Oxley Highway to Kempsey EPBC 2012/6518

Condition 8 Annual Report 2020

Transport for NSW (TfNSW) | October 2020

Document control

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Revision history

Revision	Date	Description	Approval
1	October 2020	Final	TfNSW

Contents

1 Introduction

1.1. Purpose of this document

The purpose of this report is to address EPBC (2012/6518) Approval Condition 8, which requires the preparation of a report addressing compliance with each of the conditions of approval, including implementation of the:

- Biodiversity Offset Management Plan (BOMP)
- Flora and Fauna Management Plans (FFMP)
- Ecological Monitoring Plan (EMP).

This report covers the sixth period from 22 July 2019 to 21 July 2020.

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

- Date of the approval decision under sections 130(1) and 133 of the *Environment Protection and Biodiversity Conservation Act 1999* – 24 January 2015
- Commencement of the action – 22 July 2014
- Expiry of Commonwealth approval – 31 December 2063

1.2. Project staging

The Oxley Highway to Kempsey Pacific Highway Upgrade project has been constructed in three main stages:

- Stage 1: The Sancrox Traffic Arrangement works located about two kilometers north of the Oxley Highway / Pacific Highway intersection. Note that the construction of Stage 1 was completed in November 2015
- Stage 2: Kundabung to Kempsey (K2K) consisting of about 14 kilometers of dual carriageway, commencing north of Barrys Creek near Kundabung (chainage 24,000) and connecting to the Kempsey Bypass at Stumpy Creek (Chainage 37,800). Note that construction of Stage 2 was completed in October 2017
- Stage 3: Oxley Highway to Kundabung (OH2Ku) consisting of about 24 kilometres of dual carriageway, commencing just north of the Oxley Highway / Pacific Highway intersection (chainage 700) and connecting with the Kundabung to Kempsey stage just north of Barrys Creek (chainage 24,000). Note construction of Stage 3 was completed in March 2018.

In addition, there is an ultimate upgrade to the four lane Class M (motorway) standard highway. Due to estimated traffic volumes and availability of funding some sections of the Project will initially be constructed and operated as a Class A (arterial) standard highway. Upgrade of those sections of the Project from Class A to Class M standard will occur when it is warranted by an increase in traffic volumes, and when funding becomes available.

1.3. Modifications to the Conditions of Approval

No modifications to the Conditions of Approval were approved during this reporting period.

2 Conditions of Approval

2.1. Condition 1

Condition 1

The person taking the action must not clear more than 211 hectares of Koala (*Phascolarctos cinerea)* habitat, 232 hectares of Grey-headed Flying-fox (*Pteropus poliocephalus*) habitat, 215 hectares of Spotted-tail Quoll (*Dasyurus maculatus*) habitat and 7.7 hectares of Giant-Barred Frog (*Mixophyes iteratus*) habitat within the project corridor of the proposed action.

Clearing for the three initial stages of the project (refer Section 1.2) is now complete. The clearing quantities for the first three stages against the limits outlined in Condition 1 are detailed in Table 1.

Table 1 Clearing quantities for the first three stages of the project

EPBC Species	Total estimated clearing	Total clearing	EPBC Limit Condition 1
Koala	196.8284	196.7656	211
Grey-headed flying fox	206.9144	206.8258	232
Spotted-tail Quoll	197.0330	196.2896	215
Giant-barred Frog	2.8512	2.8512	7.7

2.2. Condition 2

Condition 2

To assist in mitigating the impacts of the proposal on the Koala, Grey-headed Flying-fox, Spotted-tail Quoll and the Giant-Barred Frog during construction, the person taking the action must prepare and submit a Flora and Fauna Management Plan for each **stage** of the action, for the **Minister**'s written approval prior to **commencement** of each **stage** of the action. The Flora and Fauna Management Plan for each **stage** must be approved by the **Minister** in writing prior to **commencement** of the relevant **stage**. These plans must include:

- **a.** Measures to be implemented to avoid, suppress and control the spread of weeds, plant pathogens and invasive species;
- **b.** Measures to avoid and minimise other indirect impacts that may result from the proposal during and after construction, including erosion and sedimentation;
- **c.** Measures to manage aquatic habitat on-site to at least maintain habitat values for the Giant Barred Frog;
- **d.** A detailed description of the pre-clearance surveys to be undertaken by a **suitably qualified expert** within all areas proposed for disturbance, including: hollow bearing trees, logs, existing culverts and bridges, no earlier than 48 hours prior to the removal of vegetation occurring in that area to ensure that the area is free of the Koala, Giant-Barred Frog, Grey-headed Flying-fox and Spotted-tail Quoll.

Condition 2

e. Measures to relocate and/or ensure the **appropriate care of** individuals of the Koala, Giant-Barred Frog, Grey-headed Flying-fox and Spotted-tail Quoll that are identified during searches referred to in condition 2d; and

f. Clear key milestones, monitoring, performance indicators, corrective actions and timeframes for the completion of all actions outlined in the plan.

A Flora and Fauna Management Plan has been prepared for each stage of the project. As at 21 July 2020, these plans were approved by the Minister on the following dates:

- Stage 1: Sancrox Interchange — 24 June 2014
- Stage 2: Kundabung to Kempsey — 22 October 2014 (Revision 1); 15 November 2016 (Revision 2); 22 August 2019 (Revision 3)
- Stage 3: Oxley Highway to Kundabung — 10 October 2014 (Revision 1); 15 November 2016 (Revision 2); 22 August 2019 (Revision 3)

Construction of these three stages was completed during the 2017/18 reporting period, along with a majority of requirements of each Flora and Fauna Management Plan. The Ecological Monitoring Program (Appendix to the Flora and Fauna Management Plan) continues to be implemented, and is reported on below in Condition 4.

2.3. Condition 3

Condition 3

To assist in mitigating the impacts of the proposal on the Koala, Spotted-tail Quoll and the Giant-Barred Frog, the person taking the action must construct and maintain **fauna crossings** and **fencing** in all **areas that are likely to benefit** these species for the duration of the impact of the action.

a. The **fauna crossings** must:
   - **i.** be **effective** for the Koala, Spotted-tail Quoll and/or Giant Barred Frog (the relevant species targeted to use the **fauna crossing**);
   - **ii.** provide dry passage up to a 1 in 100 year Average Recurrence Interval (ARI) event for **dedicated fauna crossings** and up to a one in 1 year 72 hour ARI event for **combined fauna crossings**;
   - **iii.** include a minimum of 11 **dedicated fauna crossings** and 30 **combined fauna crossings** for the project;
   - **iv.** not increase in length more than 10 per cent from the lengths provided in Schedule 2 of this notice, and not reduce in width and height from the values provided in Schedule 2 of this notice without the written consent of the **Minister**;
   - **v.** be bridges in **areas that are likely to benefit** the Giant-Barred Frog.

b. If a change to the **fauna crossing** design is proposed that does not meet the parameters described in Condition 3a), the person taking the action must:
   - **i.** provide evidence to the **Minister** that these will remain **effective** for the Koala, Spotted-tail Quoll or Giant-Barred Frog

Condition 3

(as relevant for the **fauna crossing**) for the **Minister's** written approval prior to **commencement** of the **stage** relevant to that fauna crossing; or

ii. provide written evidence to the **Minister** detailing how the resulting loss in connectivity will be compensated for with increased connectivity for the impacted species. This must be approved in writing by the **Minister,** prior to **commencement** of **stage 2** and **stage 3**.

c. **Fencing** must be constructed at a minimum the locations identified in Schedule 3 of this notice.

The requirements of this condition were completed during the last reporting period (2017/18). Please refer to the 2017/18 report for further detail on compliance with this condition.

2.4. Condition 4

Condition 4

Prior to **commencement of stage 2** and **stage 3** of the action**,** the **person taking the action** must submit an Ecological Monitoring Program for approval by the **Minister** that determines the effectiveness of the mitigation measures implemented as part of the project. The Ecological Monitoring Program must be approved in writing by the **Minister** prior to **commencement** of **stage 2** and **stage 3,** and must include:

a. The baseline data collected from surveys undertaken by a **suitably qualified expert** on the Koala, Spotted-tail Quoll and Giant-Barred Frog within all habitat areas outside areas to be cleared of vegetation for the proposed action, that are likely to contain these species and that are likely to be adversely impacted by the action (as determined by a **suitably qualified expert**).The data must address the densities, distribution, habitat use and movement patterns of these species;

b. The methodology to be implemented for the ongoing monitoring of road kill, the species densities, distribution, habitat use and movement patterns, and the use of **fauna crossing** during construction and operation of the action, including the timing, and duration of the methodology;

c. Goals and performance indicators to measure the success of proposed **fauna crossings**, which must be specific, measureable, achievable, realistic and timely (SMART), and be compared against baseline data described in condition 4a)

d. Details of contingency measures that would be implemented in the event of changes to densities, distribution, habitat use and movement patterns that are attributable to the construction or operation of the project.

Monitoring must continue until mitigation measures can be demonstrated to have been **effective** for the Koala, Spotted-tail Quoll, and Giant-Barred Frog.

Should monitoring associated with this condition demonstrate that the use of **fauna crossings** and/or **fencing** is not achieving its intended purpose or is having a detrimental effect upon Koala, Spotted-tail Quoll, and Giant-Barred Frog (as determined by **the Minister**), **the Minister** may require that the person taking the action implement alternative forms of mitigation and/or corrective actions to address the relevant impacts to Koala, Spotted-tail Quoll, and Giant-Barred Frog,. Such measures must be implemented as requested.

The Ecological Monitoring Program for the project was submitted to the Minister in a letter dated 29 April 2014 and approved by the Minister on 10 October 2014. Commencement dates for Stage 2 and Stage 3 were early to mid-November 2014.

An updated Ecological Monitoring Program for the project was submitted to the Minister on 3 May 2016 and approved by the Minister on 11 November 2016.

A third revision of the Ecological Monitoring Program for the project was submitted to the Minister on 3 April 2019 and approved by the Minister on the 22 August 2019.

The compliance status of the implementation of the Ecological Monitoring Program is detailed in Appendix A.

2.5. Condition 5

Condition 5

To compensate for the loss of 240 hectares of threatened species habitat the person taking the action must prepare and submit a Biodiversity Offset Management Plan (**BOMP**) for the **Minister's** written approval within 12 months of approval of the action. The BOMP must be approved in writing by the **Minister** within 12 months of approval of the action. The **BOMP** must include:

a. the identification of the portions of the lands described as the "Proposed Biodiversity Offset Areas" in the Map at Schedule 1 of this notice that are necessary to achieve the outcomes required by the *Environmental Offsets Policy 2012* (or subsequent published revisions). This must include **offset attributes**, **shapefiles**, textual descriptions and maps to clearly define the location and boundaries of the offset area(s);

b. the results of targeted field surveys within the offset sites (undertaken at any ecologically appropriate time of the year) to assess and describe habitat suitability and presence / absence of individuals in relation to the Koala, Grey-headed Flying-fox, Spotted-tail Quoll and Giant Barred frog;

c. an assessment of the baseline population for the Koala, Spotted-tail Quoll, Giant-Barred Frog, and Grey-headed Flying-fox which are detected within the offset area during field surveys;

d. a description of the current **quality** (prior to any management activities) of the offset area(s) identified in Condition 5a with reference to the Koala, Spotted-tail Quoll, Giant-Barred Frog, and Grey-headed Flying-fox;

e. an assessment demonstrating how the offset area(s) achieve the outcomes required by the *Environmental Offsets Policy 2012* (or subsequent published revisions) and user guide;

f. Should the offset sites identified in 5a not be sufficient to achieve the outcomes required by the *Environmental Offsets Policy 2012* (or subsequent published revisions) and user guide, as determined in writing by the **Minister**, the person taking the action must provide further suitable offset sites and include these as part of the **BOMP**;

g. information about the Koala, Grey-headed Flying-fox, Spotted-tail Quoll, Grey-headed Flying-fox, and Giant Barred frog (in relation to ecology, biology and conservation status) to inform appropriate management actions;

h. targeted management actions, regeneration and revegetation strategies to be undertaken on the offset area(s) to improve the ecological quality of these areas for the Koala, Grey-headed Flying-fox, Spotted-tail Quoll and Giant Barred frog

Condition 5

i. clear performance objectives for management actions 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 Koala, Spotted-tail Quoll, Giant-Barred Frog, and Grey-headed Flying-fox onsite;

j. anticipated timeframes for achieving performance objectives.

k. performance and completion criteria for evaluating the management of the 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;

l. a program to monitor and report on the effectiveness of these measures, and progress against the performance and completion criteria;

m. details of who would be responsible for monitoring, reviewing, and implementing the **BOMP**.

n. a description of funding arrangements or agreements including work programs and responsible entities;

The approved **BOMP** must be published on the NSW Roads and Maritime Services internet web site, within 1 month of the BOMP being approved.

The approved BOMP must be implemented.

The BOMP was submitted to the Department of the Environment for the approval of the Minister in a letter dated 16 January 2015. Approval from the Minister remains outstanding.

2.6. Condition 6

Condition 6

If an offset site proposed as a part of Condition 5 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 measures required for a separate approval cannot be considered a part of the offset, in accordance with the *Environmental Offsets Policy 2012* (or subsequent published revisions).

This requirement has been noted as part of the preparation of the BOMP, required under Condition 5.

2.7. Condition 7

Condition 7

Within 12 months of approval of the Biodiversity Offset Management Plan (BOMP), the person taking the action must secure the offset area(s) identified in Condition 5a), under relevant conservation legislation. The legal instrument chosen must be registered on title, and must prevent any future development activities from occurring on the land protected, and ensure the active management of that land for the better protection of matters of national environmental significance for the duration of the impact of the action. Evidence of compliance with this condition must be provided to the **Department** within 30 days after the land(s) have been secured.

Approval from the Minister of the BOMP remains outstanding; as such compliance with this condition is not yet applicable.

2.8. Condition 8

Condition 8

Within three months of every 12 month anniversary of the **commencement** of the action, the person taking the action must publish a report on their website addressing compliance with each of the conditions of this approval, including implementation of the BOMP, Flora and Fauna Management Plans and Ecological Monitoring Plan as specified in the conditions. Documentary evidence providing proof of the date of publication must be provided to the **Department** at the same time as the compliance report is published. Noncompliance with any of the conditions of this approval must be reported to the **Department** within 2 business days of becoming aware of the non-compliance. At any time within the life of this approval the **Minister** may agree, in writing, that further reporting is not required if compliance with all requirements has been demonstrated to the **Minister's** satisfaction.

This report has been prepared to satisfy the requirements of this condition. Evidence of the date of publication will be provided to the Department when this report is published on the Roads and Maritime project website.

The BOMP was submitted to the Department of the Environment for the approval of the Minister in a letter dated 16 January 2015. Approval from the Minister remains outstanding.

Following recent consultation with the Department, Roads and Maritime is prepared to resubmit the BOMP in Q4 of 2020.

A Flora and Fauna Management Plan has been prepared for each stage of the project. As at 21 July 2020, these plans were approved by the Minister on the following dates:

- Stage 1: Sancrox Interchange — 24 June 2014
- Stage 2: Kundabung to Kempsey — 22 October 2014 (Revision 1); 15 November 2016 (Revision 2); 22 August 2019 (Revision 3)
- Stage 3: Oxley Highway to Kundabung — 10 October 2014 (Revision 1); 15 November 2016 (Revision 2); 22 August 2019 (Revision 3)

Construction of Stage 1 was completed in November 2015. Construction of Stage 2 and Stage 3 was completed in October 2017 and March 2018 respectively.

With the exception of the Ecological Monitoring Programs included as Appendices, the Flora and Fauna Management Plans are construction documents and were closed out in the Annual Report submitted to the July 2017 - July 2018 reporting period.

Details of the implementation of the Ecological Monitoring Plan is provided in Section 2.

All previous reports, and this report once published, can be found at the following link:

https://www.pacifichighway.nsw.gov.au/document-library/oxley-highway-to-kempsey-upgrade-epbc-compliance-reports

2.9. Condition 9

Condition 9

Within 30 days after the **commencement** of the action, the person taking the action must advise the **Department** in writing of the actual date of **commencement**.

In a letter to the Department, dated 19 August 2014, Roads and Maritime advised the Department of the actual date of commencement, being 22 July 2014.

2.10. Condition 10

Condition 10

The person taking the action must maintain accurate records substantiating all activities associated with or relevant to these conditions of approval, including measures taken to implement the **BOMP,** Ecological Monitoring Plan and Flora and Fauna Management Plans, and make them available upon request to the **Department**. Such 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.

TfNSW is maintaining accurate records for all activities relating to the conditions of approval, and the implementation of the BOMP, EMP and FFMPs. The potential audit by the Department is noted.

2.11. Condition 11

Condition 11

Upon the direction of the **Minister**, the person taking the action must ensure that an independent audit of compliance with the conditions of approval is conducted and a report submitted to the **Minister**. The independent auditor must be approved by the **Minister** prior to the **commencement** of the audit. Audit criteria must be approved by the **Minister** and the audit report must address the criteria to the satisfaction of the **Minister**.

The requirements of this condition are noted. A direction from the Minister under Condition 11 has not been received by TfNSWduring this reporting period.

2.12. Condition 12

Condition 12

1. If the person taking the action wishes to carry out any activity otherwise than in accordance with the **BOMP**, Ecological Monitoring Plan and Flora and Fauna Management Plans as specified in the conditions, the person taking the action must submit to the **Department** for the **Minister's** written approval a revised version of that

Condition 12

Plan. The varied activity shall not commence until the **Minister** has approved the varied Plan in writing. The **Minister** will not approve a varied Plan unless the revised Plan would result in an equivalent or improved environmental outcome over time. If the **Minister** approves the revised Plan, that Plan must be implemented in place of the Plan originally approved.

Roads and Maritime submitted an update to the Ecological Monitoring Plan to the Department for approval on 3 May 2016. The updated Ecological Monitoring Plan was also an appendix of the approved Kundabung to Kempsey and Oxley Highway to Kundabung Flora and Fauna Management plans. The EMP and FFMP updates were approved by the Minister on 15 November 2016.

A third revision of the Ecological Monitoring Program for the project was submitted to the Minister on 3 April 2019 and approved by the Minister on the 22 August 2019

The BOMP has not yet been approved by the Department, and therefore the requirements of this condition are not yet applicable to this plan.

2.13. Condition 13

Condition 13

1. If the **Minister** believes that it is necessary or convenient for the better protection of listed threatened species and ecological communities to do so, the **Minister** may request that the person taking the action make specified revisions to the **BOMP**, Ecological Monitoring Plan and Flora and Fauna Management Plans, as specified in the conditions and submit the revised **BOMP**, Ecological Monitoring Plan and Flora and Fauna Management Plans for the **Minister's** written approval. The person taking the action must comply with any such request. The revised approved **BOMP**, Ecological Monitoring Plan and Flora and Fauna Management Plans must be implemented. Unless the **Minister** has approved the revised **BOMP**, Ecological Monitoring Plan and Flora and Fauna Management Plans then the person taking the action must continue to implement the **BOMP**, Ecological Monitoring Plan and Flora and Fauna Management Plans originally approved.

Noted.

No requests from the Minister under Condition 13 were received by TfNSW in this reporting period.

2.14. Condition 14

Condition 14

If, at any time after 5 years from the date of this approval, the person taking the action has not **substantially commenced** the action, then the person taking the action must not substantially commence the action without the written agreement of the **Minister**.

Commencement of the action occurred on 22 July 2014.

2.15. Condition 15

Condition 15

Unless otherwise agreed to in writing by the **Minister**, the person taking the action must publish all plans referred to in these conditions of approval on their website. Each plan must be published on the website within 1 month of being approved.

