giant barred frog.

Of particular concern is the absence of recaptures and inability to accurately calculate a population estimate during year five. The removal of cattle from the site has enabled extensive grass growth, which would limit movement of barred frogs between riparian patches. Furthermore, construction work was centred on a morphologically complex part of the study area that included a riffle zone, with back channels and a lateral bar. Baseline surveys highlighted the importance of this are for giant barred frogs.

The monitoring program was hampered by the absence of a comparable reference site that would have provided comparative data to that collected in the study area.

6 Recommendations

Recommendations for future monitoring programs are provided in Table 6.

Table 6: Recommendations based on findings of operational phase giant barred frog monitoring program.

Number	Recommendation	Transport for NSW Response
1.	No further monitoring of giant barred frogs at Upper Warrell creek is required.	Agree
2.	Thorough consideration is required before initiating monitoring programs without inclusion of a suitable reference site.	Noted
3.	Greater consideration of baseline survey results and micro-habitat features is required during the planning phase of projects to reduce impacts on threatened species and ensure that remediation work is appropriate.	Noted

7. References

Alford, R. and Richards, S. (1999). Global amphibian declines: a problem in applied ecology. Annual Review of Ecology and Systematics 30: 133-65.

ANZECC/ARMCANZ. (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Vol 1. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Fowler, J., Cohen, L., & Jarvis, P. (1999). Practical statistics for field biology. John Wiley & Sons, New York.

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

Geolink. (2016). Annual report – WC2NH giant barred frog population monitoring. Report prepared for Pacifico.

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

Green, D. (2003). The ecology of extinction: population fluctuation and decline in amphibians. Biological Conservation 111: 331-343.

Hollanders, M., Grogan, L. F., Nock, C. J., McCallum, H. I., & Newell, D. A. (2023). Recovered frog populations coexist with endemic Batrachochytrium dendrobatidis despite load-dependent mortality. *Ecological Applications*, *33*(1), e2724.

Koch, A. J., & Hero, J.-M. (2007). The relationship between environmental conditions and activity of the giant barred frog (Mixophyes iteratus) on the Coomera River, south-east Queensland. Australian Journal of Zoology, 55(2), 89-95.

Kriger, K. M., Hines, H. B., Hyatt, A. D., Boyle, D. G., & Hero, J. M. (2006). Techniques for detecting chytridiomycosis in wild frogs: comparing histology with real-time Taqman PCR. Diseases of aquatic organisms, 71(2), 141-148.

Knowles, R., Thumm, K., Mahony, M., Hines, H., Newell, D., & Cunningham, M. (2015). Oviposition and egg mass morphology in barred frogs (Anura: Myobatrachidae: Mixophyes Günther, 1864), its phylogenetic significance and implications for conservation management. Australian Zoologist, 37(3), 381-402.

Leigh, C., Kandanaarachchi, S., McGree, J. M., Hyndman, R. J., Alsibai, O., Mengersen, K., & Peterson, E. E. (2019). Predicting sediment and nutrient concentrations from high-frequency water-quality data. PLoS One, 14(8), e0215503.

Lemckert, F., & Shoulder, J. (2007). The diets of three sympatric Barred River Frogs (Anura: Myobatrachidae) from south-eastern Australia. Herpetological Review 38(2), 152–154.

Lemkert, F., & Brassil, T. (2000). Movements and habitat use of the endangered giant barred river frog (Mixophyes iteratus) and the implications for its conservation in timber production forests. Biological Conservation: 96, 177-184.

Lewis, B. D. (2013). Pacific Highway Upgrade: Warrell Creek to Urunga green-thighed frog management strategy. Report prepared by Lewis Ecological Surveys for NSW Roads and Maritime Services.

Lewis, B. D. (2014a). Warrell Creek to Urunga: giant barred frog management strategy. Report prepared for the Roads and Maritime Services by Lewis Ecological Surveys.

Lewis, B. D. (2014b). Warrell Creek to Nambucca Heads: giant barred frog preconstruction baseline monitoring. Report prepared for the Roads and Maritime Services by Lewis Ecological Surveys.

Lewis, B. D. (2015). Giant barred frog (Mixophyes iteratus): design review at Butchers Creek following discovery of tadpoles. Letter report prepared for Pacifico by Lewis Ecological Surveys.

Lewis, B. D. (2018). Woolgoolga to Ballina: Giant Barred Frog Monitoring for Sections 1 and 2: Year 2. Report prepared for Roads and Maritime Services and Pacific Complete by Lewis Ecological Surveys.

Lintern, A., Webb, J. A., Ryu, D., Liu, S., Bende-Michl, U., Waters, D., & Western, A. W. (2018). Key factors influencing differences in stream water quality across space. Wiley Interdisciplinary Reviews: Water, 5(1), e1260.

Lips, K. R. (2016). Overview of chytrid emergence and impacts on amphibians. Philosophical Transactions of the Royal Society: 371, 20150465.

Lollback, G. W., Lockwood, M. A., & Hannah, D. S. (2021). New information on site occupancy and detection rate of Mixophyes iteratus and implications for management. Pacific Conservation Biology.

Maas, S., & Passioura, J. (1999). Response to disturbance of forest species in CRA regions in NSW – upper north east and lower north east regions. NSW CRA / RFA Steering Committee, Sydney. p134.

Niche. (2023). Giant Barred Frog monitoring: 2022/2023 – Oxley Highway to Kempsey, Pacific Highway Upgrade. Report prepared for Roads and Maritime Services by Niche Environment and Heritage Pty Ltd.

Newell, D. A., Goldingay, R. L., & Brooks, L. O. (2013). Population recovery following decline in an endangered stream-breeding frog (Mixophyes fleayi) from sub-tropical Australia. PLoS One: doi: 10.1371/journal.pone.0058559.

Newell, D. (2018). An update on frog declines from the forests of subtropical eastern Australia. In *Status of conservation and decline of amphibians: Australia, New Zealand, and Pacific Islands* (pp. 29-37). CSIRO Publishing.

Penman, T., Muir, G., Magarey, E., & Burns, E. (2008). Impact of a chytrid-related mortality event on a population of the green and golden bell frog Litoria aurea. Australian Zoologist, 34(3), 314-318.

Retallick, R. W. R., McCallum, H., & Speare, R. (2004). Endemic infection of the amphibian chytrid fungus in a frog community post-decline. PLoS Biol: 2, e351.

Lewis, B. D., & Rohweder, D. A. (2005). Distribution, habitat, and conservation status of the Giant Barred Frog Mixophyes iteratus in the Bungawalbin catchment, northeastern New South Wales. *Pacific Conservation Biology*, *11*(3), 189-197.

Sandpiper Ecological. (2019). Warrell Creek to Nambucca Heads giant barred frog monitoring report – year one operational phase. Report prepared for Transport for New South Wales.

Sandpiper Ecological. (2021). Warrell Creek to Nambucca Heads giant barred frog monitoring report – year three operational phase. Report prepared for Transport for New South Wales.

Sandpiper Ecological. (2022). Warrell Creek to Nambucca Heads giant barred frog monitoring report – year four operational phase. Report prepared for Transport for New South Wales.

Sandpiper Ecological. (2022a). Pacific Highway Upgrade – Sapphire to Woolgoolga Operational phase fauna monitoring– Greys Dam frog pipes final report. Report prepared for Transport for New South Wales.

SKM. (2010). Environmental Assessment Volume 2 - Working paper 1 Flora and Fauna. January 2010 for Roads and Traffic Authority.

Appendix A

Table A1: Operational phase monitoring field data for giant barred frog records at Upper Warrell Creek, 2018-2023.

Year	Season	Frog ID	GBF	No.	Date	Zone	Creek side	Distance from stream edge (m)	Distance ranges	Microhabitat	Sex*	Age*	S/V length (mm)	Weight (g)	Breeding condition*	Microchip ID	New or recapture	Chytrid detections
Year 1	Spring	Frog 1	GBF#	1	17/10/2018	5	North	3.4	2-4	Exposed leaf litter	Female	Adult	101.5	173.0	Gravid	991001000620130	New	N/A
Year 1	Spring	Frog 2	GBF#	2	17/10/2018	3	North	4.05	4-6	Exposed leaf litter	Male	Adult	77.1	67.0	Moderate	00078ABB9B	Recapture	N/A
Year 1	Summer	Frog 3	GBF#	3	26/02/2019	5	North	1.1	0-2	Vegetation cover	Male	Adult	83.8	85.0	Moderate	00077E8FEF	Recapture	N/A
Year 1	Summer	Frog 4	GBF#	4	26/02/2019	4	North	8.3	8-10	Exposed leaf litter	Female	Adult	101.5	141.0	Gravid	00078ABBF2	Recapture	N/A
Year 1	Summer	Frog 2	GBF#	2	26/02/2019	3	North	1.3	0-2	Leaf litter - cover	Male	Adult	74.8	76.0	Moderate-dark	00078ABB9B	Recapture	N/A
Year 1	Summer	Frog 5	GBF#	5	26/02/2019	3	South	NR	NR	N/A	Male	Adult	NR	NR	Calling	NR	New	N/A
Year 1	Autumn	Frog 5	GBF#	6	19/03/2019	2	South	1.54	0-2	Leaf litter - cover	Male	Adult	75.9	53.0	Moderate	991001000620121	New	N/A
Year 1	Autumn	Frog 6	GBF#	7	19/03/2019	17	South	5	4-6	Leaf litter - cover	Immature	Sub-adult	45.7	11.5	NA	NA	New	N/A
Year 1	Autumn	Frog 4	GBF#	4	20/03/2019	5	North	4.42	4-6	Exposed leaf litter	Female	Adult	99.5	165.0	Gravid	00078ABBF2	Recapture	N/A
Year 1	Autumn	Frog 7	GBF#	8A	20/03/2019	5	North	1.3	0-2	Leaf litter - cover	Male	Adult	73.2	57.0	Moderate	991001000620125	New	N/A
Year 1	Autumn	Frog 8	GBF#	8	20/03/2019	6	North	3.6	2-4	Leaf litter - cover	Female	Adult	92.5	116.0	Gravid	991001000620122	New	N/A
Year 1	Autumn	Frog 3	GBF#	3	20/03/2019	5	North	0.8	0-2	Vegetation cover	Male	Adult	81.8	85.0	Moderate	00077E8FEF	Recapture	N/A
Year 3	Spring	Frog 1	GBF#	3	27/10/2020	5	North	1.2	0-2	Leaf litter - cover	Male	Adult	83.7	85.0	Moderate	00077E8FEF	Recapture	N/A
Year 3	Spring	Frog 2	GBF#	4	27/10/2020	5	North	4	2-4	Exposed leaf litter	Female	Adult	98.7	141.0	Gravid	00078ABBF2	Recapture	N/A
Year 3	Spring	Frog 3	GBF#	6	28/10/2020	20	North	5	4-6	Exposed leaf litter	Male	Adult	75.3	58.0	Moderate	991001000620121	Recapture	N/A
Year 3	Summer	Frog 4	GBF#	9	17/02/2021	8	South	0.2	0-2	Exposed leaf litter	Immature	Sub-adult	51.4	15.0	N/A	NA	New	N/A
Year 3	Summer	Frog 5	GBF#	10	17/02/2021	6	South	0.7	0-2	Exposed bare earth	Male	Adult	NR	NR	Calling	NR	New	N/A
Year 3	Summer	Frog 6	GBF#	11	17/02/2021	6	South	4	2-4	Exposed leaf litter	Immature	Juvenile	36.1	5.0	N/A	NA	New	N/A
Year 3	Summer	Frog 7	GBF#	12	17/02/2021	16	South	3.5	2-4	Leaf litter - cover	Immature	Sub-adult	42.6	10.0	N/A	NA	New	N/A
Year 3	Summer	Frog 8	GBF#	13	17/02/2021	17	South	4.5	4-6	Exposed leaf litter	Immature	Sub-adult	44.2	10.0	N/A	NA	New	N/A
Year 3	Summer	Frog 9	GBF#	14	17/02/2021	17	South	5	4-6	Exposed leaf litter	Immature	Juvenile	39.4	6.0	N/A	NA	New	N/A

Year	Season	Frog ID	GBF	No.	Date	Zone	Creek side	Distance from stream edge (m)	Distance ranges	Microhabitat	Sex*	Age*	S/V length (mm)	Weight (g)	Breeding condition*	Microchip ID	New or recapture	Chytrid detections
Year 3	Autumn	Frog 10	GBF#	15	14/04/2021	3	North	5	4-6	Leaf litter - cover	Immature	Sub-adult	56.0	22.0	NA	911001000620123	New	N/A
Year 3	Autumn	Frog 11	GBF#	16	14/04/2021	3	North	0.4	0-2	Exposed bare earth - cover	Immature	Juvenile	39.0	NR	NR	NA	New	N/A
Year 3	Autumn	Frog 12	GBF#	17	14/04/2021	6	North	4	2-4	Exposed bare earth	Immature	Sub-adult	59.2	25.3	NA	991001000620129	New	N/A
Year 3	Autumn	Frog 13	GBF#	18	14/04/2021	10	North	8	6-8	Exposed leaf litter	Immature	Sub-adult	59.7	24.0	NA	956000010433861	New	N/A
Year 3	Autumn	Frog 14	GBF#	19	15/04/2021	8	South	2	0-2	Exposed bare earth - cover	Immature	Sub-adult	59.2	25.5	NA	956000010454091	New	N/A
Year 3	Autumn	Frog 15	GBF#	20	15/04/2021	6	South	2.5	2-4	Exposed bare earth - cover	Immature	Sub-adult	52.2	15.0	NA	956000010434396	New	N/A
Year 3	Autumn	Frog 16	GBF#	21	15/04/2021	5	South	4	2-4	Exposed bare earth - cover	Male	Adult	63.4	33.0	NA	956000010427097	New	N/A
Year 3	Autumn	Frog 17	GBF#	22	15/04/2021	5	North	NR	NR	N/A	Male	Adult	NR	NR	Calling	NR	New	N/A
Year 3	Autumn	Frog 18	GBF#	23	15/04/2021	5	South	3	2-4	Exposed leaf litter	Female	Adult	94.0	123.0	Gravid	956000010433901	New	N/A
Year 3	Autumn	Frog 19	GBF#	24	15/04/2021	4	South	3	2-4	Exposed bare earth - cover	Male	Adult	68.3	50.0	Dark	Not tagged	New	N/A
Year 3	Autumn	Frog 20	GBF#	25	15/04/2021	4	South	7	6-8	Exposed bare earth	Male	Adult	63.1	26.0	NA	Not tagged	New	N/A
Year 3	Autumn	Frog 21	GBF#	26	15/04/2021	4	South	8	6-8	Exposed leaf litter	Immature	Sub-adult	59.7	30.5	NA	Not tagged	New	N/A
Year 4	Spring	Frog 1	GBF#	23	17/11/2021	6	North	4	2-4	Leaf litter - cover	Female	Adult	98.1	122.0	Gravid	956000010433901	Recapture	Positive
Year 4	Spring	Frog 2	GBF#	3	17/11/2021	6	North	0.3	0-2	Vegetation cover	Female	Adult	87.3	88.0	NR	00077E8FEF	Recapture	N/A
Year 4	Spring	Frog 3	GBF#	25	18/11/2021	7	South	9	8-10	Exposed leaf litter	Male	Adult	66.8	36.0	Moderate	960000011419351	Recapture	Positive
Year 4	Spring	Frog 4	GBF#	26	18/11/2021	5	South	3	2-4	Exposed leaf litter	Male	Adult	63.5	42.0	Dark	960000011425829	Recapture	Possible
Year 4	Spring	Frog 5	GBF#	27	18/11/2021	5	South	6	4-6	Exposed leaf litter	Male	Adult	65.8	38.0	Dark	960000011423017	New	Positive
Year 4	Spring	Frog 6	GBF#	28	18/11/2021	4	South	0.8	0-2	Exposed leaf litter	Male	Adult	73.8	48.0	Dark	960000011408672	New	Possible
Year 4	Spring	Frog 7	GBF#	29	18/11/2021	4	South	0.1	0-2	Exposed bare earth	Male	Adult	76.1	50.0	Moderate	960000011459761	New	Possible
Year 4	Spring	Frog 8	GBF#	30	18/11/2021	7	South	7	6-8	Exposed leaf litter	Female	Adult	92.5	122.0	Gravid	960000011432455	New	Positive
Year 4	Summer	Frog 9	GBF#	31	9/02/2022	4	South	6.4	6-8	Exposed leaf litter	Immature	Juvenile	38.5	17.0	NA	NA	New	Negtative
Year 4	Summer	Frog 10	GBF#	29	9/02/2022	4	South	0.5	0-2	Exposed bare earth	Female	Adult	86.4	95.0	Gravid	960000011459761	Recapture	Negtative
Year 4	Summer	Frog 11	GBF#	32	9/02/2022	4	South	0.9	0-2	Leaf litter - cover	Immature	Sub-adult	53.9	18.0	NA	960000011425922	New	Negtative

Year	Season	Frog ID	GBF	No.	Date	Zone	Creek side	Distance from stream edge (m)	Distance ranges	Microhabitat	Sex*	Age*	S/V length (mm)	Weight (g)	Breeding condition*	Microchip ID	New or recapture	Chytrid detections
Year 4	Summer	Frog 12	GBF#	33	9/02/2022	4	South	2.3	2-4	Exposed leaf litter	Male	Adult	76.0	58.3	Dark	960000011427483	New	Negtative
Year 4	Summer	Frog 13	GBF#	34	9/02/2022	4	North	NR	NR	N/A	Male	Adult	NR	NR	Calling	NR	New	Negtative
Year 4	Summer	Frog 14	GBF#	35	9/02/2022	8	South	8	6-8	Exposed leaf litter	Female	Adult	79.5	80.0	NR	960000011431052	New	Negtative
Year 4	Summer	Frog 15	GBF#	36	3/03/2022	4	South	NR	NR	N/A	Male	Adult	NR	NR	Calling	NR	New	Negtative
Year 4	Summer	Frog 16	GBF#	37	3/03/2022	10	North	8.5	8-10	Leaf litter - cover	Immature	Sub-adult	50.3	23.5	N/A	NA	New	Possible
Year 4	Summer	Frog 17	GBF#	38	3/03/2022	11	North	3.2	2-4	Leaf litter - cover	Female	Adult	119.0	96.3	Gravid	Not tagged	New	Negtative
Year 4	Summer	Frog 18	GBF#	39	3/03/2022	11	North	4.5	4-6	Exposed bare earth - cover	Immature	Juvenile	36.6	19.0	NA	NA	New	Negtative
Year 4	Summer	Frog 19	GBF#	40	3/03/2022	13	North	0.6	0-2	Exposed bare earth - cover	Female	Adult	104.0	90.6	Gravid	Not tagged	New	Negtative
Year 4	Autumn	Frog 20	GBF#	41	11/04/2022	7	South	8.5	8-10	Exposed leaf litter	Immature	Sub-adult	52.9	22.0	N/A	960000011423778	New	Negtative
Year 4	Autumn	Frog 21	GBF#	42	11/04/2022	5	South	3.6	2-4	Exposed leaf litter	Female	Adult	91.4	130.0	Gravid	960000011432288	New	Negtative
Year 4	Autumn	Frog 22	GBF#	43	11/04/2022	7	South	6	4-6	Leaf litter - cover	Immature	Sub-adult	53.1	23.0	N/A	960000011450114	New	Negtative
Year 4	Autumn	Frog 23	GBF#	44	11/04/2022	12	North	4.5	4-6	Exposed bare earth	Immature	Sub-adult	55.2	25.0	N/A	960000011427302	New	Possible
Year 4	Autumn	Frog 24	GBF#	45	11/04/2022	13	North	9	8-10	Exposed leaf litter	Male	Adult	68.5	42.0	Moderate	960000011433481	New	Possible
Year 4	Autumn	Frog 25	GBF#	46	11/04/2022	11	North	7	6-8	Leaf litter - cover	Immature	Sub-adult	59.7	32.0	N/A	960000011421640	New	Positive
Year 5	Spring	Frog 1	GBF#	47	1/12/2022	8	South	5.0	4-6	Exposed leaf litter	Female	Adult	91.0	132.0	Gravid	956000011426414	New	N/A
Year 5	Spring	Frog 2	GBF#	48	1/12/2022	6	South	NR	NR	N/A	Male	Adult	NR	NR	Calling	NR	New	N/A
Year 5	Spring	Frog 3	GBF#	49	2/12/2022	11	North	6.0	4-6	Leaf litter - cover	Male	Adult	71.5	61.0	Moderate	956000010454481	New	N/A
Year 5	Spring	Frog 4	GBF#	50	2/12/2022	13	North	10.0	8-10	Exposed leaf litter	Male	Adult	68.4	59.0	Moderate	956000010427117	New	N/A
Year 5	Summer	Frog 5	GBF#	51	6/02/2023	13	North	3.0	2-4	Leaf litter - cover	Immature	Juvenile	33.2	8.0	N/A	NA	New	N/A
Year 5	Summer	Frog 6	GBF#	52	6/02/2023	13	North	4.5	4-6	Leaf litter - cover	Immature	Juvenile	26.9	6.0	N/A	NA	New	N/A
Year 5	Summer	Frog 7	GBF#	53	7/02/2023	5	North	NR	NR	N/A	Male	Adult	NR	NR	Calling	NR	New	N/A
Year 5	Autumn	Frog 8	GBF#	54	2/05/2023	4	South	2.1	2-4	Exposed leaf litter	Immature	Juvenile	39.7	9.0	Uk	NA	New	N/A

Appendix B

Table A1: Linear regression analysis summary output for giant barred frog records and seasonal rainfall totals for operational monitoring, WC2NH.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.626937929
R Square	0.393051167
Adjusted R Square	0.332356284
Standard Error	2.798149379
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	50.70360055	50.70360055	6.475853411	**0.029123987**
Residual	10	78.29639945	7.829639945		
Total	11	129			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.326329104	1.485871835	1.565632412	0.148502731	-0.98439966	5.637057868	-0.98439966	5.637057868
X Variable 1	0.005854581	0.002300633	2.544769815	0.029123987	0.000728452	0.010980711	0.000728452	0.010980711

Transport for
New South Wales

Warrell Creek to Nambucca Heads

Interim Underpass Monitoring Report - Operational Phase, Year Five interim spring/summer (2022-2023)

Transport for New South Wales | February 2023

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

Underpass and Adjacent habitat monitoring– operational phase Year Five interim report (Spring/summer 2022/23)

Sandpiper Ecological Surveys

Final Report
6 September 2023

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Table of contents

List of tables

List of figures

List of plates

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 interim results of the spring/summer year 5 operational phase underpass and adjacent habitat monitoring. The objective of fauna underpass monitoring is "to assess use of underpasses by threatened and common fauna and to assess the effect of exclusion fencing on movement of small mammals, reptiles and frogs" (RMS 2018). Effectiveness of exclusion fence is also assessed in the annual road-kill report (see Sandpiper Ecological 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;
6. No breaches in fauna exclusion fencing;
7. Low incidences of fauna road strike mortality.

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

2. Methods

2.1 Study area

The WC2NH project covers a total length of 19.75km and extends from Warrell Creek in the south to Nambucca Heads in the north (Figure 1). The alignment bypasses the town of Macksville and the northern section traverses Nambucca State Forest. The WC2NH upgrade features 23 fauna underpasses, including 13 box culverts, three pipe culverts and seven bridges. Underpasses targeted for monitoring were specified in the WC2NH EMP and include eleven box culverts and one bridge (RMS 2018; Table 1). Eleven underpasses are situated north of the Nambucca River and one (Site 1) is situated at Upper Warrell Creek near the southern extent of the project (Figure 1). Sites four to 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 (*Dasyurus maculatus*), koala (*Phascolarctos cinereus*) and giant barred frog (*Mixophyes iteratus*). Giant barred frog is known to occur at site 1 (Upper Warrell Creek) only, whilst quoll and koala could occur at sites 2-12.

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

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

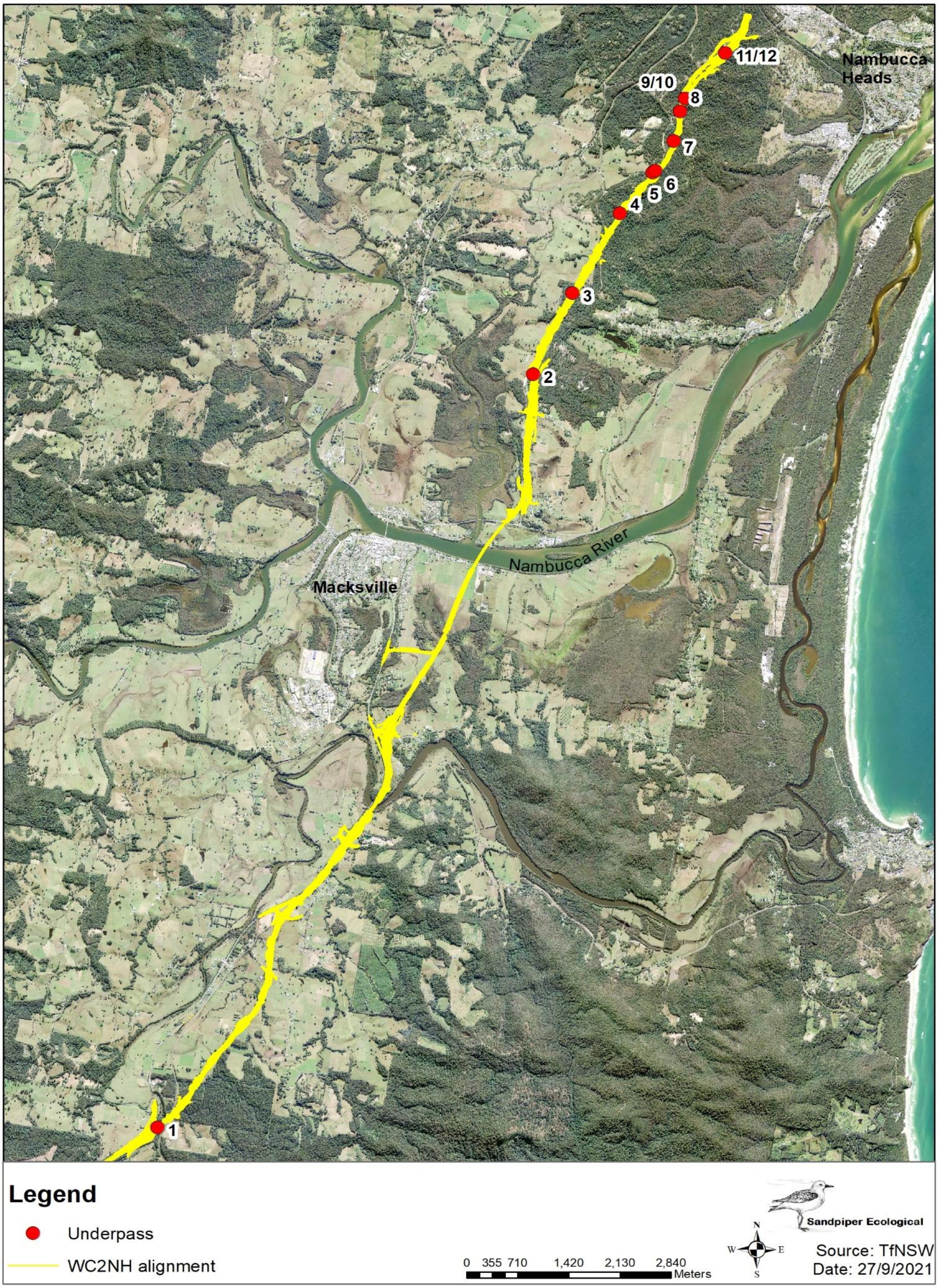

Figure 1: Underpass locations along the WC2NH alignment.

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

2.2 Timing and weather conditions

Year 5 spring/summer operational phase underpass and adjacent habitat surveys were conducted between 14 October 2022 to 6 February 2023. Wet conditions were a feature of early spring monitoring (October) when 300mm fell during the month. Dry conditions persisted from November with below average rainfall conditions from November – February with 175mm recorded at the Bellwood weather station. A total of 397mm of rainfall was recorded at the Bureau of Meteorology (BOM) Bellwood station (#059150) throughout the spring/summer monitoring period (BOM, 2023a). Relative humidity was high with >60% recorded on most days and air temperature ranged from 20.8 to 36.9 ^{0}C (BOM, 2023b).

Table 2: Summary of weather conditions recorded at Coffs Harbour Airport (station 059151) and Bellwood (station 059150) during year five spring/summer operational phase monitoring. XX = awaiting winter sample data.

Monitoring period	Total rainfall (mm)	No. rain days	Relative humidity (%)	Max temp range (^{0}C)	Min temp range (^{0}C)
Spring/Summer	397	55	>60% on 73% of days	20.8-36.9	6.8-24.6
Winter	XX	XX	XX	XX	XX

2.3 Underpass monitoring

2.2.1 Sand pads

Sand pads were installed on 30 January 2023 (spring/summer sample) 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) one sand pad was 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 for 3-4m at site 1. At sites with a concrete ledge the pad covered both the floor and ledge (Plate 2). The exception was site 5 where the pad covered the ledge only due to standing water over the culvert floor on the eastern end.

Sand pads were inspected on eight consecutive days across all sites. 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

Each underpass was searched by an ecologist for scats and tracks on two occasions during the spring/summer sample. The search involved a slow systematic traverse of each culvert using a hand-held spotlight (Led Lenser P14). Fauna furniture, the culvert floor, and 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 2023 spring/summer sample period.

2.2.4 Cameras

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

During the spring/summer sample period, cameras at sites 1-12 were installed between 14 and 21 October 2022 and were inspected during the middle of each session (i.e., after 4 weeks) to change batteries and SD cards. Cameras at sites 1-12 were retrieved on 30 December 2022 following a total sample period of 77 days (Table 3). Cameras at sites 1 (North & south), 3 (ground), 9 (ground) and 11 (ground) were reinstalled 9 January 2023 and retrieved 5/6 February 2023 following SD and camera errors during the original sample period. Two of the 24 cameras were active for less than the 60-day minimum sample period with both a result of camera malfunction/battery failure (Table 3). Overall, cameras were active for a period of 1812 days with all 12 underpasses having at least one camera active for >60 days (Table 3). The total number of camera monitoring days achieved in spring/summer year 5 (i.e., 1812) exceeded the effort required by the EMP of 1440 days.

Table 3: Camera survey effort during year five summer/spring operational phase monitoring**.** ! = SD card error * = Camera malfunction/battery failure.

Site	Camera type	Camera location	Days active
1	Reconyx	North	90*
	Reconyx	South	63*
2	Reconyx	Furniture	77
	Swift enduro	Ground	77
3	Swift enduro	Furniture	77
	Swift enduro	Ground	104!
4	Swift 3c	Ground	77
	Swift enduro	Furniture	77
5	Swift enduro	North	54*
	Swift enduro	South	77
6	Reconyx	Furniture	77
	Reconyx	Ground	77
7	Swift 3c	Ground	77
	Swift enduro	Furniture	77

Site	Camera type	Camera location	Days active
8	Swift enduro	Furniture	77
	Swift enduro	Ground	77
9	Swift 3c	Ground	33*
	Swift enduro	Furniture	77
10	Swift enduro	Furniture	77
	Swift enduro	Ground	77
11	Swift enduro	Furniture	77
	Swift enduro	Ground	82*
12	Swift enduro	Furniture	77
	Swift enduro	Ground	77

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 (i.e., complete or incomplete). A hierarchical approach was adopted to species identification that included: species, genus, or group. Microbats were recorded as presence only.

Data analysis and interpretation

To adequately assess "use of underpasses" as per the monitoring aim, complete crossings were used as the standard of 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 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. Survey effort and complete crossings at underpasses 5/6 (close 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. This same approach has been applied to data from previous monitoring years. Birds and microbats were excluded from analysis as they do not require underpasses for thoroughfare.

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

2.3 Adjacent habitat survey

2.3.1 Survey design

A total of 18 sites were sampled at the 12 underpasses as part of adjacent habitat 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 was 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 occurred at site 3 and no arboreal Elliott trapping occurred on the west side at site 3 to limit disturbance of nearby private residence. 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 30 January 2023 and 3 February 2023.

Traps were set in an “X” formation with five ground and five arboreal traps set at 20 m intervals on one axis and 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 drift fence was 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. Pitfall traps at sites 1, 4 and 2 east were closed due to rising groundwater that filled the buckets. 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 1.8 m 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 baited with sardines. A tuna oil and water mix was sprayed around the entrance to cage traps baited with sardines. All traps were checked within four hours of sunrise. In spring/summer, cage and Elliott traps were closed following the morning inspection and re-opened in the late afternoon. Pitfall traps were checked in the morning and again in mid-afternoon.

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

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. Diurnal active searches were conducted between 1 and 3 February 2023 for a total of 1080 person minutes (Table 4).

2.3.4 Nocturnal active search

Nocturnal surveys were conducted on each side of each underpass on two non-consecutive nights during the spring/summer and winter sample periods. One or two ecologists conducted spotlight surveys for 60 person minutes per underpass side/sample period, divided into two 30-person minute samples on non-consecutive nights (Table 4). Surveys were conducted using hand-held Led Lenser P14 spotlights and involved a meandering traverse of habitat within 200m of the culvert entrance. Fauna were detected by sight and call and identified to species or genus where possible. Nocturnal surveys were conducted between 1 and 7 February 2023 for a total of 1080 person minutes (Table 4).

2.3.5 Opportunistic records

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

Table 4: Survey effort for sampling adjacent habitat on the WC2NH upgrade. * Pitfall traps at sites 1, 4 and 2 east were packed down on February 1 due to the water table rising and filling up the buckets.

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

2.4 Exclusion fence

Exclusion fence monitoring is to be conducted in winter 2023.

3. Results

3.1 Underpasses

3.1.1 Camera monitoring

Year 5 spring/summer species diversity and native fauna use

Seventeen species, one unique genus (brown antechinus) and six fauna groups were confirmed making complete crossings of underpasses during year five spring/summer camera monitoring (Table 5). Of the fauna recorded, fourteen were native species with an additional six native fauna groups (Table 5). Native fauna diversity was highest at site 2 with thirteen species/groups, followed by site 11/12 (twelve species/groups), site 4 (eleven species/groups) and site 8 and 9/10 (nine species/groups). Native fauna diversity was lowest at site 1 (three species - *Antechinus* spp., lace monitor and swamp wallaby) (Table 5). Remaining sites including 3, 5/6 and 7 all recorded eight native fauna species/groups (Table 5). Four introduced species were also recorded including cat, wild dog, red fox and black rat (Table 5).

Complete crossings by native species were recorded at all sites at an overall rate of 3.05 ± 0.52cc/week/underpass (Figure 2, Figure 3, Figure 5). Sites 2, 4 and 7 featured the highest use by native fauna with a total of 4.18cc/week, 5.59cc/week and 3.91cc/week respectively (Figure 2). Sites 1 and 5/6 exhibited the lowest use by native fauna recording 0.50cc/week and 1.30cc/week respectively (Figure 2). Native fauna use was higher than that of feral predators at all sites and introduced/undefined rodents across most sites (Figure 2). Native species exhibited use of fauna furniture in all underpasses, with preferential furniture use demonstrated by *Antechinus* spp., lizard spp. and *Trichosurus* spp. (Table 5).

Short-eared brushtail possum was the most frequently recorded native species with a total of 13.54cc/week across all sites (Table 5). This was followed by bandicoot species (including long-nosed and northern brown) with 9.77cc/week, swamp wallaby (including wallaby species records) with 8.66cc/week and lace monitor with 5.92cc/week (Table 5).

Koala was the only threatened species recorded, with one complete crossing using the culvert floor at site 4 (Table 5, Plate 4).

Use by cover dependent species with low mobility

Cover dependent fauna with low mobility (see classification in methods) were recorded at all sites (Table 5). In order of use, rodent species recorded a total of 24.05 cc/week, bandicoots 9.77 cc/week, and *Antechinus* spp. 3.62 cc/week (see total Table 5). Confirmed rodent species were black rat (underpasses 2,4,5,7,8,9/10, 11/12), bush rat (sites 2, 4, 7, 11/12) and water rat (site 5/6) (Table 5). Other cover dependent species included eastern blue-tongue lizard using the culvert floor at sites 2 and 11/12 (Table 5). Lizard species were also identified using the fauna furniture at sites 2, 9/10 and 11/12, these individuals are considered probable *Egernia mcpheii*. No frogs were recorded using underpasses during camera monitoring.

Feral predator activity

Feral predators including wild dog, red fox and cat were recorded at all sites during the spring/summer monitoring period 2023 (Table 5, Figure 2). Feral predator records accounted for 14% of all complete crossings excluding rodents (Figure 3). Cat activity was recorded across five of nine sites at an average rate of 0.097 cc/week/underpass with the highest activity (combined total of 0.61 cc/week) occurring at site 3 (Table 5, Figure 2 and Figure 3). Fox activity was recorded at seven of the nine sites at an average rate of 0.24 ±0 .2 cc/week/underpass and no records at sites 3 and 4 (Table 5, Figure 2). Wild dog activity was recorded at six of the nine sites, with the highest activity at site 9 with 1.21 cc/week, and an average of 0.22±0.07 cc/wk/site and a total of 3.22 cc/week. Sites 1, 2 and 3 saw no activity on the cameras of wild dogs (Table 5, Figure 2). Feral predator activity since year 4 has fluctuated, with cat crossings decreasing by 0.43 cc/wk and dog increasing from 0.0015 cc/wk/site to 0.22±0.07 cc/wk/site (Figure 4). Complete crossings by feral predators were lowest at sites 2 (0.09cc/wk; 4.18 cc/wk), 4 (0.5 cc/wk; 5.59cc/wk) and 7 (0.18cc/wk; 3.9cc/wk) (Table 5, Figure 2). Overall, red foxes were the most prominent feral predator utilising the underpasses, with a combined total of 3.60 cc/week (Table 5).

No instances of predation were recorded occurring within the underpasses during year five spring/summer operational monitoring. However, there were several instances of feral predators carrying prey through the underpasses (see fox Plate 4).

Table 5: Total complete crossings/week/underpass made by each species/group at 12 underpass structures monitored on the WC2NH upgrade during year 5 spring/summer monitoring. FF= fauna furniture and G= ground (culvert floor), N = north, S = south. Sites 1 and 5 did not contain fauna furniture. Total number of native species/groups recorded per site (9/10 and 11/12 split median) in bold. Species in bold denote threatened species, ^=Cover dependent species and * = introduced species. See appendix B, Table B1 for all data.

Species/fauna groups	Site and camera location																		Total cc/week/spp.
	1		2		3		4		5/6		7		8		9/10		11/12		
	N	S	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	
Mammals																			
Short-beaked echidna	-	-	-	0.09	-	-	-	0.09	-	-	-	-	-	-	-	-	-	-	0.18
Antechinus spp.	0.08	-	2.82	0.09	0.09	-	-	-	0.36	0.03	-	-	0.18	-	0.05	-	-	-	3.62
Long-nosed bandicoot	-	-	-	3.18	-	-	-	1.18	-	0.40	-	0.36	-	0.09	-	0.57	-	0.18	5.97
Northern brown bandicoot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.31	0.31
Bandicoot spp.	-	-	-	0.09	-	-	-	0.45	-	0.07	-	0.36	-	0.82	-	0.64	-	1.06	3.49
Koala	-	-	-	-	-	-	-	0.09	-	-	-	-	-	-	-	-	-	-	0.09
Brushtail possum spp.	-	-	-	-	0.64	-	-	1.91	-	-	-	-	0.55	0.09	0.23	0.06	0.32	-	3.79
Short-eared brushtail possum	-	-	-	0.18	3.55	-	1.55	0.09	-	-	5.09	-	0.36	0.18	0.14	-	2.36	0.04	13.54
Eastern grey kangaroo	-	-	-	-	-	0.67	-	-	-	-	-	-	-	-	-	-	-	-	0.67
Red-necked wallaby	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	0.04	0.11
Swamp wallaby	0.54	0.11	-	0.45	-	-	-	1.45	-	0.40	-	0.18	-	1.27	-	-	-	0.18	3.94
Wallaby spp.	-	-	-	0.27	-	0.47	-	1.18	-	0.03	-	0.45	-	1.82	-	0.45	-	0.04	4.72
Macropod spp.	-	-	-	0.00	-	1.21	-	-	-	-	-	-	-	-	-	-	-	-	1.21
Water rat	-	-	-	-	-	-	-	-	-	0.07	-	-	-	-	-	-	-	-	0.07
Bush rat	-	-	0.09	-	-	-	0.36	-	-	-	0.36	-	-	-	-	-	0.59	-	1.41
Rodent spp.																			
Black rat*	0.08	-	-	0.45	-	-	0.73	0.09	-	0.03	0.36	0.73	0.18	-	0.14	0.25	0.09	0.04	3.10
Rattus spp.	-	0.11	0.18	0.27	-	-	7.09	-	4.36	0.03	4.91	0.45	0.45	0.09	1.95	0.06	4.18	-	24.05
Feral predators																			
Red fox*	0.39	-	-	0.18	-	-	-	-	-	0.17	-	0.27	-	0.82	-	0.57	-	1.58	3.60
Wild dog*	-	-	-	-	-	-	-	0.82	-	0.37	-	0.09	-	0.45	-	1.21	-	0.57	3.52
Cat*	0.08	0.22	-	-	-	0.61	-	0.18	-	0.20	-	-	-	-	-	-	-	0.04	1.03
Reptiles																			
Blue-tongue lizard	-	-	-	0.18	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.23
Eastern water dragon	-	-	-	0.09	0.36	-	-	0.09	-	0.03	-	-	-	-	-	-	-	-	0.58
Lace monitor	0.08	-	-	0.09	0.09	0.47	0.64	2.09	-	0.61	0.64	0.18	-	0.64	-	0.25	-	0.22	5.92
Lizard spp.	-	-	0.55	0.18	-	-	-	-	-	-	0.18	-	0.64	-	2.00	0.06	-	0.04	3.65
Total no. species/groups	6	3	4	15	5	5	5	13	2	13	6	9	6	10	6	11	5	14	88.81

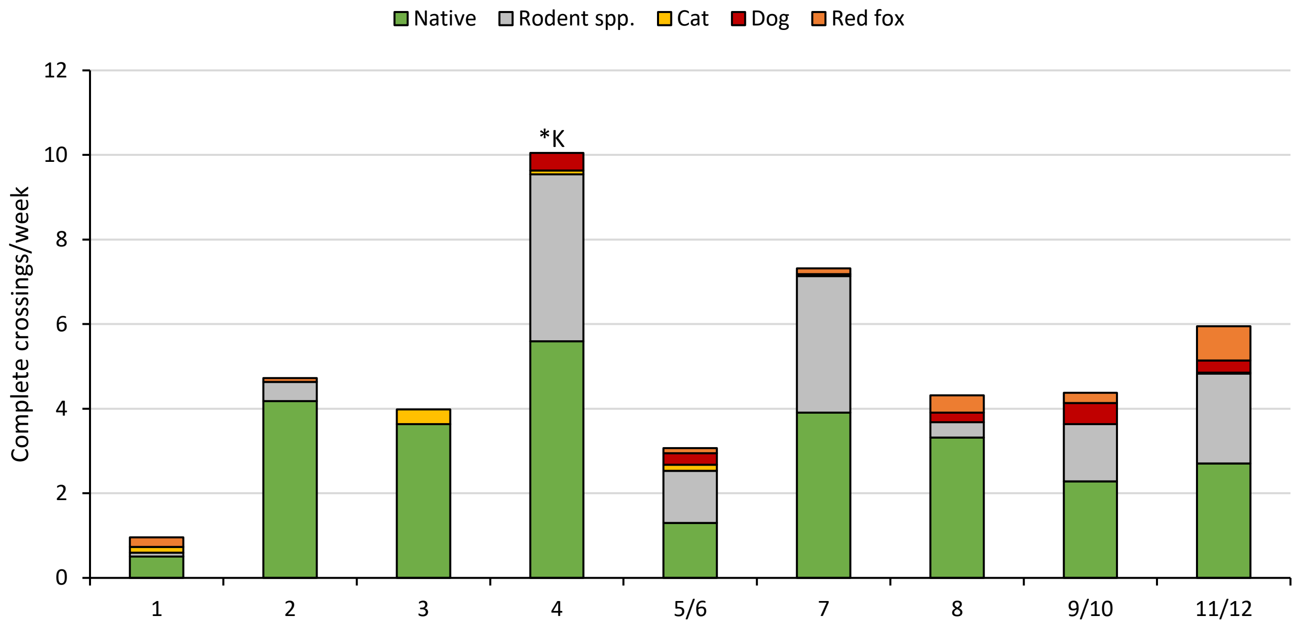

Figure 2: Total complete crossings (cc)/week/site by native species, feral predators (cat, wild dog and red fox) introduced/undefined rodent (combined black rat and rodent spp.) at each site during year five (spring/summer) operational monitoring, WC2NH, 2022/2023. *K = indicates complete crossing by koala.

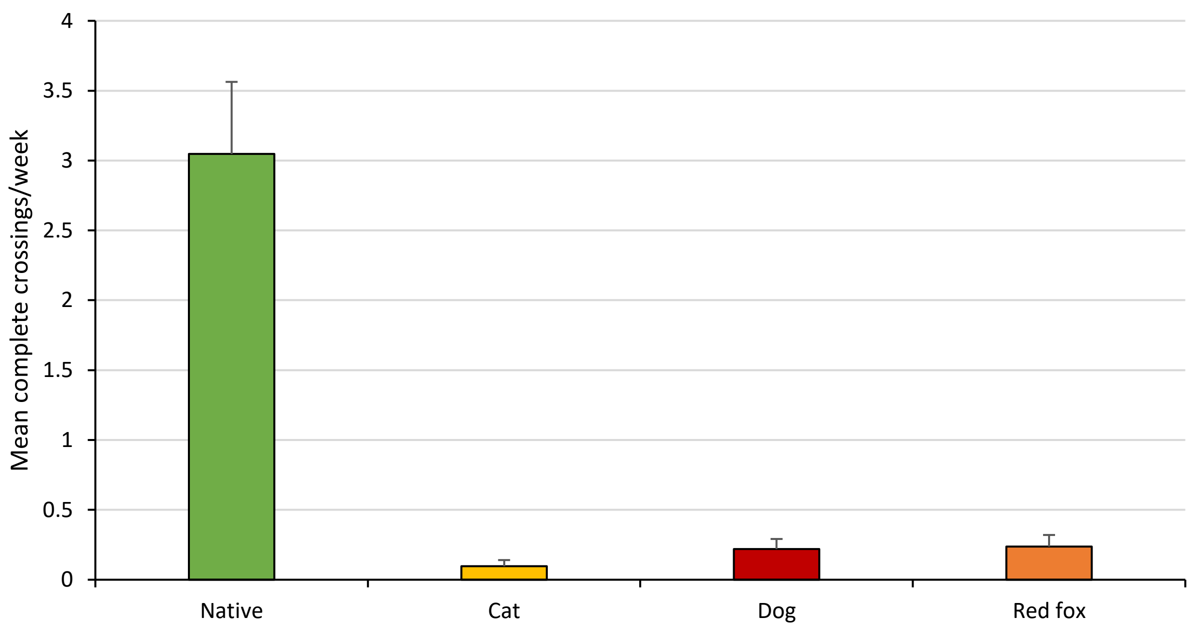

Figure 3: Mean number of complete crossing/week/underpass (+SD) for all native species, cat, wild dog and red fox during year five spring/summer operational monitoring.