The Flora and Fauna Management Plans for each stage are published at

- https://www.pacifichighway.nsw.gov.au/document-library/sancrox-traffic-arrangement-flora-and-fauna-management-sub-plan
- https://www.pacifichighway.nsw.gov.au/document-library/oxley-highway-to-kundabung-upgrade-construction-environmental-management-plan-0
- https://www.pacifichighway.nsw.gov.au/document-library/kundabung-to-kempsey-upgrade-construction-environmental-management-plan

The Ecological Monitoring Program and reports are published at

- https://www.pacifichighway.nsw.gov.au/document-library/oxley-highway-to-kempsey-upgrade-ecological-monitoring-program-and-reports

3 Ecological Monitoring Plan

Table 2 outlines the monitoring requirements from the Ecological Monitoring Plan, relevant to matters of National Environmental Significance that were required to be conducted during the last reporting period.

This monitoring was conducted in accordance with the timing requirements outlined in Table 2. The reports including the results of these monitoring events and evaluation of the project's compliance with the performance indicators, have been included in Appendix A.

In some instances, monitoring of a particular species or mitigation measure requires several monitoring events throughout the year. In these instances it is considered more informative to wait until all monitoring events have been conducted for that year, before reporting on the results. This allows analysis between seasons, further statistical analysis, etc to be conducted than if individual monitoring events are reported on.

Table 2 highlights monitoring completed to date, yet to be completed and the reports included as part of this Annual Compliance Report 2020.

Table 2 Ecological monitoring completed to date, yet to be completed and reports included in Annual Compliance Report 2020.

Species monitored	Timing	Done/ yet to be done	Reporting
Koala	Spring/Summer	Year 3 monitoring (2017) completed. Year 4 monitoring (2018) completed. Year 5 monitoring undertaken in spring 2019 and summer 2019/20. Year 6 monitoring scheduled for spring 2020 and summer 2020/21. Year 8 monitoring scheduled for spring 2022 and summer 2022/2023.	Year 5 monitoring included in this report Appendix A
Spotted-tail Quoll	Autumn/winter	Year 4 monitoring (2018) completed. Year 6 monitoring undertaken in autumn/winter 2020. Year 8 monitoring scheduled for autumn/winter 2022.	Year 6 monitoring included in this report. Appendix A Report includes recommendation relating to proposed changes to the monitoring methodology for Year 8.
Giant Barred Frog	Spring, Summer and Autumn	Year 3 monitoring (2017/18) completed. Year 4 monitoring (2018/19) completed.	Year 5 monitoring included in this report Appendix A

Species monitored	Timing	Done/ yet to be done	Reporting
		Year 5 monitoring undertaken in spring 2019, summer 2019/20 and autumn 2020. Year 6 monitoring scheduled for spring 2020, summer 2020/21and autumn 2021. Year 7 monitoring scheduled for spring 2021, summer 2021/22and autumn 2022 Year 8 monitoring scheduled for spring 2022, summer 2022/23.	
Road kill	Weekly during October (spring), January (summer) and April (autumn) in Year 4, 5, 6 and 8	Construction / post opening – July 2017 – June 2018 completed. Year 4 monitoring (2018/19) completed. Year 5 monitoring October 2019, January 2020 and April 2020 completed Year 6 monitoring scheduled for October 2020, January 2021 and April 2021 Year 8 monitoring scheduled for October 2022, January 2023 and April 2023	Year 5 monitoring included in this report Appendix A
Fauna underpasses & fauna fencing	Autumn and spring/summer year 4, 6 and 8	Year 4 monitoring (2018/19) completed. Year 6 monitoring scheduled for late autumn 2020, late spring /early summer 2020 Year 8 monitoring scheduled for late autumn 2022, late spring /early summer 2022	Year 6 to be included in the next Annual report (2020/21).

Table 3 lists the title of each of the monitoring reports where each of the EPBC reporting requirements in Table 2 have been addressed. These reports are available in Appendix A.

Table 3 EPBC monitoring reports in Appendix A

Species / aspects monitored	Report title in Appendix A
Koala (spring 2019 and summer 2019/20) Year 5 monitoring	Koala Monitoring 2019
Giant Barred Frog (spring, summer and autumn) Year 5 monitoring	Giant Barred Frog Monitoring 2019/20
Road kill monitoring (October 2019, January 2020 and April 2020) Year 5 monitoring	Road kill Monitoring 2019/20
Spotted Tailed Quoll (autumn/winter 2020) Year 6 Monitoring	Spotted Tailed Quoll Monitoring 2020

All the Ecological Monitoring Program performance measures for the monitoring events listed in Table 3 were met for the 2019/20 reporting period, except for the following, which were not found to be attributed to the project:

Giant Barred Frog: The performance measure relating to continued presence of Giant Barred Frogs during each survey event where it was identified during baseline surveys was met for 3 of the six sites. Giant Barred Frogs were not recorded at Cooperabung Creek impact site, where it was recorded during all three baseline surveys. Not recorded at Maria River impact during summer 2020, where it was recorded during baseline surveys and not recorded at Cooperabung Creek reference site during spring 2019, where it was detected during baseline surveys.

Due to lower than average rainfall and reduced records at all sites (impact and reference) it is recommended that monitoring continue as per the EMP.

Giant Barred Frog: The performance measure relating to change to densities, distribution, habitat use and movement patterns compared to baseline data during monitoring in Year 1 – 8.
The number and location of Giant Barred Frogs recorded varied between season and year at all sites. All sites appear to show an overall decreasing trend in mean records and densities. However, as this decreasing trend is evident at both impact and reference sites, it is not possible to attribute these changes to the Project at this stage. The low number of records obtained in 2019/2020 may reflect the relatively dry conditions as a result of below average rainfall for the preceding 10 months.

Within-year movement patterns that would permit comparison between baseline and subsequent monitoring events is not possible due to lack of data (surveys and captures are too infrequent), however, assessment of movement patterns of recaptured individuals over all surveys show that 31% of recaptured frogs have been found to traverse from one side of the carriageway to the other.

As highlighted above in Table 2, the Spotted Tailed Quoll (autumn/winter 2020) Year 6 Monitoring report includes a recommendation proposing changes to the current monitoring methodology for Year 8. TfNSW, working in consultation with the EPA, will update the current EMP (version 3 – August 2019) to include specifics relating to the revised monitoring program, which will be submitted to DPIE and DAWE for approval.

Appendix A: Ecological Monitoring Program Reports

Species / mitigation monitored	Report title
Koala	Koala Monitoring 2019
Giant Barred Frog	Giant Barred Frog Monitoring 2019/20
Fauna Fence and Road kill	Road kill Monitoring 2019/20
Spotted Tailed Quoll	Spotted Tailed Quoll Monitoring 2020

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Environment and Heritage

Koala Monitoring 2019

Year 5 Surveys – Oxley Highway to Kempsey, Pacific Highway Upgrade

Prepared for Transport for NSW

June 2020

Document control

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Project Manager:	Radika Michniewicz
Authors:	Jodie Danvers, Radika Michniewicz
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Local Government Area:	Port Macquarie-Hastings and Kempsey

Author	Revision	Internal review	Date Issued
Jodie Danvers	D1	Radika Michniewicz	1/06/2020
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Radika Michniewicz	R0		23/06/2020
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Cover photograph: Koala recorded in Maria River State Forest during Spotted-tailed Quoll Monitoring.

Executive Summary

Context

This report documents findings from the spring-summer 2019 monitoring period for the Koala, as required for the Oxley Highway to Kempsey (OH2K) Pacific Highway Upgrade Project (the Project).

Aims

The aim of the Koala monitoring program is to determine whether the Project is having an impact on Koala populations within the study area.

Methods

Each monitoring location was surveyed in accordance with the monitoring method and design specified in the Oxley Highway to Kempsey Pacific Highway Upgrade Ecological Monitoring Program (EMP, RMS 2019). Monitoring involved Spot Assessment Technique (SAT) plots and spotlighting. Surveys were undertaken in October, November and December 2019 and January 2020.

Key Results

- A total of 89 plots across 31 clusters were surveyed in spring-summer 2019. Koalas were found to be present within 23 of the 31 clusters (74%). This is higher than 2015, 2016, 2017 and 2018 surveys (45%, 37%, 52% and 52% respectively), but lower than the 83% recorded during baseline surveys.
- The mean SAT activity level for all plots, measured as the percentage of trees at each plot with scats present, was 3.3% and ranged from 0 to 23.3%. This is higher than the mean activity recorded for plots during 2015, 2016, 2017 and 2018 surveys (2.0%, 0.7%, 1.8% and 2.5% respectively), but lower than the mean activity during baseline surveys (4.9%).
- Koalas were recorded more frequently at impact sites (87%) than at control sites (63%), which is consistent with results observed in the previous monitoring events.
- Koalas have been recorded using three of the fourteen culverts (located within the vicinity of the monitoring sites) being monitored as part of the Fauna Underpass Monitoring for the Project.
- There was no significant change in the difference between Koala presence at control and impact clusters between 2019 and baseline surveys.
- There was no significant change in the difference between Koala presence at clusters with and without mitigation between 2019 and baseline surveys.
- Average plot activity levels for each treatment type have not decreased from the baseline surveys beyond the recommended 10% tolerance level.

Conclusions

- Performance measures relating to survey requirements have been met.
- Fauna fence has been installed as required by Schedule 3 of the EPBC approval.
- Performance measures relating to habitat use and movement have been met.
- The performance measure relating to density has been met at Cairncross State Forest impact site. Limited survey effort due to high fire risk Park closures precluded the assessment of this parameter at all other sites.

Management Implications

As no significant changes in Koala presence and activity levels from baseline surveys have been detected to date, and as Koalas have been detected using three dedicated fauna underpasses within the Project area, no additional mitigation recommendations have been made at this time.

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1. Introduction

1.1 Context

The Oxley Highway to Kempsey (OH2K) section of the Pacific Highway Upgrade Project (the Project) was approved in 2012 subject to various Ministers Conditions of Approval (MCoA) and a Statement of Commitments (SoC). A subsequent approval with additional conditions of consent (CoA) was granted in 2014 by the then Commonwealth Department of Environment (DoE) for Matters of National Environmental Significance (MNES) listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1995* (EPBC Act). The Ecological Monitoring Program (hereafter referred to as the EMP) (RMS 2019) combines these approval conditions and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project. The Koala was identified as requiring mitigation and monitoring during the Project's construction and operational periods.

1.1.1 Legal status

The Koala (*Phascolarctos cinereus*) is listed as vulnerable under both the NSW *Biodiversity Conservation Act* (BC Act 2016) and the Commonwealth EPBC Act. Monitoring of the species is required under the Project's approval.

1.1.2 Monitoring framework

The design, methods and performance indicators that define the Koala monitoring program are specified in the EMP. The monitoring program specifies that monitoring of all sites would occur in Years 1, 2 and 3 (construction phase) once substantial construction had commenced. Following the completion of the Project, monitoring was to continue in Years 4, 5, 6 and 8 (operation phase) or until the mitigation measures can be demonstrated to have been effective for the Koala.

To date, these monitoring events have been conducted and reported on as follows:

- Spring-summer 2015: *Koala Monitoring. Year 1 surveys - Oxley Highway to Kempsey Pacific Highway Upgrade* (Niche 2016a)
- Spring- summer 2016: *Koala Monitoring 2016. Year 2 surveys - Oxley Highway to Kempsey Pacific Highway Upgrade* (Niche 2017a)
- Spring-summer 2017: *Koala Monitoring 2017. Year 3 surveys - Oxley Highway to Kempsey Pacific Highway Upgrade* (Niche 2018a)
- Spring-summer 2018: *Koala Monitoring 2017. Year 4 surveys - Oxley Highway to Kempsey Pacific Highway Upgrade* (Niche 2019a)
- Spring-summer 2019: Current report.

This report represents the second of the four required operational monitoring reports. Construction monitoring was completed in spring-summer 2017.

1.1.3 Baseline data

In accordance with the EMP, baseline surveys for the Koala were undertaken in 2014 to provide baseline data that could be used to identify changes in habitat use before and after construction of the Project, and determine whether any changes can be reasonably attributed to the Project. Baseline monitoring was conducted by Lewis Ecological prior to the commencement of construction (Lewis 2014). Remote cameras were also opportunistically deployed (targeting other threatened species) in August 2013, while spotlighting and Spot Assessment Technique (SAT) plot surveys were undertaken in spring 2013.

1.1.4 Purpose of this report

This report details the findings obtained from the 2019 monitoring period. As mentioned previously, it represents the second of four monitoring reports for the operational phase of the Project.

The aim of this report is to summarise the methods and results of the spring-summer 2019 monitoring, and to compare the results with the baseline surveys to determine whether performance measures are being met and comment on whether additional measures should be considered.

1.2 Performance Measures

The EMP specifies the following performance measures for the Koala:

- *Monitoring is undertaken during baseline surveys from Year 1 – Year 6 & Year 8, or until mitigation measures are demonstrated to be effective.*
- *Monitoring during Year 1 – Year 6 & Year 8 is undertaken at the Impact and Control sites where monitoring was undertaken during baseline surveys, subject to ongoing landowner agreement. Where landowner agreement cannot be obtained and the process in Section 3.1.2 of the EMP has been followed, this performance indicator will also be considered to have been met.*
- *Mitigation measures are demonstrated to be effective as defined in the EPBC approval when all monitoring events are considered at Year 8.*
- *Fauna fence is installed at a minimum in areas identified in Schedule 3 of the EPBC approval at Year 4.*
- *Density: Koala spotlighting records are compared to and discussed with reference to the baseline records, with the baseline detection frequency rate of 1 Koala per spotlight hour considered as the baseline density, as recommended in the baseline report. Compare the NSW BioNet wildlife Atlas density ranking of 5 km^2 grids, as per the baseline report, between pre and post-construction at Year 8.*
- *Movement: Reduction in Koala road kill compared to the baseline of 1 Koala road kill per 8 weeks for an average baseline plot activity level of 5%, whereby proportional changes in average plot activity level may be reflected in the acceptable level of Koala road kill.*
- *Distribution: Compare the number of records and clustering of records, as per the baseline report, between pre-construction and construction/post-construction at Year 8.*
- *Habitat Use: Koala SAT activity levels will be compared to the baseline activity levels data (below) with a 10% tolerance level, as recommended in the baseline report, to account for variability:*
  - *Broader study area set at 5% activity;*
  - *The treatment classes of mitigation set at 8.05%, no mitigation set at 2.64% and control / reference set at 4.03%*
  - *Comparison of percent tree use with baseline tree use.*

1.3 Monitoring Timing

Spotlighting is to occur in spring and SAT plot monitoring is to occur during spring-summer.

1.4 Reporting

Annual reporting of monitoring results will include:

- A detailed description of the monitoring methodology
- Results of the monitoring surveys
- Discussion of the results, including how the results compare against performance measures and if contingency measures should be implemented.

All reports prepared under the EMP will be submitted to the NSW Department of Planning, Industry and Environment (DPIE) and the NSW Environment Protection Authority (EPA).

2. Survey Methodology

2.1 Koala Spot Assessment Technique (SAT)

2.1.1 Monitoring design

In accordance with the baseline monitoring surveys, eight broad areas within a 20 kilometre (km) radius of the Project were surveyed. These eight areas include South Sancrox, North Sancrox, Cairncross State Forest (South), Cairncross State Forest (North), Cooperabung Hill, Mingaletta Road to Smiths Creek, Kundabung Road to North of Pipers Creek and Maria River State Forest. Within each of these areas, three types of monitoring treatments were established:

- Type A: Impact with mitigation. Mitigation plots are located within 500 metres (m) of sufficiently large culverts (>1.8 m, to allow Koalas to pass under the Highway) that are paired with floppy top fencing.
- Type B: Impact without mitigation. Plots where mitigation has not been proposed or only partial mitigation is proposed. Partial mitigation plots are where only floppy top fencing is present but with obvious openings at interchanges or entry/exit points.
- Type C: Control or reference. These are located in areas at least 3 km, and often 5-10 km from the Project.

Each treatment type (A, B or C) is represented by a cluster of three SAT plots within each of the eight areas, resulting in nine SAT plots per area giving a total of 72 baseline SAT plots, established by Lewis (2014) (with the exception of Cairncross State Forest (South), which had an additional type B cluster during baseline surveys and Mingaletta to Smiths Creek where no type B cluster was established during baseline surveys). Of these 72 plots, 24 were mitigation (type A), three part mitigation and 21 no mitigation (type B) and 24 were control sites (type C). To ensure a balanced monitoring design between impact plots (mitigated and not mitigated) and control plots, an additional 24 control plots (type C) were established during the first monitoring event in 2015 (Niche 2016a). In accordance with the baseline monitoring design these additional 24 control plots were established at least 3 km from the Project and were grouped in clusters of three plots, one cluster for each of the eight broad areas.

In 2015, eight of the baseline plots had to be relocated to nearby locations because they had been established in the construction site itself or because they were located on private property and access was not possible. Three of the baseline monitoring plots that could not be accessed could not be relocated because there weren't any suitable sites nearby. These three plots were all part of the same cluster (impact, no mitigation) located in the North Sancrox area.

Details of the 96 monitoring plots are presented in Table 1 and the location of the 93 accessible monitoring plots are shown in Figure 1.