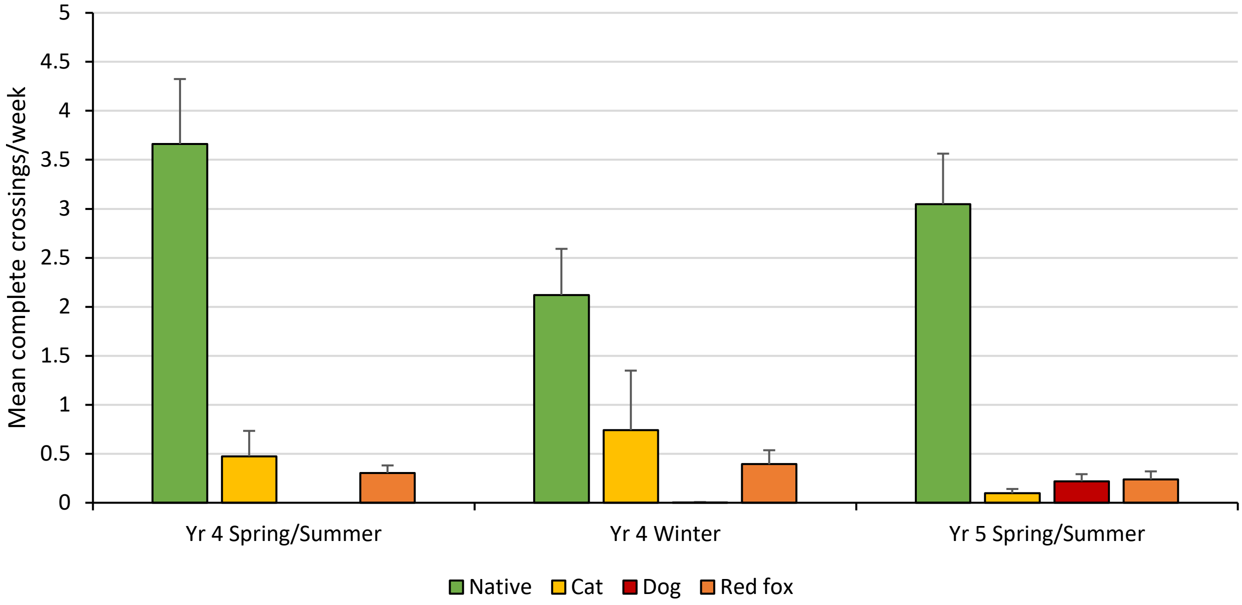

Figure 4: Mean number of complete crossing/week/underpass (+SD) for all native species, cat, wild dog and red fox during year four spring/summer, winter and year five spring/summer operational monitoring.

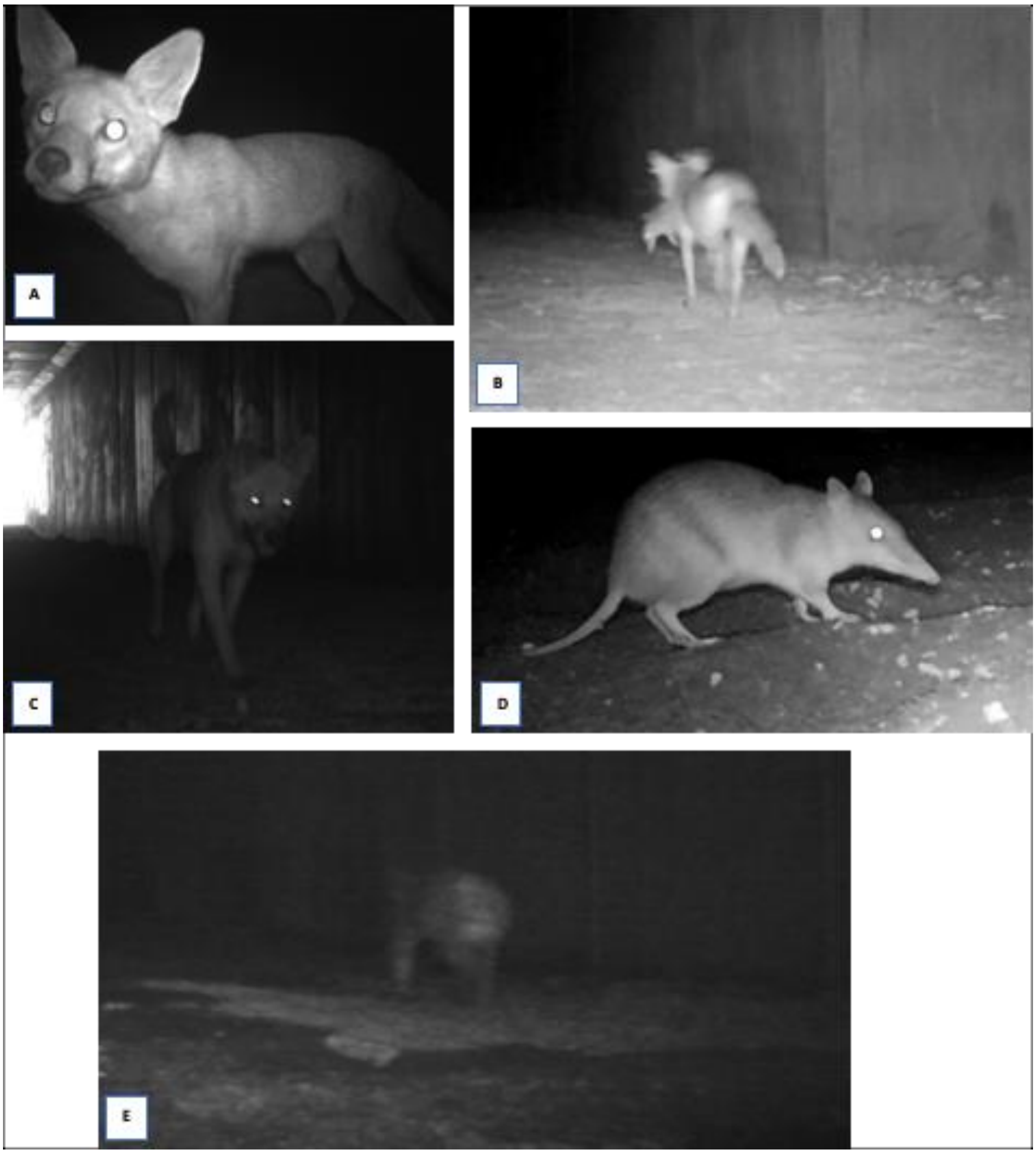

Plate 4: A. Fox heading west at site 6. **B.** Fox heading east carrying a bandicoot at site 11. **C.** Dog heading west at site 6. **D.** Bandicoot at site 2. **E.** Koala heading east at site 4

3.1.2 Sand pads

Eleven species and fauna groups were recorded on sand pads in spring/summer year 5 (Appendix B, Table B2). Of the native species, *Peramelidae spp.* (Bandicoot) and Lace monitors were the most commonly recorded fauna species with tracks identified at seven of the nine sites (Appendix B, Table B2). Feral predator tracks were found at three of the nine sites (1, 3, 5/6) (Appendix B, Table B2). Of the smaller fauna groups (i.e., small mammals, reptiles and amphibians), probable *Antechinus* spp. (sites 1, 2, 5/6, 8. 9/10 and 11/12), and small and medium lizard (1, 5/6 and 11/12; and 9/10, 11/12 respectively) were recorded during inspections (Appendix B, Table B2). No species or groups were recorded in addition to those from underpass camera monitoring.

3.1.2 Scat and track searches and tile checks

Twelve species, and eight fauna groups were recorded during scat and track surveys during year five spring/summer monitoring (Appendix B. Table B3). As seen in camera data, native species/fauna groups were found to be using all underpasses. Records of small native fauna included scats from *Antechinus* spp. at sites 2 and 11/12, and small reptiles at sites 1 and 9/10. Bandicoot tracks were prominent at seven sites, wallaby spp. at five sites and short-beaked echidna at three sites (Appendix B. Table B3). Scats and tracks from reptile species were found at all sites except for site 2. Feral predators (fox, dog, cat) were recorded at sites 1, 2, 3, 5/6, 9/10 and 11/12, with fox tracks found at five of the nine sites.

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

3.2 Adjacent habitat

Thirty-three species, seven genera, and five fauna groups were recorded in habitat adjoining underpasses during the spring/summer surveys (Table 6). Most species/groups (22 in total) were detected by diurnal and nocturnal active searches (Table 6, Appendix B, Table B5 and B6). During trapping surveys, a total of ten species and one *lampropholis* spp. were recorded (Table 6, Appendix B Table B7). Hair funnels recorded eight species (Appendix B, Table B8). Threatened species records included a probable female koala found during active diurnal search at site 9/10 on two occasions, both on the east side (Table 6, Appendix B, Table B5 and B6).

Table 6: Detection of fauna species and groups during spring/summer year five adjacent habitat monitoring at WC2NH, 2022/23. Bold denotes threatened species. [I] = Introduced. Birds, bats and 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				*
Peramelidae spp. (bandicoot)	*	*		
Koala		*		
Common brushtail possum		*		*
Short-eared brushtail possum		*		
Common ringtail possum		*		
Swamp wallaby	*			
Wallaby spp.	*			
Fawn-footed melomys			*	*
Bush rat			*	*
Black rat [I]		*	*	*
House mouse				*
Rattus spp.	*			*
Red fox [I]	*			
Cat [I]				
Dog [I]	*			
Reptiles				
Lace monitor	*		*	
Eastern water dragon	*	*		
Calyptotis ruficauda	*		*	
Eastern crevice skink				
Lampropholis delicata	*		*	
Lampropholis guichenoti				
Lampropholis spp.	*		*	
Bandy bandy		*		
Pygopus lepidopodus		*		
Yellow-faced whipsnake				
Small-eyed snake		*		
Chelidae spp.				
Small reptile				
Lophosaurus spinipes	*			
Snake spp.	*			
Frogs				
Amphibian spp.	*			
Litoria gracilenta		*		
Litoria fallax		*		
Litoria peronii		*		
Litoria caerulea				
Litoria tyleri				
Mixophyes iteratus				

Species	Active Search	Spotlight	Trapping	Hair funnel
Crinia signifera		*		
Adelotus brevis		*	*	
Uperoleia fusca				
Pseudophryne coriacea		*	*	
Limnodynastes peronii		*	*	
Total Nº. Species/groups	15	22	11	8

3.2.1 Species recorded in underpasses and adjacent habitat

With the mentioned exclusions (see Table 7 caption), 35 species and unique genera were confirmed within the adjacent habitat, with 20 using underpasses (Table 7). The proportion of species confirmed in adjacent habitat and using underpasses was 57% (Table 7). The proportion of mammals recorded in both adjacent habitat and underpasses was 89% with the common ringtail possum and fawn-footed melomys the only mammal species not recorded in underpasses (Table 7). No species of frog was recorded using underpasses, while seven species were reported in adjacent habitat (Table 7). Notably, a frog scat was recorded during active searches at site 7 (Appendix B, Table B5) however a species designation is not possible from scats alone. Further, 9 reptile species/families were recorded during monitoring, with 3 (33%) confirmed using underpasses including lace monitor, eastern blue-tongue lizard, eastern water dragon (Table 7) and probable *Egernia mcpheii* (unidentified lizard spp.).

Table 7: Species and unique genera recorded in adjacent habitat and using underpasses during year five spring/summer monitoring at WC2NH, 2022/23. 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 underpass only.

Species and unique genera	Underpass	Adjacent habitat
Mammals		
Short-beaked echidna	*	#
Brown antechinus ^	*	*
Northern brown bandicoot^	*	*
Long-nosed bandicoot^	*	#
Bandicoot spp.	*	*
Koala	*	*
Short-eared brushtail possum	*	*
Common brushtail possum	*	*
Common ringtail possum		*
Swamp wallaby	*	*
Red-necked wallaby	*	#
Eastern grey kangaroo	*	#
Water rat	*	#
Fawn-footed melomys^		*
Bush rat	*	*
Black rat^	*	*
Red fox	*	*
Cat	*	#
Dog	*	*
Sub-total mammals	**17**	**19**
Reptiles		
Lace monitor	*	*
Eastern water dragon	*	*

Species and unique genera	Underpass	Adjacent habitat
Lophosaurus spinipes		*
Eastern blue tongued lizard^	*	#
Calyptotis ruficauda ^		*
Lampropholis delicata ^		*
Bandy bandy ^		*
Pygopus lepidopodus		*
Small-eyed snake^		*
Sub-total reptiles	**3**	**9**
Frogs		
*Litoria gracilenta^*		*
Litoria fallax ^		*
Litoria peronii ^		*
Crinia signifera		*
Adelotus brevis ^		*
Pseudophryne coriacea ^		*
Limnodynastes peronii		*
Sub-total frogs	**0**	**7**
Total Nº. Species/unique genera	20	35

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, dog and fox were recorded across all the underpass sites and accounted for 20% of complete crossings excluding rodents. This represents a slight decrease from year 4 21%, but steady in comparison to years 1 and 2 where feral predators accounted for ~ 50% of complete crossings (Sandpiper Ecological 2019, 2020). Fox crossings have decreased from 0.29±0.1 cc/wk/site in year 4 to 0.24±0.1 cc/wk/site, in year 5, which represents a 17.3% decline. Further, there is a temporal trend of declining fox records since year 2 when 0.48±0.14 cc/wk/site was recorded (Sandpiper Ecological 2020). Cat activity has also decreased substantially from a peak of 0.53±0.4 cc/wk/site in year 4 down to 0.092±0.04 cc/wk/site (year 5 spring/summer), which represents an 83% decline. This decrease is mostly due to a reduction in complete crossings by resident cats at site 3, 3.68 cc/wk in year 4 down to 0.35 cc/wk in spring/summer year 5 (Sandpiper Ecological 2022a). Finally, dog records increased substantially from year 4 (0.0015 cc/wk/site) to year 5 (0.22±0.07 cc/wk/site). This is the highest number of dog crossings over the 5 year monitoring program. The previous highest occurrence was in year 3 (0.19±0.04 cc/wk/site) prior to the collaborative trapping program completed at WC2NH in autumn of 2021 (Saltair Flora and Fauna 2021). In year 5 dogs were recorded at six of the nine sites, an increase from one site in year 4. Overall feral predator use has remained relatively constant since year 4 and with individuals occurring throughout the WC2NH study area. The low number of complete crossings by feral predators coincide with the highest number of native fauna crossings at sites 2 (0.09cc/wk; 4.18 cc/wk), 4 (0.5 cc/wk; 5.59cc/wk) and 7 (0.18cc/wk; 3.9cc/wk) respectively. This suggests that feral predators may, to some extent, be influencing the use of underpasses by native fauna at other sites. To determine whether further action is warranted, dog usage will be assessed following year 5 winter monitoring.

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

Camera monitoring of native species has seen a steady increase in crossings since the start of the monitoring program. Since year 4, complete crossings by native species increased from 2.57 cc/week/site to 3.047±0.5 cc/wk/site (Sandpiper Ecological 2021a). The highest number of native species crossings in year 5 was recorded at site 4 (5.59 cc/wk) whereas site 7 had the highest crossings in year 4. The result is not unexpected as use by native fauna is expected to increase over time as site features (i.e., vegetation at culvert entrances) improve, a trend also recorded at Sapphire to Woolgoolga and recent monitoring at Nambucca Heads to Urunga (Sandpiper Ecological 2018, 2022).

A wide variety of native species and unique genera were recorded using underpasses. In total, 35 species were recorded in the adjacent habitat, with 57% of them utilising the underpasses. Of these 46% were native fauna. This result is higher than findings at previous underpass monitoring projects including Sapphire to Woolgoolga (23% to 50%) and Nambucca Heads to Urunga (38% in 2018 and 42% in 2020) (Sandpiper Ecological 2018, 2020b). The increase in the percentage of native fauna using the underpasses coincide with the surrounding habitats forming with fauna corridors establishing in the landscape adjacent to the underpasses. The speed of uptake by a wide variety of fauna may be associated with retention of established vegetation close to underpass entrances and the location of structures within the landscape. One notable feature of monitoring is the variation in native fauna use between sites, highlighting the importance of location as a determinant of use.

Koalas continue to use underpasses at WC2NH in year 5 operational phase, with one complete crossing at site 4. A koala was also recorded on two occasions at site 9/10 during nocturnal adjacent habitat searches. The number of culverts used by koalas has fluctuated between years, from four in year 1, three in year 2, two in year 3 and three in year 4 (Sandpiper Ecological 2019b, 2020b, 2022a). Continued monitoring in winter 2023 will provide further information on underpass use by koala.

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 suggest that koalas continue to maintain territory on both sides of the alignment.

4.4 Evidence of use by dispersing individuals and different age cohorts

Accurately confirming age of individuals using underpasses is difficult using the survey methods outlined in the EMP. 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 six frog species, three native mammals (brown antechinus, fawn-footed melomys and bush rat) and eight reptile species. Of these, three cover dependent species (*Antechinus* spp, bush rat and eastern blue-tongue lizard) were recorded using underpasses. Consistent with previous surveys there were limited records of frogs and reptiles in underpasses. Low occurrence of frogs and reptiles is most likely due to the inability of cameras to detect these species as opposed to avoidance. This shortfall is assisted using sand pads and scat and tracks searches with some records of small and medium reptiles being recorded at sites 1, 5/6, 9/10 and 11/12. Tile checks have proved to be ineffective at detecting cover dependent fauna with no records recorded in year five spring/summer monitoring.

5. Contingency Measures and Recommendations

5.1 Contingency Measures

Contingency measures are summarised in Table 8.

Table 8: Potential problems outlined in the EMP and possible contingency measures. 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. Dog/Fox visitation in year 5 winter 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 required – monitoring has shown that fauna furniture is functional and underpasses are providing safe passage for over 89% of the mammal species recorded in adjacent habitat.
No use of underpasses by cover-dependent species or species with low mobility or target threatened species	Modify or add potential groundcover resources	Four cover dependent species and one threatened species were recorded using underpasses. Minimising disturbance of vegetation at culvert entrances will assist in facilitating movement by cover dependent species. No action required - continue monitoring underpasses using current methods in winter year 5.
High rates of fauna road mortality.	Modify exclusion fencing design, location or extent depending on the species and location of mortalities	Issues relating to road mortality are addressed in the quarterly and annual road-kill reports. At this stage no modifications to the location or extent of exclusion fence is proposed. No mortality of target species has been recorded during the monitoring program.

5.2 Recommendations

Recommendations are summarised in Table 9. Initial monitoring in year 5 has identified a substantial increase in dog activity and further analysis of underpass use by dogs (and feral species in general) should be undertaken in the final year 5 monitoring report to determine if targeted control is warranted.

Table 9: Recommendations based on findings from year five operational phase monitoring and response from TfNSW.

Number	Recommendation	Transport for NSW Response
1.	Continue underpass and adjacent habitat monitoring in accordance with the EMP	Agreed.
2.	Assess the need for feral predator control in the final year 5 monitoring report.	To be considered pending outcomes of the Year 5 Autumn monitoring.

6. References

Bureau of Meteorology (February 13, 2023a) "*Daily rainfall Bellwood (Nambucca heads)". http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=059150*

Bureau of Meteorology (February 13, 2023b) "*Coffs harbour airport daily weather observations". http://www.bom.gov.au/climate/dwo/IDCJDW2030.latest.shtml*

GeoLink (2014) Warrell Creek to Nambucca Heads Pacific Highway Upgrade, Koala Management Plan. Report prepared for Roads and Maritime Services NSW.

GeoLink (2014) Warrell Creek to Nambucca Heads Pacific Highway Upgrade, Spotted-tailed Quoll Management Plan. Report prepared for Roads and Maritime service NSW.

Menkhorst, P. & Knight, F. (2004). *A field guide to the mammals of Australia*. Oxford University press, Melbourne.

Pizzey, G. & Knight, F. (2007). *The field guide to the birds of Australia*. Harper Collins, Sydney.

RMS (2018). *Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief*. NSW Government.

Sandpiper Ecological (2017a). *Pacific Highway Upgrade – Sapphire to Woolgoolga: operational phase fauna monitoring year 1 –*

Sandpiper Ecological (2018). *Pacific Highway Upgrade – Sapphire to Woolgoolga: operational phase fauna monitoring year 3 – Greys Dam frog pipes*. Report prepared for Roads and Maritime NSW.

Sandpiper Ecological (2019). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads underpass monitoring program– year one operational phase.* Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2020). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads underpass monitoring program– year two operational phase*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2020a). *Pacific Highway Upgrade –Nambucca Heads to Urunga underpass and vegetated median monitoring program monitoring – year two operational phase*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2021a). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads Operational Phase underpass monitoring program year three interim report*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2021b). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads Year 3 Operational Phase Giant Barred Frog monitoring program*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2022). *Pacific Highway Upgrade –Nambucca Heads to Urunga underpass and vegetated median monitoring program monitoring – year 3 operational phase*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2022a). Pacific Highway Upgrade, Warrell Creek to Nambucca Heads: Operational phase road-kill monitoring- summer 2022. Report prepared for Transport for NSW.

Saltair Flora and Fauna (2021b). *Nambucca State Forest Warrell Creek to Nambucca Heads (WC2NH) Noxious Vertebrate Trapping Program.* Report prepared for North Coast Local Land Services.

Soanes. K., Vesk, P. A. and van der Ree, R. (2015). Monitoring the use of road-crossing structures by arboreal marsupials: insights gained from motion-triggered cameras and passive integrated transponder (PIT) tags. *Wildlife Research:* 10.107.

Triggs, B. (2004). *Tracks, scats and other traces: a field guide to Australian mammals.* Oxford University Press, Melbourne.

Wilson, S. & Swan, G. (2010). A complete guide to reptiles of Australia. New Holland, Sydney.

Van Dyck, S., Gynther, I. & Baker, A. (2013). *Field companion to the mammals of Australia*. New Holland, Sydney.

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.*
Frogs	
Eastern dwarf tree frog	*Litoria fallax*

Common Name	Scientific Name
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 of year five operational monitoring WC2NH, 2022/2023. NDM – no directional movement

Order	Season	Site	Underpass	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM
1	Spring/Summer	1	1	South	Cat	Introduced	Feral predator	2		
2	Spring/Summer	1	1	South	Swamp wallaby	Native	Macropod	1	1	
3	Spring/Summer	1	1	South	Rodent spp.	NA	Introduced rodent	1		
4	Spring/Summer	1	1	North	Swamp wallaby	Native	Macropod	7		1
5	Spring/Summer	1	1	North	Antechinus spp.	Native	Antechinus	1		
6	Spring/Summer	1	1	North	Fox	Introduced	Feral predator	5		
7	Spring/Summer	1	1	North	Small frog spp.	Native	Frog	1		
8	Spring/Summer	1	1	North	Lace monitor	Native	Lizard	1		
9	Spring/Summer	1	1	North	Cat	Introduced	Feral predator	1		
10	Spring/Summer	1	1	North	Black rat	Introduced	Introduced rodent	1		
11	Spring/Summer	2	2	Furniture	Antechinus spp.	Native	Antechinus	31	3	
12	Spring/Summer	2	2	Furniture	Bush rat	Native	Native rodent	1	4	
13	Spring/Summer	2	2	Furniture	Short-eared brushtail possum	Native	Possum	0	3	
14	Spring/Summer	2	2	Furniture	Lizard spp.	NA	Lizard	6		
15	Spring/Summer	2	2	Furniture	Rattus spp.	NA	Rodent	2		
16	Spring/Summer	2	2	Gound	Long-nosed bandicoot	Native	Bandicoot	35	6	
17	Spring/Summer	2	2	Gound	Short-beaked echidna	Native	Echidna	1		
18	Spring/Summer	2	2	Gound	Eastern water dragon	Native	Lizard	1		
19	Spring/Summer	2	2	Gound	Black rat	Introduced	Introduced rodent	5		
20	Spring/Summer	2	2	Gound	Swamp wallaby	Native	Macropod	5	3	
21	Spring/Summer	2	2	Gound	Wallaby spp.	Native	Macropod	3		
22	Spring/Summer	2	2	Gound	Red fox	Introduced	Feral predator	2		
23	Spring/Summer	2	2	Gound	Rattus spp.	NA	Rodent	3		
24	Spring/Summer	2	2	Gound	Short-eared brushtail possum	Native	Possum	2		

Order	Season	Site	Underpass	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM
25	Spring/Summer	2	2	Gound	Blue-tongue lizard	Native	Lizard	2		
26	Spring/Summer	2	2	Gound	Lace monitor	Native	Lizard	1		
27	Spring/Summer	2	2	Gound	Lizard spp.	NA	Lizard	2		
28	Spring/Summer	2	2	Gound	Bandicoot spp.	Native	Bandicoot	1		
29	Spring/Summer	2	2	Gound	Antechinus spp.	Native	Antechinus	1		
30	Spring/Summer	3	3	Furniture	Brush-tail possum spp.	Native	Possum	7		
31	Spring/Summer	3	3	Furniture	Short-eared brushtail possum	Native	Possum	39	3	
32	Spring/Summer	3	3	Furniture	Eastern water dragon	Native	Lizard	4		
33	Spring/Summer	3	3	Furniture	Lace monitor	Native	Lizard	1		
34	Spring/Summer	3	3	Furniture	Antechinus spp.	Native	Antechinus	1		
35	Spring/Summer	3	3	Ground	Macropod spp.	Native	Macropod	18		
36	Spring/Summer	3	3	Ground	Lace monitor	Native	Lizard	7		
37	Spring/Summer	3	3	Ground	Cat	Introduced	Feral predator	9		
38	Spring/Summer	3	3	Ground	Eastern grey kangaroo	Native	Macropod	10		
39	Spring/Summer	3	3	Ground	Wallaby spp.	Native	Macropod	7		
40	Spring/Summer	4	4	Furniture	Lace monitor	Native	Lizard	7		
41	Spring/Summer	4	4	Furniture	Rattus spp.	NA	Rodent	78	2	
42	Spring/Summer	4	4	Furniture	Short-eared brushtail possum	Native	Possum	17	1	
43	Spring/Summer	4	4	Furniture	Black rat	Introduced	Introduced rodent	8		
44	Spring/Summer	4	4	Furniture	Bush rat	Native	Native rodent	4		
45	Spring/Summer	4	4	Ground	Koala	Native	Koala	1		
46	Spring/Summer	4	4	Ground	Black rat	Introduced	Introduced rodent	1		
47	Spring/Summer	4	4	Ground	Bandicoot spp.	Native	Bandicoot	5		
48	Spring/Summer	4	4	Ground	Long-nosed bandicoot	Native	Bandicoot	13	3	
49	Spring/Summer	4	4	Ground	Swamp wallaby	Native	Macropod	16		
50	Spring/Summer	4	4	Ground	Red fox	Introduced	Feral predator	0	2	
51	Spring/Summer	4	4	Ground	Short-beaked echidna	Native	Echidna	1		
52	Spring/Summer	4	4	Ground	Lace monitor	Native	Lizard	23	1	
53	Spring/Summer	4	4	Ground	Wallaby spp.	Native	Macropod	13		
54	Spring/Summer	4	4	Ground	Cat	Introduced	Feral predator	2		

Order	Season	Site	Underpass	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM
55	Spring/Summer	4	4	Ground	Dog	Introduced	Feral predator	9		
56	Spring/Summer	4	4	Ground	Short-eared brushtail possum	Native	Possum	1		
57	Spring/Summer	4	4	Ground	Eastern water dragon	Native	Lizard	1		
58	Spring/Summer	4	4	Ground	Brush-tail possum spp.	Native	Possum	21		
59	Spring/Summer	5	5/6	North	Dog	Introduced	Feral predator	1		
60	Spring/Summer	5	5/6	North	Bandicoot spp.	Native	Bandicoot	1		
61	Spring/Summer	5	5/6	North	Rattus spp.	NA	Rodent	1		
62	Spring/Summer	5	5/6	North	Water rat	Native	Native rodent	1	2	
63	Spring/Summer	5	5/6	North	Black rat	Introduced	Introduced rodent	0	7	
64	Spring/Summer	5	5/6	North	Antechinus spp.	Native	Antechinus	1		
65	Spring/Summer	5	5/6	South	Dog	Introduced	Feral predator	0	1	
66	Spring/Summer	5	5/6	South	Water rat	Native	Native rodent	1		
67	Spring/Summer	6	5/6	Furniture	Rattus spp.	NA	Rodent	48	2	
68	Spring/Summer	6	5/6	Furniture	Antechinus spp.	Native	Antechinus	4		
69	Spring/Summer	6	5/6	Ground	Cat	Introduced	Feral predator	6	1	
70	Spring/Summer	6	5/6	Ground	Wonga pigeon		Bird	0	1	
71	Spring/Summer	6	5/6	Ground	Long-nosed bandicoot	Native	Bandicoot	12	1	
72	Spring/Summer	6	5/6	Ground	Red fox	Introduced	Feral predator	5	1	
73	Spring/Summer	6	5/6	Ground	Lace monitor	Native	Lizard	18	1	
74	Spring/Summer	6	5/6	Ground	Dog	Introduced	Feral predator	10	1	
75	Spring/Summer	6	5/6	Ground	Swamp wallaby	Native	Macropod	12	1	
76	Spring/Summer	6	5/6	Ground	Wallaby spp.	Native	Macropod	1		
77	Spring/Summer	6	5/6	Ground	Chicken	Introduced	Bird	2	3	
78	Spring/Summer	6	5/6	Ground	Bandicoot spp.	Native	Bandicoot	1		
79	Spring/Summer	6	5/6	Ground	Black rat	Introduced	Introduced rodent	1		
80	Spring/Summer	6	5/6	Ground	Eastern water dragon	Native	Lizard	1		
81	Spring/Summer	7	7	Furniture	Bush rat	Native	Native rodent	4		
82	Spring/Summer	7	7	Furniture	Short-eared brushtail possum	Native	Possum	56		
83	Spring/Summer	7	7	Furniture	Rattus spp.	Introduced	Rodent	51	6	
84	Spring/Summer	7	7	Furniture	Black rat	Introduced	Introduced rodent	4	4	
85	Spring/Summer	7	7	Furniture	Lace monitor	Native	Lizard	7	1	

Order	Season	Site	Underpass	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM
86	Spring/Summer	7	7	Furniture	Rattus spp.	NA	Rodent	3	2	
87	Spring/Summer	7	7	Furniture	Lizard spp.	NA	Lizard	2		
88	Spring/Summer	7	7	Ground	Swamp wallaby	Native	Macropod	2		
89	Spring/Summer	7	7	Ground	Long-nosed bandicoot	Native	Bandicoot	4	2	
90	Spring/Summer	7	7	Ground	Dog	Introduced	Feral predator	1		
91	Spring/Summer	7	7	Ground	Black rat	Introduced	Introduced rodent	8	1	
92	Spring/Summer	7	7	Ground	Red fox	Introduced	Feral predator	3		
93	Spring/Summer	7	7	Ground	Rattus spp.	NA	Rodent	5		
94	Spring/Summer	7	7	Ground	Short-beaked echidna	Native	Echidna	0	1	
95	Spring/Summer	7	7	Ground	Wallaby spp.	Native	Macropod	5		
96	Spring/Summer	7	7	Ground	Lace monitor	Native	Lizard	2		
97	Spring/Summer	7	7	Ground	Bandicoot spp.	Native	Bandicoot	4		
98	Spring/Summer	8	8	Furniture	Short-eared brushtail possum	Native	Possum	4		
99	Spring/Summer	8	8	Furniture	Lizard spp.	Native	Lizard	7		
100	Spring/Summer	8	8	Furniture	Antechinus spp.	Native	Antechinus	2		
101	Spring/Summer	8	8	Furniture	Brush-tail possum spp.	Native	Possum	6	2	
102	Spring/Summer	8	8	Furniture	Black rat	Introduced	Introduced rodent	2		
103	Spring/Summer	8	8	Furniture	Rattus spp.	NA	Rodent	5		
104	Spring/Summer	8	8	Furniture	Bush rat	Native	Native rodent	0	1	
105	Spring/Summer	8	8	Ground	Wallaby spp.	Native	Macropod	20		
106	Spring/Summer	8	8	Ground	Long-nosed bandicoot	Native	Bandicoot	1		
107	Spring/Summer	8	8	Ground	Red fox	Introduced	Feral predator	9		
108	Spring/Summer	8	8	Ground	Swamp wallaby	Native	Macropod	14		
109	Spring/Summer	8	8	Ground	Brush-tail possum spp.	Native	Possum	1		
110	Spring/Summer	8	8	Ground	Bandicoot spp.	Native	Bandicoot	9		
111	Spring/Summer	8	8	Ground	Dog	Introduced	Feral predator	5		
112	Spring/Summer	8	8	Ground	Lace monitor	Native	Lizard	7		
113	Spring/Summer	8	8	Ground	Short-eared brushtail possum	Native	Possum	2		
114	Spring/Summer	8	8	Ground	Rattus spp.	NA	Rodent	1		
115	Spring/Summer	9	9/10	Furniture	Bush rat	Native	Native rodent	0	1	
116	Spring/Summer	9	9/10	Furniture	Lizard spp.	NA	Lizard	37		

Order	Season	Site	Underpass	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM
117	Spring/Summer	9	9/10	Furniture	Black rat	Introduced	Introduced rodent	3		
118	Spring/Summer	9	9/10	Furniture	Rattus spp.	NA	Rodent	40	3	
119	Spring/Summer	9	9/10	Furniture	Antechinus spp.	Native	Antechinus	1		
120	Spring/Summer	9	9/10	Ground	Northern-brown bandicoot	Native	Bandicoot	0		
121	Spring/Summer	9	9/10	Ground	Brush-tail possum spp.	Native	Possum	1		
122	Spring/Summer	9	9/10	Ground	Red fox	Introduced	Feral predator	1		
123	Spring/Summer	9	9/10	Ground	Lizard spp.	NA	Lizard	1		
124	Spring/Summer	9	9/10	Ground	Long-nosed bandicoot	Native	Bandicoot	1		
125	Spring/Summer	9	9/10	Ground	Black rat	Introduced	Introduced rodent	2		
126	Spring/Summer	9	9/10	Ground	Dog	Introduced	Feral predator	1		
127	Spring/Summer	10	9/10	Furniture	Brush-tail possum spp.	Native	Possum	5	1	
128	Spring/Summer	10	9/10	Furniture	Lizard spp.	NA	Lizard	7		
129	Spring/Summer	10	9/10	Furniture	Short-eared brushtail possum	Native	Possum	3	1	
130	Spring/Summer	10	9/10	Furniture	Rattus spp.	NA	Rodent	3	1	
131	Spring/Summer	10	9/10	Ground	Red fox	Introduced	Feral predator	8		
132	Spring/Summer	10	9/10	Ground	Bandicoot spp.	Native	Bandicoot	10	2	
133	Spring/Summer	10	9/10	Ground	Swamp wallaby	Native	Macropod	0	1	
134	Spring/Summer	10	9/10	Ground	Dog	Introduced	Feral predator	18		
135	Spring/Summer	10	9/10	Ground	Long-nosed bandicoot	Native	Bandicoot	8		
136	Spring/Summer	10	9/10	Ground	Wallaby spp.	Native	Macropod	7		
137	Spring/Summer	10	9/10	Ground	Lace monitor	Native	Lizard	4		
138	Spring/Summer	10	9/10	Ground	Red-necked wallaby	Native	Macropod	1	1	
139	Spring/Summer	10	9/10	Ground	Black rat	Introduced	Introduced rodent	2		
140	Spring/Summer	10	9/10	Ground	Rattus spp.	NA	Rodent	1		
141	Spring/Summer	11	11/12	Furniture	Rattus spp.	NA	Rodent	92	2	
142	Spring/Summer	11	11/12	Furniture	Bush rat	Native	Native rodent	13	2	
143	Spring/Summer	11	11/12	Furniture	Short-eared brushtail possum	Native	Possum	44		
144	Spring/Summer	11	11/12	Furniture	Brush-tail possum spp.	Native	Possum	7		

Order	Season	Site	Underpass	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM
145	Spring/Summer	11	11/12	Furniture	Black rat	Introduced	Introduced rodent	2		
146	Spring/Summer	11	11/12	Furniture	Lizard spp.	NA	Lizard	0	1	
147	Spring/Summer	11	11/12	Ground	Wonga pigeon		Bird	1		
148	Spring/Summer	11	11/12	Ground	Bandicoot spp.	Native	Bandicoot	17		
149	Spring/Summer	11	11/12	Ground	Red fox	Introduced	Feral predator	10		
150	Spring/Summer	11	11/12	Ground	Dog	Introduced	Feral predator	7		
151	Spring/Summer	11	11/12	Ground	Lace monitor	Native	Lizard	2		
152	Spring/Summer	11	11/12	Ground	Wallaby spp.	Native	Macropod	1		
153	Spring/Summer	11	11/12	Ground	Lizard spp.	NA	Lizard	1		
154	Spring/Summer	12	11/12	Furniture	Short-eared brushtail possum	Native	Possum	8		
155	Spring/Summer	12	11/12	Ground	Red fox	Introduced	Feral predator	26		
156	Spring/Summer	12	11/12	Ground	Northern-brown bandicoot	Native	Bandicoot	7		
157	Spring/Summer	12	11/12	Ground	Long-nosed bandicoot	Native	Bandicoot	4		
158	Spring/Summer	12	11/12	Ground	Dog	Introduced	Feral predator	6		
159	Spring/Summer	12	11/12	Ground	Lace monitor	Native	Lizard	3		
160	Spring/Summer	12	11/12	Ground	Black rat	Introduced	Introduced rodent	1	1	
161	Spring/Summer	12	11/12	Ground	Red-necked wallaby	Native	Macropod	1		
162	Spring/Summer	12	11/12	Ground	Wonga pigeon		Bird	0	6	
163	Spring/Summer	12	11/12	Ground	Bandicoot spp.	Native	Bandicoot	7		
164	Spring/Summer	12	11/12	Ground	Cat	Introduced	Feral predator	1		
165	Spring/Summer	12	11/12	Ground	Blue tongue lizard	Native	Lizard	1		
166	Spring/Summer	12	11/12	Ground	Short-eared brushtail possum	Native	Lizard	1		
167	Spring/Summer	12	11/12	Ground	Swamp wallaby	Native	Macropod	4	1	

Table B2: Sand pad data recorded over 8 nights in spring/summer (ss) during year five of operational phase monitoring WC2NH, 2022/2023. [I] = Introduced, + = probable records.

Species/group	1	2	3	4	5/6	7	8	9/10	11/12
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		*		*	*	*	*	*	*
Water dragon			*						
Skink								*	*
Small lizard	*				*				*
Small reptile									*
Medium lizard								*	*
Medium reptile					*				
Medium frog spp.									
Bird spp.									
Total no. Species/groups	5	4	4	5	7	4	4	7	7

Table B3: Scat and track data recorded during camera monitoring in spring/summer during year five operational phase monitoring WC2NH, 2022/2023. BtP = brush-tailed possum

Site	Check no.	Date	Scats	Tracks	Comments
1	1	14/10/22	Small reptile	BtP, fox, Wallaby	
	2	25/11/22	NR	Wallaby, rodent	

Site	Check no.	Date	Scats	Tracks	Comments
2	1	14/10/22	Antechinus on rail	Wallaby sp., rodent spp	
	2	25/11/22	Antechinus on rail	Bandicoot, fox, wallaby rodent	
3	1	14/10/22	Cat	Cat, eastern water dragon	
	2	25/11/22	Swallow	Nil	
4	1	14/10/22	NR	Btp, rodent, bandicoot	
	2	25/11/22	NR	Lace monitor, rodent wallaby	
5	1	14/10/22	Bandicoot	Dog	
	2	25/11/22	Rodent spp.	Nil	
6	1	14/10/22	BTP sp.	Fox, bandicoot rodent, antechinus	
	2	25/11/22	NR	Lace monitor, short-beaked echidna	
7	1	14/10/22	Rodent	Swamp wallaby, rodent spp., bandicoot spp.	
	2	25/11/22	NR	Bandicoot, rodent, lace monitor, wallaby	
8	1	14/10/22	SeBtp on rail	Rodent spp., swamp wallaby, lace monitor, bandicoot	
	2	25/11/22	NR	Swamp wallaby, rodent, bandicoot, lace monitor	
9e	1	14/10/22	Bandicoot, small lizard on rail	Bandicoot, fox, short beaked echidna, antechinus	
	2	25/11/22	Small reptile	Bandicoot, rodent, antechinus,	
10w	1	14/10/22	NR	Bandicoot, rodent, fox	
	2	25/11/22	NR	Rodent, fox, bandicoot, small lizard	
11e	1	14/10/22	Antechinus	Fox, bandicoot, rodent	
	2	25/11/22	NR	Fox, bandicoot, rodent, medium lizard	
12w	1	14/10/22	NR	Echidna, fox, bandicoot, rodent	
	2	25/11/22	NR	Bandicoot and rodent	

Table B4: Tile inspection data recorded in spring/summer during year five operational phase monitoring WC2NH, 2022/2023.

Site	No. Tiles	Check no.	Date	Fauna present	Comments
2	1	1	31/01/23	Nil	1 tile destroyed
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
3	1	1	31/01/23	Nil	1 tile destroyed/missing
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
4	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
5N	1	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	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	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
7	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
8	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
9 East	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
10 West	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	

Site	No. Tiles	Check no.	Date	Fauna present	Comments
11 East	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
12 West	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	Nil	

Table B5: Daytime searches of adjacent habitat data during year five WC2NH monitoring, 2023. Msb = moves small branches, Mlb = moves large branches and RL = rustles leaves.

Location	Side	Obs. No.	Date	Observers	Start	Finish	Species	Wind	Cloud	Rain	Air Temp	Humidity	Comment
11&12	E	1	1/02/2023	AE&EL	1:15	1:30	3 lampropholis delicata wallaby scat bandicoot digs	Nil	Nil	Nil	28	73	Nil
	W	1	1/02/2023	AE & EL	1:30	1:45	2 lampropholis delicata	Nil	Nil	Nil	28	73	Nil
	E	2	3/02/2023	LA/FM	9:05	9:20	L. Delicata	Nil	Nil	Nil	25.2	81	Nil
	W	2	3/02/2023	LA/FM	9:21	9:34	Lampropholis >20	Nil	Nil	Nil	25.2	81	Nil
9&10	E	1	1/02/2023	AE & EL	2:15	2:30	5 lampropholis delicata wallaby scat	Nil	Nil	Nil	28	73	Nil
	W	1	1/02/2023	AE & EL	2:30	2:45	3 lampropholis delicata	Nil	Nil	Nil	28	73	Nil
	E	2	3/02/2023	LA/FM	10:05	10:20	Antechinus spp	Nil	Nil	Nil	25.2	81	antechinus running along log
	W	2	3/02/2023	LA/FM	10:23	10:35	Lace monitor, lampropholis x 6, wallaby spp.	Nil	Nil	Nil	25.2	81	Nil
8	E	1	1/02/2023	AE & EL	11:15	11:30	wallaby scat bandicoot dig 4 lampropholis spp.	Nil	Nil	Nil	28	73	Nil
	W	1	1/02/2023	AE & EL	11:35	11:50	7 lampropholis spp	Nil	Nil	Nil	28	73	Nil
	E	2	3/02/2023	LA/FM	10:54	11:08	Nil	Nil	Nil	Nil	25.2	81	Nil
	W	2	3/02/2023	LA/FM	11:12	11:28	Lace monitor	Nil	Nil	Nil	25.2	81	Nil
7	E	1	1/02/2023	LA	10:33	11:03	Bandicoot digs, wallaby tracks, rodent scat	Nil	Nil	Nil	25.4	73	Nil
	W	1	1/02/2023	LA	11:05	11:35	Wallaby scat	Nil	Nil	Nil	25.4	73	Nil
	E	2	3/02/2023	AE & EL	11:15	11:30	amphibian scat 6 x lampropholis spp.	Nil	Nil	Nil	26	77	Nil
	W	2	3/02/2023	AE & EL	12:03	12:13	5 x lampropholis spp.	Nil	Nil	Nil	26	77	Nil
5&6	E	1	1/02/2023	AE/LA/EL	12:23	12:33	Lace monitor, swamp wallaby	Nil	Nil	Nil	28	73	Nil
	W	1	1/02/2023	AE/LA/EL	10:40	10:55	Nil	Nil	Nil	Nil	28	73	Nil
	E	2	3/02/2023	AE & EL	10:57	11:12	dog scatt wallaby scatt lampropholis spp.	Nil	Nil	Nil	26	77	Nil
	W	2	3/02/2023	AE & EL	11:55	12:20	4 lampropholis delicata	Nil	Nil	Nil	26	77	Nil
4	E	1	1/02/2023	LA	12:23	12:53	Lampropholis delicata x 7	Nil	Nil	Nil	25.4	73	Nil
	W	1	1/02/2023	LA	8:16	8:31	Nil	Nil	Nil	Nil	25.4	73	Nil
	E	2	3/02/2023	LA/FM	8:34	8:49	Angle headed dragon, bandicoot diggings	Nil	Nil	Nil	25.2	81	Nil
	W	2	3/02/2023	LA/FM	13:01	13:16	Nil	Nil	Nil	Nil	25.2	81	Nil
3	E	1	1/02/2023	LA	13:19	13:49	Lampropholis delicata x3, calyptotis. Wallaby scat	Nil	Nil	Nil	25.4	73	Nil

Location	Side	Obs. No.	Date	Observers	Start	Finish	Species	Wind	Cloud	Rain	Air Temp	Humidity	Comment
	W	1	1/02/2023	LA	9:05	9:20	Bandicoot and wallaby tracks	Nil	Nil	Nil	25.4	73	Nil
	E	2	3/02/2023	AE & EL	9:45	10:00	amphibian scat 6 x lampropholis spp.	Nil	Nil	Nil	26	77	Nil
	W	2	3/02/2023	AE & EL	10:05	10:20	3 x lampropholis spp. wallaby track bandicoot dig	Nil	Nil	Nil	26	77	Nil
2	E	1	1/02/2023	LA	13:55	14:25	Lace monitor, snake spp, lampropholis spp. >10	Nil	Nil	Nil	25.4	73	Snake too quick, likely yellow-faced whipsnake
	W	1	1/02/2023	LA	14:31	15:01	Nil	Nil	Nil	Nil	25.4	73	Nil
	E	2	3/02/2023	LA/FM	9:25	9:40	lampropholis delicata ×2 wallaby scat bandicoot dig fox scat	Nil	Nil	Nil	26	77	Nil
	W	2	3/02/2023	LA/FM	12:15	12:30	10x lampropholis spp. wallaby scat	Nil	Nil	Nil	26	77	Nil
1	E	1	1/02/2023	AE & EL	12:30	12:45	Lace monitor eastern water dragon 4 lampropholis delicata	Nil	Nil	Nil	28	73	Nil
	E	1	1/02/2023	AE & EL	8:10	8:40	eastern water dragon 2 lampropholis delicata	Nil	Nil	Nil	28	0.6	Nil
	W	2	3/02/2023	AE	8:10	8:40	eastern water dragon 1 lampropholis delicata	Nil	Nil	Nil	26	73	Nil
	W	2	3/02/2023	EL	8:10	8:40	nil	Nil	Nil	Nil	26	77	Nil

Table B6: Nocturnal spotlight surveys of adjacent habitat during year five WC2NH monitoring, 2022/2023. GHFF = grey-headed flying fox, SuG = sugar glider, Lit. = Litoria, SEBtP = short-eared brushtail possum, FtG = feathertail glider sp., CBtP = common brushtail possum, BtPoss = Brushtail possum species, TF = Tawny Frogmouth, CRtP = common ringtail possum, Pseud. = Pseudophryne species, Lim = Limnodynastes species, Lit = Litoria s pecies, A. brevis = Adelotus brevis, ONJ = Owlet-Nightjar. Msb = moves small branches, Mlb = moves large branches and RL = rustles leaves. Sm = saw movement, hc = heard call, se = saw eyeshine.

Location	Side	Obs. No.	Date	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	RH (%)	Comment
11&12	E	1	31/01/23	FM & AE	20:08	20:23	sm 3x flying fox hc 1 flying fox hc Crinia signifera, tusked frog striped mash frog	ML	nil	mod	23	95	
	W	1	31/1/23	EL, LA	20:06	20:21	Feather tail glider (SM), red backed toadlet (HC)	Nil	Absent	Fair	22.9	93%	
	E	2	2/2/23	LA/FM	20:18	20:32	C. Nigrescens (SM), Adelotus brevis, ff spp. microbat spp.	MLB	Nil	Good	25.3	81	Nil
	W	2	2/02/23	AE & EL	20:11	20:26	fly fox		mb	good	26	79	
9&10	E	1	31/01/23	FM & AE	21:00	21:15	koala 496651 6609328 prob female healthy se, sug se, grey headed flying fox hc	nil	nil	poor	23	97	
	W	1	31/1/23	EL, LA	20:57	21:12	Red backed toadlet, Crinia.signifera, Lit. peronii, tusked frog (all HC)	Nil	Absent	Fair	22.9	93%	
	E	2	2/2/23	LA/FM	21:04	21:19	Bandy bandy (SM), koala (SE)	MLB	Nil	Good	25.3	81	same individual as previous night
	W	2	2/02/23	AE & EL	20:58	21:13	Flying fox hc FtG sm rattus spp. sm redback toadlet hc	mb	nil	good	26	79	
8	E	1	31/1/23	EL, LA	20:37	20:52	Striped marsh frog, ringtail possum, red backed toadlet	Nil	Absent	Fair	22.9	0.93	
	W	1	31/01/23	FM & AE	20:33	20:49	red backed toadlet microbats present	nil	nil	poor	23	9700%	

Location	Side	Obs. No.	Date	Observers	Start Time	Finish Time	Species	Wind	Rain	Visibility	Air Temp	RH (%)	Comment
	E	2	2/02/23	AE & EL	20:37	20:52	red back toadlet	mb	nil	good	26	79	
	W	2	2/2/23	LA/FM	20:35	20:55	ftg (SM), c signifera, sugar glider, P. Coriacea	MLB	Nil	Good	25.3	81	Nil
7	E	1	31/01/23	FM & AE	21:25	21:40	L. fallax red backed toadlet tusked frog	nil	nil	poor	23	97	
	W	1	31/1/23	EL, LA	21:25	21:40	Tusked frog, red backed toadlet	Nil	Absent	Fair	22.9	93%	
	E	2	2/02/23	AE & EL	21:15	21:30	tusked frog hc antechnius se	mb	nil	good	26	79	
	W	2	2/2/23	LA/FM	21:27	21:52	Nil	MLB	Nil	Good	25.3	81	Nil
5&6	E	1	31/01/23	FM & AE	21:45	22:00	Lit. fallax, red backed toadlet tusked and bandicoot all hc	nil	nil	poor	23	97	
	W	1	31/1/23	EL, LA	21:47	22:02	Sugar glider, tawny frogmouth, redback toadlet, Lit. fallax	Nil	Absent	Fair	22.9	93%	
	E	2	2/2/23	LA/FM	21:53	22:08	Lim peronii, lit fallax	MLB	Nil	Good	25.3	81	Nil
	W	2	2/02/23	AE & EL	21:46	22:01	stripped marsh frog, tusked frog, peronii, red backed toadlet and scaly foot	mb	nil	good	26	79	
4	E	1	31/01/23	FM & AE	22:22	22:37	nil	nil	nil	poor	23	97	
	W	1	31/1/23	EL, LA	22:37	22:57	Red backed toadlet	Nil	Absent	Fair	22.9	93%	
	E	2	2/02/23	AE & EL	22:45	23:00	bandicoot hc red back toadlet hc	mb	nil	good	26	79	
	W	2	2/02/23	LA/FM	22:44	23:00	P. coriacea	mb	nil	good	26	79	
3 (E only)	E	1					No search, last monitoring period house tenants on east side seemed concerned						Need to get contact number for the house
	E	2					No search, last monitoring period house tenants on east side seemed concerned						
2	E	1	31/1/23	EL, LA	22:11	22:27	Nil	Nil	Absent	Fair	22.9	0.93	
	W	1	31/01/23	FM & AE	22:47	22:52	common btp se red back toadlet hc	nil	nil	poor	23	9700%	
	E	2	2/02/23	AE & EL	22:15	22:30	small eyed snake	mb	nil	good	26	79	
	W	2	2/2/23	LA/FM	22:15	22:30	Nil	MLB	Nil	Good	25.3	81	Nil
1	E	1	6/2/2023	LA/AE	20:04	20:16	Eastern water dragon, Black rat	Nil	Nil	Good	24.4	69	Combined with GBF surveys
	W	1	6/2/2023	LA/AE	23:37	0:00	Short-eared brushtail possum, Litoria fallax (HC), Striped marsh frog (SI)	Nil	Nil	Good	24.4	6900%	Combined with GBF surveys
	E	2	7/2/23	LA/AE	20:04	20:16	Nil	Nil	Nil	Good	23.9	75	Combined with GBF surveys
	W	2	7/2/23	LA/AE	22:54	22:10	Eastern water dragon, L. Gracilenta (SM)	Nil	Nil	Good	23.9	75	Combined with GBF surveys

Table B7: Fauna captured during adjacent habitat trapping surveys during year five operational monitoring WC2NH,2022/2023. Uk = unknown, F = female, M = male. Arb = arboreal, Pit = pitfall.

Site	E or W	Date	Trap type	Species	Sex	Weight (g)	Comments
1	E	1/02/2023	Gr	Brown Antechinus	F	19	
1	E	2/02/2023	Gr	Bush rat	F	Uk	

Site	E or W	Date	Trap type	Species	Sex	Weight (g)	Comments
1	E	2/02/2023	Gr	Brown Antechinus	F	Uk	
1	W	2/02/2023	-	Nil			Raided by brushtail possum
1	E	3/02/2023	-	Nil			
1	W	3/02/2023	Arb	Brown Antechinus	F	23	
2	E	31/01/2023	Gr	Bush rat	M	150	
2	E	31/01/2023	Gr	Brown Antechinus	F	32	
2	E	31/01/2023	Gr	Bush rat	M	135	
2	E	31/01/2023	Pit	Tusked frog			
2	W	31/01/2023	Gr	Black rat			Euthanized
2	W	31/01/2023	Gr	Black rat			Euthanized
2	E	1/02/2023	Gr	Bush rat	M	133	
2	W	1/02/2023	Gr	Bush rat	F	119	
2	E	2/02/2023	Gr	Bush rat	F	Uk	
2	E	2/02/2023	Pit	P. coriacea			
2	W	2/02/2023	Gr	Bush rat	M	Uk	
2	W	2/02/2023	Gr	Bush rat	F	Uk	
3	E	31/01/2023	Gr	Black rat			Euthanized
3	W	31/01/2023	-	Nil			
3	E	1/02/2023	Pit	P. coriacea			
3	W	1/02/2023	Pit	Lampro x2			
3	E	2/02/2023	Pit	Lampro delicata x5			
3	W	2/02/2023	Pit	Lampro delicata x2			
4	E	1/02/2023	Gr	Bush rat (w/ 3 young)	F	125	
4	E	1/02/2023	Gr	FF Melomys	M	72	
4	W	1/02/2023	Gr	FF Melomys	M	82	
4	W	1/02/2023	Arb	FF Melomys	F	66	
4	E	2/02/2023	Gr	Bush rat	M	Uk	
4	E	2/02/2023	Gr	Bush rat	F	Uk	
4	E	2/02/2023	Arb	FF Melomys	F	Uk	
4	W	2/02/2023	Gr	Black rat			Escaped

Site	E or W	Date	Trap type	Species	Sex	Weight (g)	Comments
4	E	3/02/2023	Gr	Black rat			Unsure of ID released
4	E	3/02/2023	Gr	Bush rat	M	Uk	
4	E	3/02/2023	Gr	Bush rat	F	Uk	
4	W	3/02/2023	Gr	Bush rat	M	Uk	
4	W	3/02/2023	Gr	FF Melomys Juvenile	Uk	Uk	
5/6	E	31/01/2023	Gr	Melomys	F	80	
5/6	E	31/01/2023	Gr	Melomys	M	90	
5/6	W	31/01/2023	Gr	Brown Antechinus	Uk	23	
5/6	W	31/01/2023	Gr	Bush rat	M	94	
5/6	W	31/01/2023	Gr	Brown Antechinus	F	28	
5/6	W	31/01/2023	Gr	Melomys	M	80	
5/6	W	31/01/2023	Pit	Antechinus, Striped marsh frog (deceased)			
5/6	E	1/02/2023	Gr	FF Melomys	F	68	
5/6	E	1/02/2023	Pit	P. coriacea			
5/6	W	1/02/2023	Gr	Brown Antechinus	F	32	
5/6	W	1/02/2023	Gr	Brown Antechinus	F	27	
5/6	W	1/02/2023	-	Black rat			Euthanized
5/6	E	2/02/2023	Pit	Lampropholis spp.			
5/6	E	2/02/2023	Gr	Brown Antechinus	F	Uk	
5/6	E	2/02/2023	Arb	Black rat			Euthanized
5/6	E	2/02/2023	Arb	Black rat			Euthanized
5/6	W	2/02/2023	Gr	Brown Antechinus	F	16	
7	E	31/01/2023	Arb	FF Melomys	F	72	
7	E	31/01/2023	Gr	FF Melomys	M	82	
7	E	31/01/2023	Pit	Red backed toadlet, F antechinus			
7	W	31/01/2023	Gr	Bush rat	F	135	
7	W	31/01/2023	Gr	Bush rat	M	175	
7	W	31/01/2023	Gr	Bush rat	M	165	
7	E	1/02/2023	Gr	FF Melomys	M	75	

Site	E or W	Date	Trap type	Species	Sex	Weight (g)	Comments
7	E	1/02/2023	Gr	FF Melomys	Uk	55	
7	W	1/02/2023	Gr	Bush rat	F	89	
7	W	1/02/2023	Gr	Bush rat	M	166	
7	E	2/02/2023	Gr	FF Melomys	-	-	Escaped
7	E	2/02/2023	Gr	Brown Antechinus	F	26	
7	E	2/02/2023	Gr	FF Melomys	F	67	
8	E	31/01/2023	Gr	Black rat			Euthanized
8	W	31/01/2023	Gr	Brown Antechinus	F	37	
8	W	31/01/2023	Gr	Bush rat	M	164	
8	W	31/01/2023	-	Black rat			Euthanized
8	W	31/01/2023	Pit	Brown Antechinus	M	-	Deceased
8	W	31/01/2023	Pit	Brown Antechinus	F	22	
8	W	31/01/2023	Pit	Brown Antechinus	M	16	
8	W	31/01/2023	Pit	FF Melomys	F	28	
8	E	1/02/2023	-	Nil			
8	W	1/02/2023	Gr	Brown Antechinus	M	21	
8	W	1/02/2023	Cage	Lace monitor			Released during day AdHab searches
8	E	2/02/2023	Gr	Bush rat	M	70	
8	E	2/02/2023	Gr	Bush rat	Uk	65	
8	W	2/02/2023	Pit	Lampro delicata x2, P. Coriacea x1			
8	W	2/02/2023	Gr	Bush rat	F	Uk	
9/10	E	31/01/2023	Pit	Antechinus	F	34	
9/10	E	31/01/2023	Gr	Melomys	F	89	
9/10	W	31/01/2023	Gr	Bush rat	M	130	
9/10	W	1/02/2023	Arb	Melomys	M	87	
9/10	W	1/02/2023	Cage	Bush rat	Uk	Uk	
9/10	W	1/02/2023	Pit	Red backed toadlet			
9/10	W	1/02/2023	Gr	Melomys	F	61	
9/10	E	2/02/2023	-	Nil			

Site	E or W	Date	Trap type	Species	Sex	Weight (g)	Comments
9/10	W	2/02/2023	Arb	Melomys	F	70	
9/10	W	2/02/2023	Pit	L. delicata			
11/12	E	31/01/2023	Gr	Bush rat	M	187	
11/12	E	31/01/2023	Pit	Antechinus	F	23	
11/12	E	31/01/2023	Gr	Bush rat	F	128	
11/12	E	1/02/2023	Gr	Bush rat	F	127	
11/12	E	1/02/2023	Gr	Bush rat	F	151	
11/12	E	1/02/2023	Gr	Black rat			Escaped
11/12	W	31/01/2023	Gr	Black rat			Euthanized
11/12	W	1/02/2023	Pit	Red backed toadlet			
11/12	E	2/02/2023	Gr	Bush rat	M	Uk	
11/12	E	2/02/2023	Gr	FF Melomys	F	Uk	
11/12	E	2/02/2023	Pit	Calyptotis ruficauda			

Table B8: Fauna recorded in hair funnel surveys during year five operational monitoring WC2NH, 2022/2023.

Site	Position	**Date**	**Species**	**Species**
1	East 1	2/06/2023	Trichosurus vulpecula	
1	East 2	2/06/2023	Trichosurus vulpecula	
1	West 1	2/06/2023	Rattus sp.	
1	West 2	2/06/2023	Rattus fuscipes	
2	East 1	2/06/2023	Rattus fuscipes	
2	East 2	2/06/2023	Isoodon macrourus	
2	West 1	2/03/2023	Rattus fuscipes	
2	West 2	2/03/2023	Rattus fuscipes	
3	East 1	2/03/2023	No hair	
3	East 2	2/03/2023	No hair	
3	West 1	2/03/2023	No hair	
3	West 2	2/03/2023	No hair	
4	East 1	2/06/2023	Rattus fuscipes	
4	East 2	2/06/2023	Trichosurus vulpecula	
4	West 1	2/06/2023	Trichosurus vulpecula	Isoodon macrourus
4	West 2	2/06/2023	Rattus fuscipes	Isoodon macrourus

5/6	East 1	2/03/2023	No hair	
5/6	East 2	2/03/2023	Melomys cervinipes	
5/6	West 1	2/03/2023	Trichosurus vulpecula	Antechinus stuartii
5/6	West 2	2/03/2023	Antechinus stuartii	
7	East 1	2/03/2023	Antechinus stuartii	
7	East 2	2/03/2023	Antechinus stuartii	
7	West 1	2/03/2023	Rattus fuscipes	
7	West 2	2/03/2023	Rattus fuscipes	
8	East 1	2/03/2023	Trichosurus vulpecula	Mus musculus
8	East 2	2/03/2023	Antechinus stuartii	Rattus rattus
8	West 1	2/03/2023	Antechinus stuartii	
8	West 2	2/03/2023	Trichosurus vulpecula	
9/10	East 1	2/03/2023	Trichosurus vulpecula	
9/10	East 2	2/03/2023	Rattus sp.	Trichosurus vulpecula
9/10	West 1	2/03/2023	Rattus fuscipes	
9/10	West 2	2/03/2023	Rattus fuscipes	
11/12	East 1	2/03/2023	Antechnius sp.	
11/12	East 2	2/03/2023	Rattus sp.	
11/12	West 1	2/03/2023	No hair	
11/12	West 2	2/03/2023	Antechnius sp.	

Transport for New South Wales

Warrell Creek to Nambucca Heads

Annual Underpass Monitoring Report - Operational Phase, Year Five (2022-2023)

Transport for New South Wales | March 2024 |

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

Underpass and adjacent habitat monitoring – Operational Phase Year Five (2022-23)

Sandpiper Ecological Surveys

Final Report

21 March 2024

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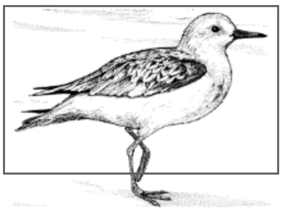

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Table of contents

List of tables

List of figures

List of plates

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 the methods and results of year five operational phase underpass and adjacent habitat monitoring. It serves as the final report for the operational monitoring period, as outlined in the EMP, and evaluates the effectiveness of the underpass structures as a mitigation measure (RMS 2018). The effectiveness of exclusion fence is assessed in the annual road-kill report (Sandpiper Ecological 2024). The results of underpass and adjacent habitat monitoring 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 included eleven box culverts and one bridge (RMS 2018; Table 1). Eleven underpasses were situated north of the Nambucca River and one (Site 1) was situated at Upper Warrell Creek near the southern extent of the project (Figure 1). Sites four to 12 adjoined Nambucca State Forest and sites two and three adjoined remnant vegetation on private land (Figure 1). Site five included 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 included a concrete ledge that provided dry passage for terrestrial fauna. Sites 9/10, and 11/12 consisted 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	

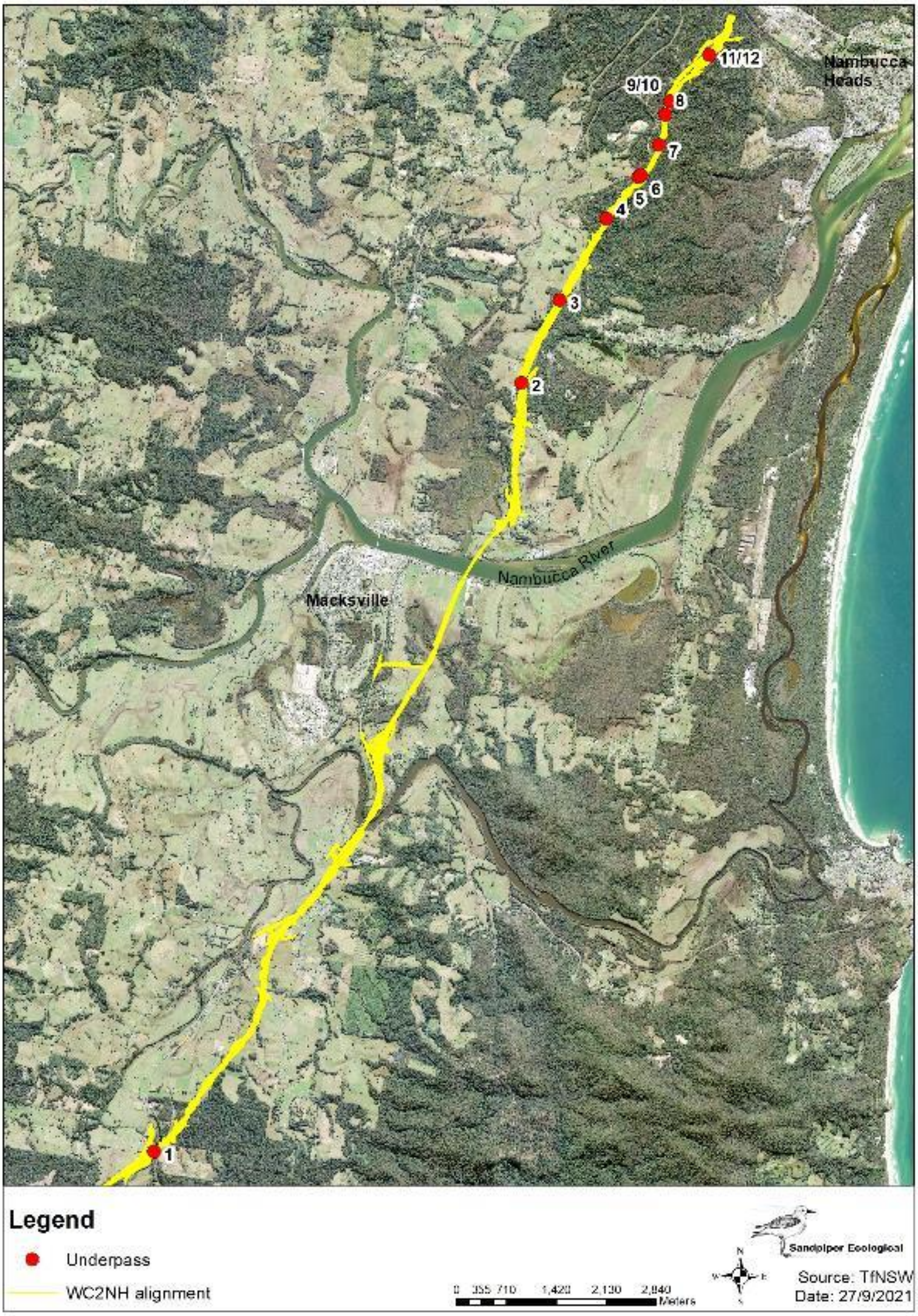

Figure 1: Underpass locations along the WC2NH alignment.

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 5 spring/summer operational phase underpass and adjacent habitat surveys were conducted between 14 October 2022 to 6 February 2023. Wet conditions were a feature of early spring monitoring when 300mm of rain fell during October (BOM, 2023). Dry conditions persisted from November to February with 175mm recorded at the Bellwood weather station (BOM, 2023). A total of 397mm of rainfall was recorded at the Bureau of Meteorology (BOM) Bellwood station (#059150) throughout the spring/summer monitoring period (BOM, 2023). Over the same period relative humidity was high with >60% recorded on most days and air temperature ranged from 20.8 to 36.9 ^{0}C (BOM, 2023a).

Winter surveys were conducted between 17 July and 22 September 2023. The surveys extended into spring to satisfy the prescribed 8-week underpass camera activity period (RMS, 2018). Conditions during this period were extremely dry with maximum temperatures ranging from 18.5 to 32.9 ^{0}C (Table 2). A total of 14 mm of rainfall was recorded for the entire period (BoM, 2023).

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

Monitoring period	Total rainfall (mm)	No. rain days	Relative humidity (%)	Max temp range (°C)	Min temp range (°C)
Spring/Summer	397	55	>60% on 73% of days	20.8 - 36.9	6.8 - 24.6
Winter	14	6	>60% on 57% of days	18.5 - 32.9	2.6 - 18.3

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 each culvert, 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 year 5 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 except 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 autumn/winter. Time-lapse mode is better suited to targeting frogs and was used successfully to monitor frog pipes on the Sapphire to Woolgoolga Pacific Highway Upgrade (Sandpiper Ecological 2017a, 2018a).

During the spring/summer sample period, cameras at sites 1-12 were installed on 14 and 21 October 2022 and were retrieved on 30 December 2022 following a total sample period of 77 days (Table 3). During the winter sample period, cameras at sites 1-12 were installed on 19 July 2023 and were retrieved on 22 September 2023 following a total sample period of 65 days (Table 3). On four occasions, camera functionality was compromised due to battery failure or camera malfunction (Table 3). Specifically, camera operation was reduced at site 5 north during summer/spring, site 7 ground in winter, site 9 ground in winter, and site 10 furniture during summer/spring (Table 3). Notably, two cameras fell short of the prescribed activity period of 56 days, or 8 weeks, as specified in the EMP (RMS 2018).

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

Site	Camera type	Camera location	Number of days active		
			Spring/summer	Winter	Total Year 5
1	Reconyx	North	90	63	153
	Reconyx	South	63	66	129
2	Reconyx	Furniture	77	65	142
	Swift enduro	Ground	77	65	142
3	Swift enduro	Furniture	77	65	142

Site	Camera type	Camera location	Number of days active Spring/summer	Winter	Total Year 5
	Swift enduro	Ground	104	65	169
4	Swift 3c	Ground	77	65	142
	Swift enduro	Furniture	77	65	142
5	Swift enduro	North	54*	65	119
	Swift enduro	South	77	65	142
6	Reconyx	Furniture	77	65	142
	Reconyx	Ground	77	65	142
7	Swift 3c	Ground	77	32*	109
	Swift enduro	Furniture	77	65	142
8	Swift enduro	Furniture	77	65	142
	Swift enduro	Ground	77	65	142
9	Swift 3c	Ground	33*	65	98
	Swift enduro	Furniture	77	65	142
10	Swift enduro	Furniture	77	52*	129
	Swift enduro	Ground	77	65	142
11	Swift enduro	Furniture	77	65	142
	Swift enduro	Ground	82	65	147
12	Swift enduro	Furniture	77	65	142
	Swift enduro	Ground	77	65	142

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 detected in underpasses were assigned to one of two movement types, “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 2017, 2018, 202022) 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 move safely from one side of a road to the other). To account for variations in survey effort (camera activity periods) between sites, complete crossings/week and complete crossings/week/underpass were adopted. Complete crossings were calculated by summing the number of crossings at each site and then dividing by the total activity period of all cameras at each respective site. This method ensures an accurate representation of crossing frequency relative to monitoring effort.

Complete crossings have been summed and presented in relation to monitoring periods (i.e., year 1 vs year 2), taxa (i.e., bandicoots, koala, 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 single sites and lack independence if treated separately. The same approach was applied to data from previous monitoring years and projects. Birds and microbats were excluded from analysis as they do not require underpasses for thoroughfare.

One potential indicator of success identified in the EMP was use of underpasses by cover-dependent species and species with low mobility, yet no specification was given for which species this encompasses. Therefore, it has been inferred that low-mobility fauna includes species whose movements are constrained by their size, behaviour or home range and includes frogs, small reptiles (excluding the goanna and water dragon), some species of rodents (bush rat, swamp rat and fawn-footed melomys), small dasyurids (*Antechinus* spp) and bandicoots. When species-specific identification was not possible, rodents were documented as 'rodent spp.' and their status as either introduced or native remained "undefined". This approach was adopted due to the difficulty in accurately distinguishing between black rat, bush rat and fawn-footed melomys from camera footage. Black rat and water rat tend to traverse open space and have been excluded from the cover dependent classification. Additionally, house mouse has also been excluded as this species is introduced and not a target for underpasses. All records of *Antechinus* spp. are considered as brown antechinus, due to the absence of other species throughout operational monitoring.

Mean capture rates of fauna from the adjacent habitat (refer section 2.3) were calculated for each site over the five-year monitoring period. The total number of captures was divided by five, the number of survey years, to obtain a mean annual capture rate. This facilitated comparison of capture rates for different species across the sites.

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 30 January and 3 February 2023, and 17 and 20 July 2023.

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. Pitfall traps at sites 1, 2 (east) and 4 were closed in the spring/summer survey due to rising groundwater that filled the buckets. 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 on a platform positioned on the trunk of a rough-barked tree 1.8m above ground. 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. 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 were 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 as opposed to population size.

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.

Table 4: Survey effort for sampling in 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	4 samples/site	1080 person minutes
Active nocturnal search	30 person minute search at UP entrance	4 samples/site	1080 person minutes

3 Results

3.1 Underpasses

3.1.1 Year five camera monitoring

Species diversity and underpass use

Excluding microbats and birds, underpass cameras yielded 3095 fauna detections (i.e., sum of complete, incomplete and non-directional movement crossings) during year five operational monitoring (See appendix B, Table B1). Complete crossings (cc) accounted for 93% (2868cc) of all fauna detections. Nineteen species/unique genera and nine fauna groups were confirmed making complete crossings of underpasses at WC2NH during year five operational phase monitoring. Fauna groups included eight taxa that could only be identified to a genus or group, including rodent spp., bandicoot spp., wallaby spp., macropod spp., lizard spp., *Egernia* spp., and *Trichosurus* spp. (Table 5). Rodent spp., bandicoot spp., wallaby spp. and *Trichosurus* spp. likely belong to confirmed species in **Error! Reference source not found.** (i.e., *Trichosurus* spp. either short-eared brushtail possum or common brushtail possum). Of the fauna recorded, 24 were native species/groups and four were introduced including cat, wild dog, red fox and black rat. Native fauna diversity was highest at sites 11/12 with 17 species/groups, followed by sites 9/10 with 15 and sites 2 and 4 with 13 species/groups (**Error! Reference source not found.**). Native fauna diversity was lowest at site 1 with seven species recorded. Sites 3, 5/6, 7 and 8 recorded between nine and twelve native fauna species/groups each.

Complete crossings (CC) by native species were observed at all sites with the frequency of crossings differing among the underpass locations. Sites 4 and 8 featured the highest use by native fauna with a mean of 4.93 and 5.42 cc/week, respectively (Figure 2). Sites 1 and 5/6 exhibited the lowest mean use by native fauna, recording 0.65 and 2.11 cc/week respectively (Figure 2). Native fauna use was higher than that of feral predators and rodent spp. at all sites (Figure 2).

Brown antechinus was the most frequently recorded native species, with a combined mean crossing rate of 29.42cc/week across all sites (**Error! Reference source not found.**). This was followed by bandicoot species, including long-nosed and northern brown with 23.45cc/week, short-eared brushtail possum (22.91cc/week), swamp wallaby (18.96cc/week), wallaby spp. (10.06cc/week) and *Trichosurus* spp. (5.23cc/week) (**Error! Reference source not found.**). Noteworthy detections included koala using the culvert floor (ground) at sites 4 (one occasion), 9/10 (two occasions) and 11/12 (two occasions, Plate 4) to make complete crossings of the alignment (**Error! Reference source not found.**, Figure 2).

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 5 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																		Total cc/week/spp.
	1		2		3		4		5/6		7		8		9/10		11/12		
	N	S	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	FF	G	
Mammals																			
Short-beaked echidna	-	-	-	0.31	-	-	-	0.31	-	-	-	0.22	-	-	-	0.22	-	0.05	1.10
Brown antechinus ^	0.08	0.11	7.56	0.09	0.41	-	-	-	3.92	0.18	1.29	0.22	6.75	-	5.37	-	3.07	0.38	29.42
Long-nosed bandicoot^	-	-	-	4.04	-	-	-	1.50	-	1.01	-	0.36	-	0.63	-	1.33	-	0.66	9.54
Northern brown bandicoot^	-	-	-	-	-	-	-	0.32	-	-	-	-	-	-	-	0.32	-	0.47	1.12
Bandicoot spp.^	-	-	-	1.06	-	-	-	0.45	-	0.75	-	3.21	-	3.40	-	2.47	-	1.54	12.88
Koala	-	-	-	-	-	-	-	0.09	-	-	-	-	-	-	-	0.11	-	0.11	0.31
Trichosurus spp	-	-	-	-	1.28	-	-	1.91	-	-	-	-	0.76	0.09	0.59	0.28	0.32	-	5.23
Short-eared brushtail possum	-	-	-	0.18	4.62	-	5.75	0.31	-	-	8.97	-	0.36	0.18	0.14	-	2.36	0.04	22.91
Eastern grey kangaroo	-	-	-	-	-	0.67	-	-	-	-	-	-	-	-	-	-	-	-	0.67
Red-necked wallaby	-	-	-	-	-	0.32	-	-	-	-	-	-	-	-	-	0.06	-	0.37	0.75
Swamp wallaby	1.10	0.75	-	1.32	-	0.54	-	2.96	-	0.69	-	4.34	-	5.47	-	0.38	-	1.41	18.96
Wallaby spp.	-	-	-	1.13	-	1.23	-	1.94	-	0.03	-	1.11	-	3.00	-	1.58	-	0.04	10.06
Macropod spp.	-	-	-	-	-	1.21	-	-	-	-	-	-	-	-	-	-	-	-	1.21
Water rat	-	-	-	-	-	-	-	-	-	1.11	-	-	-	-	-	-	-	-	1.11
Bush rat^	-	-	0.09	-	-	-	0.36	-	-	-	0.36	-	-	-	-	-	0.59	-	1.41
Rodent spp.																			
Black rat*	0.30	0.74	-	0.45	-	-	0.73	0.09	0.75	0.14	1.33	0.73	1.26	-	3.13	0.58	3.38	1.07	14.68
Rodent spp.	0.33	0.11	1.58	0.70	-	-	9.89	-	6.09	0.21	6.52	1.33	1.32	0.31	7.40	0.49	4.77	0.27	41.33
Feral predators																			
Red fox*	0.72	0.11	-	1.47	-	0.32	-	0.75	-	0.67	-	4.21	-	2.11	-	3.05	-	4.49	17.91
Wild dog*	-	-	-	-	-	-	-	1.90	-	1.09	-	2.06	-	3.36	-	1.86	-	0.79	11.05
Cat*	0.08	0.22	-	0.11	-	8.47	-	0.29	-	0.24	-	-	-	-	-	0.11	-	0.04	9.55
Reptiles and frogs																			
Blue-tongue lizard^	-	-	-	0.18	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10	0.28
Eastern water dragon	-	-	-	0.09	0.36	-	-	0.09	-	0.03	-	-	-	-	-	-	-	0.11	0.69
Egernia spp.^	-	-	-	-	-	-	-	-	-	-	0.11	-	-	-	1.14	-	-	-	1.24
Lace monitor	0.08	-	-	0.09	0.09	0.79	0.85	2.63	-	0.64	0.64	0.18	-	1.17	-	0.69	-	0.54	8.40
Lizard spp.^	-	-	0.55	0.18	-	-	-	-	-	-	0.18	-	0.64	-	2.00	0.06	-	0.04	3.65
Small frog spp.^	-	0.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11
Small-eyed snake^	0.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11
Striped marsh frog^	-	0.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11
Total no. species/groups	8	8	4	15	5	8	5	15	3	13	8	11	6	10	7	16	6	19	225.79

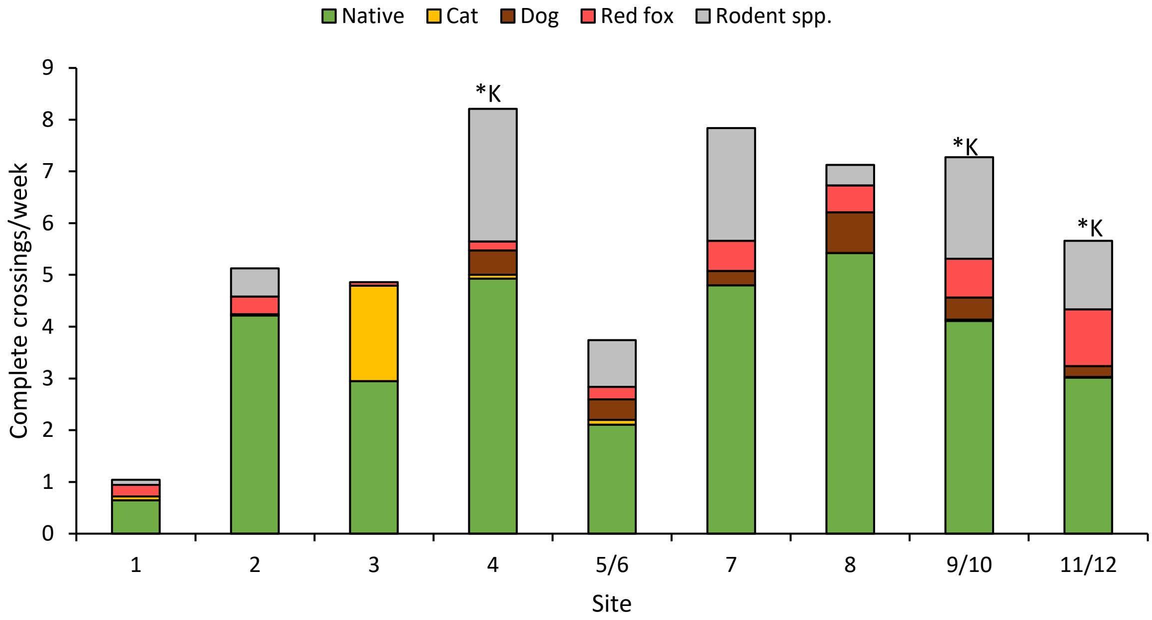

Figure 2: Complete crossings (cc)/week by native species, feral predators (cat, dog and red fox) and rodent spp. (undefined rodent) at each site during year five operational monitoring, WC2NH, 2022-2023. *K = indicates complete crossing by koala.

Plate 4: Images of fauna utilising underpasses. Koala crossing through site 12 then 6 minutes later site 11 during winter (Top Left / Right). Long-nosed bandicoot at site 2 during spring/summer (Middle Left). Fox carrying long-nosed bandicoot at site 11 during spring/summer (Middle right). Eastern grey kangaroo at site 3 during spring/summer (Bottom Left). Dog carrying bird spp. at site 8 during winter (Bottom Right).

Use by cover-dependent species

Cover-dependent fauna (see classification in methods) were recorded at all sites (Table 5), with the highest usage shown by brown antechinus (29.42 cc/week) followed by bandicoots (23.54 cc/week) and lizard spp. (3.65 cc/week) (Table 5). Other cover-dependent species included the eastern blue-tongue lizard using the culvert floor at sites 2 and 11/12, small frog spp. at site 1 and *Egernia* spp. at sites 7 and 9/10 (Table 5). Most cover-depended species favoured the fauna furniture with the exception being bandicoots, which exclusively used the culver floor (ground) (Table 5).

Furniture vs Floor

Fauna were recorded making complete crossings on both the culvert floor (51% of complete crossings) and furniture (49%) during year five operational phase monitoring (Table 5, Figure 3). Native fauna accounted for the majority of complete crossings on both the culvert floor (60%) and fauna furniture (53%) (Figure 3). Rodents tended to favour the fauna furniture whereas feral predators showed exclusive use of the culvert floor (Table 5, Figure 3). Most of the native fauna usage of the furniture can be attributed to use by brushtail possums (combined short-eared brushtail possum, common brushtail possum and *Trichosurus* spp.) at sites 3, 7, 11/12 and brown antechinus at sites 2, 8 and 9/10 (Table 5*).* Of the threatened fauna, koalas were recorded using the floor only at sites 4, 9/10 and 11/12 on five occasions (Table 5, Plate 4).

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), introduced rodents and rodent spp., at WC2NH during year five operational monitoring, 2022-2023.

Feral predator activity

Feral predators were recorded in all underpass sites and accounted for 16% of all complete crossings in year five monitoring (Figure 2, Table 5). Red fox displayed the highest combined use (17.91cc/week), followed by dog (11.05 cc/week) then cat (9.55 cc/week) (Figure 2, Table 5). Cat activity was recorded across seven of nine sites, with the highest activity (mean total of 8.47 cc/week) occurring at site 3 (Figure 2, Table 5). Fox activity was recorded at all nine sites with the highest activity at 9/10 and 11.12 (Figure 2, Table 5, Plate 4). Dog activity was recorded at six of the nine sites and was highest at site 8 (Figure 2, Table 5, Plate 4). No instances of predation were recorded within underpasses during year five operational monitoring, however feral predators carrying prey through an underpass was recorded on two occasions (Plate 4).

3.1.2 Operational camera monitoring

Trends in underpass use by native fauna during operational monitoring

Underpass use by native fauna has progressively increased from years one to five of operational monitoring (Figure 4). Initially, the underpass crossing rate by native fauna was 1.29 ± 1.32 cc/week/site in year one. It increased to 1.78 ± 1.35 cc/week/site in year two (38% increase) and further to 1.85 ± 1.78 cc/week/site in year three (4% increase from year two). This upward trend continued, reaching 2.52 ± 1.57 cc/week/site in year four (36% increase from year three), with a subsequent increase to 3.57 ± 1.53 cc/week/site in year five (42% increase from year four). Overall, the trend suggests a rapid initial increase in the usage of underpasses by native species from year one to two, stabilisation in year two to three and rapid increase in the usage rates from years four to five (Figure 4).

Similarly, underpass use by cover-dependent or low mobility fauna increased over time, although at a greater rate (CD/LM fauna, Figure 4). In year one, the initial underpass usage rate was recorded at 0.08 ± 0.10 cc/week/site. By year two, this rate substantially increased to 0.31 ± 0.42 cc/week/site, a 290% increase from year one. Crossings continued to increase in subsequent years, with year three reaching 0.48 ± 0.44 cc/week/site (a 57% increase from year two), year four 0.98 ± 0.64 cc/week/site (102% increase from year three), and year five peaking at 1.57 ± 1.25 cc/week/site, reflecting a 61% increase from year four (Figure 4). In year five, underpass use by cover-dependent or low mobility fauna accounted for 44% of all native fauna underpass use and had increased by 1862% from the initial year one monitoring period (Figure 4).

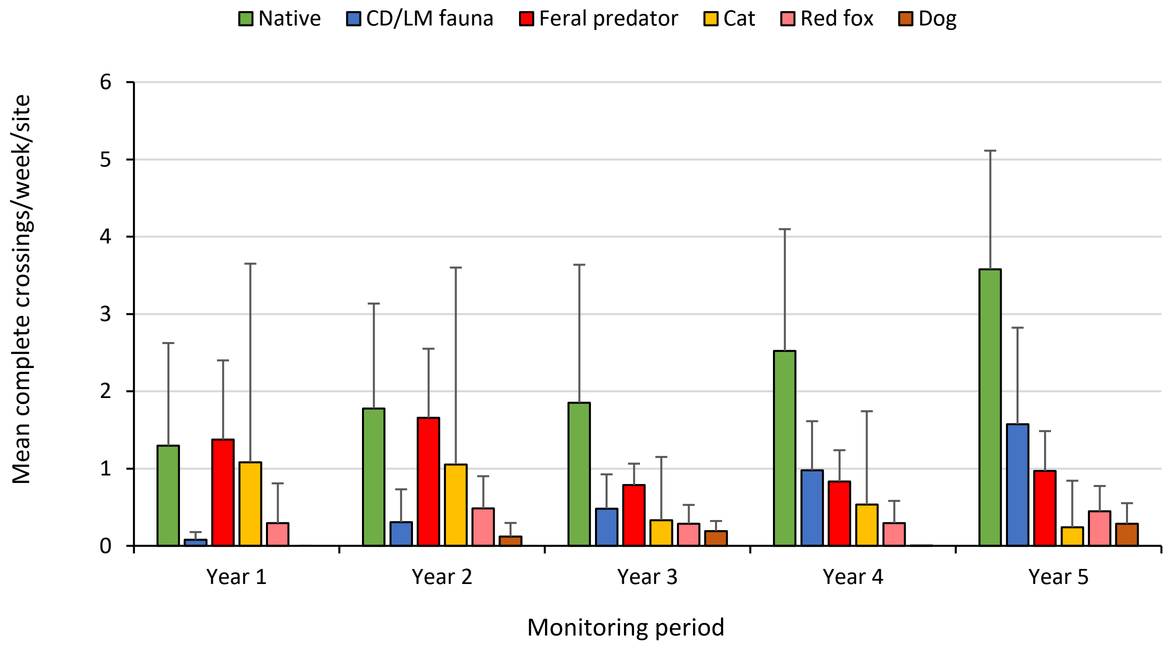

Figure 4: Mean (n=9) complete crossings/week/site (+SD) by native species, cover-dependent or low mobility fauna (CD/LM fauna) and feral predators (cat dog and red fox) at WC2NH during operational monitoring, 2018-2023. Birds and microbats have been excluded. Fauna classed as rodent spp. and introduced rodent have been excluded. Note feral predator bar is combined cat, dog, and fox and native bar is combined CD/LM fauna and other non-cover-dependent native species.

Records of cover-depended fauna throughout operational monitoring (year 1-5) were comprised of (northern brown and long-nosed) bandicoots (54.4% of complete crossings), brown antechinus (35.52%), lizard spp. (4.15%), bush rat (1.59%), *Egernia* spp. (1.34%), eastern crevice skink (0.96%) fawn-footed melomys (0.77%)., medium frog spp. (0.51%), eastern blue-tongue lizard (0.38%), swamp rat (0.13%), small frog spp. (0.13%), striped marsh frog (0.06%) and small-eyed snake (0.06%) (see appendix B, Table B1). Among these, bandicoot, swamp rat, eastern blue-tongue lizard, small-eyed snake and all frogs, were solely recorded using the ground to make complete crossings. Conversely, the remaining species/groups were predominately recorded using the fauna furniture with bush rat and brown antechinus on occasion using the ground. Note all frog records were obtained from site 1 (See appendix B, Table B1).

Variability in underpass use by native fauna was evident during operational monitoring (Figure 5). Site 8 exhibited the highest usage by native fauna with a mean rate of 3.70 ± 1.34 cc/week/year, followed by site 7 with 3.39 ± 1.71 cc/week/year, site 4 at 3.15 ± 1.85 cc/week/year, and site 2 at 2.94 ± 1.48 cc/week/year (Figure 5). In contrast, sites 1 and 5/6 were the least utilised underpasses by native fauna with 0.53 ± 0.57 cc/week/year and 0.99 ± 0.70 cc/week/year, respectively (Figure 5). Sites 9/10, 11/12, and 3 recorded intermediate use with

1.54 ± 1.64 cc/week/year, 1.84 ± 1.17 cc/week/year, and 2.01 ± 0.71 cc/week/year (Figure 5). As a general observation, sites with contiguous habitat on each side of the underpass tended to have the highest use by native fauna such as at sites 4, 7 and 8.