Table 1: SAT monitoring plots

Area	Type	Sub-category	Data source	Plot name	Easting	Northing
South Sancrox	Impact	No Mitigation	Baseline	1 Sancrox East - Cassegrains	483348	6521736
	Impact	No Mitigation	Baseline	2 Sancrox East - Cassegrains	483455	6521789
	Impact	No Mitigation	Baseline	3 Sancrox East - Cassegrains	483412	6521882
	Impact	Mitigation	Baseline_Niche relocation	1 Sancrox South	483299	6520671
	Impact	Mitigation	Baseline_Niche relocation	2 Sancrox South	483254	6520383
	Impact	Mitigation	Baseline_Niche relocation	3 Sancrox South	483196	6520217

Area	Type	Sub-category	Data source	Plot name	Easting	Northing
	Control	Control	Baseline	1 Cowarra State Forest	480608	6519056
	Control	Control	Baseline	2 Cowarra State Forest	480658	6519496
	Control	Control	Baseline	3 Cowarra State Forest	481305	6519136
	Control	New Control	Niche	COWARRA NC1	479706	6518522
	Control	New Control	Niche	COWARRA NC2	479788	6517922
	Control	New Control	Niche	SAT COWARRA NC3	479795	6518227
North Sancrox	Impact*	No Mitigation	Baseline	1 Sancrox North - Expressway Spares	483042	6521731
	Impact*	No Mitigation	Baseline	2 Sancrox North - Expressway Spares	482869	6521683
	Impact*	No Mitigation	Baseline	3 Sancrox North - Expressway Spares	482999	6521818
	Impact	Mitigation	Baseline	1 Fernbank Creek	483101	6523362
	Impact	Mitigation	Baseline	2 Fernbank Creek	483032	6523223
	Impact	Mitigation	Baseline	3 Fernbank Creek	483056	6523123
	Control	Control	Baseline	1 Lake Innes	488124	6518469
	Control	Control	Baseline	2 Lake Innes	488047	6518398
	Control	Control	Baseline	3 Lake Innes	488228	6518390
	Control	New Control	Niche	COWARRA NC3 -SAT COW4	479674	6516436
	Control	New Control	Niche	SAT COW5	479704	6516174
	Control	New Control	Niche	SAT COW6	479667	6515913
Cairncross State Forest (South)	Impact	No Mitigation	Baseline	1 Cairncross State Forest (South)	482428	6526536
	Impact	No Mitigation	Baseline	2 Cairncross State Forest (South)	482385	6526644
	Impact	No Mitigation	Baseline	3 Cairncross State Forest (South)	482393	6526416
	Impact	No Mitigation	Baseline	16 Cairncross State Forest (south)	481655	6527256
	Impact	No Mitigation	Baseline	17 Cairncross State Forest (south)	481590	6527316
	Impact	No Mitigation	Baseline	18 Cairncross State Forest (south)	481637	6527175
	Impact	Mitigation	Baseline	4 Cairncross State Forest (South)	482249	6525930
	Impact	Mitigation	Baseline	5 Cairncross State Forest (South)	482125	6526077
	Impact	Mitigation	Baseline	6 Cairncross State Forest (South)	482488	6526226
	Control	Control	Baseline	1 Limeburners Creek ""The Hatch""	487011	6529909
	Control	Control	Baseline	2 Limeburners Creek ""The Hatch""	487014	6529455
	Control	Control	Baseline	3 Limeburners Creek ""The Hatch""	487035	6528694
	Control	New Control	Niche	SAT PEVI1	476817	6528422
	Control	New Control	Niche	SAT PEVI2	476730	6528225
	Control	New Control	Niche	Cairncross NC1	475996	6528211
Cairncross State Forest (north)	Impact	No Mitigation	Baseline_Niche relocation	7 Cairncross State Forest (North)	481346	6530835
	Impact	No Mitigation	Baseline	8 Cairncross State Forest (North)	481695	6530786
	Impact	No Mitigation	Baseline	9 Cairncross State Forest (North)	481184	6530864
	Impact	Mitigation	Baseline	10 Cairncross State Forest (north)	481238	6530264
	Impact	Mitigation	Baseline	11 Cairncross State Forest (north)	481173	6530319
	Impact	Mitigation	Baseline	12Cairncross State Forest (north)	481438	6530335
	Control	Control	Baseline	13 Cairncross State Forest (Pembrooke)	473751	6528881

Area	Type	Sub-category	Data source	Plot name	Easting	Northing
	Control	Control	Baseline	14 Cairncross State Forest (Pembrooke)	473464	6528969
	Control	Control	Baseline	15 Cairncross State Forest (Pembrooke)	473424	6529115
	Control	New Control	Niche	SAT RR1	475284	6532709
	Control	New Control	Niche	SAT RR2	475113	6532603
	Control	New Control	Niche	SAT RR3	474816	6532732
Cooperabung Hill	Impact	No Mitigation	Baseline	1 Cooperabung	482793	6537012
	Impact	No Mitigation	Baseline	2 Cooperabung	482755	6537093
	Impact	No Mitigation	Baseline	3 Cooperabung	482876	6537115
	Impact	Mitigation	Baseline_Niche relocation	4 Cooperabung	482481	6539327
	Impact	Mitigation	Baseline_Niche relocation	5 Cooperabung	482364	6539761
	Impact	Mitigation	Baseline	6 Cooperabung	482364	6538610
	Control	Control	Baseline	1 Cooperabung Hill (Gum Scrub)	475489	6541854
	Control	Control	Baseline	2 Cooperabung Hill (Gum Scrub)	475570	6541903
	Control	Control	Baseline	3 Cooperabung Hill (Gum Scrub)	475838	6541962
	Control	New Control	Niche	SAT FL1	473693	6542127
	Control	New Control	Niche	SAT ST1	473346	6543256
	Control	New Control	Niche	SAT ST2	473682	6542890
Mingaletta to Smiths Creek	Impact	Mitigation	Baseline	1 Mingaletta-Smiths Creek	483304	6543632
	Impact	Mitigation	Baseline	2 Mingaletta-Smiths Creek	483444	6543585
	Impact	Mitigation	Baseline	3 Mingaletta-Smiths Creek	483100	6543670
	Control	Control	Baseline	1 Ballengara State Forest (Gregs Road)	477750	6543274
	Control	Control	Baseline	2 Ballengara State Forest (Gregs Road)	477644	6543623
	Control	Control	Baseline	3 Ballengara State Forest (Gregs Road)	477551	6543709
	Control	New Control	Niche	SAT BR1	477010	6544693
	Control	New Control	Niche	SAT BR2	476890	6544832
	Control	New Control	Niche	SAT BR3	476777	6544973
Kundabung Road to North of Pipers Creek	Impact	No Mitigation	Baseline	1 Kundabung	483095	6549036
	Impact	No Mitigation	Baseline	2 Kundabung	482873	6549112
	Impact	No Mitigation	Baseline	3 Kundabung	483285	6549374
	Impact	Mitigation	Baseline	4 Kundabung	483369	6550655
	Impact	Mitigation	Baseline	5 Kundabung	483331	6550938
	Impact	Mitigation	Baseline	6 Kundabung	483083	6550608
	Control	Control	Baseline	1 Kumbatine National Park	476044	6549609
	Control	Control	Baseline	2 Kumbatine National Park	476165	6549738
	Control	Control	Baseline	3 Kumbatine National Park	475889	6549468
	Control	New Control	Niche	SAT MAC1	476538	6552784
	Control	New Control	Niche	SAT MAC2	476558	6552361
	Control	New Control	Niche	SAT MAC3	476481	6552612
Maria River State Forest	Impact	Part Mitigation	Baseline_Niche relocation	1 Maria River	483074	6554460
	Impact	Part Mitigation	Baseline	2 Maria River	482836	6554330

Area	Type	Sub-category	Data source	Plot name	Easting	Northing
	Impact	Part Mitigation	Baseline_Niche relocation	3 Maria River	482993	6554024
	Impact	Mitigation	Baseline	4 Maria River	482886	6552623
	Impact	Mitigation	Baseline	5 Maria River	482754	6552462
	Impact	Mitigation	Baseline	6 Maria River	483135	6552449
	Control	Control	Baseline	1 Maria River National Park	486965	6554366
	Control	Control	Baseline	2 Maria River National Park	486971	6554479
	Control	Control	Baseline	3 Maria River National Park	487004	6554203
	Control	New Control	Niche	SAT CO1	486292	6552230
	Control	New Control	Niche	SAT CO3	486811	6552227
	Control	New Control	Niche	SAT MAR 1	486811	6552454

* could not be surveyed due to private landowner access restrictions.

2.1.2 SAT Methodology

Surveys were undertaken following the SAT methodology (Phillips and Callaghan 2011) in accordance with the EMP monitoring procedure for Koala population monitoring. The SAT method involves a radial assessment of Koala activity within the immediate area surrounding a tree that is known to have been used by the species or is considered to be of importance to the species. The following describes the application of this technique:

1. Locate and mark a tree that is:
   a) A tree of any species beneath which one or more Koala faecal pellets have been observed; and/or
   b) A tree in which a Koala has been observed; and/or
   c) Any other tree known or considered to be important for Koalas or of interest for other assessment purposes.
2. Identify and mark the 29 nearest trees to the tree marked initially.
3. Undertake a search for Koala faecal pellets beneath each of the 30 marked trees. Visually inspect the ground surface beneath trees to a distance of one metre from the trunk. If no pellets are observed, rake the leaf litter within the prescribed search area. Two person minutes per tree should be dedicated to the search for faecal pellets. The search should be ended once a single pellet is found or the search time has expired (whichever happens first). Faecal pellets should not be removed from the site unless verification is necessary.
4. Calculate the activity level of a site as the percentage of surveyed trees within the site (of 30 trees) that have a Koala faecal pellet recorded within its search area. The result is used to assess whether the site supports “Low”, “Medium (normal)” or “High” Koala activity.
5. Record the presence (or absence) of scats, along with a number of other attributes including the species of the tree under which the scat was located.

The selection criteria trees (SCTs) of each plot were marked (tagged) and have been used as the centre tree for the radial searches during each survey event.

2.1.3 Analysis

General SAT plot presence and activity results are presented for plot, cluster and area. More detailed analyses of impact *vs.* control sites and mitigation *vs.* no mitigation sites were undertaken using cluster presence/absence results. Plots within the same cluster are not independent from each other and therefore cannot be used for most statistical analyses. Between year activity levels were compared using mean plot activity results.

Based on the methods used to collect the data and the location of the plots, it was determined that a Chi-square test was the most suitable statistical test to assess differences in Koala presence between areas, treatments and years. This test compares the proportion of plots with and without Koala scats and so is suitable for presence/absence data. The Chi-square test also allows for analysis of data where sample sizes between categories may differ, as is the case here where there are an unequal number of impact and control sites.

2.2 Additional Surveys

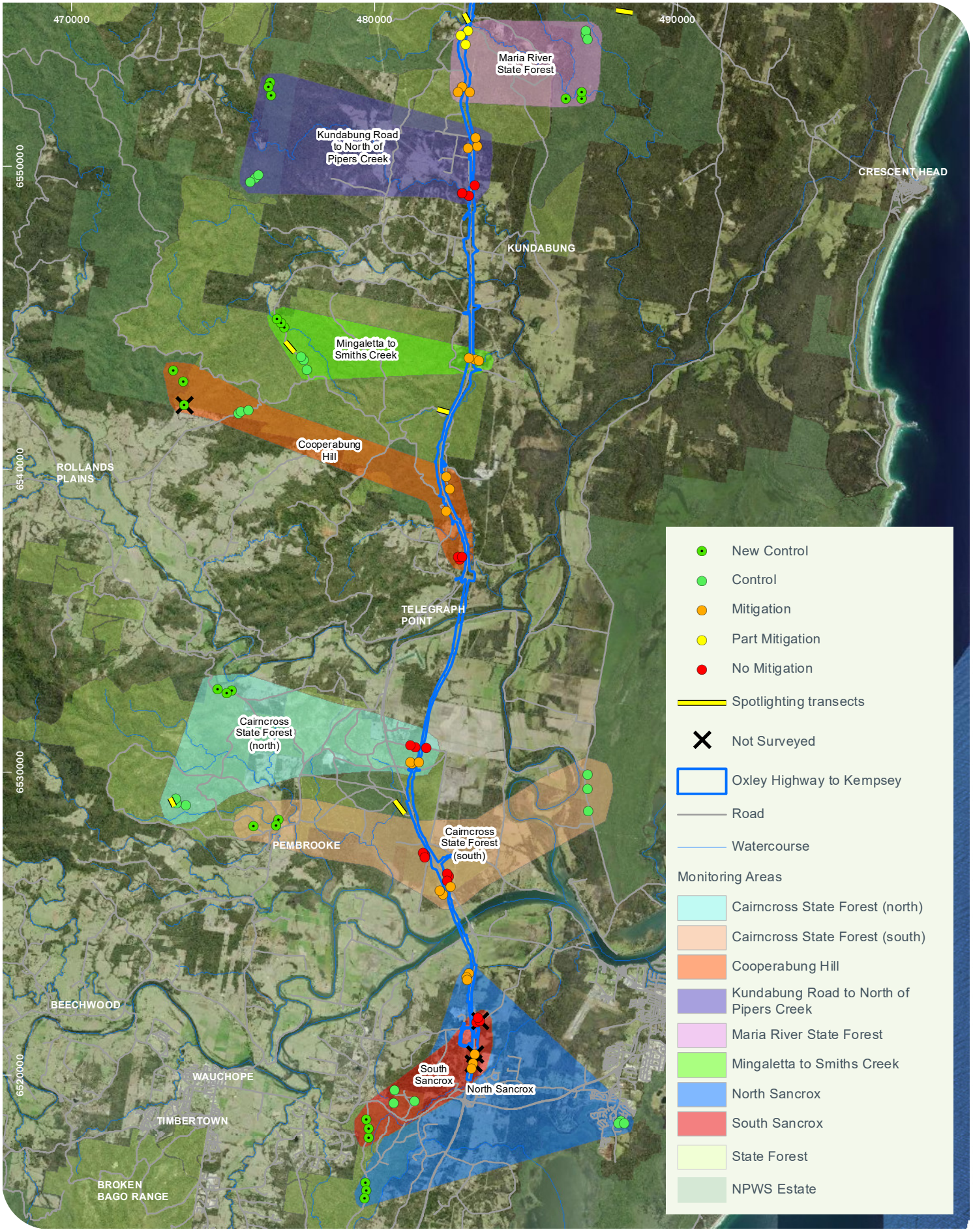
Additional survey methods were adopted in 2019 as a result of the revision and adoption of an updated EMP (RMS 2019).

2.2.1 Spotlighting

Spotlighting surveys are to be undertaken as per baseline surveys at six sites in Cairncross State Forest, Ballengarra State Forest and Maria River (Figure 1). Spotlighting locations have been set up in a paired Before After Control Impact (BACI) configuration comprising an impact site and a control site which exhibit similar vegetation/habitat type and landscape features. Field surveys involved a 10 minute listening period on arrival at site, followed by spotlighting performed by two observers using handheld variable beam ~100 watt spotlights whilst walking a 500 m transect over 30 minutes. These surveys are to be repeated on three separate occasions at least seven days apart.

2.2.2 NSW Bionet Wildlife Atlas

NSW BioNet wildlife Atlas records will be used to compare Koala distribution and density. Pre-construction records (i.e. 2004 - 2013 inclusive) will be compared to post-construction records at Year 8 (i.e. 2014 – 2022 inclusive), as per baseline methods. These analyses are to be undertaken at Year 8 and are therefore not considered in this report.



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GDA 1994 MGA Zone 56

SAT plot and spotlighting transect locations

Koala Monitoring: Pacific Highway Upgrade - Oxley Highway to Kempsey

Niche PM: Radika Michniewicz
Niche Proj. #: 1702 PI5.1
Client: Roads and Maritime Services

Figure 1

3. Results

3.1 SAT Plots

Surveys were undertaken between 27 November 2019 and 30 January 2020. Field data for each SAT plot is presented in Annex 1. The DBH (diameter at breast height) is provided for the SCT.

Four SAT plots were not surveyed in 2019 due to the plots either being burnt by recent bushfires or recently logged. Eighty nine of the 93 accessible SAT plots were surveyed across the eight monitoring areas (Figure 1). It should be noted that surveys were undertaken late in summer, as soon as access was granted, due to Sate Forests and National Parks high fire danger closures during late spring and summer.

3.1.1 Presence/absence

SAT plots

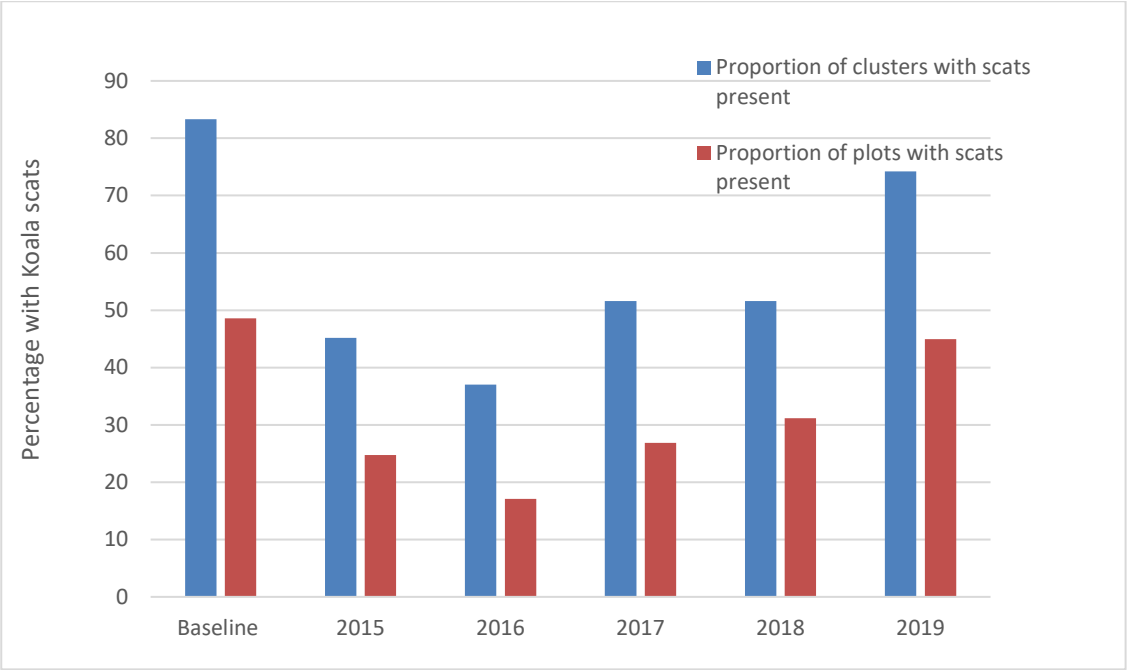
Table 2 provides a summary of presence/absence results for plots and clusters. Graph 1 shows the percentage of plots and clusters with scats present for each monitoring period to date and Graph 2 shows the percentage of clusters within each area with scats present, for each monitoring period to date. Table 3 provides a detailed comparison of the activity level for each plot and presence/absence results of each cluster for each monitoring period to date and Figure 2 shows the SAT cluster presence/absence results for the 2019 monitoring (map reference ID for each cluster is listed in Table 3).

Of the 89 surveyed plots, Koala scats were recorded at 46% (41 of 89) of the individual plots. This is higher than 2015, 2016, 2017 and 2018 surveys (25%, 17%, 27% and 31% respectively), but lower than the 49% recorded during baseline surveys. When grouped according to cluster, Koala scats were recorded at 74% of clusters (23 of 31). This is higher than 2015, 2016, 2017 and 2018 surveys (45%, 37%, 52% and 52% respectively), but lower than the 83% recorded during baseline surveys. It should be noted that baseline surveys included only 24 (*cf* 31) clusters; if we consider only those clusters in common between baseline and 2019 surveys, scats were recorded at 83% (19 of 23) of these clusters during the 2019 monitoring.

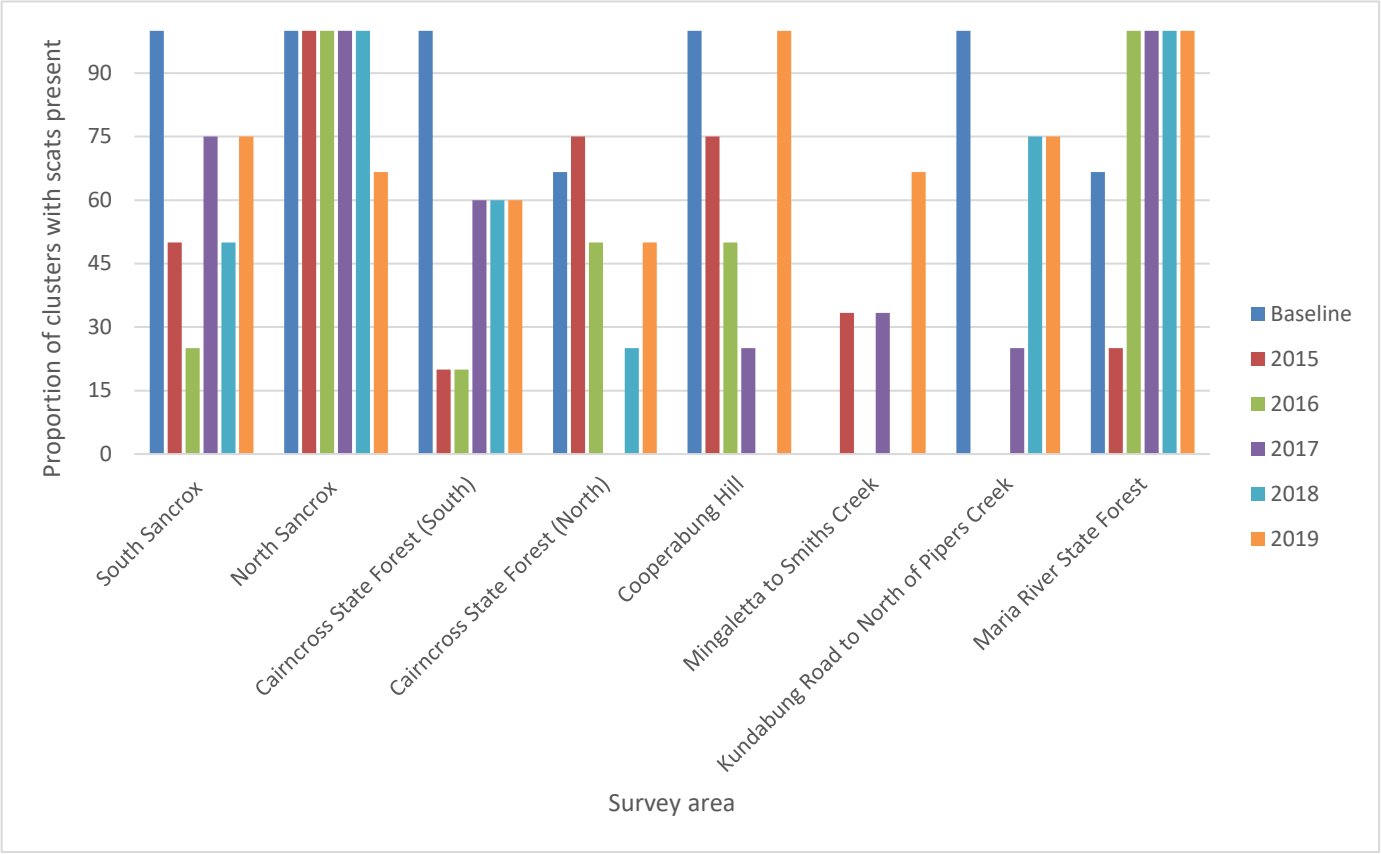
Of note is the ongoing presence of scats at the 11 plots (located within clusters KUND2, MR1, MR2 and MR4) that were not surveyed in 2016 due to wildfires that resulted in the complete loss of canopy in many areas. Prior to the wildfires, baseline surveys recorded presence at four of these plots (note only eight were surveyed during baseline as three of the 11 are new controls and were not monitored during baseline surveys) and 2015 surveys recorded presence at one of these plots. Since the 2016 wildfires, 2017, 2018 and 2019 surveys recorded presence at six, eight and 10 of the plots respectively. The substantial canopy regrowth and prevalence of young leaves on the trees in these areas may have encouraged the rapid re-use of these areas by Koalas after the fires and provides ongoing abundant foraging resources.