Similar variability was also observed in underpass use across sites by cover-dependent/low mobility fauna (Figure 5). The highest use by cover-dependent and low mobility fauna was recorded at site 2 with a rate of 1.35 ± 1.28 cc/week/year. Conversely, sites 1 and 3 demonstrated the lowest usage with rates of 0.09 ± 0.10 cc/week/year and 0.11 ± 0.10 cc/week/year, respectively. Sites 4 through to 11/12 recorded moderate use ranging from 0.43 ± 0.48 cc/week/year at site 5/6 to 0.99 ± 0.48 cc/week/year at 9/10 (Figure 5). Notably, site 9/10 was the only underpass where cover-depended fauna accounted for the majority (64%) of complete crossing by all native fauna (Figure 5).

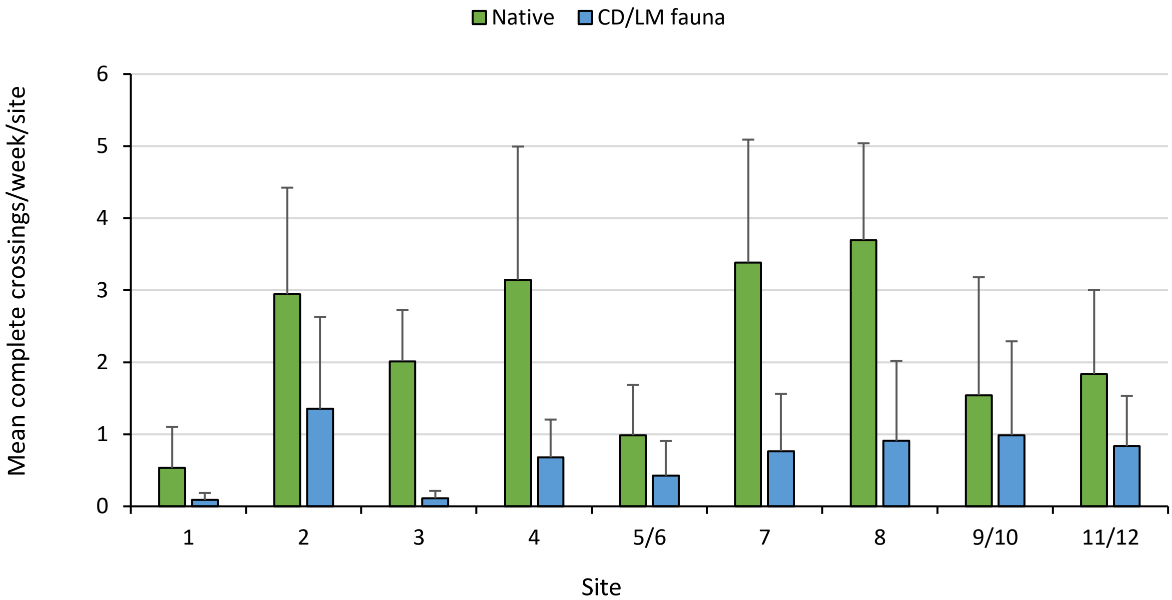

Figure 5: Mean (n=5) complete crossings/week/year (+SD) by native species, cover-dependent or low mobility fauna (CD/LM fauna) at all sites from 2018-2023. CD/LM = cover-dependent or low mobility fauna. Note value for native fauna is combined CD/LM fauna and other non-cover-dependent native species.

One targeted threatened species, koala, was consistently recorded using underpasses throughout operational monitoring (Figure 6). Koalas were recorded making complete crossings at six of the nine underpass sites including sites 2, 4, 7, 8, 9/10 and 11/12 (Figure 7). The highest use was recorded at site 4 with an average crossing rate of 0.16 ± 0.10 cc/week/year, followed by site 11/12 with 0.021 ± 0.023 cc/week/year, site 9/10 with 0.014 ± 0.013 cc/week/year, site 7 with 0.011 ± 0.025 cc/week/year, site 2 with 0.005 ± 0.012 cc/week/year, and site 8 with 0.005 ± 0.011 cc/week/year, while sites 1, 3, and 5/6 recorded no use (Figure 7). Notably, the number of complete crossings by koala has progressively declined over the survey period, from 0.41 ± 0.10 cc/week in year 1 to 0.08 ± 0.10 cc/week in year 5 (Figure 6). The trend observed is attributed to a reduction in koala crossings at site 4, decreasing from eighteen in year one to one in year five, with a consistent temporal decline (See appendix B, Table B1).

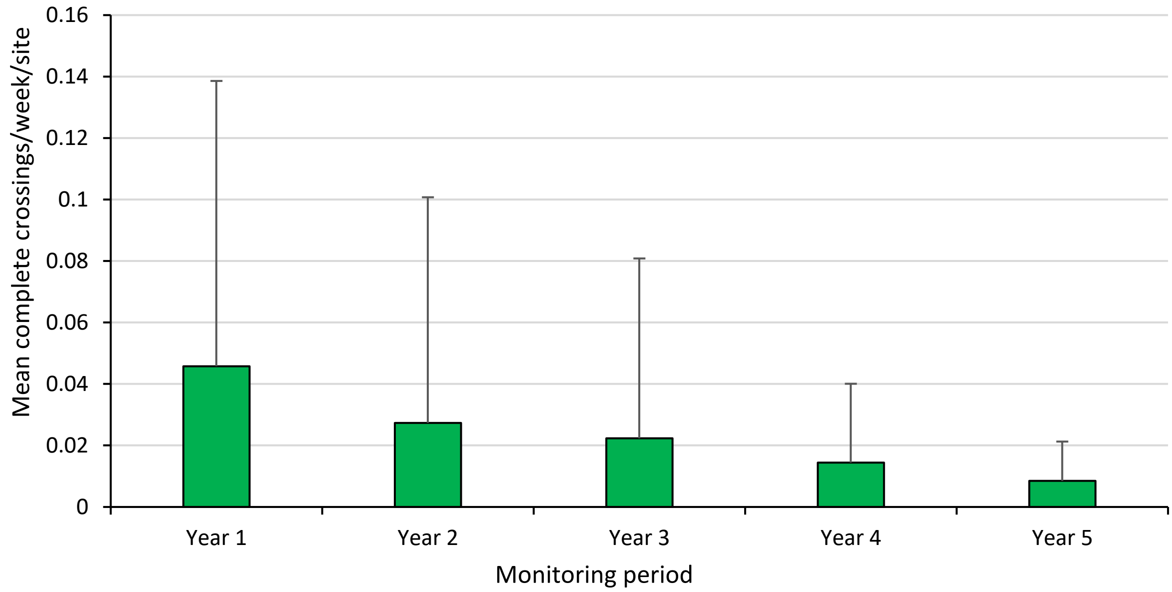

Figure 6: Mean (n=9) complete crossings/week/site (+SD) by koala at WC2NH during operational monitoring, 2018-2023.

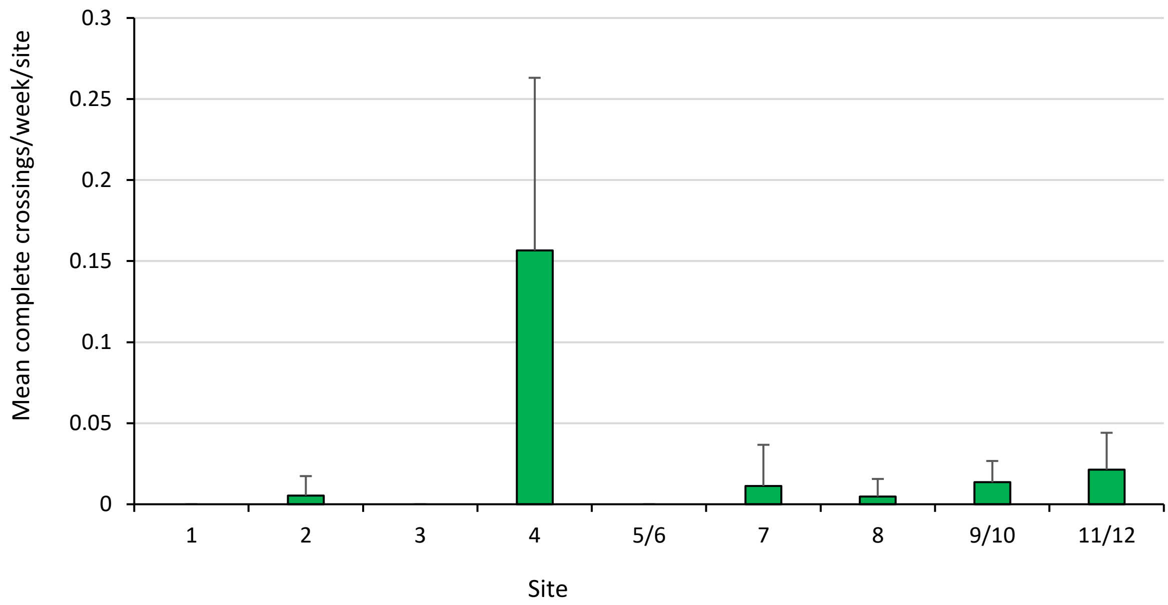

Figure 7: Mean (n=5) complete crossings/week/year (+SD) by koala at each underpass site during operational monitoring at WC2NH, 2018-2023.

Trends in underpass use by feral predators during operational monitoring

Feral predator use of the WC2NH underpasses has fluctuated over the five years of operational monitoring (Figure 4). The average complete crossing rate increased from 1.37 ± 1.03 cc/week/site in year one to 1.66 ± 0.89 cc/week/site in year two before declining substantially to 0.79 ± 0.28 cc/week/site in year three. Subsequently, crossing rates increased from 0.83 ± 0.41 cc/week/site in year four to 0.97 ± 0.52 cc/week/site in year five. The increase in feral predator activity between year four and year five is largely attributed to changes in dog activity which increased from 0.001 ± 0.001 cc/week/site in year four to 0.29 ± 0.27 cc/week/site during year five (Figure 4). Red fox activity also increased from 0.3 ± 0.1 cc/week/site in year four to 0.45 ± 0.33 cc/week/site in year five monitoring. Whereas cat activity declined between years four and five, going from 0.53 ± 0.4 cc/week/site to 0.24 ± 0.6 cc/week/underpass (Figure 4). All three feral predator species were recorded at each underpass site, with the sole exception being the absence of dog at site 1 (Figure 8).

The frequency of red fox crossings was relatively consistent between sites 2, 3, 4, 7, 8, and 9/10, with crossing rates ranging from 0.29 ± 0.28 at site 9/10 to 0.46 ± 0.66 at site 3 (Figure 8). Underpass usage peaked at sites 11/12 with 0.57 ± 0.43 cc/week and was lowest at site 1, with 0.07 ± 0.09 cc/week, and site 5/6, with 0.18 ± 0.07 cc/week (Figure 8).

Like red fox, dogs exhibited minor variability in their usage across the sites with no apparent preferential use of any sites. Amongst the sites where dogs were recorded, the highest mean usage was at site 8 with 0.17 ± 0.35 cc/week, followed closely by site 4 with 0.17 ± 0.20 cc/week (Figure 8).The lowest recorded usage was at site 5/6 with 0.09 ± 0.23 cc/week. Sites 2, 3, 7, 9/10, and 11/12 exhibited moderate usage rates, ranging from 0.10 to 0.16 cc/week (Figure 8). Cats showed strong preferential use for site 3, recording 4.76 cc/week, and relatively low-moderate use among other sites ranging from 0.05 ± 0.07 at site 1 to 0.28 ± 0.30 at site 3 (Figure 8).

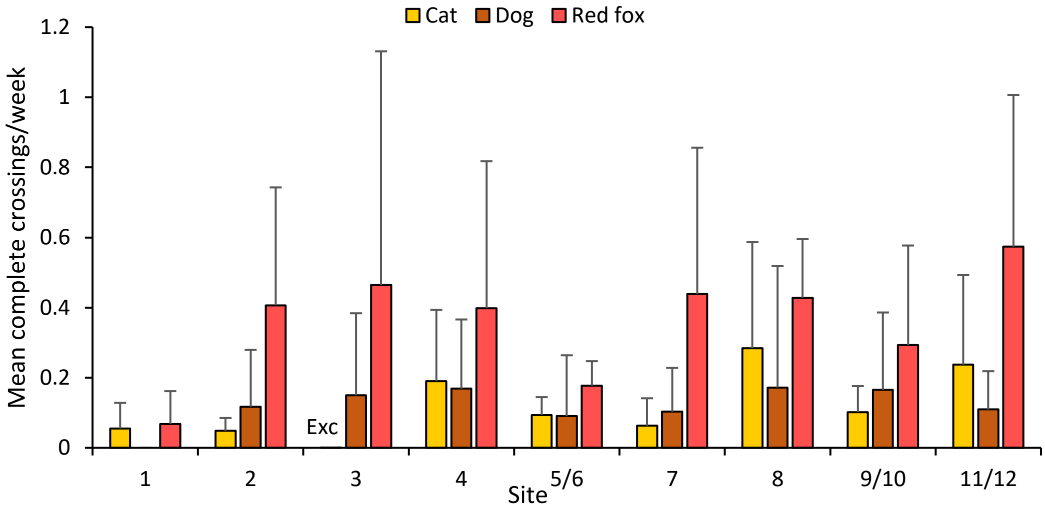

Figure 8: Mean (n=5) complete crossings/week/year (+SD) by cat, dog and red fox at each underpass site during operational monitoring at WC2NH, 2018-2023. Exc = excluded cat data for site three (value = 4.76cc/week).

3.1.3 Sand pads Year five

Eighteen species and fauna groups were recorded on sand pads in year five operational monitoring (Appendix B, Table B2). Of the native species, *Peramelidae* spp. (bandicoot) was the most frequently recorded fauna species, with tracks identified at all sites (Appendix B, Table B2**,** Plate 5). Of the smaller cover-dependent fauna groups (i.e., small mammals, reptiles and amphibians), probable *Antechinus* spp. (sites 1, 2, 3, 5/6, 9/10, 11/12) and small/medium reptiles (1, 2, 3, 5/6, 9/10, 11/12) were recorded during inspections (Appendix B, Table B2). Small lizard tracks are likely to be garden skinks (*Lampropholis* spp.) and are considered to be probable records. No species or groups were recorded in addition to those identified by cameras. However, the detection of *Antechinus* spp. was notably more frequent on sand pads compared to ground cameras located in underpasses, indicating a potential limitation in the detection capabilities of cameras for smaller fauna.

Plate 5: Bandicoot tracks (heading east and west) at site 8 (Left). *Trichosurus* spp. (brushtail possum spp.) tracks heading east through the split median 9/10 underpass (Right).

3.1.4 Scat and track searches and tile checks Year five

Ten species and seven fauna groups were recorded during scat and track surveys during year five monitoring of the WC2NH underpasses (Appendix B. Table B3). Consistent with camera data, native species/fauna groups were recorded 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 7 and 8 (Appendix B. Table B3). No fauna was recorded during tile checks (Appendix B, Table B4).

3.2 Adjacent habitat

Forty species/unique genera and eight fauna groups were recorded in habitat adjoining underpasses during year five 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 scats on the east side of sites 11/12 during active diurnal searches and sightings on the west side of site 7 and the east side of site 9/10 during spotlighting (Table 6, Appendix B, Table B5 and B6). A selection of fauna recorded in the adjacent habitat are shown in Plate 6.

Table 6: Detection of fauna species and groups during year five adjacent habitat monitoring at WC2NH, 2022-2023. 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		*		

Species	Active Search	Spotlight	Trapping	Hair funnel
Short-eared brushtail possum		*	*	
Trichosurus spp.	*			*
Common ringtail possum		*		
Swamp wallaby	*			
Wallaby spp.	*	*		
Fawn-footed melomys		*	*	
Swamp rat			*	
Bush rat			*	*
Black rat [I]		*	*	
House mouse				*
Rattus spp.	*	*		
European Hare	*			
Red fox [I]	*	*		
Cat [I]	*			
Dog [I]	*			
Reptiles				
Lace monitor	*		*	
Eastern water dragon	*	*		
Calyptotis ruficauda	*		*	
Eastern crevice skink				
Lampropholis delicata	*		*	
Lampropholis guichenoti	*			
Lampropholis spp.	*		*	
Bandy bandy		*		
Pygopus lepidopodus		*		
Yellow-faced whipsnake				
Small-eyed snake		*		
Chelidae spp.				
Small reptile	*			
Lophosaurus spinipes	*			
Snake spp.	*			
Frogs				
Amphibian spp.	*			
Litoria gracilenta		*		
Litoria fallax		*		
Litoria peronii		*		
Litoria caerulea		*		
Litoria tyleri				
Mixophyes iteratus				
Crinia signifera	*	*		
Adelotus brevis		*	*	
Uperoleia fusca				
Pseudophryne coriacea		*	*	
Limnodynastes peronii		*	*	

Species	Active Search	Spotlight	Trapping	Hair funnel
Total Nº· Species/groups	22	24	14	6

Plate 6: Fauna recorded in the adjacent habitat during the year 5 WC2NH monitoring period. Top left: Tusked frog.Top right: Bandy bandy. Bottom left: Southern angle-headed dragon. Bottom middle: Northern brown bandicoot. Bottom right: Bush rat.

3.2.1 Trapping in Year 5

During the year 5 trapping surveys, fifteen species were captured in the habitat adjacent to the monitored underpass sites at WC2NH (Table 7). Small mammals were the most frequently captured fauna group, comprising 88% (231 out of 255) of the total captures (Table 7). Captures were highest for brown antechinus (110 captures, 42% of the total), followed by the bush rat (50 captures, 19%), fawn-footed melomys (44 captures, 17%), and black rat (25 captures, 10%) (Table 7, Figure 9). Additionally, a single capture was recorded for both the house mouse and the swamp rat. Other fauna captured included frogs, with ten captures of red-backed toadlet, and single captures of striped marsh frog and the tusked frog. Reptiles captured were garden skink (6 captures), red-tailed skink, and lace monitor (1 capture each). Other mammals captured included northern brown bandicoot (2 captures), short-eared brushtail possum, and sugar glider (1 capture each) (Table 7).

3.2.2 Trapping operational monitoring

During operational monitoring 903 total captures were recorded, with 782 (87%) being mammals, 87 reptiles (10%), 30 frogs (3%) and three birds (<1%) (Table 7). Among these, 503 individuals belonged to cover-dependent/low-mobility species, comprising ~56% of all captures (Table 7).

Total captures has steadily increased over the monitoring period, from 106 individuals in year one to 258 in year five (Table 7, Figure 9). The most frequently recorded species was brown antechinus (259 captures), fawn-footed melomys (180), bush rat (155), and black rat (108), which collectively represent 78% of all captures (Table 7). The brown antechinus and bush rat, in particular, have exhibited a consistent increase in annual captures, peaking at 110 and 50 individuals respectively in year five (Figure 9). Captures of fawn-footed melomys also exhibited a general increase from 16 in year one to 44 in year 5 (Figure 9). Black rat captures were variable, with 20 captures in year one decreasing to 12 in year three an increasing to 24 and 25 in years four and five respectively (Table 7, Figure 9). The small number of individuals recorded for other species, such as reptiles, frogs, and other mammals, make it challenging to identify trends.

The annual capture rate (mean number of captures/year) of the four most frequently recorded species (i.e., brown antechinus, fawn-footed melomys, bush rat, and black rat) differed between sites at WC2NH (Figure 10). The combined (total) capture rate of the four species was highest at sites 2 (23 captures ± 6.01/year), 4 (21.6 ± 9.4/year) and 5/6 (21.2 ± 8.52/year) and lowest at sites 3 (3 ± 2.24/year) and 1 (10.6 ± 4.24/year) (Figure 10). Brown antechinus and black rat were the only species recorded across all sites. Bush rat was not recorded at site 3 and fawn-footed melomys were absent from site 1, and had a low capture rate at site 3 (Figure 10). Brown antechinus was the most frequently recorded species at sites 2, 5/6, 7, 8 and 9/10 (Figure 10). Fawn-footed melomys was the most frequently recorded species at sites 4 and 11/12 and black rat was the most frequently recorded species at sites 1 and 3. Despite not being the most frequently captured species at any site, the bush rat was the most frequently captured species at sites 4, 5/6, and 7.

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

Species	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Mammals						
Brown antechinus^	25	28	38	58	110	259
Sugar glider	1	6	8	5	1	21
Long-nosed bandicoot^				1		1
Fawn-footed melomys^	16	44	36	40	44	180
Northern brown bandicoot^	1	3	2	5	2	13
Short-eared brushtail possum	4	7	4	4	1	20
Common brushtail possum				1		1
Bush rat^	9	13	39	44	50	155
Swamp rat^			1		1	2
House mouse[I]	7	7	6	1	1	22
Black rat[I]	20	26	13	24	25	108
Cat[I]	1					1
Birds						
Eastern whipbird	1					1
Green catbird	1					1
Yellow-throated scrubwren		1				1

Species	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Reptiles						
Lace monitor			3	4	1	8
Blackish blind snake^	1	1				2
Dwarf-crowned snake^		1	2			3
Marsh snake^		2				2
Red-tailed skink^	7	3	4	2	1	17
Garden skink^	9	7	10	12	13	51
Grass skink^	4					4
Frogs						
Tusked frog^				1	1	2
Striped marsh frog^	2	3			1	6
Red-backed toadlet^	2	6	2	2	10	22
Grand Total	111	158	168	204	262	903

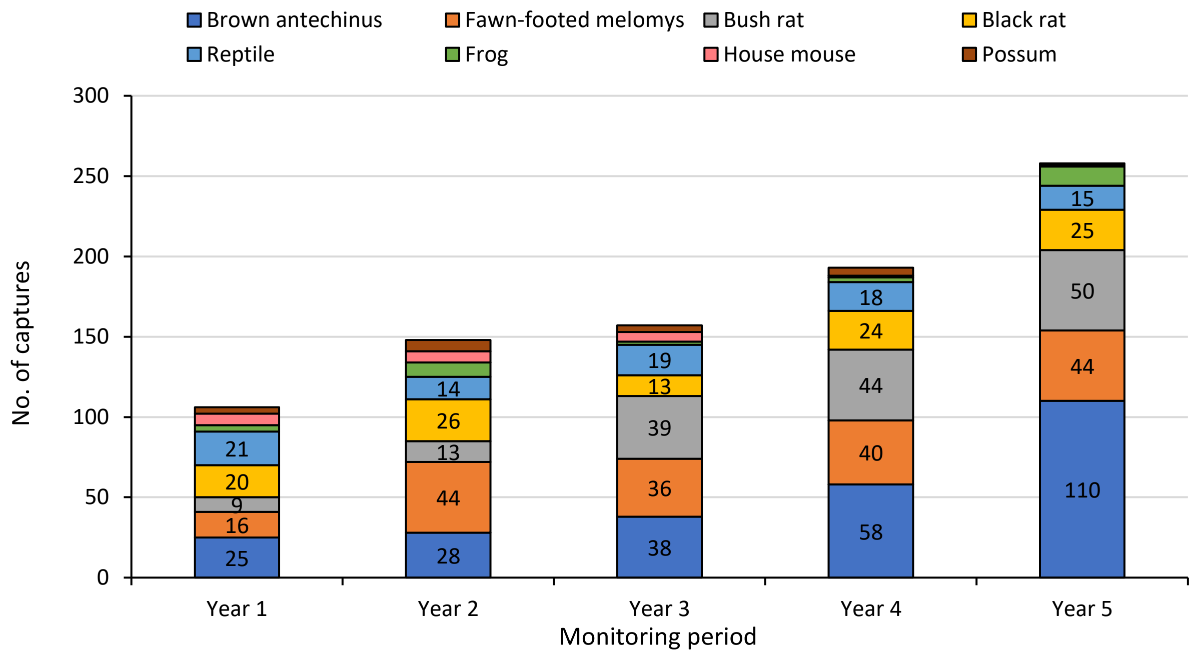

Figure 9: Temporal comparison of the total number of trap captures for each species or fauna group recorded in the adjacent habitat during operational monitoring at WC2NH, 2018-2023.

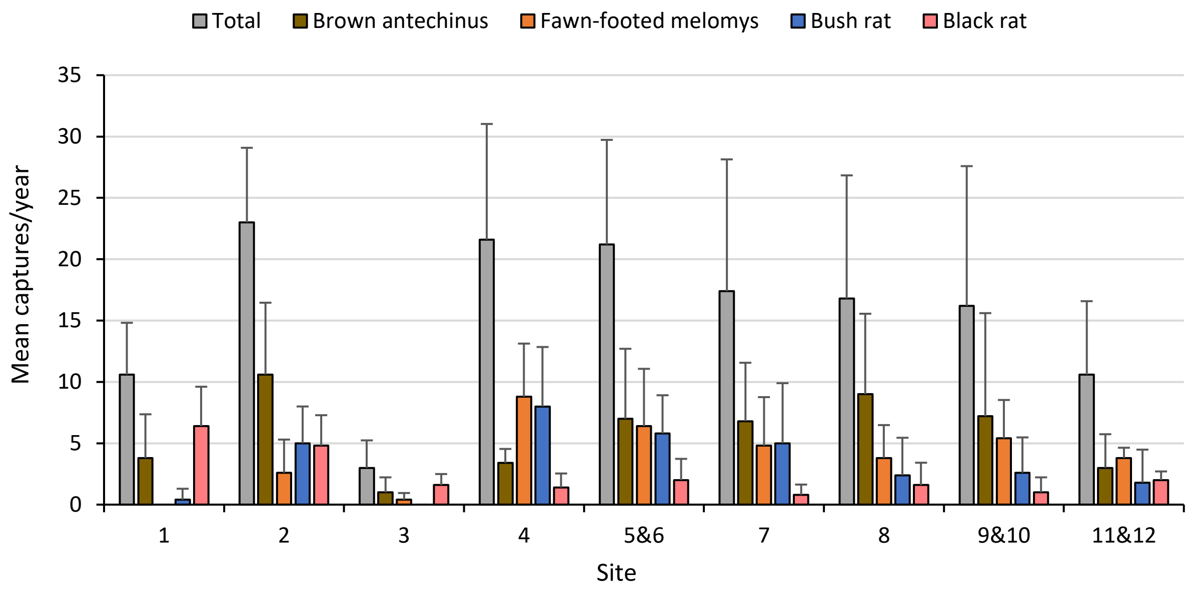

Figure 10: Mean (+SD) annual capture rate (n=5) of the four most frequently recorded species during adjacent habitat trapping at WC2NH throughout operational monitoring, 2018-2023. The total mean captures presented represent the combined capture rates of the four species.

3.2.3 Species recorded in underpasses and adjacent habitat

Excluding unconfirmed species and genera (see Table 8 caption), 39 vertebrate species and unique genera were recorded within the adjacent habitat and underpasses in year five (Table 8). Among these, 22 species were recorded using the underpasses, which accounts for 56% of the species present in the adjacent habitat (Table 8). Of the 22 species recorded in underpasses 17 (77%) were native. In the adjacent habitat, 33 species were native, indicating that 51% of all native species in the adjacent habitat were also recorded in the underpasses during year five operational monitoring (Table 8).

For mammals specifically, 76% of those recorded in the adjacent habitat were observed using the underpasses (Table 8). The common ringtail possum, common brushtail possum, swamp rat, fawn-footed melomys and European hare being the only mammal species not recorded in underpasses during year five (Table 8). Of these species, the European hare is introduced and not considered a target species for underpasses. Further, swamp rat, fawn-footed melomys, and common brushtail possum have previously been recorded using underpasses at WC2NH (Sandpiper Ecological 2022, 2023). Among these, the common ringtail possum is the only mammal species found in adjacent habitat that has not been recorded using underpasses to date at WC2NH. When all species recorded using underpasses to date is considered, 95% of mammal species recorded in year five have been recorded using underpasses.

In addition to mammals, reptiles and frogs were recorded both within underpasses and the adjacent habitat. Among the ten reptile species present in the adjacent habitat six (60%) were recorded using underpasses. Probable garden skinks were recorded during sand pad monitoring and lace monitor, eastern water dragon, eastern blue-tongue, eastern small-eyed snake (site 1 bridge) and *Egernia* spp. were recorded during camera monitoring. Among the eight frog species only one (12.5%), the striped marsh frog, was recorded during camera monitoring at site 1 Warrell Creek Bridge. Notably of the 22 cover-dependent/low mobility fauna species in the adjacent habitat, nine of them (40%) were recorded within the underpasses.

Table 8: Species and unique genera recorded in adjacent habitat and using underpasses during year five monitoring at WC2NH, 2022-2023. 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 presence assumed due to detection in only the underpass. [I] = Introduced. ^= cover dependent fauna.

Species	Underpass	Adjacent Habitat
Mammals		
Short-beaked echidna	*	#
Brown antechinus ^	*	*
Northern brown bandicoot ^	*	*
Long-nosed bandicoot ^	*	*
Koala	*	*
Common brushtail possum		*
Short-eared brushtail possum	*	*
Common ringtail possum		*
Swamp wallaby	*	*
Red-necked wallaby	*	#
Eastern grey kangaroo	*	#
Fawn-footed melomys ^		*
Swamp rat ^		*
Bush rat ^	*	*
Water rat	*	#
Black rat [I]	*	*
House mouse[I]	*	*
European Hare[I]		*
Red fox [I]	*	*
Cat [I]	*	*
Dog [I]	*	*
Sub-total mammals	16	21
Reptiles		
Lace monitor	*	*
Eastern blue-tongued lizard^	*	#
Eastern water dragon	*	*
Red-tailed calyptotis ^		*
Egernia spp.^	*	#
Garden skink ^	*	*
Bandy bandy ^		*
Common scaly-foot^		*
Eastern small-eyed snake ^	*	*
Southern angle-headed dragon^		*
Sub-total reptiles	5	10
Frogs		
Dainty green tree frog ^		*

Species	Underpass	Adjacent Habitat
Eastern dwarf tree frog ^		*
Peron's tree frog ^		*
Australian green tree frog^		*
Common eastern froglet ^		*
Tusked frog ^		*
Red-backed toadlet ^		*
Striped marsh frog ^	*	*
Sub-total frogs	1	8
Total Nº. Species/groups	22	39

4 Discussion

Operational monitoring of underpasses at WC2NH has demonstrated that monitored structures fulfill their intended purpose of facilitating safe passage for both common and threatened fauna between habitat located either side of the project alignment. In the following section, key findings from operational monitoring will first be discussed in light of relevant literature and other monitoring projects. Subsequently, the results will be evaluated against the potential indicators of success as outlined in the EMP.

4.1 Proportion of species from the adjacent habitat using underpasses

As documented in the first four years of operational monitoring (Sandpiper Ecological 2019, 2020, 2022, 2023a), numerous native species and unique genera (17 in total) were recorded utilising underpasses at WC2NH during year five. Native species recorded in underpasses represented 51% of all native species detected within the adjacent habitat in year five. This utilisation rate is comparable to Nambucca Heads to Urunga (NH2U) where it reached 52% in year 7 (Sandpiper Ecological 2024b) and surpasses the 23% to 50% range recorded at Sapphire to Woolgoolga (S2W) (Sandpiper Ecological 2018). Particularly noteworthy is the utilisation of underpasses by 95% of mammal species (all species except common ringtail possum) and 60% of reptile species detected in the adjacent habitat during year five. Additionally, two frog species, specifically the striped marsh frog (recorded at site 1 year five) and the green tree frog (scat recorded at 9/10 during year three), have been detected within underpasses at WC2NH during operational monitoring. The low level of underpass use by frogs at WC2NH is consistent with other equivalent underpass monitoring programs like NH2U (Sandpiper Ecological 2024b). Frog tracks have been noted on sand pads on several occasions during operational monitoring, although species identification is challenging. The infrequent detection of frogs may stem from the limitations of camera traps rather than avoidance of the underpasses.

4.2 Temporal trends in overall underpass use by native species

Use of underpasses at WC2NH by native fauna has progressively increased throughout the operational monitoring period, with an overall increase in the number of complete crossings of 176% from year one (1.29 ± 1.32 cc/week/site) to year five (3.57 ± 1.53 cc/week/site). This result aligns with expectations, as the use of underpasses by native fauna is expected to increase over time as site features improve (Gagnon *et al.* 2011), a pattern also documented at Sapphire to Woolgoolga (S2W) and in recent monitoring at Nambucca Heads to Urunga (NH2U) (Sandpiper Ecological 2018, 2024b). High rainfall in years three to four led to a noticeable increase in vegetation growth and cover around the culvert entrances in year five (Pers obs. L. Andrews).

Improved cover and vegetation connectivity with retained vegetation has likely facilitated increased use of the underpasses by native species, especially cover-dependent fauna such as bandicoots and brown antechinus which were frequent users of underpasses during year five.

Interestingly, the mean complete crossing rate by native species at WC2NH (3.57 ± 1.53 cc/week/site) was 51% higher than the usage rates observed at the nearby NH2U project (2.36 ± 1.99 cc/week/site), despite NH2U being in a later stage of operational monitoring (i.e., seven years since completion) where higher use might be expected (Sandpiper Ecological, 2024b). Given the similarity in the adjoining habitat type between the two projects, the higher usage at WC2NH may be due to a combination of design features such as mulch on the culvert floor and minimal scour protection, landscape position, and distance from retained vegetation to the underpass entrance. Underpasses at WC2NH are primarily dedicated to fauna passage and include mulched culvert floors, entrances close to retained vegetation, and minimal scour protection at the entrances. In contrast, the NH2U underpasses are mostly dual-purpose (i.e. drainage and fauna passage) structures with concrete floors, scour protection adjoining entrances and some flow following rainfall.

While further analysis is required to confirm the presence of a relationship between fauna abundance in adjoining habitat, weather conditions, and increased use of underpasses, such a correlation is plausible. At WC2NH, native fauna use of underpasses increased substantially from the first to the second year, with this trend continuing from years three to five. This pattern closely aligns with the climatic conditions observed throughout the monitoring period, where 2018-19 (year one) experienced below-average to severe drought conditions, followed by La Niña conditions from 2020 to early 2023. Higher rainfall years, known for enhancing foraging conditions and breeding success, have been directly linked to higher abundances of small native fauna (Magnusdottir *et al*., 2008; Lock & Wilson, 2017). Trapping data support these findings, showing a similar temporal increase in capture rates for the three most frequently recorded native species (brown antechinus, bush rat and fawn-footed melomys) within the adjacent habitat over time. The relationship between higher abundance and increased underpass use is supported by Chambers & Bencini (2015), who documented a positive correlation between underpass crossing rates and the overall population size of southern brown bandicoots in adjoining habitat. These findings point to a link between weather conditions, fauna abundance and rate of underpass use at WC2NH over time.

Notably, underpasses at WC2NH experienced a marked increase in usage by native fauna from year three (2021) to year five (2023), which is in contrast to NH2U where only a marginal increase occurred over the same period. The pronounced increase at WC2NH is a probable synergistic effect of site-specific features, such as improved vegetation cover at culvert entrances (enhanced by high rainfall), mulched culvert floors, proximity to retained vegetation, and the improved weather conditions, further increasing underpass usage by native fauna in comparison to NH2U. In summary, the overall increase in native fauna use at WC2NH appears to be the result of a combination of factors, including the establishment of vegetation cover at the culvert entrances over time, improved weather conditions throughout the monitoring period, and design specific factors of dedicated fauna underpasses such as mulched culvert floors and positioning in close proximity to retained vegetation.

4.3 Site specific trends for native fauna underpass use

Native fauna utilisation rates (cc/week) varied among the underpass sites during operational monitoring at WC2NH. The level of variability suggests that site-specific features or design factors may be influencing use by native fauna. There is evidence to show that even within areas of relatively homogenous habitat a species use of underpasses can vary substantially (Goldingay *et al.* 2022). However, exploring such relationships at WC2NH requires an advanced level of statistical analysis beyond the scope of this report and the EMP. As a general observation, sites with continuous vegetation extending over 100 metres from the culvert entrance, such as sites 4, 7, 8, and 9/10, typically had higher usage by native species. Conversely, sites with fragmented adjacent habitat on either side of the underpass, such as sites 1 and 3, exhibited the lowest native fauna usage. Correspondingly, sites 11/12 and 5/6, with moderate adjacent habitat fragmentation to the west, exhibited intermediate level of native fauna use. The west side of site 11/12 is fragment by a stockpile site and Old Coast Road, whereas the western side of site 5/6 is fragmented by various features including a retention pond, scour protection drainage lines, and farmland within a 100-metre radius of the culvert entrance.

The mean capture rates of small fauna from trapping generally mirrored trends in cover-dependent mammal use of underpasses, except for site 5/6, which recorded the third highest mean capture rate of small, cover-dependent mammals yet exhibited the third lowest rate of underpass usage by cover-dependent and low mobility species, and the second lowest crossing rate by native fauna among all monitored structures. This discrepancy is likely a combined result of the fragmented landscape on the western side and the frequency of inundation of site 5, which deters fauna from crossing. These results suggest that both the continuous habitat surrounding an underpass and the underpass's location in the landscape are crucial for encouraging more frequent use by native fauna.

Native fauna regularly used fauna furniture at WC2NH. This is consistent with findings in various highway monitoring programs that have demonstrated the effectiveness of furniture to facilitate movement of both common and threatened species (Sandpiper Ecological 2024b, Sandpiper Ecological 2021c and Sandpiper Ecological 2022b). *Trichosurus* spp. and *Antechinus* spp, demonstrated preferential use of the fauna furniture, while lace monitor, water dragon and *Egernia* spp displayed occasional use. In contrast, feral predators tended to use the culvert floor with only limited use of furniture by cat. Despite no evidence of predation occurring in the underpasses, the furniture is likely to act as a refuge for native fauna, alleviating predation risk and encouraging underpass crossings (Goldingay *et al.* 2017).

4.4 Targeted threatened fauna use of underpasses

During camera monitoring at WC2NH, two of the three target threatened species (spotted-tailed quoll and giant barred frog), were not recorded using underpasses. The absence of spotted-tailed quolls is consistent with the findings of targeted surveys which suggest the species is uncommon in the locality (GeoLink 2014), and their absence should not be interpreted as avoidance of underpasses. Spotted-tailed quolls have been recorded using underpasses sporadically on several highway upgrades (AMBS 2002; Sandpiper Ecological 2017b; 2024b; Michniewicz & Danvers, 2020). Similarly, no crossings by the giant barred frog were recorded at Site 1 (dedicated giant barred frog underpass) by cameras, although a mark-release-recapture study confirmed movement under the highway (Sandpiper Ecological 2023b). The absence of camera detection is not surprising given the underpass's substantial size (168m wide x 30m long).

Koalas have consistently used dedicated underpasses at WC2NH. Encouragingly, six out of the eight (75%) dedicated underpasses have been used by koalas. In terms of usage frequency, site 4 had the highest average complete crossing rate of 0.16 ± 0.10 cc/week/year, followed by sites 11/12, 9/10, 7, 2, and 8 with rates ranging from of 0.021 ± 0.023 to 0.005 ± 0.011 cc/week/year. No crossings were recorded at sites 1, 3, and 5/6. This pattern of usage contrasts with sporadic and occasional underpass use reported for other highway projects (Sandpiper Ecological 2024b, 2021c, 2022b). The frequency of crossings strongly suggests that the upgrade has been successful in maintaining habitat connectivity for koalas. In their study area, Frere *et al.* (2023) estimated that a minimum of eight koalas would need to disperse from each side of a highway per generation to maintain genetic connectivity. With a generation length of 6-8 years (NSW Scientific Committee 2022) it is likely that dispersal at WC2NH is sufficient to maintain genetic connectivity.

Importantly, the patterns of underpass use at WC2NH suggests use by resident, dispersing and breeding individuals. For example, a (likely) resident koala used site 4 to cross the highway 27 times during year one and year two and an individual or scats have been repeatedly recorded near site 4 over the five-year monitoring period. This contrasts with the occasional winter dispersal or spring/summer breeding movements recorded at other underpasses. Furthermore, the relatively consistent use of Sites 4, 9/10, and 7 over time likely indicate that the features and location of these specific underpasses are well-suited to facilitating koala use.

Notably, the average crossing rate (cc/week) by koalas at WC2NH has declined over time. The trend is largely attributed to a decrease in crossings at site 4 by the resident koala. At site 4, 18 crossings were recorded in year one, 9 in year two, and one each in years 3, 4 and 5. Single crossings are interpreted as more indicative of dispersal rather than breeding or home range movement. There are several possible reasons for the change in crossing frequency, including readjustment of home range to align with the highway, such as occurred at Bonville (Lassua *et al.* 2008), influence of weather (i.e., drought and La Nina) on movement, or mortality of the resident individual.

4.5 Trends in underpass use by feral predators

During the initial two years of operational monitoring at WC2NH, feral predators, notably cat and red fox, accounted for approximately 50% of the total underpass crossings (Sandpiper Ecological 2019, 2020). This pattern highlights the adaptability of both species to using artificial structures, aligning with observations from other underpass monitoring programs along the Pacific Highway (Sandpiper Ecological 2017, 2021c, 2022b, 2024b) and their established behaviour for adapting to and thriving in disturbed landscapes (Graham *et al*., 2012). Notably, underpass use by feral predators exhibited a general downward trend from year one and two, with slight increases in year four and five.

Fox activity initially increased between years one and two 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 increased between year three (0.29 ± 0.08 cc/week/underpass) and five (0.45 ± 0.33 cc/week/underpass). The increase in fox detection despite the removal of six individuals in 2021 is consistent with many fox control programs where individuals removed are replaced the following year. Favourable climatic conditions in year five summer (high rainfall) and an associated higher abundance of prey items would have ensured the rapid replacement of individuals (Johnson and Vanderwal 2009).

Cat activity decreased from 0.53 ± 0.4 cc/week/site in year four to 0.24 ± 0.6 cc/week/underpass in year 5, with continued high use at site 3, where a resident cat has been consistently recorded throughout operational monitoring (Sandpiper Ecological 2021b). The reasons for this decline are unclear but may be related to increased dog activity in year five (Fancourt et al. 2019; Kreplins et al. 2020). Despite targeted cage trapping since year two, the individual at site three has not been captured and survey findings illustrate how use by a single individual can skew underpass monitoring data.

Dog crossings have fluctuated over the monitoring period. An increase in crossings was recorded from years 1 (nil crossings) to 3 (0.19 crossings/week/underpass) and then declined substantially in year 4 (0.002 crossings/week/underpass) and increased substantially in year 5 (0.29 crossings/week/underpass). The majority of records in year five involved two individuals, with several instances of the dogs traveling in pairs across multiple sites. The presence of dogs is concerning due to the threat they pose to koalas (Lunney *et al.*, 2004, 2007). Consistent with findings on the adjoining NH2U upgrade (Sandpiper Ecological, 2024b) there was overlap in underpass use by dogs and koalas indicating that koalas do not avoid structures used by dogs. Overlap in underpass use is cause for concern, as it increases the risk that an interaction will occur within or at the entrance of the underpasses.

Both dog and red fox exhibited no strong preference for specific sites, though they demonstrated noticeably lower detection rates at sites 5/6 and site 1. The reduced detections at site 1 can likely be attributed to the limited coverage of the camera setup, while the avoidance of site 5/6 may be due to the wet conditions at site 5, which likely deter predators, as recorded at the McGrath's Creek underpass (Sandpiper Ecological, 2024b). The general lack of site preference displayed by dog and red fox could be related to their extensive home ranges and adaptability to diverse landscape types in south-eastern Australia. Wild dogs in this region are known to occupy large home ranges, spanning between 10,000 and 39,000 hectares (Claridge et al., 2009), whereas adult red foxes in coastal wilderness areas have home ranges that vary from 120 to 520 hectares (Phillips and Catling, 1991). These home range sizes fall within the range of habitat that spans between sites 2 to 11/12, suggesting that the same individuals are likely using all underpasses, except site 1, to traverse their home ranges.

4.6 Potential indicators of success summary

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

The WC2NH EMP (RMS 2018) does not define "low use" by feral predators. However, underpass use by cats and red foxes has continued to decline in comparison to the first two years of monitoring, while dog has returned to levels recorded in year 3. Levels of dog use remain higher than what was been recorded at NH2U (Sandpiper Ecological, 2024b) and at W2B S3-11 (Sandpiper Ecological, 2022b). Crucially, there was no evidence of predation by feral predators within underpasses, nor was there support for the prey-trap hypothesis, consistent with the findings of multiple studies (Little *et al.*, 2002; Martinig *et al.*, 2020; Goldingay *et al.*, 2022). A concern is the increased underpass usage by two dogs, particularly due to the potential risk of koala predation at known koala sites. The previous targeted control program conducted in year three was largely successful with few records of wild dog during year four. Implementing a similar control program in conjunction with Forestry Corporation should be considered. Whilst the benefits of such a program are short-term there is a high likelihood that it would provide a tangible benefit to koalas.

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

The underpasses at WC2NH are used by a wide range of native species from the adjacent habitat, indicating their effectiveness in achieving their intended purpose. The variety of native fauna observed using the underpasses and growing rate of use over time can be attributed to their placement within the landscape, the improvement of environmental conditions, and the gradual enhancement of site features, such as vegetation cover at culvert entrances. Overall, these findings suggest the underpass structures have been a success at Warrell Creek in facilitating high levels of use by various native species.

4.6.3 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. The absence of spotted-tailed quolls is consistent with baseline monitoring (GeoLink 2014). Importantly, underpasses at WC2NH are equivalent to structures used elsewhere and use is considered likely should a quoll encounter an underpass. One giant barred frog was recorded crossing the alignment during population monitoring at site 1 and a detailed discussion on the population of barred frogs at that site is provided by Sandpiper Ecological (2023a). Confirming population trends for koalas in the study area is challenging due to changes in survey effort over time (see Sandpiper Ecological 2024a), however, there is no evidence of changes in abundance or distribution. Sandpiper Ecological (2024a) provides a detailed discussion of koala population monitoring, focusing on distribution, movement patterns and habitat use over time.

4.6.4 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.