Table 2: Presence/absence results

	Baseline	2015	2016	2017	2018	2019
Number of plots with scats present (n = plots surveyed)	35 (49%, n = 72)	23 (25%, n = 93)	14 (17%, n = 82)	25 (27%, n = 93)	29 (31%, n = 93)	41 (46%, n = 89)
Number of clusters with scats present (n = clusters surveyed)	20 (83%, n = 24)	14 (45%, n = 31)	10 (37%, n = 27)	16 (52%, n = 31)	16 (52%, n = 31)	23 (74%, n = 31)



Graph 1: Percentage of plots and clusters with scats present for each monitoring event to date



Graph 2: Koala presence in areas across all monitoring events

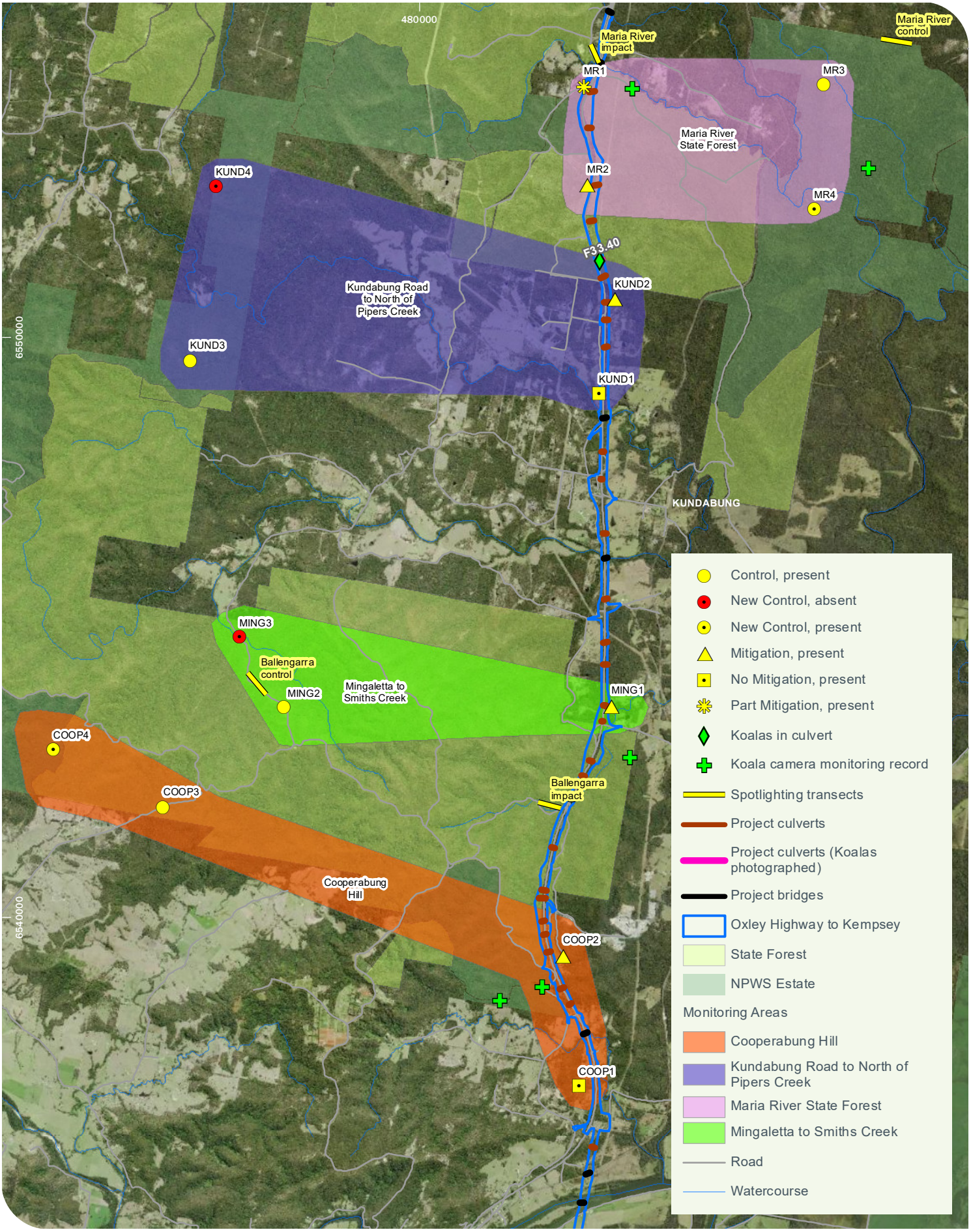
Table 3: SAT plot results baseline – 2019

Area	Type	Data source	Site ID	MapRef	Plot activity (%)						Scat presence (per cluster)					
					Baseline	2015	2016	2017	2018	2019	Baseline	2015	2016	2017	2018	2019
South Sancrox	No Mitigation	Baseline	SANCROX E1	SSAN1	10.0	3.3	0.0	23.3	6.7	3.3	present	present	absent	present	present	present
			SANCROX E2		0.0	0.0	0.0	0.0	0.0	fire						
			SANCROX E3		0.0	0.0	0.0	0.0	6.7	0.0						
	Mitigation	Baseline_Niche relocation	SANCROX S1	SSAN2	13.3	0.0	0.0	3.3	0.0	fire	present	absent	absent	present	present	present
			SANCROX S2		3.3	0.0	0.0	0.0	6.7	fire						
			SANCROX S3		10.0	0.0	0.0	0.0	3.3	3.3						
	Control	Baseline	COWARRA SF1	SSAN3	0.0	0.0	0.0	0.0	0.0	6.7	present	absent	present	absent	absent	present
			COWARRA SF2		3.3	0.0	0.0	0.0	0.0	0.0						
			COWARRA SF3		10.0	0.0	6.7	0.0	0.0	0.0						
	New Control	Niche	SAT COWARRA NC1	SSAN4	-	0.0	0.0	0.0	0.0	0.0	Not monitored	present	absent	present	absent	absent
			SAT COWARRA NC2		-	3.3	0.0	6.7	0.0	0.0						
			SAT COWARRA NC3		-	0.0	0.0	3.3	0.0	0.0						
North Sancrox	No Mitigation	Baseline	SANCROX N1	-	3.3	-	-	-	-	-	present	No access	No access	No access	No access	No access
			SANCROX N2		0.0	-	-	-	-	-						
			SANCROX N3		0.0	-	-	-	-	-						
	Mitigation	Baseline	FERNBANK CK1	NSAN1	33.3	0.0	3.3	16.7	3.3	0.0	present	present	present	present	present	absent
			FERNBANK CK2		30.0	0.0	6.7	6.7	0.0	0.0						
			FERNBANK CK3		23.3	6.7	3.3	13.3	6.7	0.0						
	Control	Baseline	LAKE INNES1	NSAN2	26.7	13.3	0.0	3.3	6.7	3.3	present	present	present	present	present	present
			LAKE INNES2		13.3	6.7	3.3	6.7	3.3	0.0						
			LAKE INNES3		3.3	6.7	0.0	0.0	3.3	10.0						
	New Control	Niche	SAT COW4	NSAN3	-	10.0	0.0	3.3	3.3	0.0	Not monitored	present	present	present	present	present
			SAT COW5		-	0.0	0.0	0.0	0.0	3.3						
			SAT COW6		-	0.0	3.3	0.0	10.0	0.0						
		Baseline	CAINCROSS SF1	CCS1	0.0	0.0	0.0	0.0	0.0	0.0	present	present	absent	absent	absent	present

Area	Type	Data source	Site ID	MapRef	Plot activity (%)						Scat presence (per cluster)					
					Baseline	2015	2016	2017	2018	2019	Baseline	2015	2016	2017	2018	2019
Cairncross State Forest (South)	No Mitigation		CAINCROSS SF2		3.3	6.7	0.0	0.0	0.0	3.3						
			CAINCROSS SF3		0.0	3.3	0.0	0.0	0.0	0.0						
	No Mitigation	Baseline	CAINCROSS SF16	CCS2	0.0	0.0	3.3	3.3	0.0	0.0	present	absent	present	present	present	absent
			CAINCROSS SF17		0.0	0.0	3.3	0.0	0.0	0.0						
			CAINCROSS SF18		13.3	0.0	0.0	6.7	3.3	0.0						
	Mitigation	Baseline	CAINCROSS SF4	CCS3	3.3	0.0	0.0	3.3	6.7	13.3	present	absent	absent	present	present	present
			CAINCROSS SF5		3.3	0.0	0.0	0.0	0.0	13.3						
			CAINCROSS SF6		0.0	0.0	0.0	0.0	0.0	0.0						
	Control	Baseline	LIMEBURNERS CK1	CCS4	0.0	0.0	0.0	3.3	0.0	0.0	present	absent	absent	present	absent	absent
			LIMEBURNERS CK2		3.3	0.0	0.0	0.0	0.0	0.0						
			LIMEBURNERS CK3		0.0	0.0	0.0	3.3	0.0	0.0						
	New Control	Niche	SAT PEVI1	CCS5	-	0.0	0.0	0.0	6.7	3.3	Not monitored	absent	absent	absent	present	present
			SAT PEVI2		-	0.0	0.0	0.0	3.3	0.0						
			SAT PEVI3		-	0.0	0.0	0.0	0.0	0.0						
Cairncross State Forest (north)	No Mitigation	Baseline_Niche relocation	CAINCROSS SF7	CCN1	0.0	3.3	0.0	0.0	0.0	0.0	absent	present	absent	absent	absent	present
		Baseline	CAINCROSS SF8		0.0	20.0	0.0	0.0	0.0	3.3						
		Baseline	CAINCROSS SF9		0.0	10.0	0.0	0.0	0.0	0.0						
	Mitigation	Baseline	CAINCROSS SF10	CCN2	3.3	0.0	0.0	0.0	3.3	6.7	present	present	present	absent	present	present
			CAINCROSS SF11		3.3	0.0	3.3	0.0	0.0	0.0						
			CAINCROSS SF12		6.7	3.3	0.0	0.0	0.0	3.3						
	Control	Baseline	CAINCROSS SF13	CCN3	6.7	3.3	3.3	0.0	0.0	0.0	present	present	present	absent	absent	absent
			CAINCROSS SF14		0.0	0.0	0.0	0.0	0.0	0.0						
			CAINCROSS SF15		0.0	3.3	0.0	0.0	0.0	0.0						
	New Control	Niche	SAT RR1	CCN4	-	0.0	0.0	0.0	0.0	0.0	Not monitored	absent	absent	absent	absent	absent
			SAT RR2		-	0.0	0.0	0.0	0.0	0.0						
			SAT RR3		-	0.0	0.0	0.0	0.0	0.0						

Area	Type	Data source	Site ID	MapRef	Plot activity (%)						Scat presence (per cluster)					
					Baseline	2015	2016	2017	2018	2019	Baseline	2015	2016	2017	2018	2019
Cooperabung Hill	No Mitigation	Baseline	COOPERABUNG1	COOP1	3.3	3.3	0.0	0.0	0.0	0.0	present	present	present	absent	absent	present
			COOPERABUNG2		0.0	23.3	3.3	0.0	0.0	3.3						
			COOPERABUNG3		10.0	0.0	0.0	0.0	0.0	10.0						
	Mitigation	Baseline_Niche relocation	COOPERABUNG4	COOP2	0.0	3.3	6.7	0.0	0.0	10.0	present	present	present	present	absent	present
		Baseline_Niche relocation	COOPERABUNG5		3.3	3.3	0.0	10.0	0.0	6.7						
		Baseline	COOPERABUNG6		0.0	0.0	0.0	0.0	0.0	3.3						
	Control	Baseline	COOP HILL1	COOP3	6.7	0.0	0.0	0.0	0.0	3.3	present	absent	absent	absent	absent	present
			COOP HILL2		0.0	0.0	0.0	0.0	0.0	6.7						
			COOP HILL3		0.0	0.0	0.0	0.0	0.0	10.0						
	New Control	Niche	SAT FL1	COOP4	-	16.7	0.0	0.0	0.0	logged	Not monitored	present	absent	absent	absent	present
			SAT ST1		-	0.0	0.0	0.0	0.0	10.0						
			SAT ST2		-	20.0	0.0	0.0	0.0	3.3						
Mingaletta to Smiths Creek	Mitigation	Baseline	MIN-SMITHS CK1	MING1	0.0	0.0	0.0	0.0	0.0	0.0	absent	absent	absent	absent	absent	present
			MIN-SMITHS CK2		0.0	0.0	0.0	0.0	0.0	0.0						
			MIN-SMITHS CK3		0.0	0.0	0.0	0.0	0.0	6.7						
	Control	Baseline	BALLENGARA SF1	MING2	0.0	0.0	0.0	0.0	0.0	0.0	absent	absent	absent	absent	absent	present
			BALLENGARA SF2		0.0	0.0	0.0	0.0	0.0	3.3						
			BALLENGARA SF3		0.0	0.0	0.0	0.0	0.0	0.0						
	New Control	Niche	SAT BR1	MING3	-	6.7	0.0	0.0	0.0	0.0	Not monitored	present	absent	present	absent	absent
			SAT BR2		-	0.0	0.0	3.3	0.0	0.0						
			SAT BR3		-	0.0	0.0	0.0	0.0	0.0						
Kundabung Road to North of Pipers Creek	No Mitigation	Baseline	KUNDABUNG 1	KUND1	0.0	0.0	0.0	0.0	0.0	0.0	present	absent	absent	absent	present	present
			KUNDABUNG 2		10.0	0.0	0.0	0.0	6.7	3.3						
			KUNDABUNG 3		0.0	0.0	0.0	0.0	0.0	0.0						
	Mitigation	Baseline	KUNDABUNG 4	KUND2	33.3	0.0	fire	0.0	13.3	10.0	present	absent	fire	present	present	present

Area	Type	Data source	Site ID	MapRef	Plot activity (%)						Scat presence (per cluster)					
					Baseline	2015	2016	2017	2018	2019	Baseline	2015	2016	2017	2018	2019
			KUNDABUNG 5		13.3	0.0	fire	3.3	16.7	13.3			fire			
			KUNDABUNG 6		10.0	0.0	0.0	0.0	0.0	0.0			absent			
	Control	Baseline	KUMBATINE NP1	KUND3	3.3	0.0	0.0	0.0	0.0	3.3	present	absent	absent	absent	present	present
			KUMBATINE NP2		0.0	0.0	0.0	0.0	0.0	0.0						
			KUMBATINE NP3		0.0	0.0	0.0	0.0	3.3	6.7						
	New Control	Niche	SAT MAC1	KUND4	-	0.0	0.0	0.0	0.0	0.0	Not monitored	absent	absent	absent	absent	absent
			SAT MAC2		-	0.0	0.0	0.0	0.0	0.0						
			SAT MAC3		-	0.0	0.0	0.0	0.0	0.0						
Maria River State Forest	Part Mitigation	Baseline_Niche relocation	MARIA RIVER 1	MR1	0.0	0.0	fire	0.0	6.7	3.3	present	absent	no access - fire	present	present	present
		Baseline	MARIA RIVER 2		3.3	0.0	fire	0.0	0.0	23.3						
		Baseline_Niche relocation	MARIA RIVER 3		6.7	0.0	fire	16.7	13.3	10.0						
	Mitigation	Baseline	MARIA RIVER 4	MR2	0.0	0.0	fire	6.7	6.7	10.0	absent	present	no access - fire	present	present	present
			MARIA RIVER 5		0.0	0.0	fire	0.0	0.0	3.3						
			MARIA RIVER 6		0.0	3.3	fire	0.0	3.3	0.0						
	Control	Baseline	MARIA NP1	MR3	0.0	0.0	0.0	3.3	20.0	10.0	present	absent	present	present	present	present
			MARIA NP2		10.0	0.0	3.3	0.0	10.0	10.0						
			MARIA NP3		10.0	0.0	3.3	3.3	36.7	13.3						
	New Control	Niche	SAT CO1	MR4	-	0.0	fire	6.7	10.0	13.3	Not monitored	absent	no access - fire	present	present	present
			SAT CO3		-	0.0	fire	3.3	0.0	3.3						
			SAT MAR 1		-	0.0	fire	6.7	3.3	6.7						



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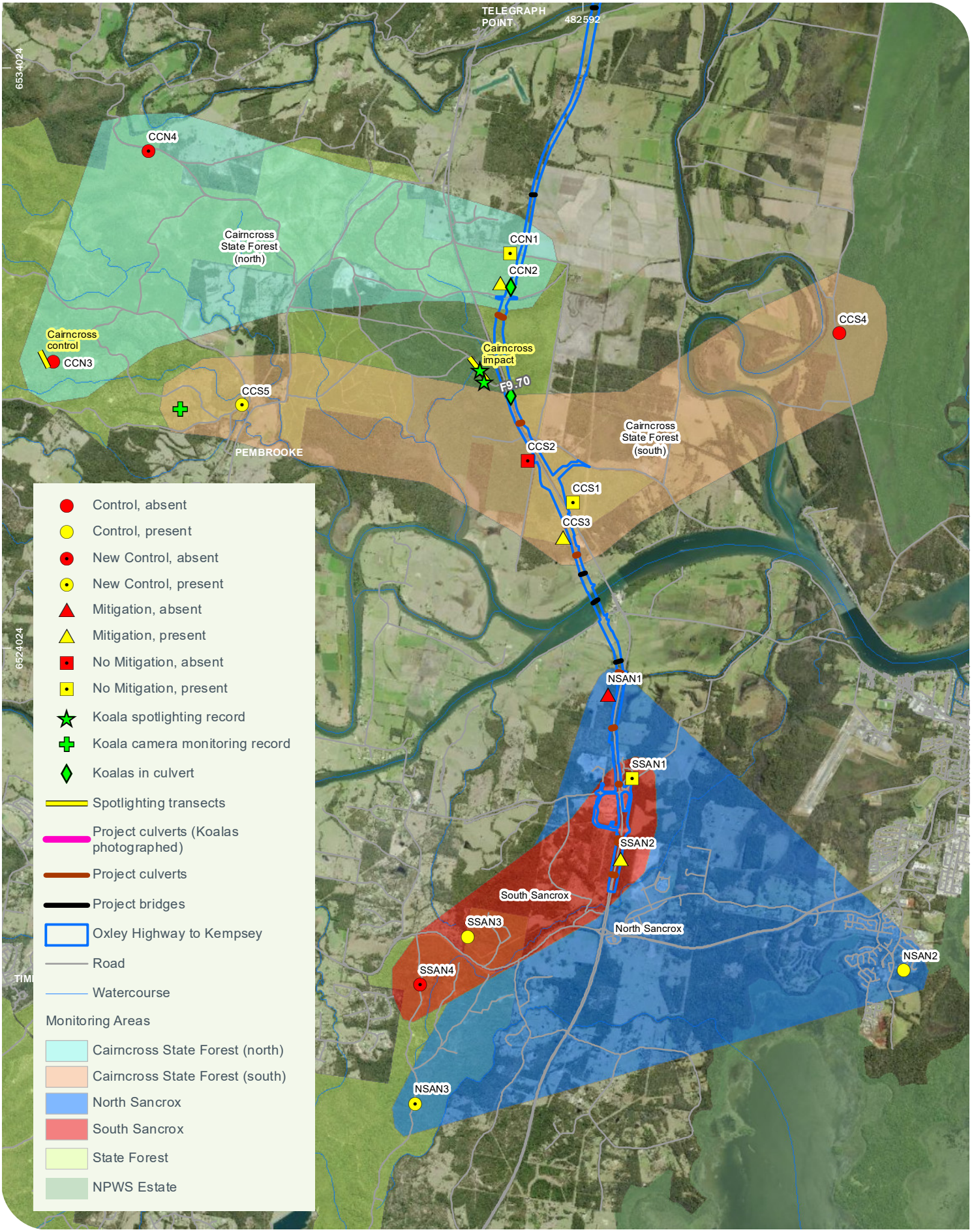
SAT cluster and spotlighting results 2019 - North

Koala Monitoring: Pacific Highway Upgrade - Oxley Highway to Kempsey

Niche PM: Radika Michniewicz
Niche Proj. #: 1702 PI5.1
Client: Roads and Maritime Services

Figure 2a



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SAT cluster and spotlighting results 2019 - South

Koala Monitoring: Pacific Highway Upgrade - Oxley Highway to Kempsey

Niche PM: Radika Michniewicz
Niche Proj. #: 1702 PI5.1
Client: Roads and Maritime Services

Figure 2b

v2.0

3.1.2 Activity levels

Individual plot activity levels are provided above in Table 3. A summary of the SAT activity level for plots, clusters and areas in all monitoring events is provided in Table 4 and Table 5.

Plot and cluster activity

The mean SAT activity level for all plots, measured as the percentage of trees at each plot with scats present, was 3.3% (standard deviation (SD) of 4.7) and ranged from 0 to 23.3%. This is higher than the mean activity recorded for plots during 2015, 2016, 2017 and 2018 surveys (2.0%, 0.7%, 1.8% and 2.5% respectively), but lower than the mean activity during baseline surveys (4.9%).

Considering the activity level within active plots only, i.e. plots where scats were found to be present, the average activity level was 7.2% (SD 5.8), which is higher than or similar to the mean activity recorded for active plots during 2015, 2016, 2017 and 2018 surveys (8.0%, 4.0%, 6.8% and 8.0% respectively), but lower than the mean activity recorded for active plots during baseline surveys (10.1%).

The EMP requires interpretation of site activity levels to assess areas as supporting low, medium or high Koala activity. Phillips and Callaghan (2011) used Atlas data to calculate activity levels of sites where Koala scats were recorded. These data were then used to define categories of habitat use in populations of varying densities. The Port Macquarie-Hastings and Kempsey LGAs support a significant Koala population, including a concentrated population in the coastal areas, east of the Pacific Highway and south of Hastings River, as well as pockets of higher density/activity in surrounding areas, including Maria River National Park (BioLink 2013, PMHC 2017). While Phillips and Callaghan (2011) use an arbitrary definition of population densities (low = ≤ 0.1 Koala/hectare), the study area naturally consists of areas of varying densities. Discussions with Port Macquarie-Hastings Council confirmed that population density varies throughout the region and therefore one general population density cannot be attributed to all sites. In addition, as site specific density data is not available for all sites, it is not possible to designate the sites as being low or high density populations according to Phillips and Callaghan. However, in compliance with the EMP, if we consider the habitat use category of Phillips and Callaghan (2011) for low density populations on the east coast, as per the baseline studies (Lewis 2014), using activity levels of SAT plots where scats were recorded, average SAT plot activity has consistency fallen into to the “medium (normal)” use category (3.3% - 12.6%) for populations in an east coast, low density area.

Table 4: Summary of SAT activity results

Average activity	**Baseline**	**2015**	**2016**	**2017**	**2018**	**2019**
Average activity per plot (n = plots surveyed)	4.9% (SD8.0, n = 72)	2.0% (SD4.6, n = 93)	0.7% (SD1.6, n = 82)	1.8% (SD4.1, n = 93)	2.5% (SD5.4, n = 93)	3.3% (SD4.7, n = 89)
Average activity per active plot (n = plots with activity)	10.1% (SD9.0, n = 35)	8.0% (SD6.3 n = 23)	4.0% (SD1.4, n = 14)	6.8% (SD5.3, n = 25)	8.0% (SD7.0, n = 29)	7.2% (SD5.8, n = 41)
Average activity per cluster (n = plots surveyed)	4.9% (SD6.9, n = 24)	2.0% (SD3.5, n = 31)	0.7% (SD1.1, n = 27)	1.8% (SD2.8, n = 31)	2.5% (SD4.5, n = 31)	3.3% (SD3.5, n = 31)
Average activity per active cluster (n = active clusters)	5.9% (SD7.1, n = 20)	4.4% (SD4.0, n = 14)	1.9% (SD1.1, n = 10)	3.5% (SD3.0, n = 16)	4.9% (SD5.5, n = 16)	4.5% (SD4.2, n = 23)
Average activity per area (n = 8)	4.8% (SD4.7)	2.1% (SD2.3)	0.9% (SD0.9)	1.9% (SD2.0)	2.6% (SD3.1)	3.4% (SD2.7)

Area activity

Table 5 and Graph 3 show Koala activity at each of the eight monitoring areas. Area activity is the mean activity of all surveyed plots with the area. As for the 2018 monitoring, SAT plot activity was highest at Maria River State Forest (8.9%), where scats were recorded at all four clusters and at 11 of the 12 SAT plots. Three of the four clusters have dense regenerating vegetation after the 2016 wildfires.

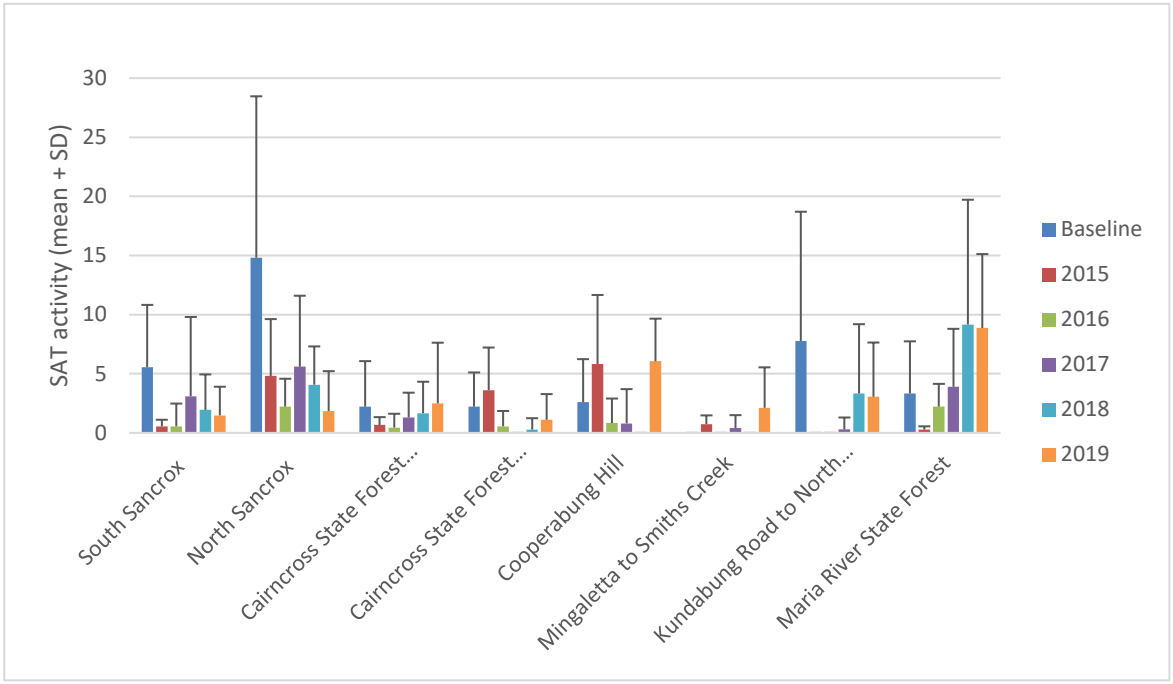
To date, activity levels appear to fluctuate across the years within each monitoring area and a definitive increasing or decreasing activity trend within any one areas is not apparent. Activity was recorded within all areas during the 2019 monitoring.

While North Sancrox has previously consistently recorded the highest activity until 2018, Maria River State Forest recorded higher activity during 2018 and 2019 monitoring due to high plot activity in regenerating areas. North Sancrox activity has decreased since 2017.

Contrary to the 2018 notable reduction in apparent activity within the Cooperabung Hill area, whereby no scats were recorded in 2018, activity in this area in 2019 increased substantially to levels not observed since 2015.

Table 5: Area activity levels

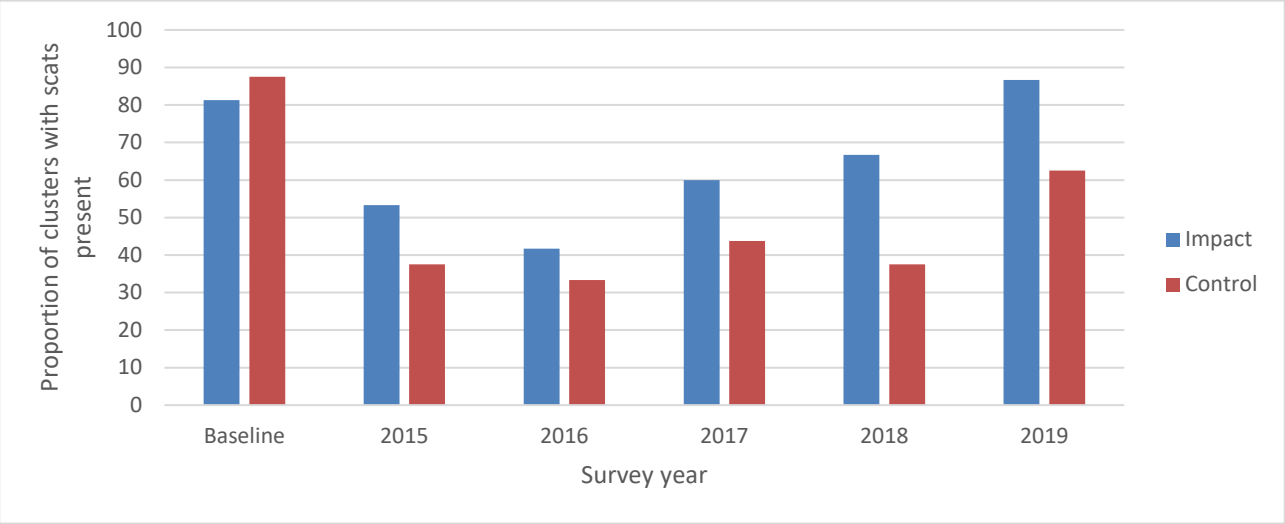
Monitoring Area	Baseline	2015	2016	2017	2018	2019
South Sancrox	5.6% (SD5.3)	0.6% (SD1.3)	0.6% (SD1.9)	3.1% (SD6.7)	1.9% (SD3.0)	1.5% (SD2.4)
North Sancrox	14.8 (SD13.7)	4.8% (SD5.0)	2.2% (SD2.4)	5.6% (SD6.0)	4.1% (SD3.2)	1.8% (SD3.4)
Cairncross State Forest (South)	2.2% (SD3.8)	0.7% (SD1.9)	0.4% (SD1.2)	1.3% (SD2.1)	1.7% (SD2.7)	2.5% (SD5.1)
Cairncross State Forest (North)	2.2% (SD2.9)	3.6% (SD5.9)	0.6% (SD1.3)	0	0.3% (SD1.0)	1.1% (SD2.2)
Cooperabung Hill	2.6% (SD3.6)	5.8% (SD8.8)	0.8% (SD2.1)	0.8% (SD2.9)	0	6.1% (SD3.6)
Mingaletta to Smiths Creek	0	0.7% (SD2.2)	0	0.4% (SD1.1)	0	2.1% (3.4)
Kundabung Road to North of Pipers Creek	7.8% (SD10.9)	0	0	0.3% (SD1.0)	3.3% (SD5.9)	3.1% (SD4.6)
Maria River State Forest	3.3% (SD4.4)	0.3% (SD1.0)	2.2% (SD1.9)	3.9% (SD4.9)	9.2% (SD10.6)	8.9% (SD6.2)



Graph 3: Koala activity across the eight monitoring areas

3.2 Impact v Control Cluster Presence/Absence Analysis

A higher percentage of impact clusters had scats present than did control clusters during the 2019 monitoring period (87% *cf* 63%). This result is the same as that of the previous monitoring years (Graph 4). If we compare the Koala presence/absence results between control and impact clusters there is no significant difference in Koala presence at impact and control clusters between the 2019 surveys and baseline, 2015, 2016, 2017 or 2018 surveys ($X^2 = 0.081$, df = 1, $p > 0.05$; $X^2 = 0.971$, df = 1, $p > 0.05$; $X^2 = 0.775$, df = 1, $p > 0.05$; $X^2 = 0.961$, df = 1, $p > 0.05$ and $X^2 = 0.351$, df = 1, $p > 0.05$ respectively).

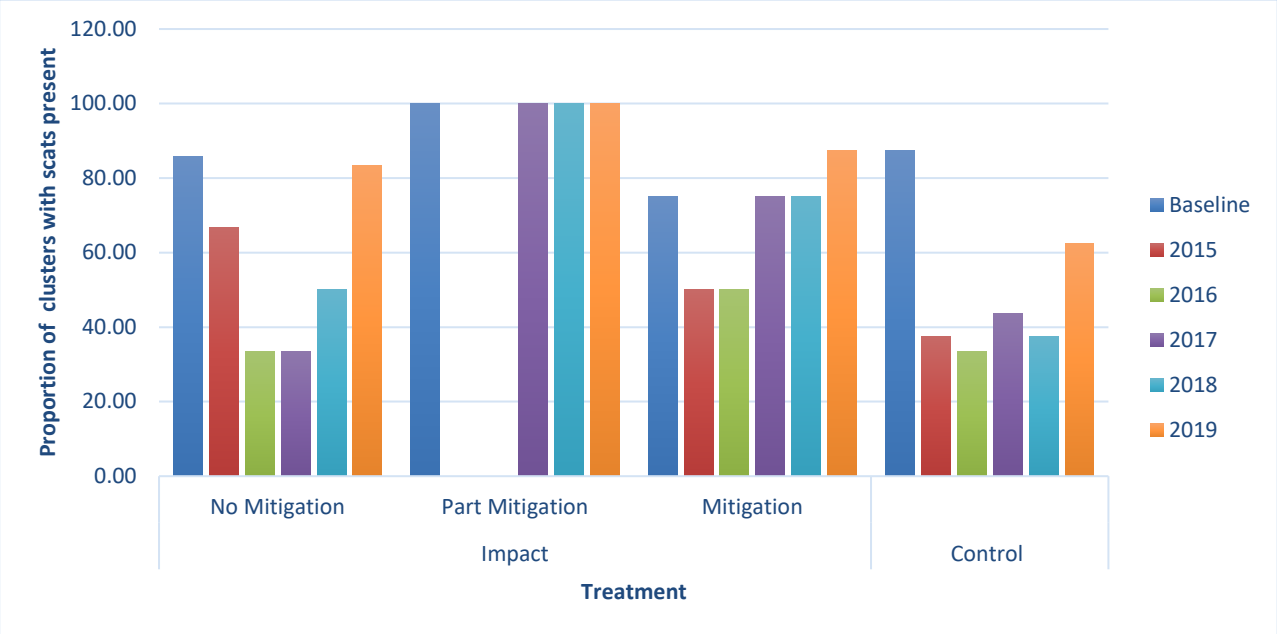


Graph 4: Koala presence at control and impact clusters

3.3 Mitigation v No Mitigation Analysis

3.3.1 Presence/absence analysis

Comparing Koala presence between mitigation and no-mitigation clusters shows no significant difference between the 2019 surveys and baseline, 2015, 2016, 2017 or 2018 surveys ($X^2 = 0.434$, df = 1, $p > 0.05$; $X^2 = 0.175$, df = 1, $p > 0.05$; $X^2 = 0.161$, df = 1, $p > 0.05$; $X^2 = 0.002$, df = 1, $p > 0.05$ and $X^2 = 0.121$, df = 1, $p > 0.05$, respectively). Graph 5 shows the percentage of clusters with scats present within different cluster types. There is no overall apparent trend between impact clusters with mitigation or without mitigation. While mitigation clusters appear to have a higher presence percentage in 2016, 2017, 2018 and 2019 than clusters with no mitigation, the presence percentage at clusters with no mitigation is similar to the presence percentage at control clusters during these years. This suggests that any difference is likely site specific and not necessarily related to construction activities.