4.6.5 Use by cover-dependent species with low mobility

Eleven cover-dependent and/or low mobility species have been recorded during operational monitoring using underpasses at WC2NH. The rate of use by cover dependent and low mobility fauna has consistently increased over time and is likely a function of improving site features such as vegetated culvert entrances and ground cover connectivity to retained vegetation. Low occurrence of frogs and reptiles is most likely due to the inability of cameras to detect these species as opposed to avoidance of underpasses. This shortfall is overcome to some extent by using other survey methods like sand pads and scat and track surveys. The culvert floor and furniture were both used by cover dependent species. Fawn-footed melomys, brown antechinus and eastern crevice skink predominantly used fauna furniture, highlighting the value of this feature in providing connectivity for cover dependent species. The increasing presence of lizards, such as eastern blue-tongue lizard and eastern crevice skink using underpasses in year five is encouraging, as these species tend to have small home ranges and predominantly reside in habitat with dense cover. Overall, underpasses at WC2NH have successfully provided connectivity for cover dependent fauna and use is increasing.

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	The use of underpasses by dogs reached its highest recorded levels to date at WC2NH, surpassing the levels recorded at NH2U and W2B in sections 3-11. Given the risk of koala predation at sites frequented by koalas, consideration should be given to implementing a control program similar to that of year three, in conjunction with the Forestry Corporation. Although the benefits of such a program are short-term, it is highly likely to offer a tangible benefit to koalas.
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 and 60% of reptile species recorded in adjacent habitats in year five.
No use of underpasses by cover-dependent species or species with low mobility or target threatened species	Modify or add potential groundcover resources	Eleven native cover-dependent species and one threatened species (koala) have been 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.

5.2 Recommendations

Recommendations are summarised in Table 10.

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

Number	Recommendation	Transport for NSW Response
1.	Liaise with Forestry Corporation to undertake a coordinated feral predator (fox and dog) control program in the vicinity of underpasses.	Agree.

6.References

Australian Museum Business Services (2002). *Fauna underpass monitoring stage two, episode five: Bulahdelah to Coolongolook.* Report prepared for NSW Roads and Traffic Authority.

Bureau of Meteorology (October 15, 2023) "*Daily rainfall Bellwood (Nambucca heads)".* *h*tp://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=059150

Bureau of Meteorology (October 15, 2023a) "*Coffs harbour airport daily weather observations". htp://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=059151*

Bond, A. R., & Jones, D. N. (2008). Temporal trends in use of fauna-friendly underpasses and overpasses. *Wildlife Research*, *35*(2), 103-112.

Claridge, A. W., Mills, D. J., Hunt, R., Jenkins, D. J., & Bean, J. (2009). Satellite tracking of wild dogs in south-eastern mainland Australian forests: implications for management of a problematic top-order carnivore. *Forest Ecology and Management*, *258*(5), 814-822.

Chambers, B., & Bencini, R. (2015). Factors affecting the use of fauna underpasses by bandicoots and bobtail lizards. *Animal Conservation*, *18*(5), 424-432.

Fancourt, B. A., Cremasco, P., Wilson, C. & Gentle, M. N. (2019). Do introduced apex predators suppress introduced mesopredators? A multiscale spatiotemporal study of dingos and feral cats in Australia suggests not. *Journal of Applied Ecology:* **56,** 2584-2595.

Frere, C. H., O'Reilly, G. D., Strickland, K., Schultz, A., Hohwieler, K., Hanger, J., de Villiers, D., Cristescu, R., Powell, D., Sherwin, W. (2023). Evaluating the genetic consequences of population subdivision as it unfolds and how to best mitigate them: a rare story about koalas. *Molecular Ecology*: **https://doi.org/10.1111/mec.16877**

Gagnon, J. W. Dodd, N. L., Ogren, K. S. & Schweinsburg, R. E. (2011). Factors associated with use of wildlife underpasses and the importance of long-term monitoring. Journal of Wildlife Management: 75, 1477-1487.

Gentle, M., Allen, B. J., Oakey, J., Speed, J., Harriott, L., Loader, J., Robbins, A., de Villiers, D., Hanger, J. (2019). Genetic sampling identifies canid predators of koalas (Phascolarctos cinereus) in peri-urban areas. *Landscape and Urban planning,* **190:** doi.org/10.1016/j.landurbplan.2019.103591.

GeoLink (2014) Warrell Creek to Nambucca Heads Pacific Highway Upgrade, Koala Management Plan. Report prepared for Roads and Maritime Services NSW.

GeoLink (2014) Warrell Creek to Nambucca Heads Pacific Highway Upgrade, Spotted-tailed Quoll Management Plan. Report prepared for Roads and Maritime service NSW.

Graham, C., Maron, M., & McAlpine, C. (2012). Influence of landscape structure on invasive predators: feral cats and red foxes in the brigalow landscapes, Queensland, Australia. *Wildlife Research*, 39, 661 - 676.

Goldingay, R. L., Taylor, B. & Parkyn, J. L. (2017). Movement of small mammals through a road-underpass is facilitated by a wildlife railing. Australian Mammalogy: 41, 142-146.

Goldingay, R. L., Rohweder, D. A., Taylor, B. D. & Parkyn, J. L. (2022). Use of road underpasses by mammals and a monitor lizard in eastern Australia and consideration of the prey-trap hypothesis. Ecology and Evolution: 12, e9075

Johnson, C. N., & VanDerWal, J. (2009). Evidence that dingoes limit abundance of a mesopredator in eastern Australian forests. *Journal of Applied Ecology*, *46*(3), 641-646.

Keplin, T. L., Kennedy, M. S., O'Leary, R. A., Adams, P. J., Dundas, S. J. & Fleming, P. A. (2020). Fighting like cats and dogs? Dingoes do not constrain spatial and temporal movements of feral cats. *Food Webs:* e00173, 2352-2496.

Lassau, S. A., Ryan, B., Close, R., Moon, C., Geraghty, P., Coyle, A. & Pile, J. (2008). Home ranges and mortality of a roadside koala *Phascolarctos cinereus* population at Bonville, New South Wales. Pp 127-136 in Too close for comfort: contentious issues in human-wildlife encounters, edited by Daniel Lunney, Adam Muir and Will Meikle. Royal Zoological Society of New South Wales.

Lada, H., Thomson, J.R., MacNally, R. & Taylor, A.C. (2008) Impacts of massive landscape change on a carnivorous marsupial in south-eastern Australia: interferences from landscape genetics analysis. *Journal of Applied Ecology* 45 (6).

Lunney, D., Gresser, S., O'Neill, L., Matthews, A., & Rhodes, J. (2007). The impact of fire and dogs on Koalas at Port Stephens, New South Wales, using population viability analysis. Pacific Conservation Biology, 13, 189-201.

Lunney, D., Gresser, S., Mahon, P. S., & Matthews, A. (2004). Post-fire survival and reproduction of rehabilitated and unburnt koalas. Biological Conservation, 120, 567-575.

Magnusdottir, R., Wilson, B., & Hersteinsson, P. (2008). Dispersal and the influence of rainfall on a population of the carnivorous marsupial swamp antechinus (*Antechinus minimus maritimus*). Wildlife Research, 35, 446-454.

Lock, M., & Wilson, B. (2017). Influence of rainfall on population dynamics and survival of a threatened rodent (*Pseudomys novaehollandiae*) under a drying climate in coastal woodlands of south-eastern Australia. Australian Journal of Zoology, 65, 60-70.

Menkhorst, P. & Knight, F. (2004). *A field guide to the mammals of Australia*. Oxford University press, Melbourne.

Michniewicz, R. J., & Danvers, J. (2020). Use of a combined drainage/fauna underpass by the Spotted-tailed Quoll, *Dasyurus maculatus*. *The Australian Zoologist*.

NSW Scientific Committee (2022). *Notice and reasons for the final determination to list koala as an endangered species.* NSW Government.

Phillips, M., & Catling, P. (1991). Home range and activity patterns of red foxes in nadgee nature reserve. *Wildlife Research*, 18, 677-686.

Pizzey, G. & Knight, F. (2007). *The field guide to the birds of Australia*. Harper Collins, Sydney.

RMS (2018). *Warrell Creek to Nambucca Heads Operational Ecological and Water Quality Monitoring Brief*. NSW Government.

Sandpiper Ecological (2017a). *Pacific Highway Upgrade – Sapphire to Woolgoolga: operational phase fauna monitoring year 1.* Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2017b). *Pacific Highway Upgrade – Glenugie: operational phase fauna crossing monitoring program years 1-3.* Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2018). *S2W Pacific Highway Upgrade: Operational Phase Fauna Crossing Monitoring, Year 3. Final Report*. Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2019). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads underpass monitoring program– year one operational phase.* Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2020a). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads underpass monitoring program– year two operational phase*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2020b). *Pacific Highway Upgrade –Nambucca Heads to Urunga underpass and vegetated median monitoring program monitoring – year two operational phase*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2021a). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads Operational Phase underpass monitoring program year three interim report*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2021b). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads Year 3 Operational Phase Giant Barred Frog monitoring program*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2021c). Woolgoolga to Ballina Pacific Highway Upgrade – Threatened Mammal Monitoring Program, Operation Phase Connectivity Structure and Road Mortality Monitoring sections 1 and 2, annual report 2020-21 (Year 3). Report prepared for Transport for New South Wales.

Sandpiper Ecological (2022). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads underpass monitoring program– year three operational phase*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2022a). *Pacific Highway Upgrade –Nambucca Heads to Urunga underpass and vegetated median monitoring program monitoring – year five operational phase*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2022b). Woolgoolga to Ballina Pacific Highway Upgrade – Threatened Mammal Monitoring Program, Operation Phase Connectivity Structure and Road Mortality Monitoring sections 3-11 annual report 2021-22 (Year 2). Report prepared for Transport for New South Wales.

Sandpiper Ecological (2023a). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads underpass monitoring program– year four operational phase*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2023b). *Pacific Highway Upgrade – Warrell Creek to Nambucca Heads Year 5 Operational Phase Giant Barred Frog monitoring program*. Report prepared for Transport for New South Wales.

Sandpiper Ecological (2024) *Pacific Highway Upgrade: Warrell Creek to Nambucca Heads. Year five Operational phase road-kill monitoring – annual report 2023*. Report prepared for Transport for NSW.

Sandpiper Ecological (2024a). *Warrell Creek to Nambucca Heads Koala Monitoring Report – Year five Operational Phase – Final Report.* Report prepared for Transport for New South Wales.

Sandpiper Ecological (2024b). *Pacific Highway Upgrade –Nambucca Heads to Urunga underpass monitoring program monitoring – year seven operational phase*. Report prepared for Transport for New South Wales.

Saltair Flora and Fauna (2021b). *Nambucca State Forest Warrell Creek to Nambucca Heads (WC2NH) Noxious Vertebrate Trapping Program.* Report prepared for North Coast Local Land Services.

Soanes. K., Vesk, P. A. and van der Ree, R. (2015). Monitoring the use of road-crossing structures by arboreal marsupials: insights gained from motion-triggered cameras and passive integrated transponder (PIT) tags. *Wildlife Research:* 10.107.

Triggs, B. (2004). *Tracks, scats and other traces: a field guide to Australian mammals.* Oxford University Press, Melbourne.

Wilson, S. & Swan, G. (2010). A complete guide to reptiles of Australia. New Holland, Sydney.

Van Dyck, S., Gynther, I. & Baker, A. (2013). *Field companion to the mammals of Australia*. New Holland, Sydney.

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 five operational monitoring WC2NH, 2022-2023.

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	1	South	Cat	Introduced	Feral predator				
Spring/Summer	1	South	Swamp wallaby	Native	Macropod		1		
Spring/Summer	1	South	Rodent spp.	NA	Introduced rodent				
Spring/Summer	1	North	Swamp wallaby	Native	Macropod			1	
Spring/Summer	1	North	Antechinus spp.	Native	Antechinus				
Spring/Summer	1	North	Fox	Introduced	Feral predator				
Spring/Summer	1	North	Small frog spp.	Native	Frog				Difficult to distinguish - most likely striped marsh 20mm
Spring/Summer	1	North	Lace monitor	Native	Lizard				
Spring/Summer	1	North	Cat	Introduced	Feral predator				
Spring/Summer	1	North	Black rat	Introduced	Introduced rodent				
Spring/Summer	2	Furniture	Antechinus spp.	Native	Antechinus	31	3		
Spring/Summer	2	Furniture	Bush rat	Native	Native rodent	1	4		
Spring/Summer	2	Furniture	Short-eared brushtail possum	Native	Possum	0	3		
Spring/Summer	2	Furniture	Lizard spp.	NA	Lizard	6			
Spring/Summer	2	Furniture	Rattus spp.	NA	Rodent	2			
Spring/Summer	2	Gound	Long-nosed bandicoot	Native	Bandicoot	35	6		
Spring/Summer	2	Gound	Short-beaked echidna	Native	Echidna	1			
Spring/Summer	2	Gound	Eastern water dragon	Native	Lizard	1			
Spring/Summer	2	Gound	Black rat	Introduced	Introduced rodent	5			
Spring/Summer	2	Gound	Swamp wallaby	Native	Macropod	5	3		
Spring/Summer	2	Gound	Wallaby spp.	Native	Macropod	3			
Spring/Summer	2	Gound	Red fox	Introduced	Feral predator	2			
Spring/Summer	2	Gound	Rattus spp.	NA	Rodent	3			
Spring/Summer	2	Gound	Short-eared brushtail possum	Native	Possum	2			
Spring/Summer	2	Gound	Blue-tongue lizard	Native	Lizard	2			

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	2	Gound	Lace monitor	Native	Lizard	1			
Spring/Summer	2	Gound	Lizard spp.	NA	Lizard	2			
Spring/Summer	2	Gound	Bandicoot spp.	Native	Bandicoot	1			
Spring/Summer	2	Gound	Antechinus spp.	Native	Antechinus	1			
Spring/Summer	3	Furniture	Brush-tail possum spp.	Native	Possum	7			Microbats and welcome swallows present
Spring/Summer	3	Furniture	Short-eared brushtail possum	Native	Possum	39	3		
Spring/Summer	3	Furniture	Eastern water dragon	Native	Lizard	4			
Spring/Summer	3	Furniture	Lace monitor	Native	Lizard	1			
Spring/Summer	3	Furniture	Antechinus spp.	Native	Antechinus	1			
Spring/Summer	3	Ground	Macropod spp.	Native	Macropod	18			
Spring/Summer	3	Ground	Lace monitor	Native	Lizard	7			
Spring/Summer	3	Ground	Cat	Introduced	Feral predator	9			Cat at site three still present - must be restricted and kept indoors more often - in the past crossings were nightly
Spring/Summer	3	Ground	Eastern grey kangaroo	Native	Macropod	10			
Spring/Summer	3	Ground	Wallaby spp.	Native	Macropod	7			
Spring/Summer	4	Furniture	Lace monitor	Native	Lizard	7			
Spring/Summer	4	Furniture	Rattus spp.	NA	Rodent	78	2		
Spring/Summer	4	Furniture	Short-eared brushtail possum	Native	Possum	17	1		
Spring/Summer	4	Furniture	Black rat	Introduced	Introduced rodent	8			
Spring/Summer	4	Furniture	Bush rat	Native	Native rodent	4			
Spring/Summer	4	Ground	Koala	Native	Koala	1			
Spring/Summer	4	Ground	Black rat	Introduced	Introduced rodent				
Spring/Summer	4	Ground	Bandicoot spp.	Native	Bandicoot				
Spring/Summer	4	Ground	Long-nosed bandicoot	Native	Bandicoot	13	3		
Spring/Summer	4	Ground	Swamp wallaby	Native	Macropod	16			
Spring/Summer	4	Ground	Red fox	Introduced	Feral predator	0	2		
Spring/Summer	4	Ground	Short-beaked echidna	Native	Echidna	1			
Spring/Summer	4	Ground	Lace monitor	Native	Lizard	23	1		

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	4	Ground	Wallaby spp.	Native	Macropod	13			
Spring/Summer	4	Ground	Cat	Introduced	Feral predator	2			
Spring/Summer	4	Ground	Dog	Introduced	Feral predator	9			
Spring/Summer	4	Ground	Short-eared brushtail possum	Native	Possum	1			
Spring/Summer	4	Ground	Eastern water dragon	Native	Lizard	1			
Spring/Summer	4	Ground	Brush-tail possum spp.	Native	Possum	21			
Spring/Summer	5	North	Dog	Introduced	Feral predator	1			Microbats present
Spring/Summer	5	North	Bandicoot spp.	Native	Bandicoot	1			
Spring/Summer	5	North	Rattus spp.	NA	Rodent	1			
Spring/Summer	5	North	Water rat	Native	Native rodent	1	2		
Spring/Summer	5	North	Black rat	Introduced	Introduced rodent	0	7		
Spring/Summer	5	North	Antechinus spp.	Native	Antechinus	1			
Spring/Summer	5	South	Dog	Introduced	Feral predator	0	1		Microbats present
Spring/Summer	5	South	Water rat	Native	Native rodent	1			
Spring/Summer	6	Furniture	Rattus spp.	NA	Rodent	48	2		
Spring/Summer	6	Furniture	Antechinus spp.	Native	Antechinus	4			
Spring/Summer	6	Ground	Cat	Introduced	Feral predator	6	1		
Spring/Summer	6	Ground	Wonga pigeon		Bird	0	1		don’t include birds in the analysis
Spring/Summer	6	Ground	Long-nosed bandicoot	Native	Bandicoot	12	1		
Spring/Summer	6	Ground	Red fox	Introduced	Feral predator	5	1		
Spring/Summer	6	Ground	Lace monitor	Native	Lizard	18	1		
Spring/Summer	6	Ground	Dog	Introduced	Feral predator	10	1		
Spring/Summer	6	Ground	Swamp wallaby	Native	Macropod	12	1		
Spring/Summer	6	Ground	Wallaby spp.	Native	Macropod	1			
Spring/Summer	6	Ground	Chicken	Introduced	Bird	2	3		
Spring/Summer	6	Ground	Bandicoot spp.	Native	Bandicoot	1			
Spring/Summer	6	Ground	Black rat	Introduced	Introduced rodent	1			
Spring/Summer	6	Ground	Eastern water dragon	Native	Lizard	1			

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	7	Furniture	Bush rat	Native	Native rodent	4			
Spring/Summer	7	Furniture	Short-eared brushtail possum	Native	Possum	56			
Spring/Summer	7	Furniture	Rattus spp.	Introduced	Rodent	51	6		
Spring/Summer	7	Furniture	Black rat	Introduced	Introduced rodent	4	4		
Spring/Summer	7	Furniture	Lace monitor	Native	Lizard	7	1		
Spring/Summer	7	Furniture	Rattus spp.	NA	Rodent	3	2		
Spring/Summer	7	Furniture	Lizard spp.	NA	Lizard	2			
Spring/Summer	7	Ground	Swamp wallaby	Native	Macropod	2			
Spring/Summer	7	Ground	Long-nosed bandicoot	Native	Bandicoot	4	2		
Spring/Summer	7	Ground	Dog	Introduced	Feral predator	1			
Spring/Summer	7	Ground	Black rat	Introduced	Introduced rodent	8	1		
Spring/Summer	7	Ground	Red fox	Introduced	Feral predator	3			
Spring/Summer	7	Ground	Rattus spp.	NA	Rodent	5			
Spring/Summer	7	Ground	Short-beaked echidna	Native	Echidna	0	1		
Spring/Summer	7	Ground	Wallaby spp.	Native	Macropod	5			
Spring/Summer	7	Ground	Lace monitor	Native	Lizard	2			
Spring/Summer	7	Ground	Bandicoot spp.	Native	Bandicoot	4			
Spring/Summer	8	Furniture	Short-eared brushtail possum	Native	Possum	4			
Spring/Summer	8	Furniture	Lizard spp.	Native	Lizard	7			
Spring/Summer	8	Furniture	Antechinus spp.	Native	Antechinus	2			
Spring/Summer	8	Furniture	Brush-tail possum spp.	Native	Possum	6	2		
Spring/Summer	8	Furniture	Black rat	Introduced	Introduced rodent	2			
Spring/Summer	8	Furniture	Rattus spp.	NA	Rodent	5			
Spring/Summer	8	Furniture	Bush rat	Native	Native rodent	0	1		
Spring/Summer	8	Ground	Wallaby spp.	Native	Macropod	20			
Spring/Summer	8	Ground	Long-nosed bandicoot	Native	Bandicoot	1			
Spring/Summer	8	Ground	Red fox	Introduced	Feral predator	9			

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	8	Ground	Swamp wallaby	Native	Macropod	14			
Spring/Summer	8	Ground	Brush-tail possum spp.	Native	Possum	1			
Spring/Summer	8	Ground	Bandicoot spp.	Native	Bandicoot	9			
Spring/Summer	8	Ground	Dog	Introduced	Feral predator	5			
Spring/Summer	8	Ground	Lace monitor	Native	Lizard	7			
Spring/Summer	8	Ground	Short-eared brushtail possum	Native	Possum	2			
Spring/Summer	8	Ground	Rattus spp.	NA	Rodent	1			
Spring/Summer	9	Furniture	Bush rat	Native	Native rodent	0	1		
Spring/Summer	9	Furniture	Lizard spp.	NA	Lizard	37			
Spring/Summer	9	Furniture	Black rat	Introduced	Introduced rodent	3			
Spring/Summer	9	Furniture	Rattus spp.	NA	Rodent	40	3		
Spring/Summer	9	Furniture	Antechinus spp.	Native	Antechinus	1			
Spring/Summer	9	Ground	Northern-brown bandicoot	Native	Bandicoot	0			
Spring/Summer	9	Ground	Brush-tail possum spp.	Native	Possum	1			
Spring/Summer	9	Ground	Red fox	Introduced	Feral predator	1			
Spring/Summer	9	Ground	Lizard spp.	NA	Lizard	1			
Spring/Summer	9	Ground	Long-nosed bandicoot	Native	Bandicoot	1			
Spring/Summer	9	Ground	Black rat	Introduced	Introduced rodent	2			
Spring/Summer	9	Ground	Dog	Introduced	Feral predator	1			
Spring/Summer	10	Furniture	Brush-tail possum spp.	Native	Possum	5	1		
Spring/Summer	10	Furniture	Lizard spp.	NA	Lizard	7			
Spring/Summer	10	Furniture	Short-eared brushtail possum	Native	Possum	3	1		
Spring/Summer	10	Furniture	Rattus spp.	NA	Rodent	3	1		
Spring/Summer	10	Ground	Red fox	Introduced	Feral predator	8			
Spring/Summer	10	Ground	Bandicoot spp.	Native	Bandicoot	10	2		
Spring/Summer	10	Ground	Swamp wallaby	Native	Macropod	0	1		
Spring/Summer	10	Ground	Dog	Introduced	Feral predator	18			
Spring/Summer	10	Ground	Long-nosed bandicoot	Native	Bandicoot	8			

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	10	Ground	Wallaby spp.	Native	Macropod	7			
Spring/Summer	10	Ground	Lace monitor	Native	Lizard	4			
Spring/Summer	10	Ground	Red-necked wallaby	Native	Macropod	1	1		
Spring/Summer	10	Ground	Black rat	Introduced	Introduced rodent	2			
Spring/Summer	10	Ground	Rattus spp.	NA	Rodent	1			
Spring/Summer	11	Furniture	Rattus spp.	NA	Rodent	92	2		Microbats present - also don't include in the analysis
Spring/Summer	11	Furniture	Bush rat	Native	Native rodent	13	2		
Spring/Summer	11	Furniture	Short-eared brushtail possum	Native	Possum	44			
Spring/Summer	11	Furniture	Brush-tail possum spp.	Native	Possum	7			
Spring/Summer	11	Furniture	Black rat	Introduced	Introduced rodent	2			
Spring/Summer	11	Furniture	Lizard spp.	NA	Lizard	0	1		
Spring/Summer	11	Ground	Wonga pigeon		Bird	1			
Spring/Summer	11	Ground	Bandicoot spp.	Native	Bandicoot	17			Fixed 114 to 14 - error in recording data - additional records added from reinstall
Spring/Summer	11	Ground	Red fox	Introduced	Feral predator	10			
Spring/Summer	11	Ground	Dog	Introduced	Feral predator	7			
Spring/Summer	11	Ground	Lace monitor	Native	Lizard	2			
Spring/Summer	11	Ground	Wallaby spp.	Native	Macropod	1			
Spring/Summer	11	Ground	Lizard spp.	NA	Lizard	1			
Spring/Summer	12	Furniture	Short-eared brushtail possum	Native	Possum	8			
Spring/Summer	12	Ground	Red fox	Introduced	Feral predator	26			
Spring/Summer	12	Ground	Northern-brown bandicoot	Native	Bandicoot	7			
Spring/Summer	12	Ground	Long-nosed bandicoot	Native	Bandicoot	4			
Spring/Summer	12	Ground	Dog	Introduced	Feral predator	6			
Spring/Summer	12	Ground	Lace monitor	Native	Lizard	3			
Spring/Summer	12	Ground	Black rat	Introduced	Introduced rodent	1	1		
Spring/Summer	12	Ground	Red-necked wallaby	Native	Macropod	1			
Spring/Summer	12	Ground	Wonga pigeon		Bird	0	6		

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Spring/Summer	12	Ground	Bandicoot spp.	Native	Bandicoot	7			
Spring/Summer	12	Ground	Cat	Introduced	Feral predator	1			
Spring/Summer	12	Ground	Blue tongue lizard	Native	Lizard	1			
Spring/Summer	12	Ground	Short-eared brushtail possum	Native	Lizard	1			
Spring/Summer	12	Ground	Swamp wallaby	Native	Macropod	4	1		
Winter	12	Ground	Bandicoot spp.	Native	Bandicoot	5	0	0	Nil
Winter	12	Ground	Black rat	Introduced	Introduced rodent	19	2	1	Nil
Winter	12	Ground	Brown antechinus	Native	Antechinus	7	0	1	Nil
Winter	12	Ground	Eastern blue-tongued lizard	Native	Lizard	1	0	0	Nil
Winter	12	Ground	Eastern water dragon	Native	Lizard	2	0	0	Nil
Winter	12	Ground	Koala	Native	Koala	1	0	0	Appears healthy, unsure of sex
Winter	12	Ground	Lace monitor	Native	Lizard	3	0	0	Nil
Winter	12	Ground	Long-nosed bandicoot	Native	Bandicoot	6	0	0	Nil
Winter	12	Ground	Northern-brown bandicoot	Native	Bandicoot	3	0	0	Nil
Winter	12	Ground	Rattus spp.	NA	Rodent	5	0	0	Nil
Winter	12	Ground	Red fox	Introduced	Feral predator	35	0	0	Nil
Winter	12	Ground	Red-necked wallaby	Native	Macropod	3	0	0	Nil
Winter	12	Ground	Short-beaked echidna	Native	Echidna	1	0	0	Nil
Winter	12	Ground	Swamp wallaby	Native	Macropod	12	0	0	Nil
Winter	12	Ground	Wild dog	Introduced	Feral predator	0	0	0	One black and one sandy dog, two individuals
Winter	12	Furniture	Black rat	Introduced	Introduced rodent	35	1	5	Nil
Winter	12	Furniture	Brown antechinus	Native	Antechinus	19	0	0	Nil
Winter	12	Furniture	Rattus spp.	Native	Rodent	7	0	0	Nil
Winter	11	Ground	Bandicoot spp.	Native	Bandicoot	4	0	0	Nil
Winter	11	Ground	Koala	Native	Koala	1	0	0	Made complete crossing on 25/8/2023 2:20am
Winter	11	Ground	Lace monitor	Native	Lizard	3	0	0	Nil
Winter	11	Ground	Long-nosed bandicoot	Native	Bandicoot	3	0	0	Nil
Winter	11	Ground	Red fox	Introduced	Feral predator	19	1	0	Nil

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Winter	11	Ground	Red-necked wallaby	Native	Macropod	3	0	0	Nil
Winter	11	Ground	Swamp wallaby	Native	Macropod	11	0	0	Nil
Winter	11	Ground	Wild dog	Introduced	Feral predator	4	0	0	One black and one sandy dog, two individuals
Winter	11	Furniture	Black rat	Introduced	Introduced rodent	26	0	0	Nil
Winter	11	Furniture	Brown antechinus	Native	Antechinus	38	9	0	Nil
Winter	11	Furniture	Rattus spp.	NA	Rodent	4	0	0	Nil
Winter	10	Ground	Bandicoot spp.	Native	Bandicoot	17	1	0	Nil
Winter	10	Ground	Black rat	Introduced	Introduced rodent	3	0	0	Nil
Winter	10	Ground	Brush-tail possum spp.	Native	Possum	3	0	0	Nil
Winter	10	Ground	Cat	Introduced	Feral predator	1	0	0	Nil
Winter	10	Ground	Koala	Native	Koala	1	0	0	Completed crossing in 9 and 10
Winter	10	Ground	Lace monitor	Native	Lizard	4	0	0	Nil
Winter	10	Ground	Long-nosed bandicoot	Native	Bandicoot	5	0	0	Nil
Winter	10	Ground	Northern-brown bandicoot	Native	Bandicoot	2	0	0	Nil
Winter	10	Ground	Rattus spp.	NA	Rodent	6	0	0	Nil
Winter	10	Ground	Red fox	Introduced	Feral predator	26	3	0	Nil
Winter	10	Ground	Short-beaked echidna	Native	Echidna	1	0	0	Nil
Winter	10	Ground	Swamp wallaby	Native	Macropod	2	0	0	Nil
Winter	10	Ground	Wallaby spp.	Native	Macropod	13	0	0	Nil
Winter	10	Ground	Wild dog	Introduced	Feral predator	3	0	0	Same individuals at 11/12, in pairs at times
Winter	10	Furniture	Black rat	Introduced	Introduced rodent	16	2	0	Nil
Winter	10	Furniture	Brown antechinus	Native	Antechinus	78	17	1	Nil
Winter	10	Furniture	Brush-tail possum spp.	Native	Possum	2	0	0	Nil
Winter	10	Furniture	Rattus spp.	NA	Rodent	32	0	0	Nil
Winter	9	Ground	Bandicoot spp.	Native	Bandicoot	17	1	0	Nil
Winter	9	Ground	Black rat	Introduced	Introduced rodent	3	0	0	Nil
Winter	9	Ground	Brush-tail possum spp.	Native	Possum	1	0	0	Nil
Winter	9	Ground	Cat	Introduced	Feral predator	1	0	0	Nil

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Winter	9	Ground	Koala	Native	Koala	1	0	0	Nil
Winter	9	Ground	Lace monitor	Native	Lizard	4	0	0	Nil
Winter	9	Ground	Long-nosed bandicoot	Native	Bandicoot	9	0	0	Nil
Winter	9	Ground	Northern-brown bandicoot	Native	Bandicoot	4	0	0	Nil
Winter	9	Ground	Rattus spp.	NA	Rodent	2	0	0	Nil
Winter	9	Ground	Red fox	Introduced	Feral predator	20	0	0	Nil
Winter	9	Ground	Short-beaked echidna	Native	Echidna	3	0	0	Nil
Winter	9	Ground	Swamp wallaby	Native	Macropod	5	0	0	Nil
Winter	9	Ground	Wallaby spp.	Native	Macropod	8	0	0	Nil
Winter	9	Ground	Wild dog	Introduced	Feral predator	9	2	0	Same individuals at 11/12, in pairs at times
Winter	9	Furniture	Black rat	Introduced	Introduced rodent	34	5	4	Nil
Winter	9	Furniture	Brown antechinus	Native	Antechinus	11	1	1	Nil
Winter	9	Furniture	Brush-tail possum spp.	Native	Possum	4	0	0	Nil
Winter	9	Furniture	Egernia spp.	Native	Lizard	19	3	3	Nil
Winter	9	Furniture	Rattus spp.	NA	Rodent	59	1	1	Nil
Winter	8	Ground	Bandicoot spp.	Native	Bandicoot	24	0	0	Nil
Winter	8	Ground	Lace monitor	Native	Lizard	5	0	0	Nil
Winter	8	Ground	Long-nosed bandicoot	Native	Bandicoot	5	0	1	Nil
Winter	8	Ground	Rattus spp.	NA	Rodent	2	0	0	Nil
Winter	8	Ground	Red fox	Introduced	Feral predator	12	0	1	Nil
Winter	8	Ground	Swamp wallaby	Native	Macropod	39	0	3	Nil
Winter	8	Ground	Wallaby spp.	Native	Macropod	11	0	0	Nil
Winter	8	Ground	Wild dog	Introduced	Feral predator	27	0	0	Same individuals at 11/12, in pairs at times
Winter	8	Furniture	Black rat	Introduced	Introduced rodent	10	1	0	Nil
Winter	8	Furniture	Brown antechinus	Native	Antechinus	61	11	5	Nil
Winter	8	Furniture	Brush-tail possum spp.	Native	Possum	2	0	0	Nil
Winter	8	Furniture	Rattus spp.	NA	Rodent	8	0	0	Nil
Winter	7	Ground	Bandicoot spp.	Native	Bandicoot	13	0	0	Nil
Winter	7	Ground	Brown antechinus	Native	Antechinus	1	0	0	Nil

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Winter	7	Ground	Rattus spp.	NA	Rodent	4	0	2	Nil
Winter	7	Ground	Red fox	Introduced	Feral predator	18	0	0	Nil
Winter	7	Ground	Short-beaked echidna	Native	Echidna	1	0	0	Nil
Winter	7	Ground	Swamp wallaby	Native	Macropod	19	0	0	Nil
Winter	7	Ground	Wallaby spp.	Native	Macropod	3	0	0	Nil
Winter	7	Ground	Wild dog	Introduced	Feral predator	9	0	0	Same individuals at 11/12, in pairs at times
Winter	7	Furniture	Black rat	Introduced	Introduced rodent	9	0	0	Nil
Winter	7	Furniture	Brown antechinus	Native	Antechinus	12	0	0	Nil
Winter	7	Furniture	Egernia spp.	Native	Lizard	1	0	0	Nil
Winter	7	Furniture	Rattus spp.	Introduced	Rodent	15	0	0	Nil
Winter	7	Furniture	Short-eared brushtail possum	Native	Possum	36	0	0	Nil
Winter	6	Ground	Bandicoot spp.	Native	Bandicoot	12	0	0	Nil
Winter	6	Ground	Cat	Introduced	Feral predator	1	1	0	Nil
Winter	6	Ground	Lace monitor	Native	Lizard	1	0	0	Nil
Winter	6	Ground	Long-nosed bandicoot	Native	Bandicoot	17	0	1	Nil
Winter	6	Ground	Red fox	Introduced	Feral predator	14	0	0	Nil
Winter	6	Ground	Swamp wallaby	Native	Macropod	8	0	0	Nil
Winter	6	Ground	Wild dog	Introduced	Feral predator	20	0	0	Same individuals at 11/12, in pairs at times
Winter	6	Furniture	Black rat	Introduced	Introduced rodent	7	0	0	Nil
Winter	6	Furniture	Brown antechinus	Native	Antechinus	33	4	0	Nil
Winter	6	Furniture	Rattus spp.	NA	Rodent	16	0	0	Nil
Winter	5	Ground	Bandicoot spp.	Native	Bandicoot	1	1	0	Nil
Winter	5	Ground	Water rat	Native	Native rodent	17	2	0	Nil
Winter	5	Ground	Bandicoot spp.	Native	Bandicoot	6	3	0	Nil
Winter	5	Ground	Black rat	Introduced	Introduced rodent	3	1	0	Nil
Winter	5	Ground	Brown antechinus	Native	Antechinus	4	4	0	Nil
Winter	5	Ground	Rattus spp.	NA	Rodent	5	2	0	Nil
Winter	5	Ground	Water rat	Native	Native rodent	12	6	0	Nil

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Winter	4	Ground	Cat	Introduced	Feral predator	1	1	0	Nil
Winter	4	Ground	Eastern water dragon	Native	lizard		0	0	Nil
Winter	4	Ground	Lace monitor	Native	Lizard	5	0	0	Nil
Winter	4	Ground	Long-nosed bandicoot	Native	Bandicoot	3	1	0	Nil
Winter	4	Ground	Northern-brown bandicoot	Native	Bandicoot	3	0	0	Nil
Winter	4	Ground	Red fox	Introduced	Feral predator	7	0	0	Nil
Winter	4	Ground	Short-beaked echidna	Native	Echidna	2	0	0	Nil
Winter	4	Ground	Short-eared brushtail possum	Native	Possum	2	0	0	Nil
Winter	4	Ground	Swamp wallaby	Native	Macropod	14	0	0	Nil
Winter	4	Ground	Wallaby spp.	Native	Macropod	7	0	0	Nil
Winter	4	Ground	Wild dog	Introduced	Feral predator	10	0	0	Same individuals at 11/12, in pairs at times
Winter	4	Furniture	Lace monitor	Native	Lizard	2	0	0	Nil
Winter	4	Furniture	Rattus spp.	NA	Rodent	26	2	0	Probable bush rat
Winter	4	Furniture	Short-eared brushtail possum	Native	Possum	39	3	0	Carrying back young
Winter	3	Ground	Cat	Introduced	Feral predator	73	6	0	Two individuals (same a previous years) white socks and tabby
Winter	3	Ground	Lace monitor	Native	Lizard	3	0	0	Nil
Winter	3	Ground	Red fox	Introduced	Feral predator	3	0	0	Nil
Winter	3	Ground	Red-necked wallaby	Native	Macropod	3	0	0	Nil
Winter	3	Ground	Swamp wallaby	Native	Macropod	5	0	0	Nil
Winter	3	Ground	Wallaby spp.	Native	Macropod	7	0	0	Nil
Winter	3	Furniture	Brown antechinus	Native	Antechinus	3	0	0	Nil
Winter	3	Furniture	Brush-tail possum spp.	Native	Possum	6	0	0	Nil
Winter	3	Furniture	Short-eared brushtail possum	Native	Possum	10	0	0	Nil
Winter	2	Gound	Bandicoot spp.	Native	Bandicoot	9	1	1	Nil
Winter	2	Gound	Cat	Introduced	Feral predator	1	0	0	Nil
Winter	2	Gound	Long-nosed bandicoot	Native	Bandicoot	8	3	0	Nil
Winter	2	Gound	Rattus spp.	NA	Rodent	4	0	0	Nil
Winter	2	Gound	Red fox	Introduced	Feral predator	12	0	0	Nil

Season	Site	Cam Location	Common name	Class	Specific taxa	Complete	Incomplete	NDM	Comments
Winter	2	Gound	Short-beaked echidna	Native	Echidna	2	0	0	Nil
Winter	2	Gound	Swamp wallaby	Native	Macropod	8	0	2	Nil
Winter	2	Gound	Wallaby spp.	Native	Macropod	8	0	0	Nil
Winter	2	Furniture	Brown antechinus	Native	Antechinus	44	0	0	Nil
Winter	2	Furniture	Rattus spp.	NA	Rodent	13	0	0	Nil
Winter	1	North	Rattus spp.	NA	Rodent	3			Nil
Winter	1	North	Black rat	Introduced	Introduced rodent	2			Nil
Winter	1	North	Swamp wallaby	Native	Macropod	5			Nil
Winter	1	North	Small-eyed snake	Native	Snake	1			Nil
Winter	1	North	Red fox	Introduced	Feral predator	3			Nil
Winter	1	South	Brown antechinus	Native	Antechinus	1			Nil
Winter	1	South	Striped marsh frog	Native	Frog	1			Nil
Winter	1	South	Small frog spp.	Native	Frog	1	3		Frog resting on grass prob L. Fallax
Winter	1	South	Black rat	Introduced	Introduced rodent	7			Nil
Winter	1	South	Swamp wallaby	Native	Macropod	6			Nil
Winter	1	South	Red fox	Introduced	Feral predator	1			Nil

Table B2: Sand pad data recorded over 8 nights in spring/summer (ss) and winter (w) during year five of operational phase monitoring WC2NH, 2023. I = Introduced, + = probable records.

	1		2		3		4		5/6		7		8		9/10		11/12	
Species/group	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			*				*		*		*		*		*		*	
Water dragon					*													
Skink															*		*	
Small lizard	*								*								*	
Small reptile																	*	*
Medium lizard				*						*					*		*	
Medium reptile									*									
Total no. Species/groups	5	1	4	4	4	3	5	4	7	8	4	5	4	6	7	9	7	6

Table B3: Scat and track data recorded during camera monitoring during winter (w) and summer (ss) year five operational phase monitoring WC2NH, 2023.

	1		2		3		4		5/6		7		8		9/10		11/12	
Species/group	**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)		*	*	*			*	*	*		*		*	*	*	*	*	*
Short-eared brushtail possum							*						*	*				
Trichosurus spp.	*							*	*									
Red-necked wallaby																		
Swamp wallaby				*							*	*	*	*				
Wallaby spp.	*		*				*		*		*							
Water rat										*								
Rodent spp.	*	*	*	*			*	*		*	*	*	*	*	*	*	*	*
Dog									*			*						*
Red fox [I]	*	*	*	*				*	*	*					*	*	*	*
Cat [I]				*	*	*				*								

Lace monitor							*		*	*	*		*	*				
Water dragon					*					*								
Small lizard															*	*		
Small reptile	*	*		*											*	*		
Medium lizard																	*	*
Medium reptile						*				*								
Total no. Species/groups	5	4	5	7	2	2	5	4	8	7	5	3	5	5	7	7	6	7

Table B4: Tile inspection data recorded during year five operational phase monitoring WC2NH, 2023.

Site	No. Tiles	Check no.	Date	Fauna present	Comments
2	1	1	31/01/23	Nil	1 tile destroyed
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
3	1	1	31/01/23	Nil	1 tile destroyed/missing
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	

Site	No. Tiles	Check no.	Date	Fauna present	Comments
4	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
5N	1	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
5S		1		No check	Missing
		2		No check	
		3		No check	
		4		No check	
		5		No check	
		6		No check	
		7		No check	
		8		No check	
6	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
7	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
8	2	1	31/01/23	Nil	
		2	01/02/23	Nil	

Site	No. Tiles	Check no.	Date	Fauna present	Comments
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
9 East	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
10 West	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
11 East	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	nil	
12 West	2	1	31/01/23	Nil	
		2	01/02/23	Nil	
		3	02/02/23	Nil	
		4	03/02/23	Nil	
		5	04/02/23	Nil	
		6	05/02/23	Nil	
		7	06/02/23	Nil	
		8	07/02/23	Nil	

Table B5: Daytime searches of adjacent habitat data during winter year five WC2NH monitoring, 2023. Msb = moves small branches, Mlb = moves large branches and RL = rustles leaves, NR = no record.

Site	Side	Obs. No.	Date	Observers	Wind	Cloud	Rain	Temp	Humidity	Start	Finish	Species
11&12	E	1	19/7/23	AE & NM	NR	NR	NR	NR	NR	1605	1620	Koala scat, bandicoot digging
	W	1	19/7/23	AE & NM	NR	NR	NR	NR	NR	1540	1555	Wallaby scat
	E	2	21/7/23	AE SM	NR	NR	NR	NR	NR	1100	1115	Wallaby scat, bandicoot digs, bent wing in culvert gap, fox scat, koala scat
	W	2	21/7/23	AE SM	NR	NR	NR	NR	NR	1045	1100	Lampropholis guichenoti, wallaby scat
9&10	E	1	19/7/23	AE & NM	NR	NR	NR	NR	NR	1520	1535	BTP scat, wallaby scat, bandicoot digs, rodent scat, old Turkey mound (nest)
	W	1	19/7/23	AE & NM	NR	NR	NR	NR	NR	1545	1600	Fox scat, swamp wallaby scat
	E	2	21/7/23	AE SM	NR	NR	NR	NR	NR	11:23	11:40	Nil
	W	2	21/7/23	AE SM	NR	NR	NR	NR	NR	11:42	11:55	Lampropholis delicata x3
8	E	1	17/7/23	AE & NM	NR	NR	NR	NR	NR	1445	1500	Bandicoot spp. digging wallaby scat
	W	1	17/7/23	AE & NM	NR	NR	NR	NR	NR	1500	1515	Dog scat, bandicoot digs, wallaby scat
	E	2	31/7/23	LA/SM	NR	NR	NR	NR	NR	1433	1448	Bandicoot digs, wallaby scat,dog , bandicoot scat
	W	2	31/7/23	LA/SM	NR	NR	NR	NR	NR	1451	1506	Uk scat, rodent scat, wallaby scat, cat scat
7	E	1	19/7/23	LA NM and AE	NR	NR	NR	NR	NR	15:40	15:50	Swamp wallaby scat, fox scat, Lampropholis x 3, C. signifera HC
	W	1	19/7/23	LA NM and AE	NR	NR	NR	NR	NR	15:55	16:05	Swamp Wallaby scat, antechinus scat
	E	2	31/7/23	LA/SM	NR	NR	NR	NR	NR	1513	1528	Bandicoot digs, dog scat
	W	2	31/7/23	LA/SM	NR	NR	NR	NR	NR	1541	1556	Antechinus scat
5&6	E	1	19/7/23	AE & NM	NR	NR	NR	NR	NR	1405	1420	Bandicoot spp. Digging, wallaby scat, lampropholis spp.
	W	1	19/7/23	LA AE & NM	NR	NR	NR	NR	NR	1400	1425	Wallaby scat, old native bee hive, crinia signifera
	E	2	17/7/23	AE & NM	NR	NR	NR	NR	NR	1311	1326	BtP scat
	W	2	17/7/23	AE & NM	NR	NR	NR	NR	NR	1335	1350	Lampropholis spp. x 2
4	E	1	19/7/23	NM	NR	NR	NR	NR	NR	850	920	Wallaby scat
	W	1	19/7/23	LA	NR	NR	NR	NR	NR	850	920	Bandicoot spp.
	E	2	17/7/23	AE & NM	NR	NR	NR	NR	NR	12:30	12:45	Nil
	W	2	17/7/23	AE & NM	NR	NR	NR	NR	NR	12:48	13:03	Bandicoot digs and wallaby spp. scat
3	E	1	19/7/23	AE NM	MLB	nil	nil	18	38	12:30	12:45	Bandicoot spp. Digging, wallaby scat
	W	1	19/7/23	LA	NR	NR	NR	NR	NR	12:00	12:30	Bandicoot digging, crinia signifera hc
	E	2	3/8/23	LA	NR	NR	NR	NR	NR	1515	1545	No new records
	W	2	3/8/23	LA	Nil	Nil	Nil	18.2	58	1552	1622	Lampropholis delicata x3
2	E	1	31/7/23	LA/sM	NR	NR	NR	NR	NR	1625	1640	Wallaby scat and bandicoot scats
	W	1	31/7/23	LA/SM	NR	NR	NR	NR	NR	1615	1621	Wallaby scat, bandicoot digs, old eaten European hare

	E	2	3/8/23	LA	Nil	Nil	Nil	18.2	58	1624	1654	No new records
	W	2	3/8/23	LA	Nil	Nil	Nil	18.2	58	1525	1555	Egernia spp.
1	E	1	19/7/23	LA	NR	NR	NR	NR	NR	802	832	Swamp wallaby scat and tracks, fox tracks
	E	1	21/7/23	NM,LA	NR	NR	NR	NR	NR	915	930	Wallaby scat
	W	2	19/7/23	NM	NR	NR	NR	NR	NR	802	832	Fox scat
	W	2	21/7/23	AE SM	NR	NR	NR	NR	NR	915	930	BtP scat, bandicoot diggings, wallaby, reptile and rodent scat

Table B6: Nocturnal spotlight surveys of adjacent habitat during winter year five WC2NH monitoring, 2023. GHFF = grey-headed flying fox, SuG = sugar glider, Lit = Litoria species, A. brevis = Adelotus brevis, ONJ = Owlet-Nightjar. SE = saw eyeshine, HC = heard call, SM = saw movement, HM = heard movement.