Graph 5: Koala presence and cluster type

3.3.2 Treatment activity analysis

Koala activity (mean activity of plots) for the treatment types is provided in Table 6 and is shown for each area in Graph 6 (mean activity of all plots within each cluster type for each area). When considering all plots, average activity levels were lower than baseline levels for control and mitigation and higher than baseline for the first time since 2015 at no mitigation plots. When considering only active plots (with scats present), activity levels were slightly lower than, or the same as, baseline levels for all treatments. The 2019 monitoring plot activity levels were similar among treatments. Lewis 2014 recommends that analyses should:

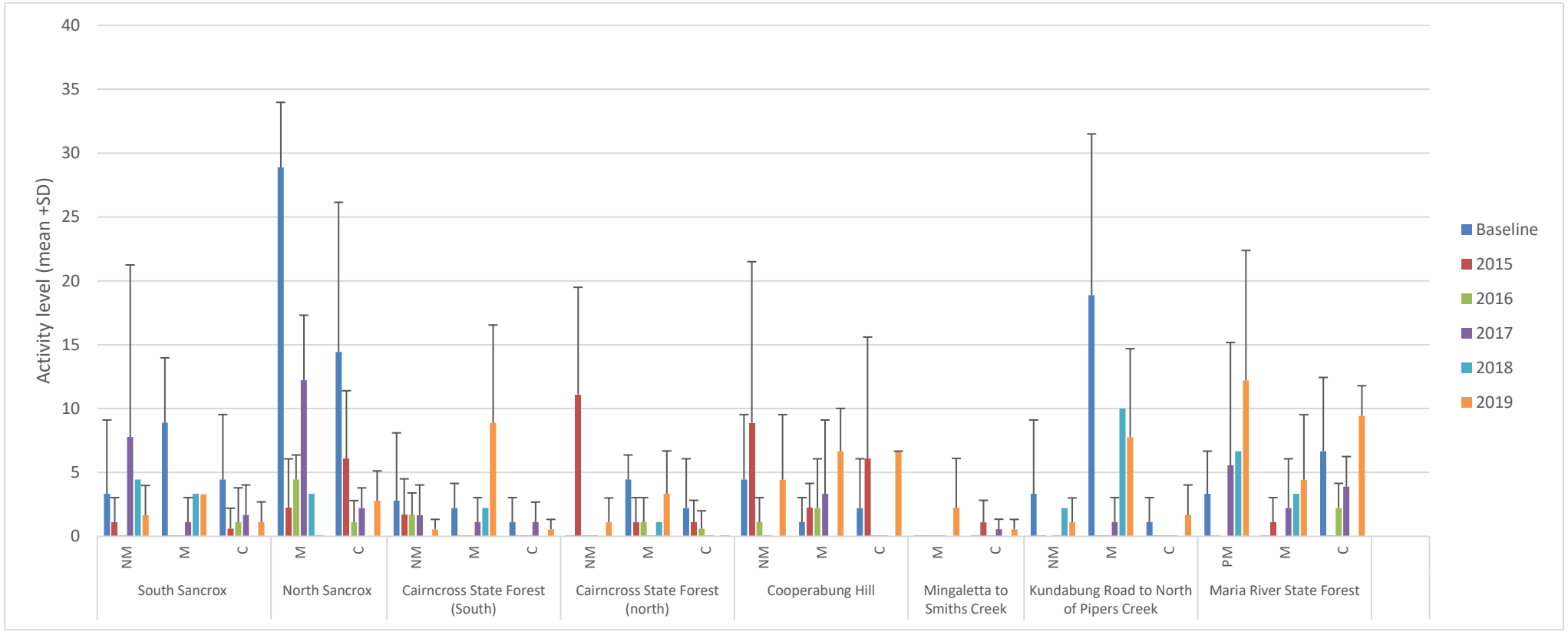
"Ensure any future comparison of Koala activity levels take into account the following baseline data and with a 10% tolerance level to account for variability:

- *Broader study area set at 5% activity;*
- *The three treatment classes of Mitigation set at 8.05%, control reference set at 4.03% and no mitigation set at 2.64%."*

When considering all plots or active plots only, activity levels for each treatment type have not decreased from the baseline surveys beyond the recommended 10% tolerance level. Nor is there a greater than 10% difference between treatment types.

Table 6: Control, mitigation and no mitigation plot activity levels

	Control						Mitigation						No Mitigation					
	Base	2015	2016	2017	2018	2019	Base	2015	2016	2017	2018	2019	Base	2015	2016	2017	2018	2019
All plots (n = plots surveyed)	4.0 (24) (SD6.4)	1.9 (38) (SD4.5)	0.5 (45) (SD1.4)	1.2 (48) (SD2.1)	2.5 (48) (SD6.4)	2.8 (47) (SD4.1)	8.1 (24) (SD11.0)	0.8 (24) (SD1.8)	1.2 (19) (SD2.3)	2.6 (24) (SD4.7)	2.9 (24) (SD4.5)	4.7 (22) (SD5.0)	2.6 (24) (SD4.2)	3.5 (21) (SD6.6)	0.6 (18) (SD1.3)	2.4 (21) (SD6.2)	2.1 (21) (SD3.7)	3.2 (20) (SD5.7)
Active plots (n = active plots)	8.8 (11) (SD6.9)	9.0 (10) (SD5.9)	3.9 (6) (SD1.4)	4.4 (13) (SD1.6)	9.2 (13) (SD9.5)	6.8 (19) (SD3.6)	12.9 (15) (SD11.5)	4.0 (5) (SD1.5)	4.7 (5) (SD1.8)	7.9 (8) (SD5.0)	7.0 (10) (SD4.6)	7.9 (13) (SD4.0)	7.0 (9) (SD3.9)	9.2 (8) (SD8.1)	3.3 (3) (SD0.0)	12.5 (4) (SD9.2)	7.2 (6) (SD3.3)	7.0 (9) (SD6.8)



Graph 6. Mean Koala activity for cluster type within areas (mean ± SD)

NM = no mitigation; M = mitigation; C = control; PM = part mitigation.

3.4 Tree Species Use

A total of 2,670 trees were assessed across the 89 plots (30 at each plot). Koala scats were recorded at 89 (3.3%) of the trees surveyed. Surveyed trees included 29 different tree species. The most commonly surveyed tree species were Tallowwood (*Eucalyptus microcorys*, 22.4%), Small-fruited Grey-Gum (*E. propinqua*, 9.7%), Coastal Blackbutt (*E. pilularis*, 9.6%), and Pink Bloodwood (*Corymbia intermedia*, 9.4%), together representing 53.3% of all trees surveyed. Koala scats were recorded at 15 (51.7%) different species (Table 7). Considering the percentage of individual tree species where scats were recorded, Koala scats were most commonly recorded beneath Forest Red Gum (*E. tereticornis*, 10.5%), Scribbly Gum (*E. signata*, 9.4%), Broad-leaved Paperbark (*Melaleuca quinquenervia*, 7.7%) and Tallowwood (6.6%). Diameter at breast height for SCTs are provided in Annex 1.

The baseline study (Lewis 2014) suggests comparing activity levels at Tallowwood trees given that they are widespread, are frequently surveyed and yielded relatively high activity scores during baseline surveys (i.e. 9.5%). Use of Tallowwoods (percent of surveyed Tallowwoods with scats) was 2.68%, 0.75%, 4.7%, 5.3% and 6.6% in 2015, 2016, 2017, 2018 and 2019, respectively. As such, compared to the baseline surveys, activity at Tallowwood trees has been consistently lower, but has increased during each subsequent monitoring event. This reflects the overall lower activity levels observed since the baseline studies were undertaken.

It should be noted that interpretation of these data should be undertaken with caution, as it is unlikely to reflect the actual use of tree species by Koalas. The detectability of Koala scats is largely determined by the level of leaf litter and fallen bark around the base of trees. For example, species such as Sydney Blue Gums (*E. saligna*) and Flooded Gum (*E. grandis*) shed substantial amounts of bark in comparison to species such as Tallowwoods, resulting in dense, layered groundcover and leaf litter, amongst which scats are more difficult to find.

Table 7: Tree species where scats were recorded – 2019 monitoring

Common name	Species name	Total surveyed	No. with scats	Percent use (%)
Swamp Mahogany	*Eucalyptus robusta*	33	1	3.03
Small-fruited Grey Gum	*Eucalyptus propinqua*	270	6	2.22
Coastal Blackbutt	*Eucalyptus pilularis*	268	11	4.10
Pink Bloodwood	*Corymbia intermedia*	262	8	3.05
Tallowwood	*Eucalyptus microcorys*	624	41	6.57
Turpentine	*Syncarpia glomulifera*	162	2	1.23
White Stringy bark	*Eucalyptus globoidea*	110	4	3.64
Broad-leaved Paperbark	*Melaleuca quinquenervia*	13	1	7.69
Thin-leaved Stringybark	*Eucalyptus eugenioides*	70	2	2.86
Forest Red Gum	*Eucalyptus tereticornis*	19	2	10.53
Thick-leaved Mahogany	*Eucalyptus carnea*	115	1	0.87
Red Bloodwood	*Corymbia gummifera*	201	1	0.50
Brush Box	*Lophostemon confertus*	34	1	2.94
Grey Ironbark	*Eucalyptus paniculata*	45	2	4.44
Scribbly Gum	*Eucalyptus signata*	64	6	9.38

3.5 Weather Conditions

Weather conditions during the field surveys were generally warm to hot (maximum temperatures between 26 and 38 degrees) with a few light to moderate rainfall events (Kempsey weather station 059007, Table 8).

Table 8: Weather conditions - 2019 monitoring

Date	Rainfall (mm)	Temp (°C) (max)	Temp (°C) (min)	Wind speed at 9am (km/h)
27/11/2019	0.2	26.2	14.2	15
29/11/2019	3.0	30.8	19.3	6
4/12/2019	0	32.2	*	7
10/01/2020	0	33.9	17.4	11
13/01/2020	0	30.1	15.3	11
15/01/2020	0	29.5	18.6	2
16/01/2020	*	32.4	21.1	7
17/01/2020	*	29.4	19.8	6
20/01/2020	*	34.8	21.1	9
22/01/2020	*	37.6	20.9	11
30/01/2020	*	32.6	23.0	9

* no data available

3.6 Road Kill

Lewis 2014 notes that "*During the current baseline survey only one individual was recorded during the weekly surveys performed in October and January/February. Ad hoc monitoring which spanned a 7 month period revealed additional road killed individuals but was consistent with Koala being struck every 6-8 weeks during the breeding period*". As per recommendations with the baseline report, the baseline road kill has therefore been set to 1 individual every 8 weeks. Table 9 lists the Koala road kill for the Project recorded during road kill surveys for the Project and any additional records. There has been a noticeable reduction in Koala road kill between clearing/construction and operational periods.

Table 9: Koala road kill records

Monitoring	Period	Date	Easting	Northing	Notes	Survey wks
Baseline*	2013-2014	4/10/2013	482178	6540579	Where the Project passes through Ballengarra State Forest	12
Clearing	2014-2015	17/11/2014	483187	6544354	Adult female struck on Tuesday/Wednesday (11/12th Nov)	35
		17/11/2014	483187	6544354	Young struck on Tuesday/Wednesday (11/12th Nov)	
		3/12/2014			300m North of Yarrabee Rd	
		21/7/2015			200 m North of Yarrabee Rd	
Construction	2015-2016	22/12/2015			1km north of Ravenswood Rd	50
Construction	2016-2017	5/10/2016	483413	6555959	Adolescent	49
		12/10/2016	482816	6553852	Adolescent	
Construction	2017-2018	Nil				14
Operational	2018-2019	17/9/2018			Young male. Barry's Creek	12
Operational	2019-2020	Nil				12

* = An additional three Koala road kill were recorded between August 2013 and February 2014, outside of the monitoring period

3.7 Additional Survey Results

3.7.1 Spotlighting

Spotlighting surveys commenced in October 2019, however, due to State Forests and National Parks high fire danger closures during summer, the required surveys could not be completed. Table 10 summarises the resulting 2019 survey effort. One Koala was observed at the Cairncross State Forest impact site (Figure 2).

As per the EMP, a detection frequency rate of 1 Koala/spotlight hour is considered as the baseline target density. Within the limited survey effort for 2019, the Cairncross State Forest impact site has recorded baseline density. The limited survey effort precludes comparison with baseline density for all other sites.

Table 10: 2019 spotlighting surveys and weather conditions

Site	Survey#	Date	Start time	Finish time	Temp (°C)	Humidity (%)	Rain (mm)	Wind (0-3)	# Koalas	Note
Ballengarra SF impact	1	23/10/2019	22:20	23:25	15.9	94	0	1	0	
Ballengarra SF control	1	23/10/2019	20:59	22:05	16.9	89	0	1	0	
Cairncross SF impact	1	22/10/2019	22:25	23:30	12.8	92	0	0	0	
Cairncross SF control	1	22/10/2019	20:55	22:05	15.1	84	0	0	0	
Maria River SF impact	1	29/10/2019	22:30	23:30	15.7	86	0	0	0	
Maria River SF control	1	29/10/2019	21:10	22:10	18.0	77	0	0	0	
Ballengarra SF impact	2	Site closed								
Ballengarra SF control	2	Site closed								
Cairncross SF impact	2	30/10/2019	22:25	23:30	19.6	80	0	1	1	Observed
Cairncross SF control	2	30/10/2019	21:00	22:00	20.0	79	0	1	0	
Maria River SF impact	2	Site closed								
Maria River SF control	2	Site closed								
Ballengarra SF impact	3	Site closed								
Ballengarra SF control	3	Site closed								
Cairncross SF impact	3	Site closed								
Cairncross SF control	3	Site closed								
Maria River SF impact	3	Site closed								
Maria River SF control	3	Site closed								

3.7.2 Additional Koala records

Additional records of Koala presence have been obtained during surveys undertaken for other monitoring components of the Project. These records are summarised below and in Table 11. All occur in areas where Koalas were detected during SAT surveys.

Fauna underpass monitoring

There are a number of culverts and bridges along the length of the Project that may provide passage for Koalas (Figure 2). Fourteen of these are being monitored as part of the Fauna Underpass Monitoring component of the Project. Koalas have been photographed on remote cameras using three of the dedicated fauna underpasses to date and these are shown on Figure 2 (Niche 2019c).

Yellow-bellied Glider monitoring

A Koala was observed during spotlighting surveys undertaken as part of the Yellow-bellied Glider monitoring component of the Project within the Cairncross State Forest impact site (Figure 2) (Niche 2019d).

Spotted-tailed Quoll monitoring

Koalas have been photographed on remote cameras as part of the Spotted-tailed Quoll monitoring component of the Project within Cairncross State Forest, Ballengarra State Forest, and Maria River (Figure 2) (Niche 2018b and 2020 unpublished data).

Table 11: Additional Koala records

Monitoring type	Monitoring-specific site name	Date
Underpass	F9.70	16/12/2018
Underpass	F11.67	24/11/2018
Underpass	F33.40	23/11/2018
Yellow-bellied Glider	Cairncross SF impact	27/11/2018
Spotted-tailed Quoll	MM1B	Winter 2018
Spotted-tailed Quoll	MNM1D	Winter 2018
Spotted-tailed Quoll	MREF2D	Winter 2018
Spotted-tailed Quoll	BNM2B	Winter 2018
Spotted-tailed Quoll	BM1C	Winter 2018
Spotted-tailed Quoll	BM1A	Winter 2020
Spotted-tailed Quoll	CREF1B	Winter 2020

4. Discussion

4.1 Performance Measures

A discussion of the 2019 survey results in relation to the performance measures is provided in Table 12.

Table 12: Performance measures

Performance measure	Response
Monitoring is undertaken during baseline surveys and from Year 1 – Year 6 & 8, or until mitigation measures are demonstrated to be effective.	**This performance measure has been met**. To date, SAT plot monitoring has been undertaken during baseline, Year 1 (2015), Year 2 (2016), Year 3 (2017), Year 4 (2018) and Year 5 (2019) of the Project.
Monitoring during Year 1 – Year 6 & 8 is undertaken at the Impact and Control sites where monitoring was undertaken during baseline surveys, subject to ongoing landowner agreement. Where landowner agreement cannot be obtained and the process in Section 3.1.2 of the EMP has been followed, this performance indicator will also be considered to have been met.	**This performance measure has been met**. Monitoring was undertaken at the same sites as surveyed in 2015. In 2015, eight of the baseline plots had to be relocated to nearby locations because they had been established in the construction site itself or because they were located on private property and access was not possible. Also, three of the baseline monitoring plots that could not be accessed could not be relocated because there weren't any suitable sites nearby. These three plots were all part of the same cluster (impact, no mitigation) located in the North Sancrox area. Details of all 96 monitoring plots are presented in Table 1 and the location of the 93 accessible monitoring plots are shown in Figure 1.
Mitigation measures are demonstrated to be effective as defined in the EPBC approval when all monitoring events are considered at Year 8.	Not applicable for Year 5. However, a summary of the efficacy of the mitigation measures to date in relation to treatment Type A: impact with mitigation (sufficiently large culverts and floppy top fencing), indicates: • Three of the fourteen monitored culverts have recorded use by the Koala (Figure 2) • Since commencement of construction (year 1), six Koalas have been recorded as road kill, five during construction and one during operation. The last construction Koala road kill occurred in October 2016, year 2 of the Project (Niche 2018c). The Project became operational in year 4, March 2018 and in September 2018 a Koala road kill occurred at Barry's Creek, between clusters MING1 and COOP2. It was considered most likely that the Koala accessed the road corridor via a flood damaged section of the fauna fence, which has since been repaired.
Fauna fence is installed at a minimum in areas identified in Schedule 3 of the EPBC approval at Year 4.	**This performance measure has been met.** TfNSW have advised that fauna fencing is complete in all areas in accordance with Condition 3c and Schedule 3 of EPBC Approval 2012/6518.
Density: Koala spotlighting records are compared to and discussed with reference to the baseline records, with the baseline detection frequency rate of 1 Koala per spotlight hour considered as the baseline density, as recommended in the baseline report. Compare the NSW BioNet wildlife Atlas density ranking of 5 km^2 grids, as per the baseline report, between pre and post-construction at Year 8.	*Spotlighting* **This performance measure has been at the Cairncross State Forest impact site**. Limited survey effort due to high fire risk park closures precluded the assessment of this parameter at all other sites. *BioNet Atlas analysis* These analyses are to be undertaken at Year 8 and are therefore not considered in this report.

Performance measure	Response
Movement: Reduction in Koala road kill compared to the baseline of 1 Koala road kill per 8 weeks for an average baseline plot activity level of 5%, whereby proportional changes in average plot activity level may be reflected in the acceptable level of koala road kill.	**This performance measure has been met.** During 2019 monitoring, plot activity level for all plots was 3.3% (Baseline 4.9%) and for active plots was 7.2% (Baseline 10.1%). As such, if considering activity level for all plots for the Project, road kill should be proportionally less than 1 Koala per 8 weeks: a 1.7% reduction in activity level reflects a proportional reduction of 34%, which should therefore be reflected by a 34% reduction in road kill, i.e. 1 Koala road kill every 10.5 weeks. Road kill monitoring is undertaken for 12 weeks each year (four weeks in spring, summer and autumn) and incidental or additional reports of Koala road kill are considered. Operational Koala road kill is as follows: • 2018: September 2018 a Koala road kill occurred at Barry's Creek, between clusters MING1 and COOP2. • 2019: no Koala road kill reported. Therefore the Koala road kill rate for 2019 monitoring is lower than the baseline average.
Distribution: Compare the number of records and clustering of records, as per the baseline report, between pre-construction and construction/post-construction at year 8.	These analyses are to be undertaken at Year 8 and are therefore not considered in this report.
Habitat Use: Koala SAT activity levels will be compared to the baseline activity levels data (below) with a 10% tolerance level, as recommended in the baseline report, to account for variability: • Broader study area set at 5% activity; • The treatment classes of mitigation set at 8.05%, no mitigation set at 2.64% and control / reference set at 4.03% • Comparison of percent tree use with baseline tree use.	**This performance measure has been met.** When considering all plots or active plots only, activity levels for each treatment type have not decreased from the baseline surveys beyond the recommended 10% tolerance level. Nor is there a greater than 10% difference between treatment type. Use of Tallowwoods (percent of surveyed Tallowwoods with scats) was 2.68%, 0.75%, 4.7%, 5.3% and 6.6% in 2015, 2016, 2017, 2018 and 2019, respectively. As such, compared to the baseline surveys, activity at Tallowwood trees has been consistently lower, but has increased during each subsequent monitoring event. This reflects the overall lower activity levels observed since the baseline studies were undertaken.

5. Recommendations

5.1 Contingency Measures and Recommendations

The EMP lists potential problems and contingency measures for various components of the monitoring program. Those that are considered to be relevant to the Koala monitoring program are listed and discussed in Table 13. No additional mitigation recommendations have been made at this stage based on the following:

- No significant changes from baseline surveys have been detected to date
- Koalas have been detected using three of the dedicated fauna underpasses within the Project area
- Limited spotlighting survey effort precludes assessment of density levels at all sites.

Table 13: Contingency measures

Potential problem	Contingency measure proposed in EMP	Discussion of proposed measure
Decline in presence of target species recorded at Impact sites after the upgrade has been completed, when compared to change in Control sites.	• Investigate cause of decline in consultation with EPA and DoTE within two weeks of results reported by ecologist. • If the cause of the decline is considered most likely attributable to the upgrade of the highway, mitigation measures will be reviewed within two months of the above consultation.	**This contingency measure is not considered relevant.** To date, no significant change has been detected in the difference in Koala presence at control and impact sites between baseline and subsequent monitoring events.