Site	Side	Sample	Date	Staff	Visibility	Rain	Wind	Temp	RH (%)	Start	End	Species	Comment
11&12	E	1	31/07/23	AE&NM	Good	Nil	RL	14.8	86%	1800	1800	Owl spp. SE, bandicoot HC	
	W	1	31/07/23	AE&NM	Good	Nil	RL	14.8	86%	1745	1800	Nil	
	E	2	02/08/23	AE&SM	Good	nil	nil	14	76	1820	1835	Owlet nightjar hc	
	W	2	02/08/23	AE&SM	Good	nil	nil	14	76	1800	1816	Nil	
9&10	E	1	31/07/23	AE&NM	Good	Nil	RL	14.8	86%	1940	1955	Nil	
	W	1	31/07/23	AE&NM	Good	Nil	RL	14.8	86%	1910	1925	Crinia signifera, adelotus brevis	
	E	2	02/08/23	AE&SM	Good	nil	nil	14	76	1930	1945	Bandicoot HM	
	W	2	02/08/23	AE&SM	Good	nil	nil	14	76	1945	2000	Microbat spp. SM, crinia signifera HC, frogmouth SM, bandicoot HC	
8	E	1	02/08/23	AE&SM	Good	nil	Nil	14	76	1800	1816	Nil	
	W	1	31/07/23	AE&NM	Good	Nil	RL	14.8	86%	1830	1845	2xmicrobats (flying around)	
	E	2	02/08/23	AE&SM	Good	nil	nil	14	76	1845	1900	Bandicoot x2 HM, HC rattus spp. possible melomy climbed not a black rat SE, microbat SM	
	W	2	02/08/23	AE&SM	Good	nil	nil	14	76	1905	1920	SuG HM, microbat SM	
7	E	1	31/7/23	LA	Good	Nil	RL	14.8	86%	1841	1911	Crinia signifera	
	W	1	31/7/23	SM	Good	Nil	RL	14.8	86%	1841	1911	Koala, melomys, bandicoot spp	Koala 30m from culvert entrance,496454, 6608790
	E	2	3/8/23	LA	Good	Nil	Nil	14.6	74%	2047	2107	C. Signifera	
	W	2	3/8/23	LA	Good	Nil	Nil	14.6	74%	2016	2046	Long-nosed bandicoot	
5&6	E	1	31/7/23	SM	Good	Nil	RL	14.8	86%	1926	1956	C. Signifera	
	W	1	31/7/23	LA	Good	Nil	RL	14.8	86%	1926	1956	L. Caerula	
	E	2	02/08/23	AE&SM	Good	nil	Nil	14	76	2030	2045	Bandicoot HC, wallaby HM, SuG SE	
	W	2	02/08/23	AE&SM	Good	nil	Nil	14	76	2015	2030	Crinia signifera	

Site	Side	Sample	Date	Staff	Visibility	Rain	Wind	Temp	RH (%)	Start	End	Species	Comment
4	E	1	31/7/23	LA	Good	Nil	RL	14.8	86%	2000	2030	Nil	
	W	1	31/7/23	SM	Good	Nil	RL	14.8	86%	2000	2030	Microbat spp.	
	E	2	3/8/23	LA	Good	Nil	Nil	14.6	74%	1902	1932	Nil	
	W	2	3/8/23	LA	Good	Nil	Nil	14.6	0.74	1933	2003	Melomys sm	
3 (E only)	E	1	31/07/23	AE&NM	Good	Nil	RL	14.8	86%	2010	2025	Nil	crinia signifera HC West side
	E	2	02/08/23	AE&SM	Good	nil	Nil	14	76	2120	2135	Nil	
2	E	1	31/07/23	AE&NM	Good	Nil	RL	14.8	86%	2035	2050	Nil	
	W	1	31/7/23	LA &SM	Good	Nil	RL	14.8	86%	2044	2059	Litoria fallax (HC).	
	E	2	3/8/23	LA	Good	Nil	Nil	14.6	76	2113	2143	GHFF, SuG	
	W	2	02/08/23	AE&SM	Good	nil	Nil	14	76	2120	2135	GHFF HC	
1	E	1	31/7/23	LA	Good	Nil	Nil	14.8	86%	1750	1820	Eastern water dragon	
	W	1	31/7/23	SM	Good	Nil	RL	14.8	86%	1750	1820	Sebtp, microbat spp.	
	E	2	3/8/23	LA	Good	Nil	Nil	14.6	74%	1746	1816	Fox and rodent scat	
	W	2	3/8/23	LA	Good	Nil	Nil	14.6	74%	1818	1848	Fox Se, Sebtp SE	

Table B7: Fauna captured during adjacent habitat trapping surveys during year five operational monitoring WC2NH, 2022-2023. Uk = unknown, FF = Fawn-footed, NR= no record, W = winter, SS = spring/summer

Season	Date	Site	E or W	Trap type	Species	Sex	Weight (g)	Comments
W	19/7/23	1	East	Cage trap	Black rat	-	-	Escape
W	19/7/23	1	East	Ground Elliot	Brown Antechinus	F	27	
W	19/7/23	1	west	Ground Elliot	Brown Antechinus	M	Uk	-
W	19/7/23	1	west	Ground Elliot	Brown Antechinus	F	Uk	-
W	19/7/23	1	west	Ground Elliot	Bush rat	F	74	-
W	20/7/23	1	East	Cage trap	Black rat	-	-	Escape
W	20/7/23	1	East	Ground Elliot	Brown Antechinus	-	-	-
W	21/7/23	1	East	Cage trap	Black rat	-	-	Escape
W	21/7/23	1	East	Ground Elliot	Brown Antechinus	-	-	-
W	21/7/23	1	West	Ground Elliot	Brown Antechinus	F	-	-
W	18/7/23	11/12	west	Ground Elliot	Brown Antechinus	M	34	Nil
W	18/7/23	11/12	East	Ground Elliot	Fawn-footed melomys	M	87	Nil

Season	Date	Site	E or W	Trap type	Species	Sex	Weight (g)	Comments
W	19/7/23	11/12	West	Ground Elliot	Black rat	-	-	Deceased
W	19/7/23	11/12	East	Ground Elliot	Brown Antechinus	F	26	-
W	19/7/23	11/12	East	Ground Elliot	Bush rat	-	-	-
W	19/7/23	11/12	West	Arboreal elliot	Sugar glider	F	Uk	
W	20/7/23	11/12	East	Arboreal elliot	Brown Antechinus	-	-	-
W	20/7/23	11/12	East	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	11/12	West	Arboreal elliot	Brown Antechinus	-	-	-
W	20/7/23	11/12	West	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	11/12	East	Ground Elliot	Fawn-footed melomys	-	-	-
W	20/7/23	11/12	East	Ground Elliot	Fawn-footed melomys	-	-	-
W	20/7/23	11/12	West	Ground Elliot	Swamp rat	M	-	Swamp rat
W	18/7/23	2	East	Ground Elliot	Brown Antechinus	F	25	-
W	18/7/23	2	East	Arboreal elliot	Brown Antechinus	Uk	Uk	Escapee
W	18/7/23	2	East	Arboreal elliot	Brown Antechinus	M	32	-
W	18/7/23	2	west	Ground Elliot	Brown Antechinus	-	19	Female
W	18/7/23	2	West	Arboreal elliot	Brown Antechinus	-	40	Male
W	18/7/23	2	west	Ground Elliot	Brown Antechinus	-	32	Male
W	18/7/23	2	East	Ground Elliot	Bush rat	M	145	-
W	18/7/23	2	East	Ground Elliot	Bush rat	F	133	-
W	18/7/23	2	East	Pitfall	House mouse	F	-	Escapee
W	19/7/23	2	West	Ground Elliot	Black rat	-	-	Euthanised
W	19/7/23	2	East	Ground Elliot	Brown Antechinus	F	29	-
W	19/7/23	2	East	Ground Elliot	Brown Antechinus	M	33	-
W	19/7/23	2	West	Arboreal elliot	Brown Antechinus	M	31	-
W	19/7/23	2	West	Ground Elliot	Brown Antechinus	M	27	-
W	19/7/23	2	East	Ground Elliot	Bush rat	F	74	-
W	19/7/23	2	East	Cage trap	Northern brown bandicoot	Uk	Uk	Released
W	19/7/23	2	East	Pitfall	Red-backed toadlet	Uk	Uk	-
W	20/7/23	2	West	Ground Elliot	Black rat	-	-	Euthanised
W	20/7/23	2	East	Arboreal elliot	Brown Antechinus	-	-	-

Season	Date	Site	E or W	Trap type	Species	Sex	Weight (g)	Comments
W	20/7/23	2	East	Arboreal elliot	Brown Antechinus	-	-	-
W	20/7/23	2	East	Arboreal elliot	Brown Antechinus	-	-	-
W	20/7/23	2	East	Arboreal elliot	Brown Antechinus	-	-	-
W	20/7/23	2	East	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	2	East	Ground Elliot	Brown Antechinus	M	-	-
W	20/7/23	2	East	Arboreal elliot	Fawn-footed melomys	M	-	-
W	20/7/23	2	East	Cage trap	Northern brown bandicoot	-	-	-
W	20/7/23	3	West	Ground Elliot	Black rat	-	-	Euthanised
W	20/7/23	3	West	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	3	East	Ground Elliot	Brown Antechinus	-	-	-
W	21/7/23	3	East	Ground Elliot	Brown Antechinus	-	-	-
W	21/7/23	3	West	Ground Elliot	Fawn-footed melomys	-	-	-
W	19/7/23	4	West	Ground Elliot	Bush rat	F	85	-
W	19/7/23	4	West	Ground Elliot	Bush rat	M	109	-
W	19/7/23	4	West	Cage trap	Bush rat	Uk	Uk	-
W	19/7/23	4	West	Arboreal elliot	Fawn-footed melomys	F	55	-
W	20/7/23	4	East	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	4	West	Ground Elliot	Fawn-footed melomys	-	-	-
W	21/7/23	4	West	Ground Elliot	Brown Antechinus	M	-	-
W	21/7/23	4	West	Ground Elliot	Brown Antechinus	M	-	-
W	21/7/23	4	East	Arboreal elliot	Brown Antechinus	-	-	-
W	21/7/23	4	East	Arboreal elliot	Brown Antechinus	-	-	-
W	21/7/23	4	West	Cage trap	Bush rat	-	-	-
W	21/7/23	4	East	Arboreal elliot	Fawn-footed melomys	-	-	-
W	20/7/23	5/6	East	Ground Elliot	Fawn-footed melomys	F	-	-
W	18/7/23	5/6	west	Ground Elliot	Black rat	-	-	Euthanised
W	18/7/23	5/6	west	Ground Elliot	Brown Antechinus	F	16	-
W	18/7/23	5/6	west	Ground Elliot	Brown Antechinus	F	17	-
W	18/7/23	5/6	East	Cage trap	Bush rat	Uk	Uk	-
W	18/7/23	5/6	west	Arboreal elliot	Bush rat	M	Uk	Trap on Ground Elliotound

Season	Date	Site	E or W	Trap type	Species	Sex	Weight (g)	Comments
W	18/7/23	5/6	East	Ground Elliot	Fawn-footed melomys	M	85	-
W	18/7/23	5/6	East	Arboreal elliot	Fawn-footed melomys	M	80	-
W	18/7/23	5/6	East	Ground Elliot	Fawn-footed melomys	M	Uk	-
W	19/7/23	5/6	west	Ground Elliot	Black rat	-	-	Euthanised
W	19/7/23	5/6	west	Ground Elliot	Brown Antechinus	M	22	-
W	19/7/23	5/6	west	Arboreal elliot	Brown Antechinus	M	30	-
W	19/7/23	5/6	west	Ground Elliot	Bush rat	M	105	-
W	20/7/23	5/6	East	Arboreal elliot	Brown Antechinus	-	-	-
W	20/7/23	5/6	East	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	5/6	West	Ground Elliot	Brown Antechinus	-	-	Nil
W	20/7/23	5/6	West	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	5/6	West	Ground Elliot	Brown Antechinus	M	-	-
W	20/7/23	5/6	East	Ground Elliot	Fawn-footed melomys	-	-	-
W	18/7/23	7	west	Arboreal elliot	Brown Antechinus	Uk	Uk	Escapee - tail caught in trap door
W	18/7/23	7	west	Ground Elliot	Brown Antechinus	M	31	-
W	18/7/23	7	west	Ground Elliot	Brown Antechinus	M	38	-
W	18/7/23	7	west	Ground Elliot	Brown Antechinus	F	20	-
W	18/7/23	7	west	Ground Elliot	Bush rat	F	98	-
W	18/7/23	7	East	Ground Elliot	Fawn-footed melomys	F	65	-
W	18/7/23	7	East	Ground Elliot	Fawn-footed melomys	M	90	-
W	19/7/23	7	West	Arboreal elliot	Black rat	-	-	Euthanised
W	19/7/23	7	East	Ground Elliot	Black rat	-	-	Euthanised
W	19/7/23	7	West	Ground Elliot	Brown Antechinus	M	37	-
W	19/7/23	7	West	Ground Elliot	Brown Antechinus	M	30	-
W	19/7/23	7	West	Arboreal elliot	Brown Antechinus	M	36	-
W	19/7/23	7	West	Arboreal elliot	Brown Antechinus	M	37	-
W	19/7/23	7	East	Ground Elliot	Brown Antechinus	F	Uk	Nil
W	19/7/23	7	East	Arboreal elliot	Brown Antechinus	M	Uk	-
W	19/7/23	7	West	Ground Elliot	Bush rat	M	116	-
W	19/7/23	7	East	Ground Elliot	Fawn-footed melomys	F	Uk	-

Season	Date	Site	E or W	Trap type	Species	Sex	Weight (g)	Comments
W	19/7/23	7	East	Pitfall	Red-backed toadlet	-	-	-
W	20/7/23	7	West	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	7	West	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	7	West	Ground Elliot	Bush rat	-	-	-
W	20/7/23	7	West	Ground Elliot	Fawn-footed melomys	-	-	-
W	18/7/23	8	west	Ground Elliot	Brown Antechinus	M	31	Nil
W	18/7/23	8	west	Ground Elliot	Brown Antechinus	M	24	Nil
W	18/7/23	8	East	Arboreal elliot	Brown Antechinus	F	21	-
W	18/7/23	8	East	Ground Elliot	Brown Antechinus	M	34	-
W	18/7/23	8	East	Ground Elliot	Brown Antechinus	M	28	-
W	18/7/23	8	East	Ground Elliot	Brown Antechinus	M	22	-
W	18/7/23	8	west	Ground Elliot	Bush rat	M	155	Nil
W	18/7/23	8	west	Pitfall	Red-backed toadlet	-	-	-
W	18/7/23	8	west	Pitfall	Red-backed toadlet	-	-	-
W	19/7/23	8	west	Arboreal elliot	Black rat	-	-	Uk
W	19/7/23	8	west	Ground Elliot	Brown Antechinus	M	32	-
W	19/7/23	8	west	Ground Elliot	Brown Antechinus	M	22	-
W	19/7/23	8	east	Ground Elliot	Brown Antechinus	F	27	-
W	19/7/23	8	east	Ground Elliot	Brown Antechinus	M	37	-
W	19/7/23	8	east	Arboreal elliot	Brown Antechinus	M	35	-
W	20/7/23	8	West	Arboreal elliot	Black rat	-	-	Uk
W	20/7/23	8	East	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	8	East	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	8	East	Ground Elliot	Bush rat	-	-	-
W	20/7/23	8	West	Ground Elliot	Bush rat	-	-	-
W	18/7/23	9/10	west	Arboreal elliot	Brown Antechinus	Uk	Uk	Escaped
W	18/7/23	9/10	west	Ground Elliot	Brown Antechinus	M	36	-
W	18/7/23	9/10	East	Ground Elliot	Brown Antechinus	F	23	-
W	18/7/23	9/10	East	Pitfall	Brown Antechinus	F	-	-
W	18/7/23	9/10	East	Pitfall	Brown Antechinus	F	-	-

Season	Date	Site	E or W	Trap type	Species	Sex	Weight (g)	Comments
W	18/7/23	9/10	west	Ground Elliot	Fawn-footed melomys	M	73	-
W	18/7/23	9/10	East	Ground Elliot	Fawn-footed melomys	M	71	-
W	18/7/23	9/10	East	Ground Elliot	Fawn-footed melomys	M	73	-
W	19/7/23	9/10	west	Ground Elliot	Brown Antechinus	M	36	-
W	19/7/23	9/10	west	Ground Elliot	Brown Antechinus	F	28	-
W	19/7/23	9/10	west	Ground Elliot	Brown Antechinus	M	26	-
W	19/7/23	9/10	west	Arboreal elliot	Brown Antechinus	M	25	-
W	19/7/23	9/10	East	Arboreal elliot	Brown Antechinus	M	35	-
W	19/7/23	9/10	East	Arboreal elliot	Brown Antechinus	UK	-	Escaped in same trap as one above
W	19/7/23	9/10	East	Ground Elliot	Brown Antechinus	F	20	-
W	19/7/23	9/10	East	Ground Elliot	Fawn-footed melomys	M	60	-
W	19/7/23	9/10	East	Cage trap	Short-eared brushtail possum	F	-	-
W	20/7/23	9/10	west	Ground Elliot	Brown Antechinus	M	-	-
W	20/7/23	9/10	west	Arboreal elliot	Brown Antechinus	Uk	-	-
W	20/7/23	9/10	west	Ground Elliot	Brown Antechinus	M	-	-
W	20/7/23	9/10	west	Ground Elliot	Brown Antechinus	M	-	-
W	20/7/23	9/10	East	Arboreal elliot	Brown Antechinus	-	-	-
W	20/7/23	9/10	East	Arboreal elliot	Brown Antechinus	-	-	-
W	20/7/23	9/10	East	Ground Elliot	Brown Antechinus	-	-	Deceased
W	20/7/23	9/10	East	Ground Elliot	Brown Antechinus	-	-	-
W	20/7/23	9/10	west	Ground Elliot	Bush rat	Uk	-	-
W	20/7/23	9/10	East	Ground Elliot	Fawn-footed melomys	-	-	-
W	20/7/23	9/10	East	Ground Elliot	Fawn-footed melomys	-	-	-
SS	1/2/23	1	E	Ground Elliot	Brown Antechinus	F	19	
SS	2/2/23	1	E	Ground Elliot	Bush rat	F	Uk	
SS	2/2/23	1	E	Ground Elliot	Brown Antechinus	F	Uk	
SS	2/2/23	1	W	-	Nil			Raided by brushtail possum
SS	3/2/23	1	E	-	Nil			
SS	3/2/23	1	W	Arboreal elliot	Brown Antechinus	F	23	

Season	Date	Site	E or W	Trap type	Species	Sex	Weight (g)	Comments
SS	31/1/23	2	E	Ground Elliot	Bush rat	M	150	
SS	31/1/23	2	E	Ground Elliot	Brown Antechinus	F	32	
SS	31/1/23	2	E	Ground Elliot	Bush rat	M	135	
SS	31/1/23	2	E	Pitfall	Tusked frog			
SS	31/1/23	2	W	Ground Elliot	Black rat			Euthanized
SS	31/1/23	2	W	Ground Elliot	Black rat			Euthanized
SS	1/2/23	2	E	Ground Elliot	Bush rat	M	133	
SS	1/2/23	2	W	Ground Elliot	Bush rat	F	119	
SS	2/2/23	2	E	Ground Elliot	Bush rat	F	Uk	
SS	2/2/23	2	E	Pitfall	P. coriacea			
SS	2/2/23	2	W	Ground Elliot	Bush rat	M	Uk	
SS	2/2/23	2	W	Ground Elliot	Bush rat	F	Uk	
SS	31/1/23	3	E	Ground Elliot	Black rat			Euthanized
SS	31/1/23	3	W	-	Nil			
SS	1/2/23	3	E	Pitfall	P. coriacea			
SS	1/2/23	3	W	Pitfall	Lampro x2			
SS	2/2/23	3	E	Pitfall	Lampro delicata x5			
SS	2/2/23	3	W	Pitfall	Lampro delicata x2			
SS	1/2/23	4	E	Ground Elliot	Bush rat (w/ 3 young)	F	125	
SS	1/2/23	4	E	Ground Elliot	FF Melomys	M	72	
SS	1/2/23	4	W	Ground Elliot	FF Melomys	M	82	
SS	1/2/23	4	W	Arboreal elliot	FF Melomys	F	66	
SS	2/2/23	4	E	Ground Elliot	Bush rat	M	Uk	
SS	2/2/23	4	E	Ground Elliot	Bush rat	F	Uk	
SS	2/2/23	4	E	Arboreal elliot	FF Melomys	F	Uk	

Season	Date	Site	E or W	Trap type	Species	Sex	Weight (g)	Comments
SS	2/2/23	4	W	Ground Elliot	Black rat			Escaped
SS	3/2/23	4	E	Ground Elliot	Black rat			Unsure of ID released
SS	3/2/23	4	E	Ground Elliot	Bush rat	M	Uk	
SS	3/2/23	4	E	Ground Elliot	Bush rat	F	Uk	
SS	3/2/23	4	W	Ground Elliot	Bush rat	M	Uk	
SS	3/2/23	4	W	Ground Elliot	FF Melomys Juvenile	Uk	Uk	
SS	31/1/23	5/6	E	Ground Elliot	Melomys	F	80	
SS	31/1/23	5/6	E	Ground Elliot	Melomys	M	90	
SS	31/1/23	5/6	W	Ground Elliot	Brown Antechinus	Uk	23	
SS	31/1/23	5/6	W	Ground Elliot	Bush rat	M	94	
SS	31/1/23	5/6	W	Ground Elliot	Brown Antechinus	F	28	
SS	31/1/23	5/6	W	Ground Elliot	Melomys	M	80	
SS	31/1/23	5/6	W	Pitfall	Antechinus, Striped marsh frog (deceased)			
SS	1/2/23	5/6	E	Ground Elliot	FF Melomys	F	68	
SS	1/2/23	5/6	E	Pitfall	P. coriacea			
SS	1/2/23	5/6	W	Ground Elliot	Brown Antechinus	F	32	
SS	1/2/23	5/6	W	Ground Elliot	Brown Antechinus	F	27	
SS	1/2/23	5/6	W	-	Black rat			Euthanized
SS	2/2/23	5/6	E	Pitfall	Lampropholis spp.			
SS	2/2/23	5/6	E	Ground Elliot	Brown Antechinus	F	Uk	
SS	2/2/23	5/6	E	Arboreal elliot	Black rat			Euthanized
SS	2/2/23	5/6	E	Arboreal elliot	Black rat			Euthanized
SS	2/2/23	5/6	W	Ground Elliot	Brown Antechinus	F	16	
SS	31/1/23	7	E	Arboreal elliot	FF Melomys	F	72	
SS	31/1/23	7	E	Ground Elliot	FF Melomys	M	82	

Season	Date	Site	E or W	Trap type	Species	Sex	Weight (g)	Comments
SS	31/1/23	7	E	Pitfall	Red backed toadlet, F antechinus			
SS	31/1/23	7	W	Ground Elliot	Bush rat	F	135	
SS	31/1/23	7	W	Ground Elliot	Bush rat	M	175	
SS	31/1/23	7	W	Ground Elliot	Bush rat	M	165	
SS	1/2/23	7	E	Ground Elliot	FF Melomys	M	75	
SS	1/2/23	7	E	Ground Elliot	FF Melomys	Uk	55	
SS	1/2/23	7	W	Ground Elliot	Bush rat	F	89	
SS	1/2/23	7	W	Ground Elliot	Bush rat	M	166	
SS	2/2/23	7	E	Ground Elliot	FF Melomys	-	-	Escaped
SS	2/2/23	7	E	Ground Elliot	Brown Antechinus	F	26	
SS	2/2/23	7	E	Ground Elliot	FF Melomys	F	67	
SS	31/1/23	8	E	Ground Elliot	Black rat			Euthanized
SS	31/1/23	8	W	Ground Elliot	Brown Antechinus	F	37	
SS	31/1/23	8	W	Ground Elliot	Bush rat	M	164	
SS	31/1/23	8	W	-	Black rat			Euthanized
SS	31/1/23	8	W	Pitfall	Brown Antechinus	M	-	Deceased
SS	31/1/23	8	W	Pitfall	Brown Antechinus	F	22	
SS	31/1/23	8	W	Pitfall	Brown Antechinus	M	16	
SS	31/1/23	8	W	Pitfall	FF Melomys	F	28	
SS	1/2/23	8	E	-	Nil			
SS	1/2/23	8	W	Ground Elliot	Brown Antechinus	M	21	
SS	1/2/23	8	W	Cage	Lace monitor			Released during day AdHab searches
SS	2/2/23	8	E	Ground Elliot	Bush rat	M	70	
SS	2/2/23	8	E	Ground Elliot	Bush rat	Uk	65	
SS	2/2/23	8	W	Pitfall	Lampro delicata x2, P. Coriacea x1			

Season	Date	Site	E or W	Trap type	Species	Sex	Weight (g)	Comments
SS	2/2/23	8	W	Ground Elliot	Bush rat	F	Uk	
SS	31/1/23	9/10	E	Pitfall	Antechinus	F	34	
SS	31/1/23	9/10	E	Ground Elliot	Melomys	F	89	
SS	31/1/23	9/10	W	Ground Elliot	Bush rat	M	130	
SS	1/2/23	9/10	W	Arboreal elliot	Melomys	M	87	
SS	1/2/23	9/10	W	Cage	Bush rat	Uk	Uk	
SS	1/2/23	9/10	W	Pitfall	Red backed toadlet			
SS	1/2/23	9/10	W	Ground Elliot	Melomys	F	61	
SS	2/2/23	9/10	E	-	Nil			
SS	2/2/23	9/10	W	Arboreal elliot	Melomys	F	70	
SS	2/2/23	9/10	W	Pitfall	L. delicata			
SS	31/1/23	11/12	E	Ground Elliot	Bush rat	M	187	
SS	31/1/23	11/12	E	Pitfall	Antechinus	F	23	
SS	31/1/23	11/12	E	Ground Elliot	Bush rat	F	128	
SS	1/2/23	11/12	E	Ground Elliot	Bush rat	F	127	
SS	1/2/23	11/12	E	Ground Elliot	Bush rat	F	151	
SS	1/2/23	11/12	E	Ground Elliot	Black rat			Escaped
SS	31/1/23	11/12	W	Ground Elliot	Black rat			Euthanized
SS	1/2/23	11/12	W	Pitfall	Red backed toadlet			
SS	2/2/23	11/12	E	Ground Elliot	Bush rat	M	Uk	
SS	2/2/23	11/12	E	Ground Elliot	FF Melomys	F	Uk	
SS	2/2/23	11/12	E	Pitfall	Calyptotis ruficauda			

Table B8: Fauna recorded in hair funnel surveys during year four operational monitoring WC2NH, 2022-2023.

Date	Site	Position	Species #1	Species #2
21/7/23	1	West	Isoodon macrourus	Nil
21/7/23	1	East	Mus musculus	Trichosurus sp.

21/7/23	2			Isoodon macrourus
21/7/23	2	West	Antechinus stuartii	Nil
21/7/23	3	West	Mus musculus	Nil
21/7/23	3	East	Mus musculus	Nil
21/7/23	4	West	Antechinus sp.	Nil
21/7/23	4	East	Mus musculus	Antechinus sp.
21/7/23	5/6	West	Mus musculus	Nil
21/7/23	5/6	East	Rattus fuscipes	Nil
21/7/23	7	East	Antechinus stuartii	Nil
21/7/23	8	East	Antechinus stuartii	Nil
21/7/23	8	West	Antechinus stuartii	Nil
21/7/23	9/10	East	Mus musculus	Nil
21/7/23	9/10	East	Antechinus stuartii	Nil
21/7/23	11/12	West	Mus musculus	Nil
21/7/23	11/12	East	No hair	Nil

Transport for New South Wales

Warrell Creek to Nambucca Heads

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

Transport for New South Wales | July 2023

Pacific Highway upgrade: Warrell Creek to Nambucca Heads

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

Sandpiper Ecological Surveys

Final Report
6 September 2023

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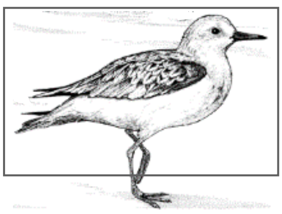

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Table of contents

List of tables

List of figures

List of plates

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 April 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).

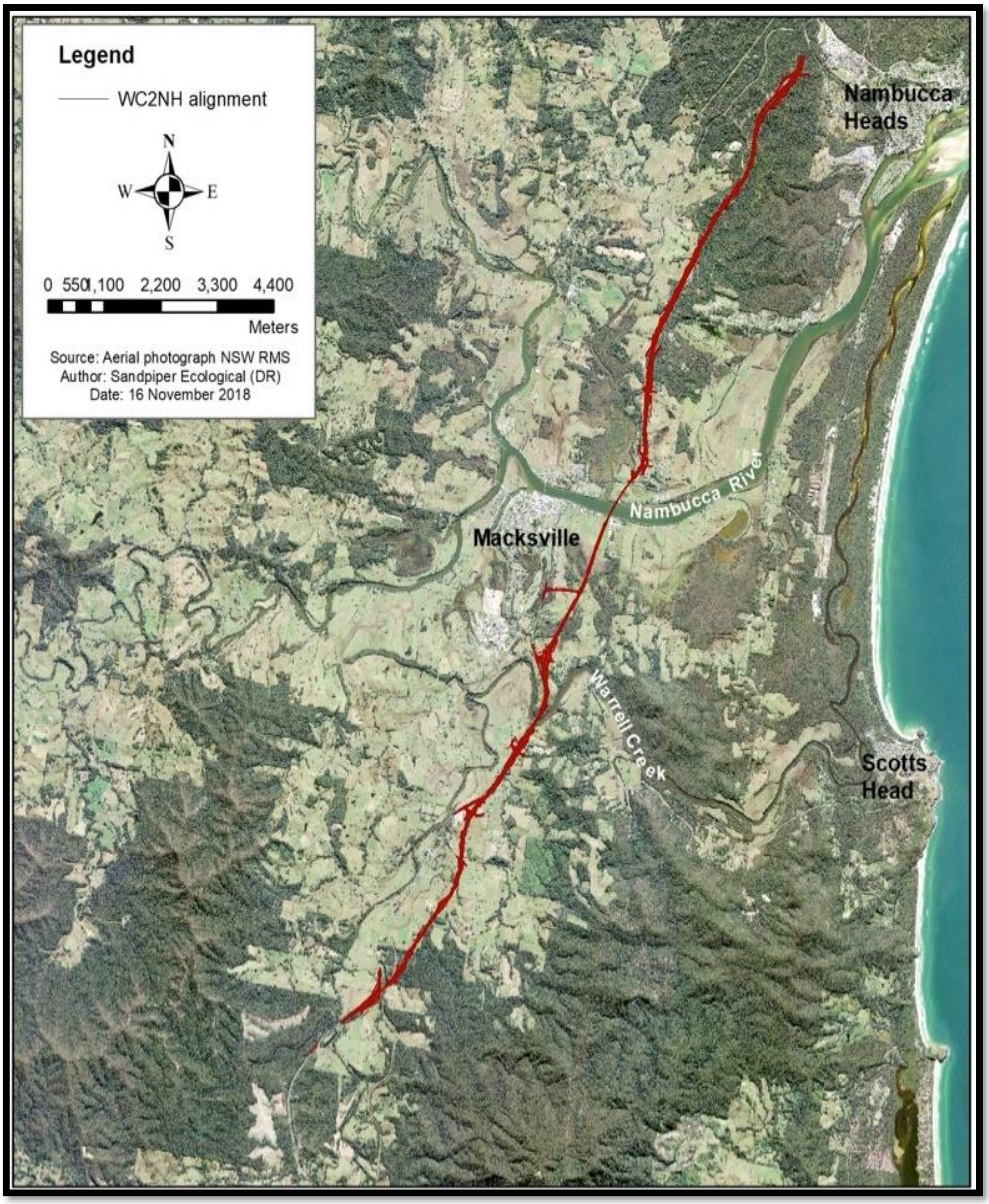

Figure 1: Location of the WC2NH alignment.

2.2 Road-kill surveys

Prior to the autumn 2021 monitoring event 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 required a vehicle to pull off the highway each time a fauna mortality was observed.

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 android application.

In cases where the fauna records were likely to be a potential target species, such as spotted-tailed quoll, koala, grey-headed flying-fox, or 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 the Australia Topo maps application 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

To identify potential duplicates in the road-kill data, the mapping software QGIS was employed. Initially, all road-kill data was uploaded into QGIS and cross-referenced with data from the previous week and/or season (specifically summer 2023). This process aimed to identify duplicate records and improve data accuracy.

In order to determine the location of each road-kill relative to the exclusion fence, road-kill records were overlaid onto a plan showcasing the extent of the exclusion fence using QGIS. If the exclusion fence was present on only one side, the corresponding record was classified as having "No fence." For road-kill incidents on bridges, they were considered unfenced unless the exclusion fence extended at least 100 meters beyond both ends of the bridge.

Additionally, road-kill were categorised into two groups. The first group consisted of species or groups whose natural movement would typically not be hindered by the presence of an exclusion fence, including birds, small reptiles, frogs, small mammals, and flying-foxes (not excluded species). The second group comprised species or groups likely to be excluded by the fence (excluded species – Table 1). Freshwater turtles were included in this group due to the expectation that an exclusion fence with a ground return would effectively obstruct their movement onto the carriageway (Table 1). Although small lace monitors have the ability to traverse an exclusion fence, they were still included as it is rare to observe individuals of that size in open habitats (Table 1).

For the purpose of temporal (years, seasons, and weeks) and spatial (fenced vs. unfenced) comparisons of road-kill during operational monitoring (2019-2023), road-kill totals were pooled across years and taxonomic groups (e.g., bandicoots, macropods). These totals were then converted to a rate of road-kill per kilometer per week, enabling meaningful comparisons with other highway projects that may have varying alignment lengths. Notably, the 2018 survey data was excluded from the pooled comparison due to the staged opening of the project occurring between 2017 and 2018.

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 Statistical analysis

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

3. Results

3.1 Autumn 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 varied from low – high, ranging from 48% to 74%, and the temperature ranged from 18.5°C to 21.7°C (Table 2). During the surveys, no rainfall was recorded. However, it should be noted that rain was recorded in the 24 hours leading up to the surveys including light rain on 2/4/23, when 2 mm of rainfall was recorded and 9 mm on 25/4/23. Visibility was good during all surveys and favorable for detecting road-kill.

Table 2: Weather conditions were recorded at 9 am on each sample day in April 2023. 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
2/4/23	Nil	2.0	73	20.2	8	Good
10/4/23	Nil	0	52	18.5	0	Good
17/4/23	Nil	0	48	21.7	0	Good
25/4/23	Nil	9.0	74	19.7	4	Good

3.1.2 Road-kill survey

A total of 29 road-killed fauna were recorded during the Autumn 2023 sample at an overall rate of 0.37 rk/km/week (number of road-killed individuals per kilometer per week) (Table 3). Mammals were the most diverse group, with two species and four groups recorded, birds with three species and three groups, and reptile species with two species and two groups (Table 3). Mammals were also the most frequently detected fauna group, with 14 individuals, followed by birds (10 individuals) and reptiles (4 individuals) (Table 3). Bandicoot spp. Unidentifiable bird species had the highest frequency of road-kill with five records, followed by rodent species (4) and medium mammal species (3) (Table 3). One introduced species (dog) was recorded along the fence at Cocksburn lane overpass. No frogs or raptor species were recorded during the autumn 2023 surveys. A single threatened species, the grey headed flying fox was recorded east of Macksville along Gumma floodplain. The full summary of fauna recorded to date is included in Appendix A, Table A2.

Table 3: Species of vertebrate fauna recorded during year five (2023) summer (January) and autumn (April) road-kill surveys along the WC2NH alignment. For a full road-kill summary of all surveys to date, see Appendix A, Table A2. RK=Road-kill. Pr. = probable

Species	Sum 23	Aut 23	Win 23	Spr 23	Total
Birds					
Little pied cormorant	1				
Tawny frogmouth	2	1			
Tytonidae spp.		1			
Laughing kookaburra					
Heron		1			
Magpie lark		1			
Corvus spp.	1				
Raptor spp. (pr. Whistling kite)	1				
Small bird spp.	2	1			
Unidentifiable bird spp.	4	5			
Total birds	11	10	0	0	0
Mammals					
Short-beaked echidna	1				
Red-necked wallaby	1				
Northern brown bandicoot	1				
Long-nosed bandicoot	1				
Bandicoot spp.	8	5			
Grey Headed Flying fox		1			
Microbat spp.	1				
Rodent spp.	3	4			
Small mammal spp.	1	1			
Medium mammal spp.	1	3			
Total mammals	18	14	0	0	0
Reptiles					
Eastern blue-tongued lizard	1				
Chelidae spp.		1			
Lace monitor		1			
Small eyed snake		1			
Unidentified reptile spp.	1	1			
Lizard spp.	1				
Total reptiles	3	4	0	0	0
Introduced species					
Dog	0	1	0	0	0
Total introduced	0	1	0	0	0
Grand total	32	29	0	0	0
Rk/week/km	0.41	0.37	0.00	0.00	0.00

3.1.3 Distribution of road-kill

In autumn of 2023, road-killed fauna was recorded in various sections of the WC2NH alignment (Figures 2 and 3). The highest incidence of road-kill was recorded in the northern section of the alignment to the west of Nambucca Heads (7 records), and between the unfenced section south of the Mattick Road Overpass to Nambucca Bridge (4 records), (Figures 2 and 3). Five road-kills, including one grey headed flying fox, were recorded in the fenced section along Gumma Floodplain. The one introduced species (dog) was recorded at Cockburns Lane Overpass. Other records were distributed between the Bald Hill Road Overpass and the project's southern extent at Upper Warrell Creek Bridge (Figure 3).

More road-kill was recorded in the fenced section of the alignment (16 records) compared to the unfenced (13 records) sections (Figures 2, 3, and Table 4). Six of the fifteen records in fenced areas were individuals that the fauna fence should block under normal circumstances, including two bandicoots, one lace monitor, one dog ,one medium mammal and a freshwater turtle (Table 4). The remaining eleven individuals were fauna that readily move through (rodent spp.) or over (birds and flying foxes) exclusion fencing (Table 4).

Bandicoots tended to be recorded along the unfenced section of the alignment between the Rosewood Road Overpass and south of Upper Warrell Creek Bridge (Figure 3, 3 records), with two other records in the fenced section north of Mattick Road Overpass (Figure 2). Birds were recorded north of Alberts Drive Overpass and south of Nambucca Bridge (Figure 3, 5 records) and in the northern extent of the highway through Nambucca State Forest (Figure 2). One lace monitor was recorded in the fenced section at Lower Warrell Creek Bridge (Figure 3). No macropods were recorded during the autumn 2023 surveys.

Table 4: The number of road-killed fauna recorded in fenced and unfenced sections of the WC2NH alignment during the April (autumn) 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
Bandicoot spp.	Excluded	2	3
Lace monitor	Excluded	1	
Chelidae spp.	Excluded	1	
Medium mammal spp.	Excluded	1	2
Dog	Excluded	1	
Sub-total (excluded)		6	5
Bird spp.	Not excluded	3	2
Reptile spp.	Not excluded	1	
Rodent spp.	Not excluded	1	3
Small bird spp.	Not excluded		1
Small mammal spp.	Not excluded	1	
Grey Headed Flying fox	Not excluded	1	
Tawny frog mouth	Not excluded	1	
White -faced heron	Not excluded	1	
Magpie lark	Not excluded	1	
Tytonidae spp.	Not excluded		1
Small-eyed snake	Not excluded		1
Sub-total (not excluded)		11	8
Grand Total		16	13

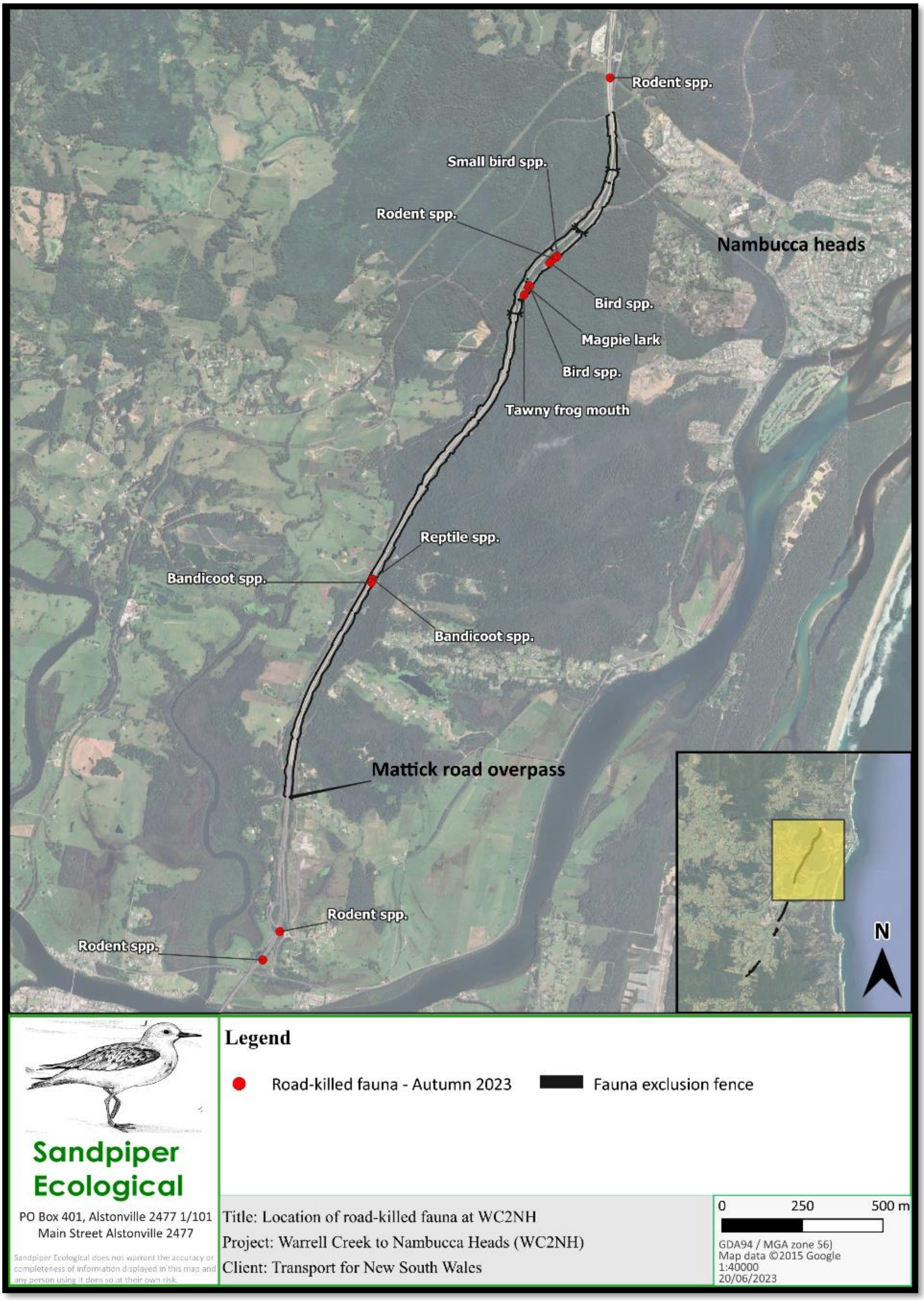

Figure 2: Location of road-killed fauna recorded in autumn 2023 along the WC2NH alignment (northern extent).

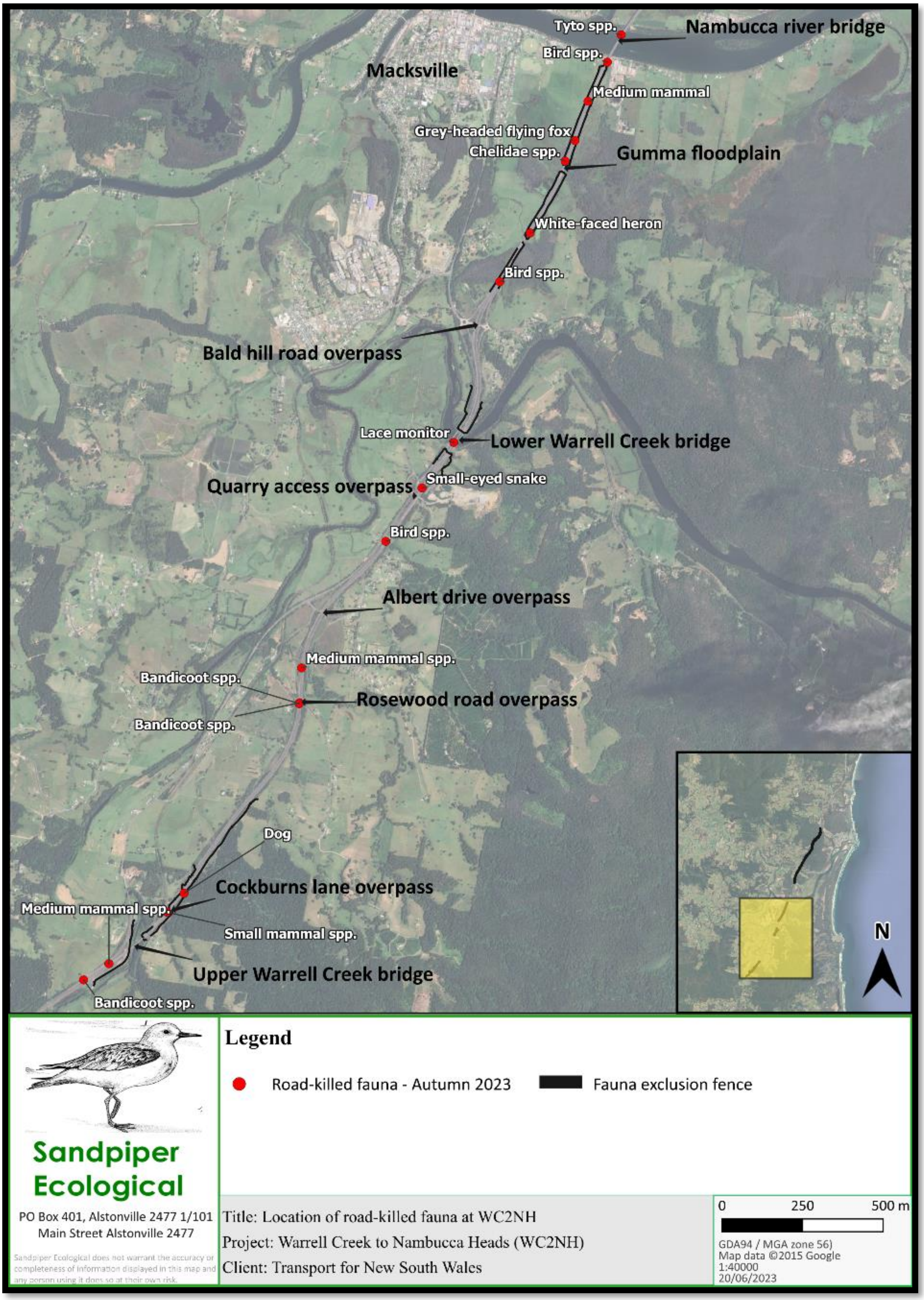

Figure 3: Location of road-killed fauna recorded in autumn 2023 along the WC2NH alignment (southern extent).

4. Discussion

4.1 Autumn 2023

In April 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 autumn sample recorded 29 individuals, resulting in a road-kill rate of 0.37 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). Autumn 2023 records were equal to the autumn 2022 roadkill records and 9.8% less than the summer 2023 records when 0.41 individuals/km/week was recorded. 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 and environmental conditions, as well as survey conditions, with some survey periods favoring increased carcass retention and detection such as during the dry recent autumn 2023 survey. Interestingly, the observed autumn road-kill rate exceeded the rate of 0.3 rk/km/week reported by Taylor and Goldingay (2004) for three major, unfenced roads in north-eastern New South Wales.

Across all surveys mammals and birds have consistently accounted for the majority of road-kill incidents. It is worth noting that the survey method employed has a bias towards larger and more long-lasting carcasses, which are commonly observed among birds and mammals (Ogletree and Mead 2020). Additionally, this method limits the ability to confidently identify all carcasses, resulting in some individuals being categorised based on their size and general fauna group. The absence of amphibians in April 2023 is consistent with previous surveys and further emphasises the difficulty of identifying road-killed amphibians during vehicle-based surveys (Sandpiper Ecological 2022).

Despite the presence of exclusion fence, some fauna species that would normally be prevented from entering the carriageway continue to be recorded as road-kill within fenced sections of the alignment similar to findings in 2021 and 2022 (Sandpiper Ecological 2021, 2022). Even though fenced areas reported a higher road-kill incidence in 2021 and 2022, our results do not quantify the number of individuals deterred from entering the carriageway by the exclusion fence. At WC2NH, the exclusion fences align with vegetated regions where a greater fauna abundance is anticipated. Without these fences, road-kill in these areas would likely be significantly higher, as indicated by de Carvalho et al. (2014). Notably, bandicoots make up the majority of road-kill records within fenced areas, especially north of Mattick road, likely due to their behaviour 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. This survey was the first to record a lace monitor road-kill within the WC2NH alignment, with one individual recorded at the lower Warrell Creek Bridge. Fauna fence is designed to exclude large reptiles like lace monitors and the subject record was found in an unfenced section between two small fenced sections of highway. During winter, a thorough assessment will be carried out to inspect and verify the integrity of the exclusion fence stretching from Warrell Creek to Nambucca Heads.

There was no macropod road-kill recorded during autumn 2023 monitoring which is the first time this has occurred since monitoring commenced (See appendix Table A1). With the data available it is difficult to confirm if the decrease is due to a decline in local abundance caused by high road-kills in 2020 (27 individuals), or a combination of seasonal changes in behaviour and environmental conditions (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 autumn 2023. One grey-headed flying fox was recorded on the Gumma Floodplain, within an area of Type 4 exclusion fence, which was designed to reduce flying-fox mortality. The presence of a single flying-fox mortality in the type 4 fenced area is not evidence that the fence has failed. 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

Overall, the road-kill rate in autumn 2023 was less than the previous summer survey and 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 autumn 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	Agreed.

6. References

Bond, A. R., & Jones, D. N. (2013). Roads and macropods: interactions and implications. *Australian Mammalogy*, *36*(1), 1-14.Carvalho, N. C., Bordignon, M. O. & Shapiro, J. T. (2014). Fast and furious: a look at the death of animals on the highway MS-080, southwestern Brazil. *Iheringia, Ser. Zool:* **104,**

de Carvalho, W. D., Rosalino, L. M., Magioli, M., Rodrigues, F. A., & Adania, C. H. (2014). Roadkill hotspots in a protected area of Cerrado in Brazil: implications for landscape and faunaOecologia Australis, 18(4), 908-922.

Geolink (2018a). *Road-kill monitoring report: WC2NH Stage 2A*. Report prepared for NSW Roads and Maritime Services.

Taylor, B. D., & Goldingay, R. L. (2004). Wildlife road-kills on three major roads in north-eastern New South Wales. *Wildlife Research*, *31*(1), 83-91.

McDonald, J. H. (2013). *Handbook of biological statistics*. Sparky House Publishing, Baltimore, Maryland.

RMS (2018). *Warrell Creek to Nambucca Heads Stage 2 Ecological Monitoring Program*. Report prepared by NSW Roads and Maritime Services.

Sandpiper Ecological (2015). *Pacific Highway Upgrade: Nambucca to Urunga – underpass monitoring year one construction phase.* Report prepared for Lend Lease Engineering.

Sandpiper Ecological (2019). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2019*. Report prepared for Transport for NSW.

Sandpiper Ecological (2019b). *Escape structure monitoring – autumn 2019*. Letter report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2020). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2020.* Report prepared for Transport for NSW.

Sandpiper Ecological (2021). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2021.* Report prepared for Transport for NSW.

Sandpiper Ecological (2022). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – year four annual report 2022.* Report prepared for Transport for NSW.

Appendix A – Field data

Table A1: Road-kill summary of all fauna recorded to date during operational phase monitoring at WC2NH (2018-2023). * 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	Aut 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	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	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	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	1	15
Australian white ibis	0	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	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	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	0	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	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	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	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	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	0	3
Galah	7	0	0	0	1	0	0	3	0	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	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	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	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	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	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	1	25

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	Aut 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	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	0	21
Forest kingfisher	1	0	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	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	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	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	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	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	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	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	0	4
Dollarbird	0	0	0	0	2	0	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	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	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	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	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	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	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	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	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	0	1
Duck spp.	0	0	0	0	0	1	0	0	0	1	0	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	0	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	2
Heron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Small bird	0	0	0	0	0	0	0	2	0	0	0	0	0	1	1	0	1	2	2	0	2	1	12

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	Aut 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	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	5	42
Total birds	53	8	22	17	18	16	13	25	16	11	8	9	10	12	8	11	6	14	4	2	11	10	304
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	0	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	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	1	18
Pteropus spp.	0	0	0	0	3	8	1	0	1	1	0	0	0	1	0	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	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	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	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	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	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	0	62
Swamp wallaby	2	1	0	1	0	1	1	0	0	1	1	2	1	0	2	1	1	0	4	0	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	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	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	0	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	0	1
Bandicoot spp.	0	0	0	0	0	1	0	4	0	0	0	1	0	2	4	2	4	3	4	9	8	5	47
Chalinolobus spp. (microbat)	0	0	0	1	0	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	0	3
Swamp rat	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	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	4	16
Small mammal	0	0	0	0	2	0	0	0	0	0	1	0	1	3	0	0	0	1	0	0	1	1	10
Medium mammal	0	0	0	2	4	2	4	5	2	2	2	0	0	2	4	2	2	3	1	0	1	3	41

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	Aut 23	Total
Large mammal	0	0	0	1	1	0	0	1	0	0	1	0	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	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	14	333
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	0	8
Carpet python	1	0	0	2	1	1	0	1	0	0	0	0	1	0	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	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	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	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	1	20
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	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	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	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	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	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	1	12
Lace monitor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Lizard spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2
Small eyed snake	0	0	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	3	4	80
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	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	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	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	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	Sum 23	Aut 23	Total
Total frogs	5	0	0	4	0	0	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	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	2
European fox	3	1	1	2	1	1	2	0	0	0	0	0	0	1	2	0	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	0	8
Rabbit	1	0	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	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	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	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	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	1	37
Grand total	**92**	**14**	**34**	**55**	**59**	**40**	**33**	**53**	**36**	**27**	**28**	**25**	**20**	**37**	**29**	**22**	**24**	**29**	**23**	**22**	**32**	**29**	**763**
Grand total	**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**	**0.37**	**0.44**

Transport for New South Wales

Warrell Creek to Nambucca Heads

Annual road-kill Monitoring Report- Operational Phase, Year Five (2023)

Transport for New South Wales | March 2024

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

Road-kill monitoring – operational phase year five (2023)

Sandpiper Ecological Surveys

March 2024
Final Report

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Table of contents

List of tables

List of figures

List of plates

1 Introduction

In 2015, Transport for New South Wales (formerly Roads and Maritime Services) 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 camp. 1 km 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 2018). 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. Sandpiper Ecological commenced monitoring in October 2018, making the Winter 2023 survey the conclusion of the five-year operational monitoring.

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 Winter 2023 sample, summarises findings from year five (2023) 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).

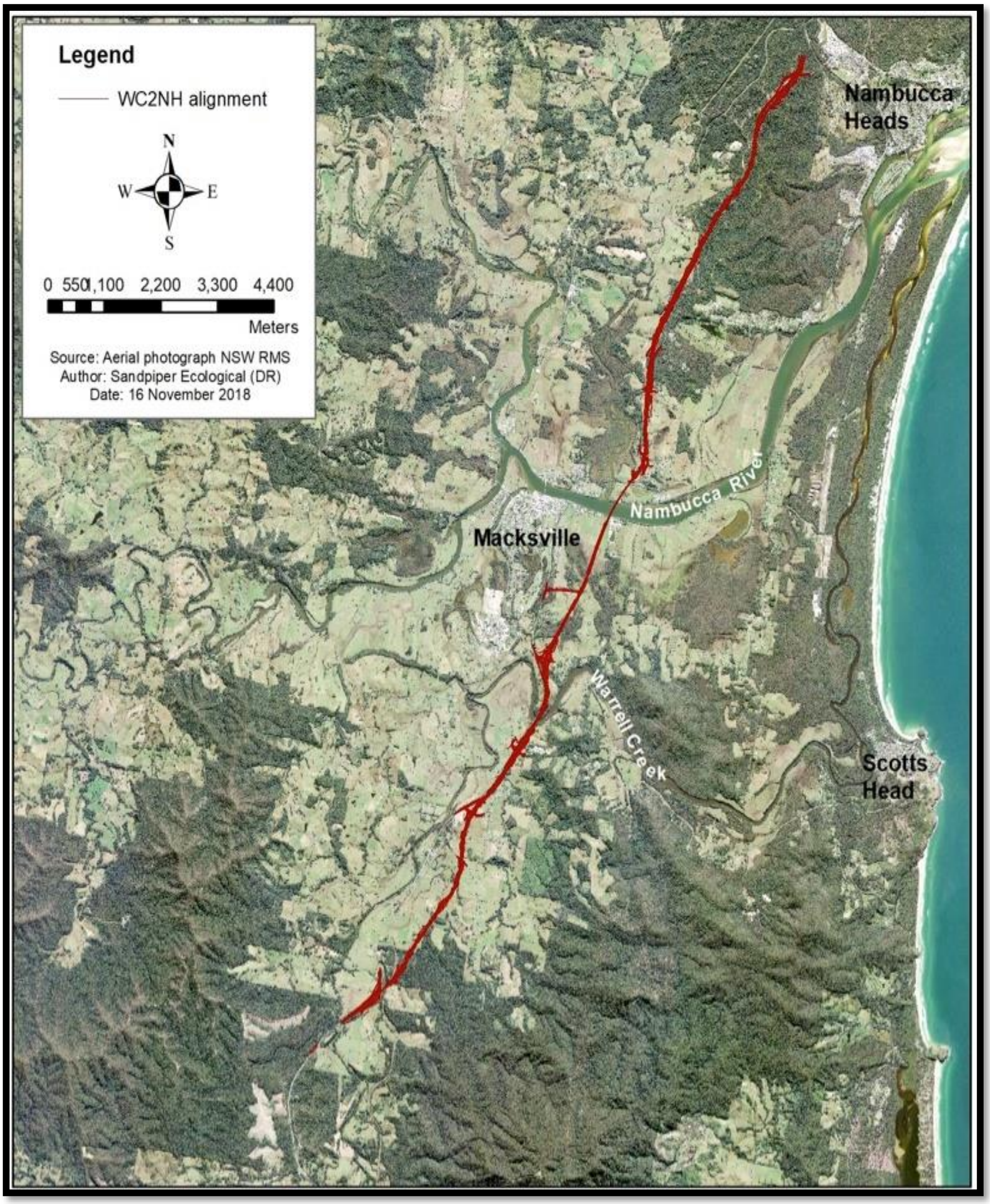

Figure 1: Location of the WC2NH alignment.

2.2 Road-kill surveys

Prior to the Autumn 2021 monitoring event 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) a wire rope barrier, 11 m from the fog line if there is no wire rope barrier, and pedestrians to walk 3 m behind the wire rope. These distance restrictions could not be achieved using the former method which required a vehicle to pull off the highway each time a fauna mortality was observed.

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 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 android application.

Potential target species, that is spotted-tailed quoll, koala, grey-headed flying-fox, or giant barred frog, were inspected more closely from a safe location. At the end of each survey, the data were uploaded as a CSV file from Australia Topo maps application 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

Mapping software 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., autumn 2023). 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 summed 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 due to the staged opening of the project occurring between 2017-2018.

To analyse spatial patterns of fauna road-kill, a heat map was generated using QGIS software (version 3.30). Road-kill point locality data from Years 1-5 of monitoring was imported into QGIS as point data from a CSV file. The analysis focused on species likely to be impeded by exclusion fencing which were extracted from the dataset and mapped overlaying the WC2NH alignment (Table 1).

The heat map was generated by selecting the “heatmap” option under vector processing. Layer rendering was adjusted to enhance contrast, using a dark rendering theme and a red color ramp with darker shades of red transitioning to brown to signify areas of higher density road-kill, effectively delineating hot-spot regions. A radius of 720 map units was applied to determine the spatial extent of influence for each road-kill point locality.

Additionally, the potential impact of fence terminations (the end points of exclusion fencing) on road-kill fauna was explored in QGIS. Using the measure function in QGIS, road-kill occurrences within 250 meters of where the fence ends were extracted, ensuring records were in areas where the fence was installed on both sides of the road. Furthermore, analysis focused on species that would under normal circumstance be blocked by exclusion fence. Mid-fence sections that were > 500 m and had exclusion fencing were also selected for comparison. The road-kill rate/km/week for each of these sections (mid fence versus fence ends) was calculated, using the data from Years 1-5 of monitoring. The road-kill rates between the fence ends and the mid-fence sections were compared to assess the potential impact of fence ends on fauna mortality.

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. Juvenile 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 were summed 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

Four persons traversed the exclusion fence on foot on 20 and 21 August 2023. 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). 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 Australia topo maps with a written description of the issue and location.

3 Results

3.1 Winter 2023 sample

3.1.1 Weather condition

Weather conditions during the road-kill surveys were good, with no rain or cloud cover during any of the surveys (Table 2). The relative humidity was moderate to high, ranging from 57% to 74%, and the temperature ranged from 15.6°C to 16.7°C (Table 2). There was no rainfall to 9am on all survey days. Visibility was good during all surveys and favourable for detecting road-kill.

Table 2: Weather conditions were recorded at 9 am on each sample day in July 2023. 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 (°C)	Cloud cover (Oktas)	Visibility
2/7/23	Nil	0	59	15.6	0	Good
9/7/23	Nil	0	57	15.8	0	Good
16/7/23	Nil	0	74	16.7	0	Good
23/7/23	Nil	0	57	15.9	0	Good

3.1.2 Winter 2023 road-kill survey

A total of 32 road-killed fauna were recorded during the winter (July) 2023 sample period (Table 3). Birds were the most diverse group with five species and four groups, followed by mammals with five species and three groups (including introduced species). Reptiles were the least diverse with one group (Table 3). Mammals were the most frequently detected fauna group, with 16 individuals, followed by birds (14 individuals) and reptiles (2 individuals) (Table 3). Bandicoot spp. had the highest frequency of road-kill with six records, followed by unidentifiable bird spp. (4), magpie lark (3), and red necked wallaby, medium mammal spp., rodent spp. and reptile spp. with 2 records each (Table 3). The remaining road-kill records were of single individual species or groups (Table 3). There was one threatened koala recorded on 2 July 2023. No frogs were recorded. The full summary of fauna recorded to date is included in Appendix A, Table A1.

Road-kill during the winter sample period was recorded at an overall rate of 0.41 rk/km/week (number of road-killed individuals per kilometer per week). This is the same as summer and slightly higher than autumn (0.37 rk/km.week) 2023 (Table 3).

Table 3: Species of vertebrate fauna recorded during year five (2023) road-kill surveys along the WC2NH alignment. For a full road-kill summary of all surveys to date, see Appendix A, Table A1. RK=Roadkill.

Species	Sum 23	Aut 23	Win 23	Total
Birds				
Little pied cormorant	1			1
Cormorant spp.			1	1
Tawny frogmouth	2	1		3
Eastern barn owl			1	1
Tyto spp.		1	1	2
Laughing kookaburra			1	1
White-faced heron		1		1
Cattle egret			1	1
Pheasant coucal			1	1
Magpie lark		1	3	4
Corvus spp.	1			1
Raptor spp.	1			1
Small bird spp.	2	1	1	4
Unidentifiable bird spp.	4	5	4	13
Total birds	11	10	14	35
Mammals				
Short-beaked echidna	1			1

Species	Sum 23	Aut 23	Win 23	Total
Red-necked wallaby	1		2	3
Eastern grey kangaroo			1	1
Koala			1	1
Northern brown bandicoot	1			1
Long-nosed bandicoot	1		1	2
Bandicoot spp.	8	5	6	19
Grey Headed Flying fox		1		1
Microbat spp.	1			1
Rodent spp.	3	4	2	9
Small mammal spp.	1	1		2
Medium mammal spp.	1	3	2	6
Total mammals	18	14	15	47
Reptiles				
Eastern blue-tongued lizard	1			1
Chelidae spp.		1		1
Lace monitor		1		1
Small eyed snake		1		1
Unidentified reptile spp.	1	1	2	4
Lizard spp.	1			1
Total reptiles	3	4	2	9
Introduced species				
Red fox			1	1
Dog		1		1
Total introduced	0	1	1	2
Grand total	32	29	32	93
Rk/week/km	0.41	0.37	0.41	0.39

3.1.3 Distribution of road-kill

In winter of 2023, road-killed fauna was recorded in various sections of the WC2NH alignment (Figures 2 and 3). More road-kill was recorded in the unfenced sections of the alignment (18 records) compared to the fenced (14 records) sections (Figures 2, 3, and Table 4). Seven of the 14 records in fenced areas were individuals that the fauna fence should block under normal circumstances, including four unidentified bandicoots and one long-nosed bandicoot, koala and medium mammal (Table 4). The remaining seven individuals were fauna that readily move through (reptile spp., rodent spp.) or over (birds) exclusion fencing (Table 4).

Road-kill records were more frequent along the Gumma floodplain from the Nambucca River bridge to the Bald Hill Road overpass (9 records), the unfenced section between the Quarry Access overpass to just south of the Rosewood Road overpass (8 records), around the Mattick road overpass (6 records) and just south of the Old Coast Road overpass (4 records) (Figures 2 and 3).

Table 4: The number of road-killed fauna recorded in fenced and unfenced sections of the WC2NH alignment during the July (winter) 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
Bandicoot spp.	Excluded	4	2
Eastern grey kangaroo	Excluded		1
Koala	Excluded	1	
Long-nosed bandicoot	Excluded	1	
Medium mammal	Excluded	1	
Possum spp.	Excluded		1
Red fox	Excluded		1
Red necked wallaby	Excluded		2
Sub-total (excluded)		**7**	**7**
Barn owl	Not excluded	1	
Bird spp.	Not excluded	2	2
Cattle egret	Not excluded	1	
Cormorant spp.	Not excluded	1	
Laughing kookaburra	Not excluded	1	
Magpie lark	Not excluded		3
Pheasant coucal	Not excluded		1
Reptile spp.	Not excluded		2
Rodent spp.	Not excluded	1	1
Small bird spp.	Not excluded		1
Tyto spp.	Not excluded		1
Sub-total (not excluded)		**7**	**11**
Grand total		**14**	**18**

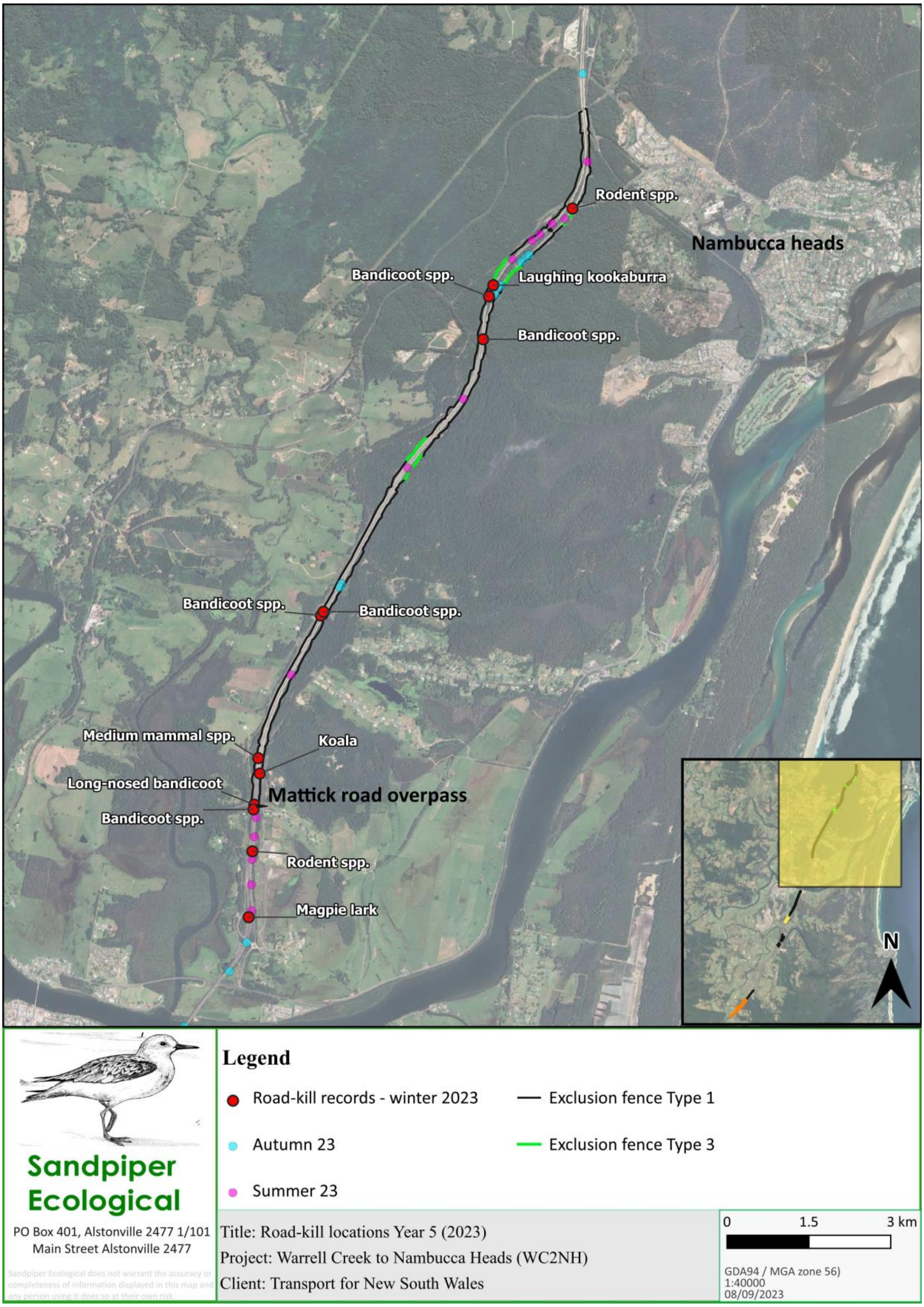

Figure 2: Location of road-killed fauna recorded in winter 2023 along the WC2NH alignment (northern extent).

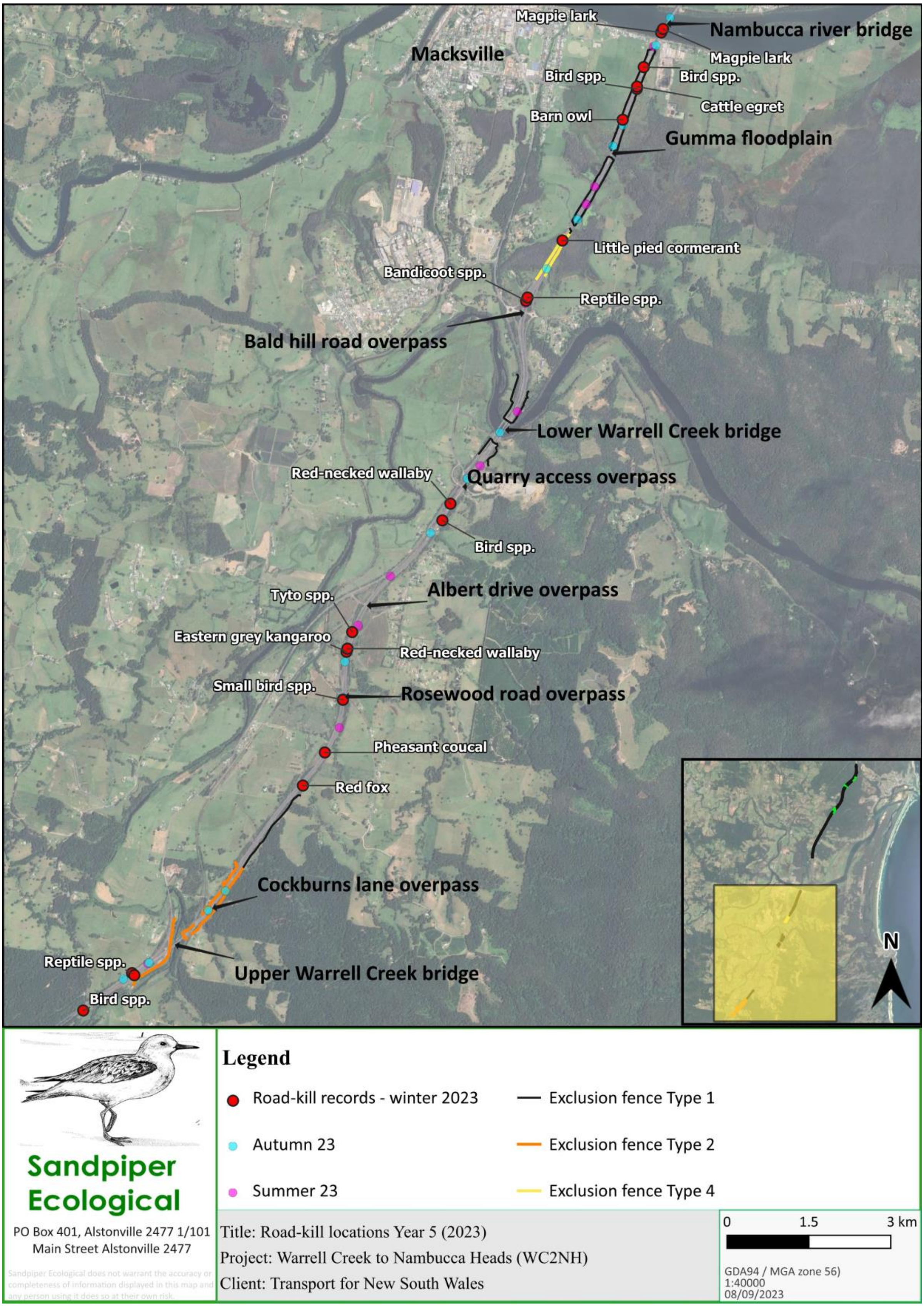

Figure 3: Location of road-killed fauna recorded in winter 2023 along the WC2NH alignment (southern extent).

3.2 Year 5 operational monitoring

3.2.1 Species richness and abundance

A total of 93 road-killed fauna were recorded during 2023 road-kill surveys with a mean road-kill rate of 0.39 individuals/km/week (Table 3). This included 20 species and a further 16 fauna groups (Table 3). Mammals were the most diverse group represented by nine confirmed species (including introduced species), followed by birds (8 individuals) and reptiles (3 individuals) (Table 3). The most frequently recorded species were magpie lark (4 individuals), red-necked wallaby (3) and tawny frogmouth (3) (Table 3). Of the fauna groups, mammals were the most frequently recorded group, with 47 records, followed by birds (35 records), reptiles (9 records), and introduced species (2 records) (Table 3). The majority of road-kills were bandicoots (22), unidentified bird spp. (13) and rodent spp. (9) (Table 3). One threatened species, the koala, was recorded on two occasions during year 5. An incidental record was found by TfNSW on 9 Novemebr 2022. A second individual was recorded during the year 5 winter survey on 2 July 2023.

3.2.2 Koala road mortalities

An incidental road-kill koala (Plate 2) was observed on the northbound carriageway at 495821, 6607892 on 9 November 2022, approximately 2.8 km south of the Old Coast Road overpass and approximately 3.4 km north of the exclusion fence end (Figure 4). A fauna fence inspection was conducted 500m either side of the road-kill location on 10 November 2022 by TfNSW maintenance team to identify any obvious breech locations. Multiple potential points of entry were identified, including vegetation against fauna fencing, gap in access gate and two missing panels in fauna fence. Work commenced on the week of 21 November 2022 to rectify and eliminate these possible breech causes.

During the winter road-kill survey on 3 July 2023, a deceased adult male koala was recorded 290 meters north of the Mattick Road overpass on the southbound roadside verge (Figure 4). The koala was presumed to have been struck during the preceding night or early morning. An immediate search was conducted 200 m either side of the incident which found a eucalyptus tree with a diameter of approximately 150mm was observed growing through the fence on the west side, located just south of Site 2 underpass. Additionally, some acacia branches were found resting on the fence, they were assessed as unlikely to facilitate easy access for koalas. No other apparent breaches or holes in the fence were detected during the inspection. A follow up inspection was carried out by the TfNSW maintenance team on 7 July 2023. This examination aimed to identify potential breaches and factors contributing to the road-kill event. The inspection revealed a small tree with koala claw markings on the east fence line, over 500 meters north of the incident site, which was removed. Additionally, heavy vegetation overgrowth, similar to conditions found across the fauna fence network, was noted and scheduled for mulching. A damaged or missing panel in the fence near the Mattick Road bridge was documented; however, it was deemed not to pose a significant risk due to the absence of a contiguous fauna fence south of the Mattick Road Overpass, which is less than 200 meters from the koala's location.

Plate 2: Carcass of a koala on the northbound carriageway of the WC2NH Pacific highway.

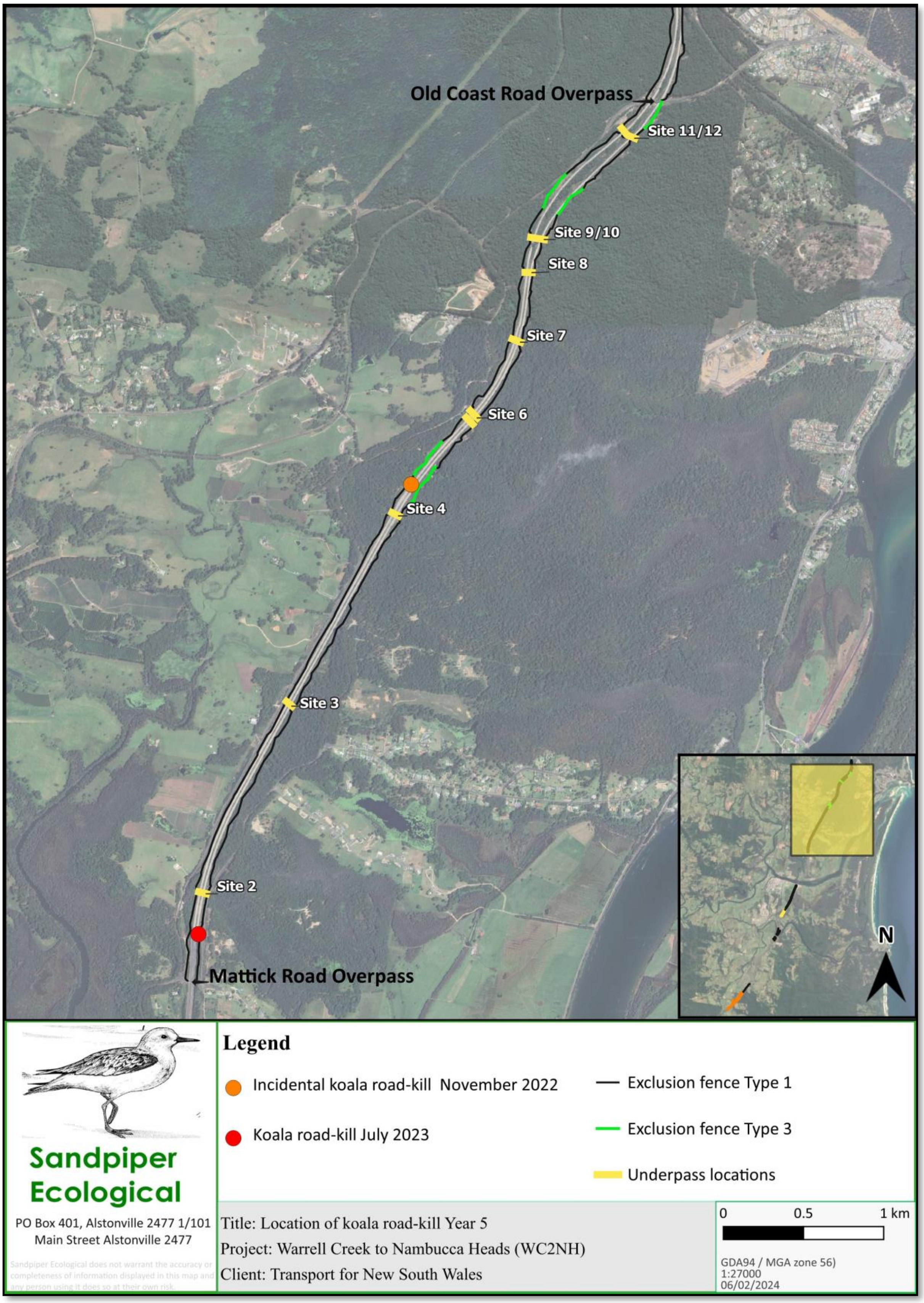

Figure 4: Koala road-kill records 2023 at WC2NH.

3.3 Operational monitoring – Years 1-5

3.3.1 Temporal comparisons

There was a decline in the annual mean road-kill rate from 2019 to 2022. The mean road-kill rate in 2023 was slightly higher than 2020-2022, but remained lower than 2019 (Figure 5). Mean road-kill rate decreased from 0.57 (± 0.40) rk/km/week in 2019 to 0.37 (± 0.19) rk/km/week in 2020, 0.34 (± 0.22) rk/km/week in 2021, 0.31 (± 0.20) rk/km/week in 2022, and increased slightly in 2023 to 0.39 (± 0.14) rk/km week (Figure 5). By comparison, the road-kill rate in 2023 was 33% lower than 2019, 7% higher than 2020, 14% higher than 2021 and 27% higher than 2022 (Figure 5). No distinct seasonal trends in total road-kill were evident over the monitoring period.

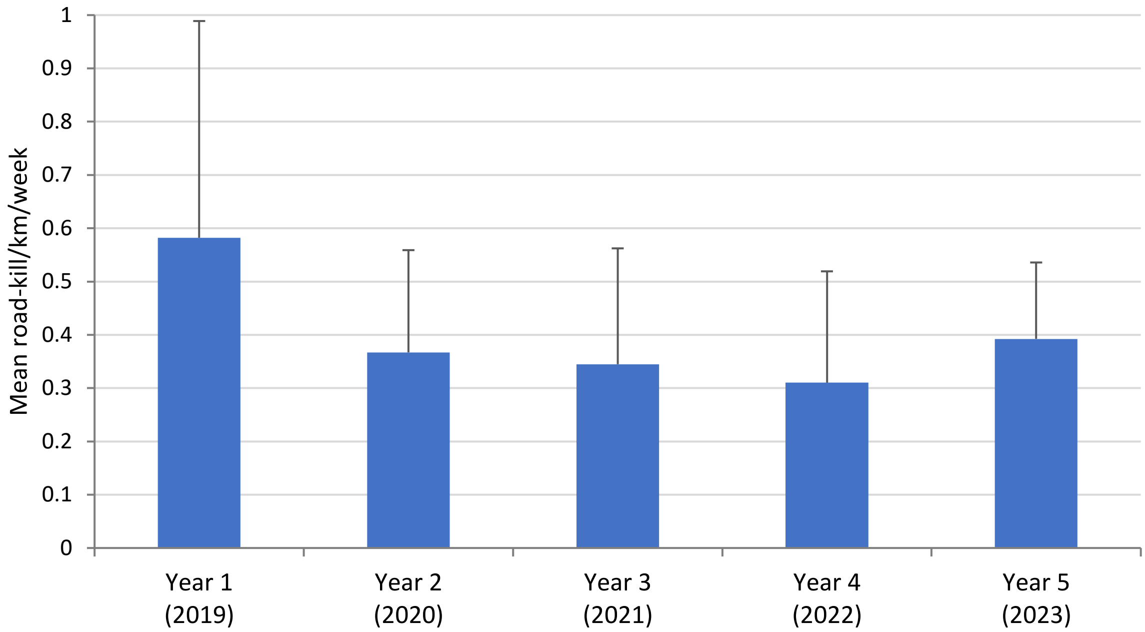

Figure 5: Mean (+SD) number of road-kill per kilometre per week. Years 1-4 (n=16), year 5 (n=12).

Road-kill rates have varied between and within fauna groups across operational monitoring (Figure 6). Since the commencement of operational monitoring and in order of detection, birds, macropods, bandicoots, medium mammals and flying foxes have recorded the highest road-kill rates (Figure 6). Road-kill rates for flying foxes and medium mammals have consistently declined since 2019 (Figure 6). 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 maintained in 2021 (0.013 ± 0.3 rk/km/week) and 2022 (0.006 ± 0.02 rk/km/week), and only one record in 2023 (0.004 ± 0.01 rk/km/week) (Figure 6). Macropod records peaked during 2020 (0.1 ± 0.09 rk/km/week) and have declined by 83% in 2023 (0.017 ± 0.03 rk/km/week) (Figure 6). In contrast, road-kill rates for bandicoots have consistently increased from 2019 monitoring, with the highest rate recorded in 2023 (0.09 ± 0.05 rk/km/week) (Figure 5). Consistently low mean annual road-kill rates less than 0.025 rk/km/week were recorded for feral predators, possums, echidnas and microbats (Figure 6). The mean annual road-kill rate for small mammals (i.e. rodents, antechinus etc) increased from <0.025 (in previous years) to 0.05 rk/km/week in 2023.

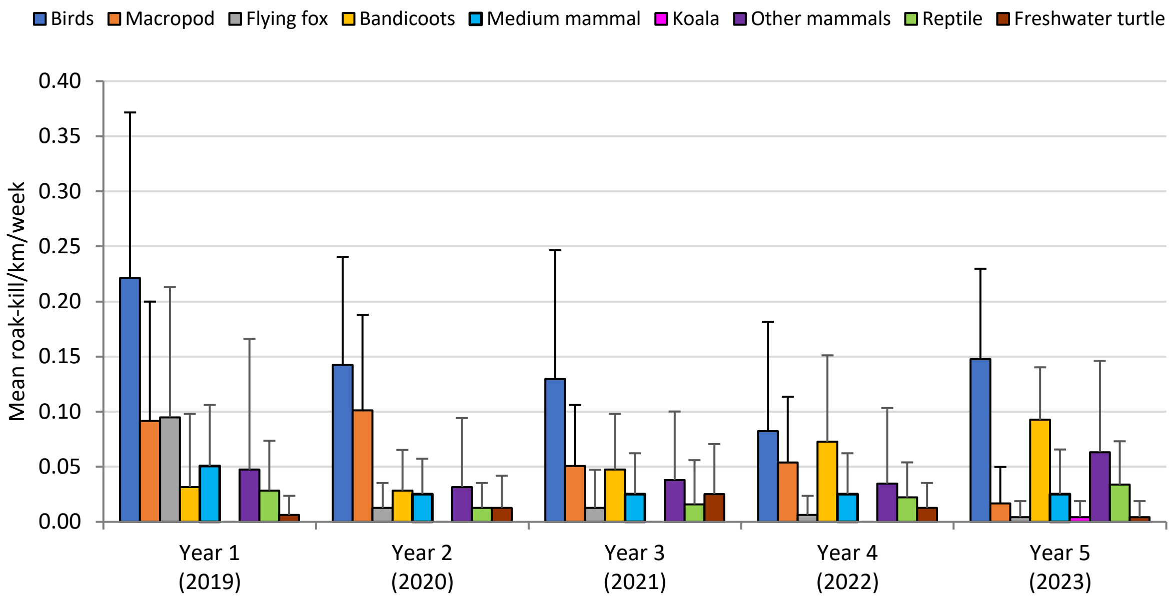

Figure 6: Mean (+SD) number of road-kill per kilometre per week. Year 1-4 (n=16), Year 5 (n=12). Other mammals = combined microbat spp., echidna, feral predators, and small mammal spp.

3.3.2 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 7). 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 7, Table 5). During 2021 and 2022, fenced and unfenced sections of the alignment recorded no statistically significant difference. This result continued in 2023, with no statistically significant difference (P=0.656; DF=1; Table 5) between fenced and unfenced sections of the alignment (Figure 7). Road-kill rates in unfenced areas have decreased over time from 0.28 ± 0.37 rk/km/week in 2019 to 0.17 ± 0.12 rk/km/week in 2023 (Figure 7). In fenced areas, road-kill peaked in 2022 (0.17 ± 0.17 rk/km/week) with a slight decrease recorded in 2023 (0.15 ± 0.11 rk/km/week) (Figure 7).

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 5, Figure 8). Throughout operational monitoring, macropods have consistently recorded higher road-kill rates in unfenced alignment sections (Figure 8). During 2023, there were no macropod road-kill in fenced sections, whereas, in unfenced sections the rate was 0.037 ± 0.07 rk/km/week (Figure 8).

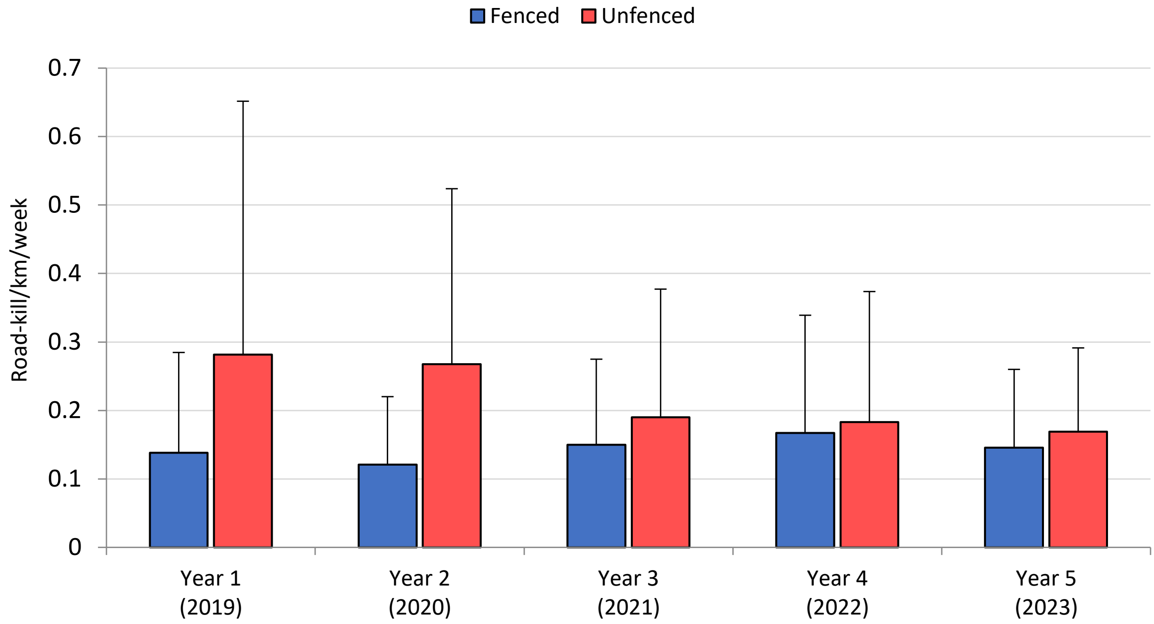

Figure 7: Annual comparison in the mean (+SD) number of road-kill per kilometre per week during 2019-2022 (n=16) and 2023 (n = 12) recorded in fenced (10.86km) versus unfenced (8.89km) sections of the WC2NH alignment. Only includes fauna that, under normal circumstances, would be blocked by the exclusion 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 1-5). Note, only fauna that should be blocked by exclusion fence under normal circumstances has been included (see Table 1).