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Annex 1. Koala SAT results – 2019 monitoring

SCT = selection criteria tree; DBH = diameter at breast height in centimetres (cm); Radial = radial distance of search area from SCT in metres (m).

Monitoring area	Treatment	Sub-category	Site_ID	Map ref	Activity	SCT	DBH (cm)	Radial (m)	Notes
South Sancrox	Impact	No Mitigation	SANCROX E1	SSAN1	3.3	Tallowwood	46	25	
South Sancrox	Impact	No Mitigation	SANCROX E2		fire	Thin-leaved Stringybark			fire
South Sancrox	Impact	No Mitigation	SANCROX E3		0.0	Tallowwood	45	17	
South Sancrox	Impact	Mitigation	SANCROX S1	SSAN2	fire	Blackbutt			fire
South Sancrox	Impact	Mitigation	SANCROX S2		fire	Thin-leaved Stringybark			fire
South Sancrox	Impact	Mitigation	SANCROX S3		3.3	Flooded Gum	68	30	not tagged
South Sancrox	Control	Control	COWARRA SF1	SSAN3	6.7	Small-fruited Grey Gum	70	20	not tagged
South Sancrox	Control	Control	COWARRA SF2		0.0	Blackbutt	165	20	
South Sancrox	Control	Control	COWARRA SF3		0.0	Small-fruited Grey Gum	38	15	
South Sancrox	Control	New Control	SAT COWARRA NC1	SSAN4	0.0	Blackbutt	55	20	
South Sancrox	Control	New Control	SAT COWARRA NC2		0.0	*E. carnea*	49	28	
South Sancrox	Control	New Control	SAT COWARRA NC3		0.0	Blackbutt	52	22	
North Sancrox	Impact	Mitigation	FERNBANK CK1	NSAN1	0.0	Tallowwood	63	20	
North Sancrox	Impact	Mitigation	FERNBANK CK2		0.0	Tallowwood	37	18	
North Sancrox	Impact	Mitigation	FERNBANK CK3		0.0	Tallowwood	43	22	
North Sancrox	Control	Control	LAKE INNES1	NSAN2	3.3	Tallowwood	75	22	not tagged
North Sancrox	Control	Control	LAKE INNES2		0.0	Swamp Mahogany	47	25	
North Sancrox	Control	Control	LAKE INNES3		10.0	Swamp Mahogany	46	35	
North Sancrox	Control	New Control	SAT COW4	NSAN3	0.0	Blackbutt	65	27	
North Sancrox	Control	New Control	SAT COW5		3.3	Small-fruited Grey Gum	32	22	
North Sancrox	Control	New Control	SAT COW6		0.0	*E. acmenoides*	46	17	
Cairncross State Forest (South)	Impact	No Mitigation	CAINCROSS SF1	CCS1	0.0	Tallowwood	36	30	

Monitoring area	Treatment	Sub-category	Site_ID	Map ref	Activity	SCT	DBH (cm)	Radial (m)	Notes
Cairncross State Forest (South)	Impact	No Mitigation	CAINCROSS SF2		3.3	Tallowwood	55	35	
Cairncross State Forest (South)	Impact	No Mitigation	CAINCROSS SF3		0.0	Tallowwood	24	22	
Cairncross State Forest (south)	Impact	No Mitigation	CAINCROSS SF16	CCS2	0.0	Tallowwood	38	20	
Cairncross State Forest (south)	Impact	No Mitigation	CAINCROSS SF17		0.0	Tallowwood	43	18	
Cairncross State Forest (south)	Impact	No Mitigation	CAINCROSS SF18		0.0	Tallowwood	36	26	not tagged
Cairncross State Forest (South)	Impact	Mitigation	CAINCROSS SF4	CCS3	13.3	Tallowwood	55	22	
Cairncross State Forest (South)	Impact	Mitigation	CAINCROSS SF5		13.3	Tallowwood	43	18	
Cairncross State Forest (South)	Impact	Mitigation	CAINCROSS SF6		0.0	Blackbutt	70	25	
Cairncross State Forest (South)	Control	Control	LIMEBURNERS CK1	CCS4	0.0	Scribbly Gum	111	27	not tagged
Cairncross State Forest (South)	Control	Control	LIMEBURNERS CK2		0.0	Scribbly Gum	80	35	not tagged
Cairncross State Forest (South)	Control	Control	LIMEBURNERS CK3		0.0	Scribbly Gum	51	25	not tagged
Cairncross State Forest (South)	Control	New Control	SAT PEVI1	CCS5	3.3	Sydney Blue Gum	62	28	
Cairncross State Forest (South)	Control	New Control	SAT PEVI2		0.0	Sydney Blue Gum	38	22	
Cairncross State Forest (South)	Control	New Control	SAT PEVI3		0.0	Sydney Blue Gum	48	30	
Cairncross State Forest (north)	Impact	No Mitigation	CAINCROSS SF7	CCN1	0.0	Blackbutt	72	28	
Cairncross State Forest (north)	Impact	No Mitigation	CAINCROSS SF8		3.3	Forest Red Gum	59	35	
Cairncross State Forest (north)	Impact	No Mitigation	CAINCROSS SF9		0.0	Blackbutt	68	22	
Cairncross State Forest (north)	Impact	Mitigation	CAINCROSS SF10	CCN2	6.7	Swamp Mahogany	38	22	
Cairncross State Forest (north)	Impact	Mitigation	CAINCROSS SF11		0.0	Tallowwood	57	25	
Cairncross State Forest (north)	Impact	Mitigation	CAINCROSS SF12		3.3	Tallowwood	84	18	
Cairncross State Forest (north)	Control	Control	CAINCROSS SF13	CCN3	0.0	Small-fruited Grey Gum	47	25	
Cairncross State Forest (north)	Control	Control	CAINCROSS SF14		0.0	Sydney Blue Gum	37	20	
Cairncross State Forest (north)	Control	Control	CAINCROSS SF15		0.0	Sydney Blue Gum	109	38	not tagged
Cairncross State Forest (north)	Control	New Control	SAT RR1	CCN4	0.0	Tallowwood	50	30	
Cairncross State Forest (north)	Control	New Control	SAT RR2		0.0	Small-fruited Grey Gum	60	16	
Cairncross State Forest (north)	Control	New Control	SAT RR3		0.0	Tallowwood	48	20	

Monitoring area	Treatment	Sub-category	Site_ID	Map ref	Activity	SCT	DBH (cm)	Radial (m)	Notes
Cooperabung Hill	Impact	No Mitigation	COOPERABUNG1	COOP1	0.0	Tallowwood	68	40	
Cooperabung Hill	Impact	No Mitigation	COOPERABUNG2		3.3	Small-fruited Grey Gum	48	40	
Cooperabung Hill	Impact	No Mitigation	COOPERABUNG3		10.0	Tallowwood	53	25	
Cooperabung Hill	Impact	Mitigation	COOPERABUNG4	COOP2	10.0	Tallowwood	35	35	
Cooperabung Hill	Impact	Mitigation	COOPERABUNG5		6.7	Tallowwood	24	23	
Cooperabung Hill	Impact	Mitigation	COOPERABUNG6		3.3	Tallowwood	64	20	
Cooperabung Hill	Control	Control	COOP HILL1	COOP3	3.3	Tallowwood	53	20	
Cooperabung Hill	Control	Control	COOP HILL2		6.7	Small Fruited Grey Gum	47	25	
Cooperabung Hill	Control	Control	COOP HILL3		10.0	Tallowwood	32	15	
Cooperabung Hill	Control	New Control	SAT FL1	COOP4		Red Mahogany			
Cooperabung Hill	Control	New Control	SAT ST1		10.0	Tallowwood	47	15	
Cooperabung Hill	Control	New Control	SAT ST2		3.3	Tallowwood	35	20	
Mingaletta to Smiths Creek	Impact	Mitigation	MIN-SMITHS CK1	MING1	0.0	Blackbutt	42	18	
Mingaletta to Smiths Creek	Impact	Mitigation	MIN-SMITHS CK2		0.0	Tallowwood	56	30	
Mingaletta to Smiths Creek	Impact	Mitigation	MIN-SMITHS CK3		6.7	Small-fruited Grey Gum	39	25	
Mingaletta to Smiths Creek	Control	Control	BALLENGARA SF1	MING2	0.0	Tallowwood	35	20	Half plot logged and burnt
Mingaletta to Smiths Creek	Control	Control	BALLENGARA SF2		3.3	Tallowwood	32	40	
Mingaletta to Smiths Creek	Control	Control	BALLENGARA SF3		0.0	Tallowwood	33	35	
Mingaletta to Smiths Creek	Control	New Control	SAT BR1	MING3	0.0	Sydney Blue Gum	41	30	logging in plot
Mingaletta to Smiths Creek	Control	New Control	SAT BR2		0.0	Sydney Blue Gum	54	25	logging immediately adjacent (east of rd)
Mingaletta to Smiths Creek	Control	New Control	SAT BR3		0.0	Flooded Gum	60	40	
Kundabung Road to North of Pipers Creek	Impact	No Mitigation	KUNDABUNG 1	KUND1	0.0	Flooded Gum	41	15	
Kundabung Road to North of Pipers Creek	Impact	No Mitigation	KUNDABUNG 2		3.3	Tallowwood	42	25	
Kundabung Road to North of Pipers Creek	Impact	No Mitigation	KUNDABUNG 3		0.0	Pink Bloodwood	40	18	
Kundabung Road to North of Pipers Creek	Impact	Mitigation	KUNDABUNG 4	KUND2	10.0	Small Fruited Grey Gum	40	23	

Monitoring area	Treatment	Sub-category	Site_ID	Map ref	Activity	SCT	DBH (cm)	Radial (m)	Notes
Kundabung Road to North of Pipers Creek	Impact	Mitigation	KUNDABUNG 5		13.3	Blackbutt	54	18	
Kundabung Road to North of Pipers Creek	Impact	Mitigation	KUNDABUNG 6		0.0	Grey Ironbark	56	45	
Kundabung Road to North of Pipers Creek	Control	Control	KUMBATINE NP1	KUND3	3.3	Tallowwood	38	25	
Kundabung Road to North of Pipers Creek	Control	Control	KUMBATINE NP2		0.0	Tallowwood	42	18	
Kundabung Road to North of Pipers Creek	Control	Control	KUMBATINE NP3		6.7	*E. carnea*	54	32	
Kundabung Road to North of Pipers Creek	Control	New Control	SAT MAC1	KUND4	0.0	Red Mahogany	96	35	
Kundabung Road to North of Pipers Creek	Control	New Control	SAT MAC2		0.0	Spotted Gum	44	18	
Kundabung Road to North of Pipers Creek	Control	New Control	SAT MAC3		0.0	Spotted Gum	52	25	
Maria River State Forest	Impact	Part Mitigation	MARIA RIVER 1	MR1	3.3	Pink Bloodwood	38	35	
Maria River State Forest	Impact	Part Mitigation	MARIA RIVER 2		23.3	Tallowwood	42	30	
Maria River State Forest	Impact	Part Mitigation	MARIA RIVER 3		10.0	Tallowwood	50	23	
Maria River State Forest	Impact	Mitigation	MARIA RIVER 4	MR2	10.0	Thin-leaved Stringybark	39	22	
Maria River State Forest	Impact	Mitigation	MARIA RIVER 5		3.3	Tallowwood	65	25	
Maria River State Forest	Impact	Mitigation	MARIA RIVER 6		0.0	Tallowwood	41	18	
Maria River State Forest	Control	Control	MARIA NP1	MR3	10.0	Tallowwood	31	38	
Maria River State Forest	Control	Control	MARIA NP2		10.0	Tallowwood	65	33	
Maria River State Forest	Control	Control	MARIA NP3		13.3	Tallowwood	40	40	
Maria River State Forest	Control	New Control	SAT CO1	MR4	13.3	White Stringybark	80	27	
Maria River State Forest	Control	New Control	SAT CO3		3.3	Blackbutt	70	30	
Maria River State Forest	Control	New Control	SAT MAR 1		6.7	Tallowwood	100	18	

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Giant Barred Frog Monitoring 2019/2020

Oxley Highway to Kempsey, Pacific Highway Upgrade

Prepared for Transport for NSW

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Cover photograph: Giant Barred Frog (Photo: Matthew Stanton)

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Executive summary

Context

This report documents findings of the second of five operational monitoring periods for the Giant Barred Frog (*Mixophyes iteratus*), as required for the Oxley Highway to Kempsey (OH2K) Pacific Highway Upgrade Project (the Project), and specified in the Oxley Highway to Kempsey (OH2K) Ecological Monitoring Program (EMP, RMS 2019). Transport for NSW (TfNSW) is required to manage and monitor the effectiveness of biodiversity mitigation measures implemented as part of the Project. The Giant Barred Frog is one of the threatened species identified as requiring mitigation and monitoring throughout the course of the construction and operational periods of the Project.

Aims

The aim of the Giant Barred Frog monitoring program is to determine, through evaluation of the performance indicators outlined in the EMP, if the Project is having an impact on the species and whether corrective actions are required.

Methods

Six sites (two reference and four impact) were monitored. Each site consists of a one kilometre transect along the creek line, divided into 10 x 100 metre zones. Each monitoring location was surveyed in accordance with the monitoring method and design specified in the EMP. Surveys were undertaken after a sufficient rainfall trigger event (> 10 millimetres within a 24 hour period) and involved passive listening, call playback (upon arrival and at intervals during searches), active searching (within 20 metres of each creek bank) and habitat surveys within each of the 100 metre zones.

Key results

Surveys were undertaken on the 15 – 17 October 2019 (spring), 21 – 23 Janaury 2020 (summer) and 17 – 19 March 2020 (autumn) after suitable rainfall. A total of 46 Giant Barred Frogs were recorded during the 2019/2020 monitoring period and 30% (n = 12) of those captured were recaptures. Frogs were recorded at three of the six sites in all seasons including Smiths Creek impact, Pipers Creek impact and Pipers Creek reference. A single Giant Barred Frog was recorded at Maria River impact site and Giant Barred Frogs were not recorded at Cooperabung Creek impact site. The highest mean number of Giant Barred Frogs was recorded at Pipers Creek reference site.

Evidence of breeding via the presence of juveniles or sub-adults, gravid females or reproductive males was observed at all sites where frogs were recorded during at least one survey event during 2019/2020.

Fifteen (31%) of the 49 recaptures from impact sites have been captured on both sides of the carriageway over successive monitoring events.

Eleven (29%) of the 38 recaptures from reference sites have been captured on both sides of the midpoint over successive monitoring events

All sites had at least one water quality parameter for one or more monthly results for which the median downstream value exceeded the 80th percentile of the upstream value.

Conclusions

Performance measures relating to undertaking monitoring have to date been met.

The performance measure relating to continued presence of Giant Barred Frogs during each survey event where it was identified during baseline surveys was met for three of the six sites. The three sites where Giant Barred Frogs were recorded during baseline surveys but not in the current monitoring included: Cooperabung Creek impact site (where it was recorded during all three baseline surveys), Maria River impact, during summer 2020, and Cooperabung Creek reference site during spring 2019.

The performance measure relating to changes in density and mean records was not met. All sites appear to show an overall decreasing trend in mean records and densities. However, as this decreasing trend is evident at both impact and reference sites, it is not possible to attribute these changes to the Project at this stage.

The water quality performance measure was met for all parameters. Exceedances were not considered to be attributable to construction activities.

Management implications

Given the variable nature of annual mean records among sites, the evidence of decreasing trends at reference sites and the lack of a distinct difference between impact and reference sites, it is not possible to attribute observed changes in frog numbers to the Project. As such, it is recommended that monitoring continue as per the EMP.

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1. Introduction

1.1 Context

The Oxley Highway to Kempsey (OH2K) section of the Pacific Highway Upgrade Project (the Project) was approved in 2012 subject to various Ministers Conditions of Approval (MCoA) and a Statement of Commitments (SoC). A subsequent approval with additional conditions of consent (CoA) was granted in 2014 by the Commonwealth Department of Agriculture, Water and the Environment (DAWE, previously the Department of Environment (DoE)) for Matters of National Environmental Significance (MNES) listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Ecological Monitoring Program (hereafter referred to as the EMP) (RMS 2019) combines these approval conditions and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project.

The Giant Barred Frog (*Mixophyes iteratus*) was one threatened species identified as requiring mitigation and monitoring through the course of the Project's construction and operational period.

1.1.1 Legal status

The Giant Barred Frog is listed as endangered under the New South Wales *Biodiversity Conservation Act 2016* (BC Act) and Commonwealth EPBC Act. Monitoring of the species is required under the Project's approval.

1.1.2 Monitoring framework

The design, methods and performance indicators that define the Giant Barred Frog monitoring program are specified in the EMP and Giant Barred Frog Management Strategy (GBFMS, Lewis 2013). Where there are discrepancies between the EMP and the GBFMS, the EMP takes precedence (Section 1.2 RMS 2019).

The EMP required monitoring of the Giant Barred Frog three times a year (spring, summer and autumn) in years 1, 2 and 3 once substantial construction commenced. Following completion of the Project, surveys are to be undertaken for five consecutive years, in spring, summer and autumn of Year 4, 5, 6, 7 and 8 (operational phase) or until mitigation measures can be demonstrated to have been effective. To date, these monitoring events have been undertaken and reported as follows:

- Construction phase monitoring:
  - *Autumn 2015* (Year 1): Niche 2015a
  - *Spring 2015, summer and autumn 2016* (Year 1): Niche 2016
  - *Spring 2016, summer and autumn 2017* (Year 2): Niche 2017
  - *Spring 2017, summer 2018* (Year 3): Niche 2018.
- Operational phase monitoring:
  - *Autumn 2018* (Year 3)*:* Niche 2018
  - *Spring 2018, (summer 2019 insufficient rainfall) and autumn 2019* (Year 4): Niche 2019
  - *Spring 2019, summer and autumn 2020* (Year 5): Current report

This report addresses Year 5 of the operational phase monitoring for the Project. This report therefore represents the sixth of nine monitoring reports for the Giant Barred Frog. The next round of operational monitoring will commence in spring 2020.

Water quality monitoring is also being conducted within Giant-Barred Frog habitat and potential habitat. Water quality monitoring commenced prior to construction, continued during construction and will

continue for three years during the operational phase. Water monitoring results for the Giant Barred Frog impact sites are included in this report.

1.1.3 Baseline data

The EMP specifies the following regarding the Giant Barred Frog:

"The Giant Barred Frog was recorded at Maria River and suitable habitat was identified at Smiths Creek, Pipers Creek and Cooperabung Creek during surveys undertaken to inform the Environmental Assessment (GHD 2010). Targeted surveys undertaken over eight nights between late November 2012 and late January 2013, involving spotlighting, call-playback and tadpole searches, identified the Giant Barred Frog at Cooperabung Creek (south), Cooperabung Creek downstream at Haydons Wharf Road, Smiths Creek, Pipers Creek and Maria River. Areas of suitable habitat for the Giant Barred Frog were also identified at both Stumpy Creek and Barrys Creek"

The EMP lists six sites to be monitored:

- Four impact sites: Cooperabung Creek, Smiths Creek, Pipers Creek, and Maria River.
- Two reference sites: Sun Valley Road (where it crosses Cooperabung Creek), and Old Coast Road (where it crosses Pipers Creek).

Baseline surveys (Niche 2015b) recorded a total of 152 Giant Barred Frogs, at all six monitoring sites in spring and summer and at four sites in autumn. Frogs were absent from the Maria River impact site and Pipers Creek reference site during the autumn 2014 baseline survey.

1.1.4 Purpose of this report

The purpose of this report is to summarise the methods and results of the 2019/2020 monitoring and determine if performance measures are being met, as per the EMP.