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	<u>**0.005**</u>
	No fence	40	0.45	28.8			
2020	Fence	21	0.55	32.45	1	8.973	<u>**0.003**</u>
	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			
2023	Fence	19	0.55	20.35	1	0.198	0.656
	No fence	18	0.45	16.65			

Bandicoot records continued to increase during operational road-kill monitoring and they were the most frequently detected fauna group in 2023 that, under normal circumstances, would be blocked by the fauna fence (Figure 8). Bandicoots have been recorded in both unfenced and fenced sections of the alignment, with road-kill rates in 2023 being slightly higher in fenced (0.10 ± 0.08 rk/km/week) than unfenced (0.08 ± 0.07 rk/km/week) sections (Figure 8). Medium mammal records were slightly higher in unfenced sections than fenced sections in 2020, 2022 and 2023 (Figure 8). Feral predators and possum records have been recorded at relatively low rates regardless of the presence or absence of fencing (Figure 8). There were no freshwater turtle road-kill in 2023, however, previously they have been recorded in predominantly fenced sections of the alignment, particularly around the Gumma floodplain (Figure 8), whereas echidnas have exclusively been recorded in unfenced sections of the alignment (Figure 8). In 2023, for the first time in operational monitoring, two instances of koala road-kill were recorded within the fenced section of the alignment (Figure 4, Figure 8).

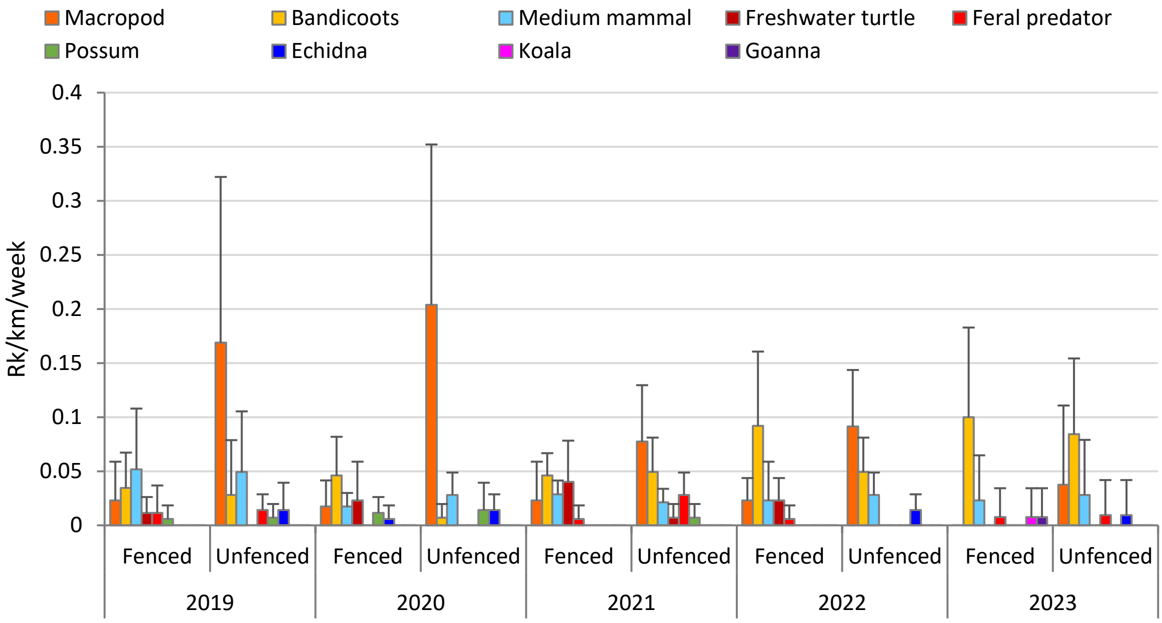

Figure 8: Annual comparison in the mean (+SD) number of road-kill per kilometre per week (2019-2022: n = 16; 2023: n = 12) along the WC2NH alignment in fenced (10.86km) and unfenced (8.89km) sections. Only includes fauna groups that, under normal circumstances, would be blocked by the exclusion fence (see Table 1).

3.3.3 Distribution of road-kill

Heat map analysis of road-killed fauna (2019-2023) that should, under normal circumstances, be blocked by exclusion fence (see table 1) identified several areas of high road-kill density (Figure 9 and 10). Prominent hot-spots were identified at unfenced interchanges, including the south side of Mattick Road overpass, Bald Hill Road overpass, Rosewood Road overpass and 1.5km north of the Mattick road overpass in a fenced section. Less prominent hot-spots included the fenced Gumma floodplain, the unfenced alignment near the Quarry Access overpass and the south side of Upper Warrell Creek bridge (Figure 9 and 10). Hot-spot analysis and the road-kill overlay (2019-2023) 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).

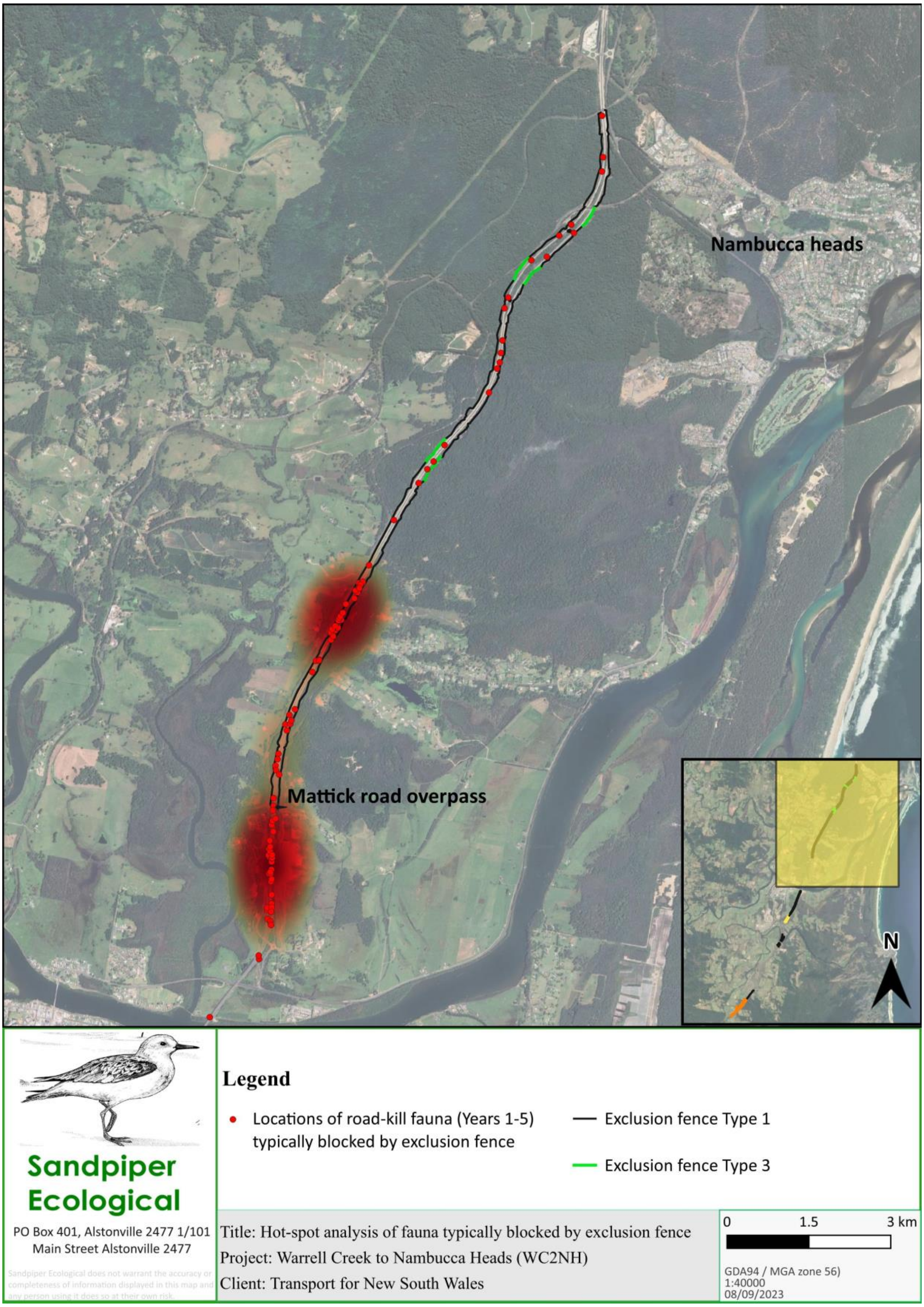

Figure 9: Heat map analysis of road-killed fauna that, under normal circumstances would be blocked by fauna fence (see Table 1) during operational monitoring surveys (2019-2023) at WC2NH. Overlaid red dots indicate the location of road-killed individuals recorded between 2019 and 2023.

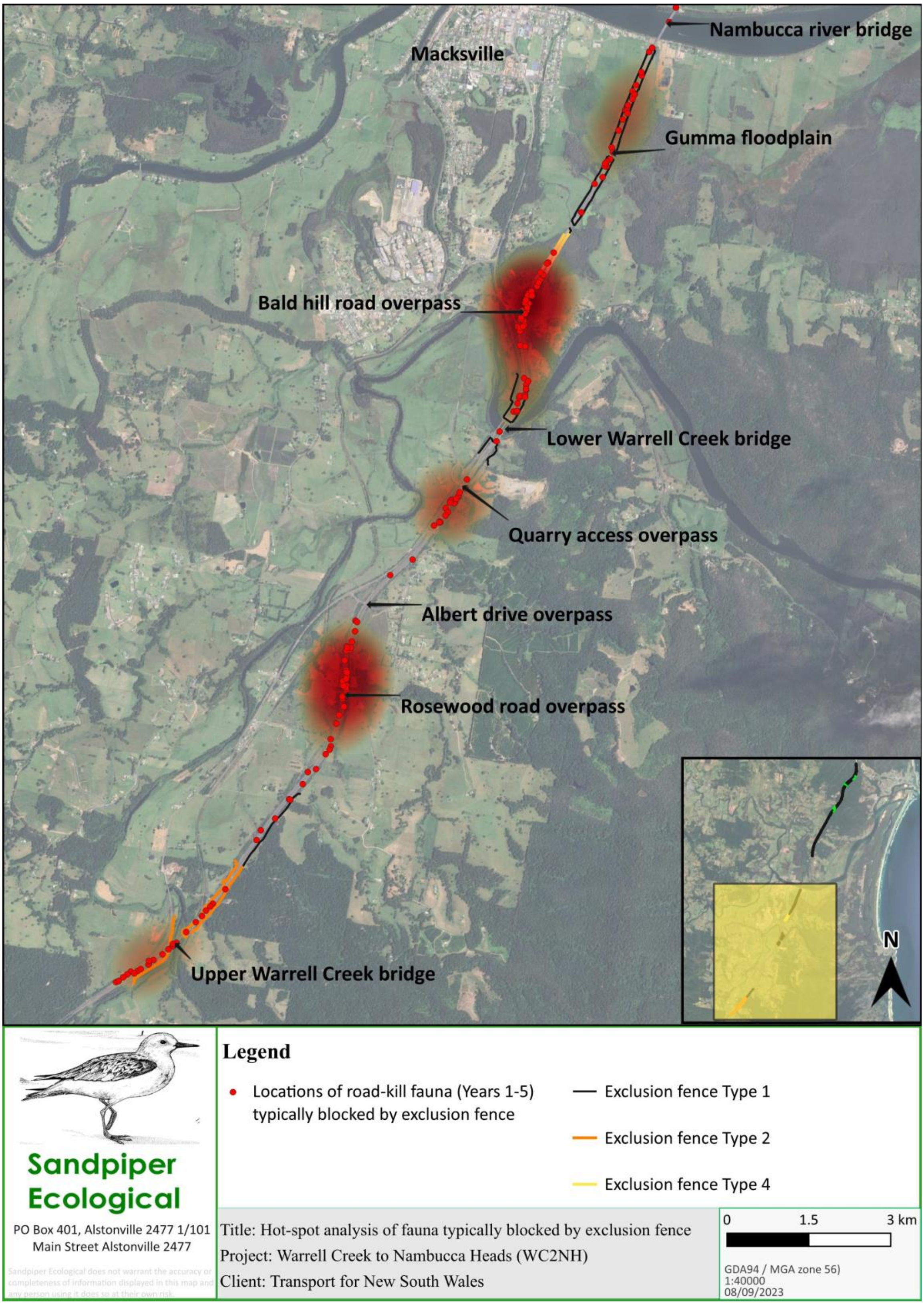

Figure 10: Heat map analysis of road-killed fauna that, under normal circumstances would be blocked by fauna fence (see Table 1) during operational monitoring surveys (2019-2023) at WC2NH. Overlaid red dots indicate the location of road-killed individuals recorded between 2019 and 2023.

3.3.4 Fence ends

Road-kill rates varied between areas in proximity (within 250m) to fence ends with areas where exclusion fencing is continuous (>500m on both sides). The average road-kill rate adjacent to fence ends was 1.44 ± 2.13 rk/km/week, which is higher than within sections that are fenced, where the rate was observed to be 0.42 ± 0.88 rk/km/week (Figure 11).

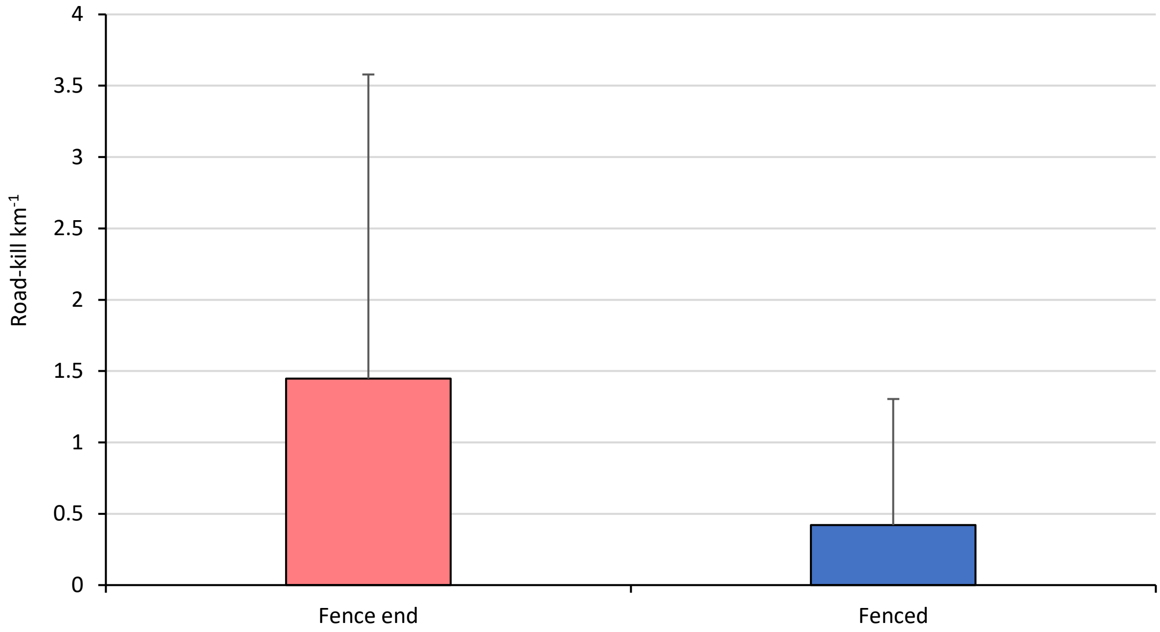

Figure 11: Mean (+SD) number of road-kill per kilometre per week during 2019-2022 (n=16) and 2023 (n=12) recorded in fence end and fenced sections of the WC2NH alignment. Only includes fauna groups that, under normal circumstances, would be blocked by the exclusion fence (see Table 1).

3.4 Exclusion fence inspection

Seventy-seven fence issues were recorded during the 2023 winter inspection (Table 6, see Appendix A, Table A2). The most frequently encountered issue was sections of tree overgrowth (tree/branch growing through or over the fence) (36), followed by vegetation overgrowth (dense vegetation engulfing fence, including grass) (20), fallen branches or trees on the fence (15) and compromised structural integrity, including open gate (2), fence top folded down (2), holes in fence (1) and missing fauna fence (1) (Table 6). Of the 15 fallen branches or trees, three fallen branches were removed during the inspection, and both open gates were closed, but were not able to be locked.

Twenty-six exclusion fence issues were classified as a high priority (likely to facilitate threatened fauna including koala or quoll to access alignment), 33 moderate priority (some potential to facilitate movement onto the alignment), and 18 low priority (not likely to facilitate access to highway) (Table 6). Priority issues include moderate-sized (≥100mm diameter) trees or branches that are growing through or over the exclusion fence (12), trees or branches fallen on the fence (9), unlocked gates (2), missing fauna fence (1), holes in fence (1) and vegetation overgrowth coupled with a fallen branch (1). Most issues of tree overgrowth and trees/branches on the fence are attributed to *Acacia* spp. regrowth on and around the batters. Also, dense grasses growing through and over the fauna fence was a common feature (Plate 3, Appendix A, Table A2). All high priority issues identified have been addressed and closed out. Medium an low priority issues are being progressed by TfNSW Maintenance Crews.

Plate 3: Thick grass protruding through and over the fence (left), and fallen tree/branches onto the fence (right).

Table 6: Issues identified and their priority for action from the exclusion fence inspection at WC2NH, 2023. ^ Three of the five branches have been removed.

Issues identified	High	Moderate	Low	Grand Total
Vegetation overgrowth	1	5	14	20
Tree/branch growing through or over fence	12	23	1	36
Tree/branch fallen on fence	9	5^	1	15
Fauna fence missing	1			1
Holes in fence	1			1
Unlocked gate	2			2
Fence top collapsed			2	2
Grand Total	26	33	18	77

4 Discussion

4.1 July 2023

Road-kill monitoring over the entire WC2NH alignment in July 2023 indicated that fauna continued to be killed by vehicles almost five years after the entire alignment was open to traffic. Road-kill was recorded at an overall rate of 0.41 individuals/km/week, which is the same as summer 2023 and slightly higher than autumn 2023 (0.37 rk/km/week). 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 July 2023 is consistent with previous surveys and further emphasises the difficulty of identifying road-killed amphibians during vehicle-based surveys.

4.2 Temporal variation in road-kill

The temporal decline in road-kill abundance from 2019-2022 was not evident in 2023. By comparison, the road-kill rate in 2023 was 33% lower than 2019, 7% higher than 2020, 14% higher than 2021, and 27% higher than 2022. The 2023 rate was slightly higher than the rate of 0.3 rk/km/week recorded on three major roads in north-eastern New South Wales (Taylor and Goldingay 2004). There is likely to be a number of reasons for the temporal changes in road-kill rates, including changes in habitat quality, fauna abundance, weather conditions and time since opening. The peak in 2019 could be due to a combination of drought and the recent opening of the highway, whilst the decline from 2020 to 2022 may be associated with the La Nina weather pattern with the increase recorded in 2023 due to drought.

4.2.1 Temporal changes in mammals

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 2023. Better climatic conditions since 2021 have likely contributed to an increase in the abundance and movement of bandicoots (Vernes and Pope 2009) and decomposition of mulch applied to batters and bunds has created favourable foraging habitat within the road corridor. Numerous bandicoot diggings have been observed on mulch bunds situated on the road side of exclusion fence (L. Andrews pers obs). Increased abundance of bandicoots combined with favourable feeding habitat in the road corridor means more individuals are accessing the road corridor to forage, resulting in a higher incidence of vehicle strike.

The abundance of macropod records peaked in 2020 (27 road-kills), remained relatively stable between 2021 (15 road-kills) and 2022 (17 road-kills) and decreased substantially in 2023 (4 road-kills). The lower abundance of macropods in 2023 on the back of favourable climatic conditions further supports the hypothesis that the higher road-kill rates recorded in 2019 and 2020 were due to drought (Klocker *et al.* 2006). Reduced grass quality and quantity during drought means individuals move larger distances in search of new growth, which may occur along road-sides, or cause individuals to cross roads more frequently. Nonetheless, it is difficult to confirm if the decrease in vehicle strike is due to a decline in local abundance caused by high mortality between 2019 and 2022, 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. If drought influences road-kill rate of macropods an increase would have been expected in the second half of 2023 after monitoring was completed.

4.2.2 Temporal changes in birds

The density of road-killed birds declined from 2019 to 2022 yet increased to 0.15 ± 0.08 rk/km/week in 2023 which was higher than both 2021 and 2022, and noticeably lower than 2019 when the mean rate was 0.22 ± 0.15 rk/km/week. Previous declines may have been due to changes in habitat within the highway corridor and avoidance of the highway (Sandpiper Ecological 2022). During the latter stages of construction, highways provide favourable foraging habitat for species adapted to open habitats with abundant food, such as magpies, galahs, and wood ducks. Once a highway becomes operational individuals that have used the corridor for foraging are subject to a high risk of vehicle strike. The decline in bird vehicle strike in the early operational phase may be due to mortality of individuals that were regularly using the corridor and to changes in habitat as vegetation grows on batters and open habitat species are replaced by small passerines adapted to dense ground and midstorey vegetation. These species are still subject to vehicle strike yet are not detected by vehicle-based surveys.

The higher density of bird vehicle strike in 2023 may be due to improved climatic conditions from 2020-2022 which contributed to increased abundance, more feeding on roadsides and wider movements (Sadleir & Linklater 2016). A response to below average rainfall in autumn and winter 2023 cannot be discounted. Good seasonal conditions are not responsible for increases in all species with mortality of some species, such as barn owls, peaking during the drought years of 2018 and 2019 (Table A1, Appendix A). The highway may represent a population sink for resident territorial species, such as frogmouths, owls and kookaburras (Loss *et al.* 2014). Over the five years of monitoring 32 *Tyto* species, 22 laughing kookaburra and 25 tawny frogmouths have been recorded as road-kill over the 19km of highway surveyed. The results for *Tyto* spp., which is dominated by the barn owl (*T. alba*) is consistent with Clancy

(2004) who also recorded a high incidence of barn owl road-kill in northern NSW. In addition, Grilo *et al.* (2014) found that changes in movement patterns is the primary behavioural mechanisim that threatens owls in roaded landscapes. This finding is consistent with changes in owl behaviour associated with drought.

4.2.3 Seasonal changes

The spring and summer peaks in road-kill numbers recorded in 2018 and 2019 were not recorded between 2020 and 2023. In 2023, road-kill was the same in summer and winter (32 individuals each) and lower in autumn (29). The previously recorded spring/summer peak was attributed to seasonal changes in breeding cycles and foraging demands (Sandpiper Ecological 2019a), however, climatic conditions may be a primary driver in road mortality rate over time rather than season.

4.3 Distribution and fenced vs unfenced

The G-test identified no significant difference ($P>0.05$) in road-kill density between fenced and unfenced sections of the alignment in 2023. 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, and is similar to findings in 2021 and 2022. It should be noted that this does not take into account comparable habitat between fenced and unfenced sections of the highway.

Despite the higher incidence of road-kill in fenced areas in 2021-2023, the results do not show how many individuals are blocked from entering the carriageway by the exclusion fence. Clevenger *et al.* (2011) found that following fencing, there were 80% fewer road-kills and Rytwinski *et al.* (2016) found that fences with or without crossing structures reduced road-kill by 54%. At WC2NH, exclusion fence corresponds with vegetated areas where a higher abundance of fauna is expected; without exclusion fence roadkill would be substantially higher in those areas (Carvalho *et al.* 2014). Despite equivalence in road-kill density between fenced and unfenced areas exclusion fence would be reducing vehicle strike.

Hot-spot analysis over the five year monitoring period identified interchanges (Mattick Road overpass, Bald Hill Road overpass and Rosewood Road overpass) as prominent road-kill hotspots, and a possible fence end effect was evident. Despite some evidence of a fence end effect the absence of sections of road without exclusion fence for comparison negates the ability to draw firm conclusions.

Hot-spot analysis also showed that the fauna fence is effective in the forested northern extent of the project, around 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. Results are consistent with Clevenger *et al.* (2001) and Plante *et al.* (2019) who highlighted the effectiveness of longer fences that discourage animals from moving along the fence to the fence ends.

Bandicoots have predominantly contributed to the higher number of road-kill in fenced sections during 2021-2023, and are the main contributer to the prominent fenced hotspot 1.5 km north of Mattick Road (Figure 9). Modification to exclusion fence in that area have been ineffective due to the ability of bandicoots to move through small gaps especially around open drains. It is highly unlikely that an exclusion fence would be 100% effective at all times and some level of road mortality is expected even in areas with continuous fence. Fence breaches which provide access for priority species such as spotted-tailed quoll, koala and giant barred frog should remain the focus of remediation.

Throughout operational monitoring, macropod road-kills mostly occured in unfenced sections of the alignment near Rosehill Road, Upper Warrell Creek and fence ends/interchanges at Bald Hill Road and south of Mattick Road. This fence end effect is consistent with the findings of other studies (e.g. Clevenger *et al.* 2001, Plante *et al.* 2019 and Song *et al.* 2011), and 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 investigation this observation is consistent with drop-down monitoring in northern NSW which showed negligible use by native fauna (Sandpiper Ecological 2019b). Indeed, growth of dense vegetation on batters makes some drop-downs inaccessible to larger species.

4.4 Threatened fauna

Since WC2NH became operational, five threatened species have been recorded as road-kill (grey-headed flying fox, masked owl, black bittern, eastern grass owl and koala). 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 rainfall, and less visitation to roadside trees to forage. Vehicle strike is not identified as a major threat to grey-headed flying foxes (DotEE 2017) and Scheelings and Frith (2015) found that only 2.4% of individuals presented at Victoria clinics were due to a vehicle strike.

A road-killed koala was recorded for the first time on 2 July 2023 during the winter surveys, with a second incidental road-kill reported on 9 November 2022. In response to both individuals, fauna fence inspections 500m either side of the strike were undertaken to investigate possible causes. Works (i.e. tree removal, mulching, installation of gate and fence panels) were then implemented to rectify the issues identified. These records of road-killed koalas highlight the importance of ongoing fence maintenance to maximise effectiveness and reduce the likelihood of threatened species accessing the road corridor. Fauna fence inspections have identified a range of issues including tree and vegetation overgrowth, fallen trees/branches on fence and structural integrity issues (e.g. open gates, missing fence, holes in fence and collapsed fence top). Inspection regimes need to focus on identifying these issues and prioritising action depending on risk level.

5 Conclusion and recommendations

The temporal decline in road-kill recorded in 2021 and 2022 was not evident in 2023, however, numbers remain substantially lower than 2019. In 2023, bandicoots were a major contributor to road-kill for species that the fauna fence should exclude. This result is likely due to higher abundance, ability to move through small gaps in the fence, especially around open drains, and suitable foraging habitat within the road corridor. During the five years of monitoring, most 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 minimising the number of fence ends. No modifications of exclusion fencing design, location or extent are recommended (Table 7), however, the records of road-killed koalas highlight the importance of ongoing fence inspections and maintenance to maximise effectiveness and reduce the likelihood of threatened species accessing the road corridor (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 five monitoring remains substantially lower than 2019.

Table 8: Recommendations based on findings of the year 5 operational phase road-kill monitoring program.

Number	Recommendation	Transport for NSW Response
1.	Ongoing inspection and maintenance of the exclusion fence by TfNSW road maintenance crews to ensure the risk of threatened species accessing the corridor is reduced.	Agreed.

5.1 Lessons learnt from road-kill monitoring

Five years of quarterly road-kill monitoring over a 19km section of the Pacific Highway has revealed several lessons that should be considered for future highway upgrade projects. Some key lessons include:

1. Fauna exclusion fence should be as continuous and extensive as possible with equivalent extents occurring on each side of a road. Design features to be avoided include short sections of fence, fencing on one side of a road only and uneven fence extents.
2. No exclusion fence will be 100% effective and some level of fauna vehicle strike should be expected particularly where fences cross open drains. Notwithstanding, all care and effort should be expended to minimise the number of drain crossings and ensure that open drains do not provide easy access to the road corridor.
3. Tall trees/shrubs >2m should not be planted or seeded within 3m of fauna fence. This is to reduce the damage to exclusion fence from falling shrubs and shrubs growing through the fence.
4. Avoid creating thick mulch bunds in areas inside the road corridor that are likely to be used by bandicoots. Forest or dense grass near forest abutting the fence represent potential bandicoot habitat.
5. Additional exclusion fence combined with grids should be considered to reduce vehicle strike at interchanges, particularly where koalas are likely to occur, noting that operational road traffic noise associated with grids will need to be considered.
6. Where suitable fill heights and road geometry exist, consider installing underpass structures at terminal points of fauna exclusion fencing to reduce the fence-end effect.
7. Maintenance of exclusion fence should be conducted in perpetuity, acknowledging that continued vegetation regrowth is likely to diminish the effectiveness of the exclusion fence over time.

6 References

Bond, A. R., & Jones, D. N. (2013). Roads and macropods: interactions and implications. *Australian Mammalogy, 36*(1), 1-14.

Carvalho, N. C., Bordignon, M. O. & Shapiro, J. T. (2014). Fast and furious: a look at the death of animals on the highway MS-080, southwestern Brazil. *Iheringia, Ser. Zool:* **104**, 43-49

Clancy, G. P. (2004). A survey of road-killed owls in north-eastern New South Wales. *Corella: **28,*** 89-92.

Clevenger, A. P., Chruszcz, B., & Gunson, K. E. (2001). Highway mitigation fencing reduces wildlife-vehicle collisions. *Wildlife society bulletin*, 646-653.

Department of the Environment and Energy (2017). *Draft recovery plan for the grey-headed flying-fox Pteropus poliocephalus*. Commonwealth of Australia.

Grilo, C., Reto, D., Filipe, J. & Ascensao, F. (2014). Understanding the mechanisms behind road effects: linking occurrence with road mortality in owls. *Animal Conservation:* **17,** DOI:10.1111/acv.12120

Klocker, U., Croft, D. B. & Ramp, D. (2006). Frequency and causes of kangaroo-vehicle collisions on an Australian outback highway. *Wildlife Research*: **33,** 5-15.

Loss, S. R., Will, T., & Marra, P. P. (2014). Estimation of bird-vehicle collision mortality on U.S. roads. *The Journal of Wildlife Management*: https://doi.org/10.1002/jwmg.721

McDonald, J. H. (2013). *Handbook of biological statistics*. Sparky House Publishing, Baltimore, Maryland.

Ogletree, K. A., & Mead, A. J. (2020). What roadkills did we miss in a driving survey? A comparison of driving and walking surveys in Baldwin County, Georgia. *Georgia Journal of Science*, *78*(2), 8.

Plante, J., Jaeger, J. A., & Desrochers, A. (2019). How do landscape context and fences influence roadkill locations of small and medium-sized mammals?. *Journal of environmental management*, 235, 511-520.

RMS (2018). *Warrell Creek to Nambucca Heads Stage 2 Ecological Monitoring Program*. Report prepared by NSW Roads and Maritime Services.

Rytwinski, T., Soanes, K., Jaeger, J. A., Fahrig, L., Findlay, C. S., Houlahan, J., ... & van der Grift, E. A. (2016*).* How effective is road mitigation at reducing road-kill? A meta-analysis. *PLoS one*, 11(11), e0166941.

Sadleir, R. M., & Linklater, W. L. (2016). Annual and seasonal patterns in wildlife road-kill and their relationship with traffic density. *New Zealand journal of zoology*, 43(3), 275-291.

Sandpiper Ecological (2019a). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2019*. Report prepared for Transport for NSW.

Sandpiper Ecological (2019b). *Escape structure monitoring – autumn 2019*. Letter report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2020). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2020.* Report prepared for Transport for NSW.

Sandpiper Ecological (2021). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2021.* Report prepared for Transport for NSW.

Sandpiper Ecological (2022). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – year four annual report 2022.* Report prepared for Transport for NSW.

Scheelings, T., F. & Frith, S. E. (2015). Anthropogenic factors are the major cause of hospital admission of a threatened species, the grey-headed flying-fox (Pteropus poliocephalus), in Victoria Australia. *PLos One:* **10,** e0133638

Song, J. S., Lee, K. J., Ki, K. S., & Jun, I. Y. (2011). The efficiency and improvement of the highway wild-life fences for decrease of mammals road-kill-In case of Manjong~ Hongchun section on Jungang highway. *Korean Journal of Environment and Ecology*, 25(5), 649-657.

Taylor, B. D., & Goldingay, R. L. (2004). Wildlife road-kills on three major roads in north-eastern New South Wales. *Wildlife Research*, 31(1), 83-91.

Vernes, K., & Pope, L. C. (2009). Reproduction in the northern brown bandicoot (*Isoodon macrourus*) in the Australian Wet Tropics. *Australian Journal of Zoology*, 57(2), 105-109.

Appendix A – Field data

Table A1: Road-kill summary of all fauna recorded to date during operational phase monitoring at WC2NH (2018-2023). * 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	Aut 23	Win 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	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	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	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	1	3	18
Australian white ibis	0	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	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	0	1	3
Little pied cormorant	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	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	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	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	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	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	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	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	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	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	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	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	0	1	25
Tawny frogmouth	1	3	1	2	0	6	0	4	0	1	0	1	1	1	1	0	0	0	1	0	1	1	0	25

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	Aut 23	Win 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	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	0	1	22
Forest kingfisher	1	0	0	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	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	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	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	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	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	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	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	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	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	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	0	0	1
White-faced heron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	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	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	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	0	1	5
Masked lapwing	0	0	0	0	0	0	1	0	0	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	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	0	0	1
Cormorant spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Raptor spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	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	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	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	Sum 23	Aut 23	Win 23	Total
Tyto spp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	3
Small bird	0	0	0	0	0	0	0	2	0	0	0	0	0	1	1	0	1	2	2	0	2	1	1	13
Medium bird	0	0	0	1	2	2	2	2	6	1	1	0	0	2	0	2	0	0	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	5	4	46
Total birds	53	8	22	17	18	16	13	25	16	11	8	9	10	12	8	11	6	14	4	2	11	10	14	318
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	0	0	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	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	1	0	18
Pteropus spp.	0	0	0	0	3	8	1	0	1	1	0	0	0	1	0	0	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	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	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	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	0	0	2
Koala *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Eastern grey kangaroo	0	0	0	3	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	6
Red-necked wallaby	0	0	6	0	8	2	8	3	7	1	8	3	1	1	4	2	1	0	3	3	1	0	2	64
Swamp wallaby	2	1	0	1	0	1	1	0	0	1	1	2	1	0	2	1	1	0	4	0	0	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	0	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	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	0	0	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	0	1	2
Bandicoot spp.	0	0	0	0	0	1	0	4	0	0	0	1	0	2	4	2	4	3	4	9	8	5	6	53
Chalinolobus spp. (microbat)	0	0	0	1	0	0	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	0	0	3

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	Aut 23	Win 23	Total
Swamp rat	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	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	4	2	18
Small mammal	0	0	0	0	2	0	0	0	0	0	1	0	1	3	0	0	0	1	0	0	1	1	0	10
Medium mammal	0	0	0	2	4	2	4	5	2	2	2	0	0	2	4	2	2	3	1	0	1	3	2	43
Large mammal	0	0	0	1	1	0	0	1	0	0	1	0	0	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	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	14	15	348
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	0	0	8
Carpet python	1	0	0	2	1	1	0	1	0	0	0	0	1	0	0	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	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	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	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	1	0	20
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	0	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	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	0	0	2
Lace monitor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Blackish blind snake	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Small eyed snake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	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	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	1	2	14
Lizard spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
Total reptiles	17	3	0	12	2	2	1	5	2	2	0	4	4	7	1	0	2	4	1	4	3	4	2	82
Frogs																								

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	Aut 23	Win 23	Total
Green tree frog	2	0	0	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	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	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	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	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	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	0	2
European fox	3	1	1	2	1	1	2	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	1	15
European hare	2	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	1	0	0	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	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	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	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	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	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	1	1	38
Grand total	**92**	**14**	**34**	**55**	**59**	**40**	**33**	**53**	**36**	**27**	**28**	**25**	**20**	**37**	**29**	**22**	**24**	**29**	**23**	**22**	**32**	**29**	**32**	**795**
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**	**0.37**	**0.41**	**0.44**

Table A2: Exclusion fence inspection notes, WC2NH (winter 2023).

Date	Observer	Issue number	Count	Easting	Northing	Issue type	Rating	Description	Action taken	Comments	Note if photos
20/07/2023	SM	1	1	496233	6608255	Tree overgrowth	Moderate =	Thin acacia growing over fence			Y
20/07/2023	SM	2	1	496201	6608221	Tree overgrowth	Moderate =	Small tree against fence			Y
20/07/2023	SM	3	1	496146	6608178	Tree overgrowth	Moderate =	Small acacia against fence plus more for 20m to the north			Y
20/07/2023	SM	4	1	496143	6608154	Structural integrity compromised	High =	Gate was open	Gate closed		N
20/07/2023	SM	5	1	496126	6608117	Tree overgrowth	High =	Trees over 100mm plus smaller growth for around 10m to north and 100m to south			Y

Date	Observer	Issue number	Count	Easting	Northing	Issue type	Rating	Description	Action taken	Comments	Note if photos
20/07/2023	SM	6	1	496038	6608035	Tree overgrowth	Moderate =	90mm tree against fence			Y
20/07/2023	SM	7	1	496023	6608018	Tree overgrowth	Moderate =	Small tree close to fence			Y
20/07/2023	SM	8	1	496002	6607995	Tree overgrowth	High =	100mm tree plus more for 50m south			Y
20/07/2023	SM	9	1	495661	6607523	Vegetation overgrowth	Low =	Patch of small eucalypts			Y
20/07/2023	SM	10	1	495568	6607305	Tree overgrowth	Moderate =	Small Eucalypts			Y
20/07/2023	SM	11	1	495446	6607097	Vegetation overgrowth	Low =	Patch of thin tea tree			Y
20/07/2023	SM	12	1	495401	6607007	Tree overgrowth	Moderate =	Small climbable trees against fence			Y
20/07/2023	SM	13	1	495363	6606935	Tree overgrowth	High =	Few bigger trees against fence, another one 10m to south			Y
20/07/2023	SM	14	1	495320	6606829	Vegetation overgrowth	Low =	Patch of small acacias on lean against fence			Y
20/07/2023	SM	15	1	495243	6606753	Fallen branches or trees	Low =	Large acacia tree fallen on fence from Hwy side		Branches not touching ground on my side	Y
20/07/2023	SM	16	1	495221	6606731	Tree overgrowth	Low =	Acacia with thin branches over fence, another 20m south			Y
20/07/2023	SM	17	1	495212	6606690	Tree overgrowth	Moderate =	Small climbable eucalypt through fence			Y
20/07/2023	SM	18	1	495229	6606638	Tree overgrowth	Moderate =	100mm eucalypt through fence, smaller one 5m south			Y
20/07/2023	SM	19	1	496691	6609460	Fallen branches or trees	High =	Tree fallen on fence, creating easy bridge over fence			Y
20/07/2023	SM	20	1	496987	6609773	Tree overgrowth	Moderate =	Couple of trees with branches overhanging fence			Y
20/07/2023	AE	21	1	492642	6600443	Vegetation overgrowth	Low =	dense growth from this point-300m N			
20/07/2023	AE	22	1	492743	6600604	Structural integrity compromised	Low =	Top of fence folded down			
20/07/2023	AE	23	1	495238	6606867	Tree overgrowth	Moderate =	Large branch over fence			
20/07/2023	AE	24	1	495295	6606969	Tree overgrowth	Moderate =	Large branch over fence			
20/07/2023	AE	25	1	495328	6607018	Tree overgrowth	Moderate =	Large branch over fence			
20/07/2023	AE	26	1	495353	6607069	Tree overgrowth	Moderate =	Large branch over fence			
20/07/2023	AE	27	1	495402	6607153	Vegetation overgrowth	Low =	Tall grass though fence and dense growth all under 100mm DBH. From this point back to culvert.			
20/07/2023	AE	28	1	495460	6607264	Vegetation overgrowth	Low =	Tall grass though fence and dense growth all under 100mm DBH. From this point north 200m			
20/07/2023	AE	29	1	495599	6607523	Vegetation overgrowth	Low =	Dense growth all under 100mm DBH. From this point north 50m			
20/07/2023	AE	30	1	495653	6607618	Vegetation overgrowth	Low =	Dense growth all under 100mm DBH. From this point north 200m			
20/07/2023	AE	31	1	495811	6607847	Vegetation overgrowth	Low =	Dense growth all under 100mm DBH. From this point north 25m			
20/07/2023	AE	32	1	495936	6608049	Structural integrity compromised	High =	Fauna fence missing ~25m north from this point		Appear to be stolen - entire	

Date	Observer	Issue number	Count	Easting	Northing	Issue type	Rating	Description	Action taken	Comments	Note if photos
										floppy top section missing	
20/07/2023	AE	33	1	496068	6608182	Vegetation overgrowth	Low =	Dense growth all under 100mm DBH. From this point north 200m			
20/07/2023	AE	34	1	497011	6609985	Vegetation overgrowth	Low =	Dense growth all under 100mm DBH. From this point north 100m			
20/07/2023	AE	35	1	497011	6609985	Vegetation overgrowth	Moderate =	50mm DBH tree growing through fence			
20/07/2023	AE	36	1	496881	6609878	Vegetation overgrowth	Low =	Dense growth all under 100mm DBH. From this point north 100m			
20/07/2023	AE	37	1	496575	6609481	Vegetation overgrowth	Low =	Dense growth all under 100mm DBH. From this point north 200m			
20/07/2023	AE	38	1	496661	6609616	Structural integrity compromised	Low =	Top of fence folded over horizontal to ground			
20/07/2023	NM	39	1	495054	6606383	Fallen branches or trees	High =	Couple of branches on fence			Y
20/07/2023	NM	40	1	495004	6606314	Tree overgrowth	Moderate =	Acacia tree overhanging fence			Y
20/07/2023	NM	41	1	494981	6606273	Fallen branches or trees	High =	Acacia trees fallen on fence with mat of grass			Y
20/07/2023	NM	42	1	494925	6606162	Tree overgrowth	Moderate =	Fallen acacia overhanging fence			Y
20/07/2023	NM	43	1	494909	6606133	Fallen branches or trees	High =	Fallen acacia on fence			Y
20/07/2023	NM	44	1	494859	6606042	Fallen branches or trees	High =	Multiple branches for 10mS			Y
20/07/2023	NM	45	1	494811	6605957	Fallen branches or trees	Moderate =	Branch fallen on fence	Branch removed		N
20/07/2023	NM	46	1	494802	6605948	Fallen branches or trees	Moderate =	Branch fallen on fence	Branch removed		N
20/07/2023	NM	47	1	494670	6605664	Vegetation overgrowth	Low =	Grass engulfing fence for 200mN			Y
20/07/2023	NM	48	1	494608	6605536	Tree overgrowth	Moderate =	Fallen acacia tree overhanging fence			Y
20/07/2023	NM	49	1	494508	6604979	Fallen branches or trees	High =	Multiple branches on fence			Y
20/07/2023	NM	50	1	494501	6604897	Fallen branches or trees	Moderate =	Fallen acacia from hway side			Y
20/07/2023	NM	51	1	494495	6604846	Tree overgrowth	High =	Acacia growing over fence			Y
20/07/2023	NM	52	1	494494	6604901	Tree overgrowth	High =	Acacia growing over fence			Y
20/07/2023	NM	53	1	496498	6609080	Fallen branches or trees	High =	Acacia fallen on fence			Y
20/07/2023	NM	54	1	496477	6608891	Fallen branches or trees	High =	Fallen branch on fence			Y
20/07/2023	NM	55	1	496378	6608615	Fallen branches or trees	Moderate =	Fallen branch on fence	Branch removed		N
20/07/2023	NM	56	1	497255	6610221	Fallen branches or trees	High =	Fallen branches on fence			Y
20/07/2023	NM	57	1	497437	6610598	Tree overgrowth	Moderate =	Fallen acacia overhanging fence			Y
20/07/2023	NM	58	1	497441	6610723	Structural integrity compromised	High =	2 holes in fence, potential for young koala to fit through, not adult			Y
20/07/2023	NM	59	1	497406	6610941	Structural integrity compromised	High =	Gate open	Closed gate, but no		Y

OFFICIAL

Date	Observer	Issue number	Count	Easting	Northing	Issue type	Rating	Description	Action taken	Comments	Note if photos
									useable padlock to lock		
20/07/2023	NM	60	1	497406	6611053	Vegetation overgrowth	High =	Branch and thick mat grass over fence, multiple places for 20m north of point			Y
20/07/2023	NM	61	1	497431	6611089	Fallen branches or trees	Moderate =	Acacia tree fallen on fence - moderate size			Y
20/07/2023	LA	62	1	496553	6608917	Tree overgrowth	High =	Moderate acacia regrowth 100m north and south			Y
20/07/2023	LA	63	1	496581	6609158	Tree overgrowth	Moderate =	3 x eucalyptus spp with dbh of 60mm potential climb point			Y
20/07/2023	LA	64	1	497459	6610355	Tree overgrowth	Moderate =	acacia growing up through fence dbh 60mm			Y
20/07/2023	LA	65	1	497498	6610484	Tree overgrowth	Moderate =	Thick heavy acacia regrowth 80m north			Y
20/07/2023	LA	66	1	497531	6610689	Tree overgrowth	High =	Large acacia abutting fence dbh 150mm		Easy access point	Y
20/07/2023	LA	67	1	497535	6610719	Vegetation overgrowth	Moderate =	thick.matt grass and acacia limbs and branches laying on fence all the way to railway line 300m North			Y
20/07/2023	LA	68	1	497539	6610734	Tree overgrowth	High =	Large acacia leaning over fence dbh 15cm			Y
20/07/2023	LA	69	1	494431	6604791	Tree overgrowth	High =	Eucalyptus 100mm dbh growing next to fence			Y
20/07/2023	LA	70	1	494437	6605058	Tree overgrowth	High =	Euc 100mm dbh growing onto fence			Y
20/07/2023	LA	71	1	494447	6605146	Tree overgrowth	Moderate =	acacia 60mm dbh growing through fence			Y
20/07/2023	LA	72	1	494458	6605161	Vegetation overgrowth	Moderate =	Eucalyptus 80mm growing through fence also gahnia thick 100m north			Y
20/07/2023	LA	73	1	494486	6605300	Vegetation overgrowth	Moderate =	thick acacia and gahnia regrowth 200m north			Y
20/07/2023	LA	74	1	494486	6605316	Tree overgrowth	High =	2 x eucalyptus 100mm dbh growing through and over the fence			Y
20/07/2023	LA	75	1	494564	6605558	Vegetation overgrowth	Moderate =	Thick matt grass and moderate acacia over growth to c3			Y
20/07/2023	LA	76	1	496516	6608757	Tree overgrowth	Moderate =	50mm dbh eucalyptus growing through fence			Y
20/07/2023	LA	77	1	496520	6608815	Tree overgrowth	High =	2 x eucalyptus 100mm dbh growing over fence			Y