1.2 Performance Measures

The EMP specifies the following performance measures for the Giant Barred Frog:

- *Monitoring is undertaken during baseline surveys and Years 1 – 8 or until monitoring can demonstrate that mitigation measures are effective.*
- *Monitoring during Years 1 – 8 is undertaken at the Impact and Control sites where baseline monitoring was undertaken, subject to landowner agreement.*
- *Continued presence of Giant Barred Frogs during each survey event in Years 1 – 8 at sites where it was identified during baseline surveys, subject to access due to landowner agreement.*
- *Mitigation measures are effective as defined in the EPBC approval when all monitoring events are considered at Year 8.*
- *Median values of all downstream water quality monitoring at GBF habitat or potential habitat locations during construction and operation (Year 1 – 6) is less than the 80th percentile value of the upstream site (where 80th percentile is the value at which median values at the downstream site are above 80% of the recorded background water quality records), where this change is found to be attributable to construction or operation.*
- *At Year 8, no change to GBF densities, distribution, habitat use and movement patterns compared to baseline data.*

1.3 Monitoring Timing

Monitoring is to occur three times a year: spring, summer and autumn. Monitoring is to occur in the middle of the season, within one week of rainfall of 10 millimetres within a 24 hour period.

1.4 Reporting

As per the EMP, annual reporting of monitoring results will include:

- Detailed description of monitoring methodology
- Results of the monitoring period
- Discussion of results, including how the results compare against performance measures, if any modifications to timing or frequency of monitoring periods or monitoring methodology are required and any other recommendations
- If contingency measures should be implemented.

This report prepared under the EMP will be submitted to NSW Department of Planning, Industry and Environment (DPIE), the NSW Environment Protection Authority (EPA) and DAWE.

1.5 Limitations

The following limitations to the monitoring procedure were encountered:

- As reported in Niche (2017), increasing density of Lantana (*Lantana camara*) at a number of sites, notably Maria River impact site and Pipers Creek impact site, is hampering survey efforts. Safe navigation of the creek lines has become difficult due to low visibility and steep creek banks. Giant Barred Frogs have become difficult to detect and impossible to access in areas due to this Lantana growth. TfNSW will undertake localised thinning of Lantana to improve access however, given the presence of Lantana immediately adjacent, the role of Lantana acting as shelter for the species, the extent of this species (and others) and their high likelihood of re-establishment, TfNSW considered that localised management of weeds would be ineffective in the long term.

2. Methodology

2.1 Monitoring Sites

Monitoring was undertaken at the four impact and two reference sites. Each site consists of a one kilometre transect along the creek line.

Where possible, impact site transects extend 450 metres upstream and 450 metres downstream of the Project footprint (assumes Project boundary width of 100 metres) and are divided into 10 x 100 metre zones, resulting in four to five zones downstream of the Project footprint, one within the Project footprint, and four to five upstream of the Project footprint. As for previous monitoring events, the Cooperabung Creek impact site was not surveyed for the full kilometre as access agreements with landowners could not be obtained for the final downstream zone, and for the first two upstream zones.

The two reference sites are located several kilometres upstream of the Project footprint within Cooperabung Creek and Pipers Creek.

The location of all monitoring sites is shown in Figure 1, with detailed locations for each site transect provided in Figure 2 to Figure 7.

2.2 Giant Barred Frog Survey Method

Surveys were undertaken in accordance with the EMP after sufficient rainfall events.

A two hour minimum search time, using two ecologists, at each site was employed, however access and movement difficulties due to dense vegetation often resulted in increased survey time. Surveys involved passive listening, call playback (upon arrival and at intervals during searches), active searching (within 20 metres of creek bank) and habitat surveys. In accordance with the EMP, the following habitat data was collected within each of the 100 metre zones:

- Overstorey vegetation cover (OS, expressed as a cover percentage out of 100%)
- Shrub cover (expressed as a cover percentage out of 100%)
- Ground cover (expressed as a cover percentage out of 100%)
- Leaf litter cover (expressed as a cover percentage out of 100%)
- Bare soil/earth (expressed as a cover percentage out of 100%)
- Presence of cattle (based on hoof marks, manure and whether it is recent or aged evidence)
- Number of pools and riffles within the zone
- Approximate depth of the deepest pool within the zone
- Number of breaches in frog fencing, if applicable.

The position of all observed Giant Barred Frogs was recorded and, where possible, individuals were captured. Captured individuals were checked for recapture status and fitted with a Passive Integrated Transponder (PIT) tag if the individual was previously unknown. In accordance with the EMP, the following data were collected for captured individuals:

- Location according to demarcated survey zone
- Distance from stream edge
- Sex (male, female, unknown)
- Breeding condition with:
    - Males assessed on the colouration of their nuptial pads (i.e. no colour, light, moderate, dark)

- Females based on whether they are gravid or not gravid (egg bearing).
- Snout-vent length (millimetres)
- Weight (grams).

Temperature and humidity (either by windwatch or hygrometer), % cloud cover and broad wind level (scale of 0-3 where 0 = no wind) were recorded for each survey. Rainfall (millimetres) within the previous 24 hours was recorded from the Port Macquarie Airport (BOM Station No. 060183) and Maria River (BOM Station No. 560003) Bureau of Meterorology weather stations.

2.3 Water Quality

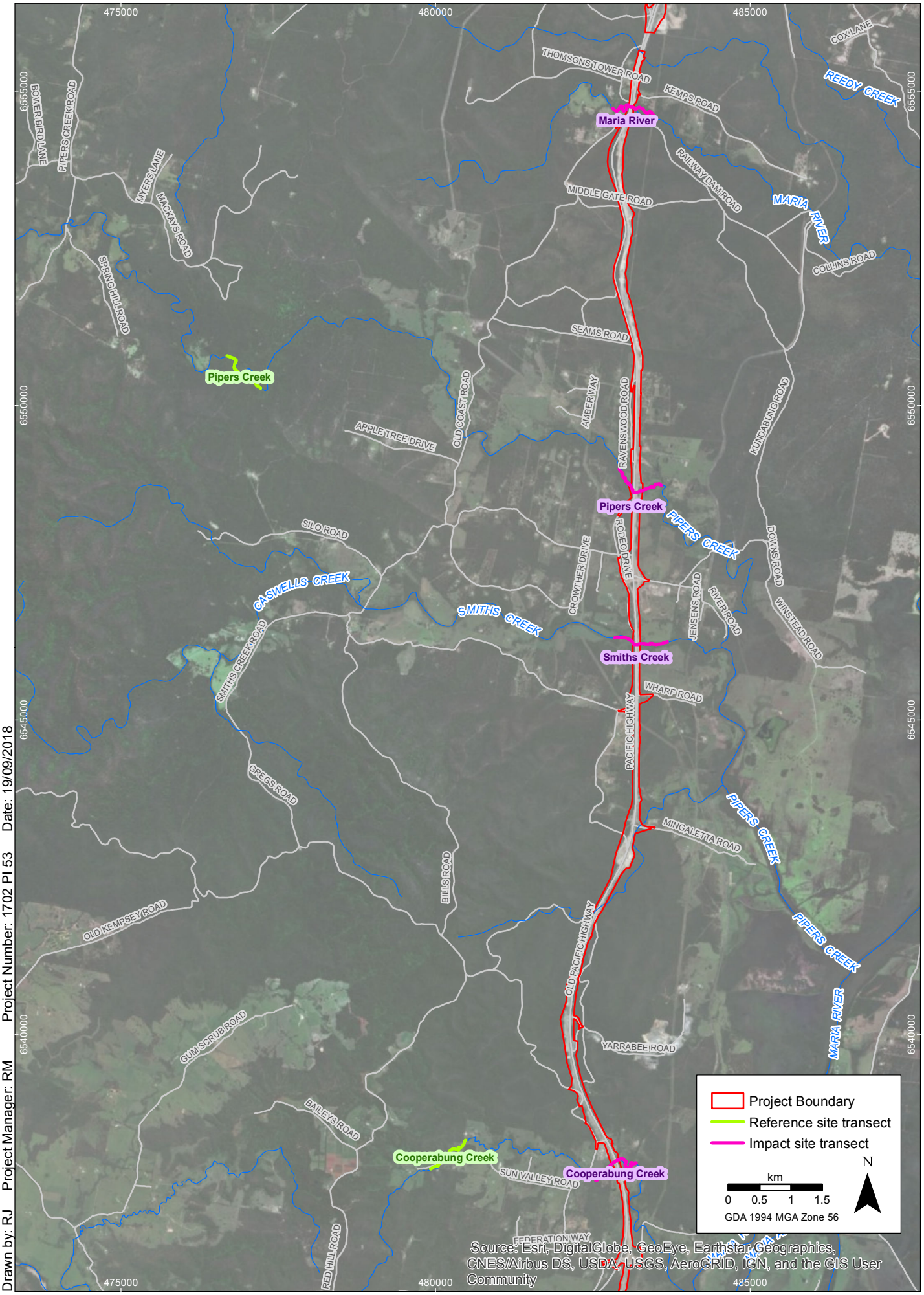
Water quality monitoring was undertaken by TfNSW between 30 March 2019 and 29 March 2020 (TfNSW 2020). TfNSW (2020) presents results from the first operational water quality monitoring period and this report summarises water quality data from both upstream and downstream sites for Cooperabung Creek, Smiths Creek, Pipers Creek, and Maria River.

The median water quality value for downstream sites was compared with the site specific trigger values developed for the upstream site based on: the 80th percentile and, where relevant, the 20th percentile, as well as the ANZECC default trigger values for physical and chemical stressors for south-east Australian slightly disturbed, freshwater ecosystems. Trigger values were derived from 24 sampling events up to and including the month indicated, where data was available.

2.4 Analysis

For consistancy with Baseline analyses and previous reporting, the Minimum Number Known Alive (MNA) (see Sutherland 2006) was calculated for each of the sites. The MNA is based on the number of new individuals encountered over multiple visits, where any new animals are summed, providing an aggregate total. As this method does not account for any migration out of the population or any death, it may over-estimate the total population size if counts are completed over a long period of time. As baseline studies commenced in 2013 it is possible that considering cumulative records over these last five years may overestimate the actual population. Data is provided for the annual new captures and a cumulative MNA over the years is also provided, however this data should be approached with caution, as the lifespan of the Giant Barred Frog may not extend beyond four or five years (Michael Mahony unpublished data).

Changes in Giant Barred Frog density within the zones and distribution along transects across the years were investigated by considering mean annual records within each specific zone. In addition, movement of individuals between zones was examined for recaptured frogs.



Drawn by: RJ Project Manager: RM Project Number: 1702 PI 53 Date: 19/09/2018

Giant Barred Frog Monitoring Sites: overview

Pacific Highway Upgrade - Oxley Highway to Kempsey

FIGURE 1

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Giant Barred Frog monitoring: Cooperabung Creek impact site

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FIGURE 2

Imagery: (c) DigitalGlobe

Giant Barred Frog monitoring: Smiths Creek impact site

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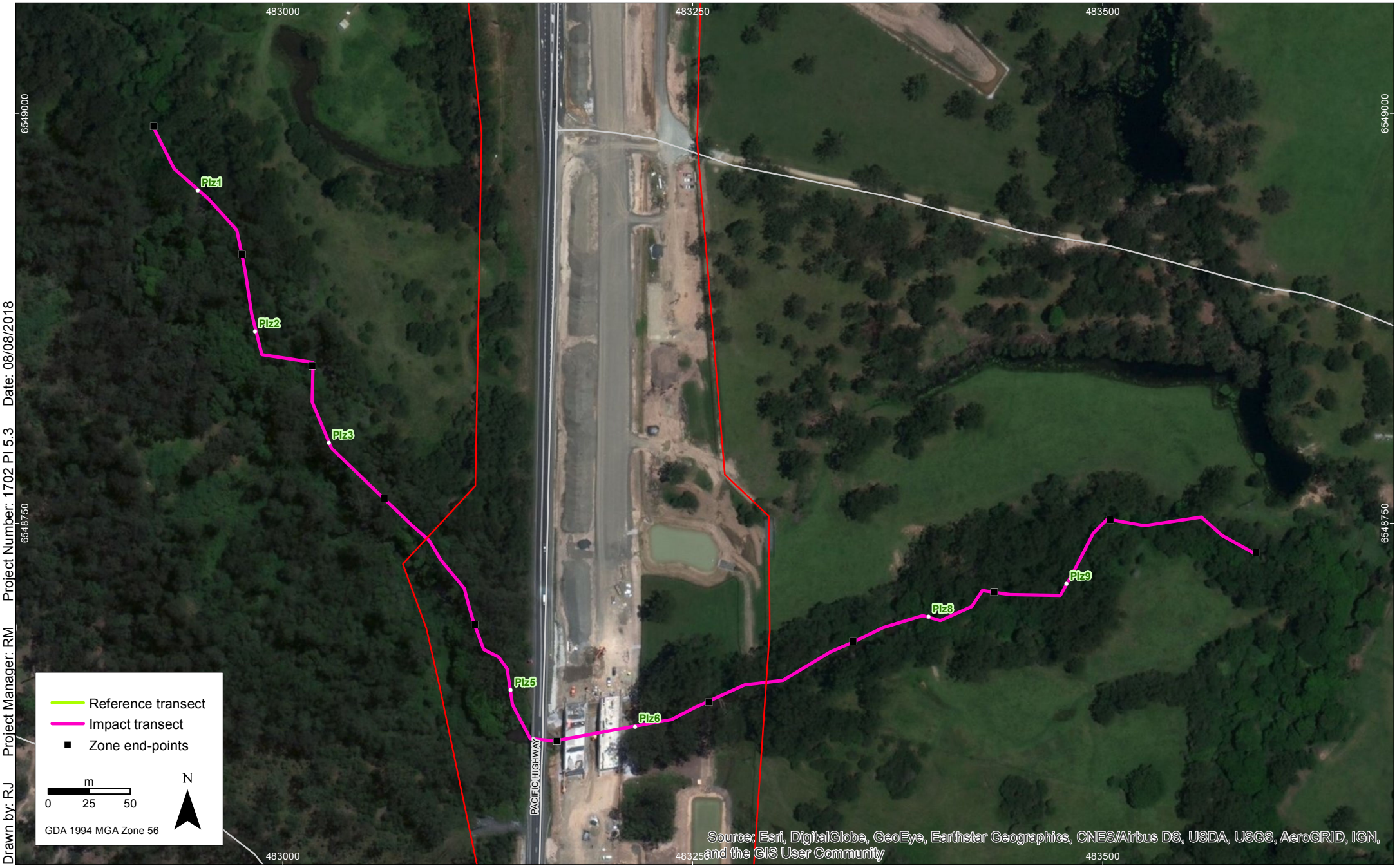
FIGURE 3

Imagery: (c) DigitalGlobe



Giant Barred Frog monitoring: Pipers Creek impact site

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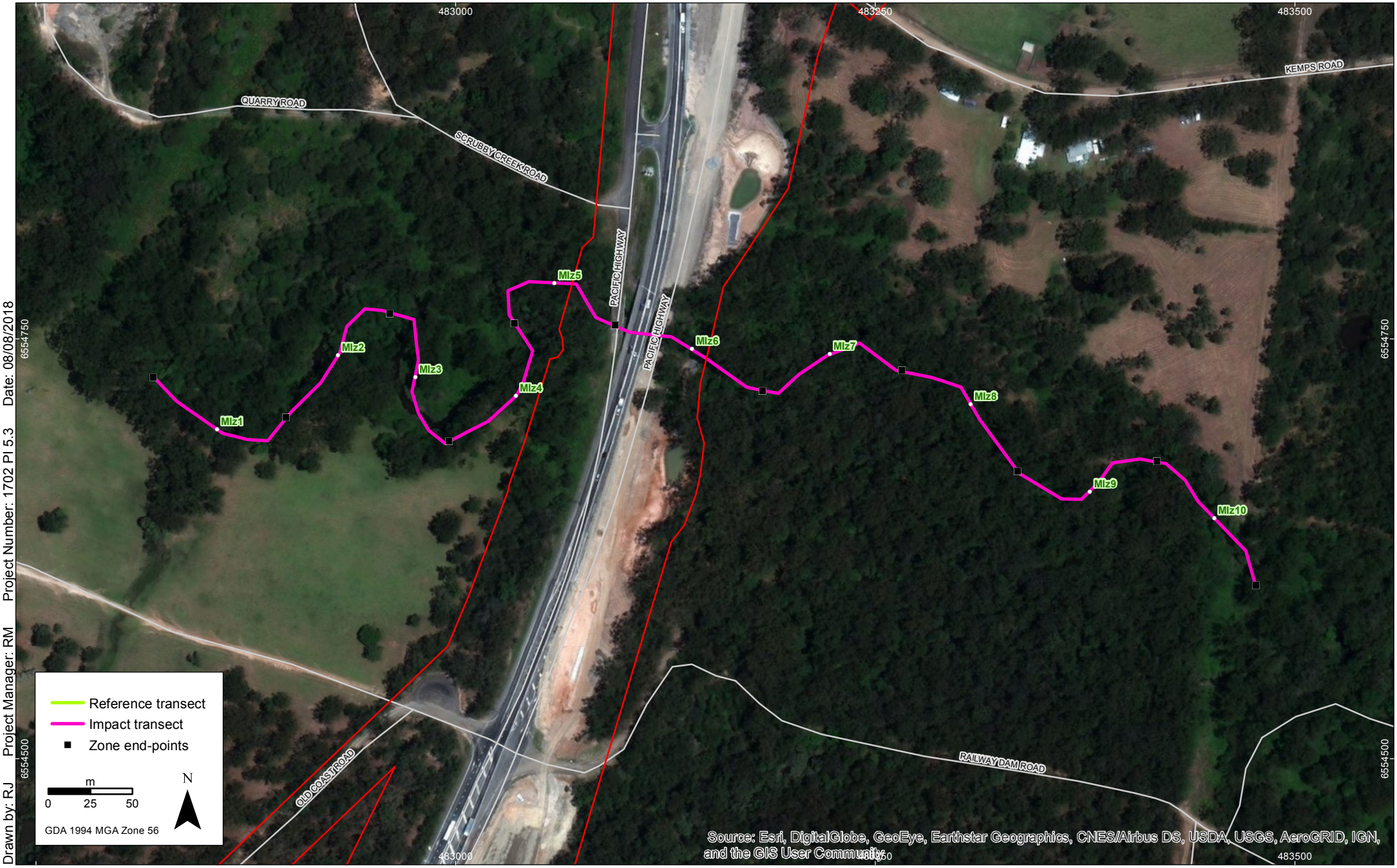
FIGURE 4

Imagery: (c) DigitalGlobe



Drawn by: RJ Project Manager: RM Project Number: 1702 PI 5.3 Date: 08/08/2018

Giant Barred Frog monitoring: Maria River impact site

Pacific Highway Upgrade - Oxley Highway to Kempsey

FIGURE 5

Imagery: (c) DigitalGlobe

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Giant Barred Frog monitoring: Cooperabung Creek reference site

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FIGURE 6

Imagery: (c) DigitalGlobe

Giant Barred Frog monitoring: Pipers Creek reference site

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FIGURE 7

Imagery: (c) DigitalGlobe

3. Results

3.1 2019/2020 Giant Barred Frog Monitoring Results

Field data are presented in Annex 1 and Annex 2. Survey dates and trigger rainfall events measured at Port Macquarie Airport (060183) weather station were as follows:

- 15 - 17 October 2019 (spring): 11.6 millimetres recorded on the 13th October 2019 prior to surveys
- 21 – 23 January 2020 (summer): 53.6 millimetres recorded on the 19th January 2020 prior to surveys
- 17 – 19 March 2020 (autumn): 35.4 millimetres recorded on the 15th March 2019 prior to surveys.

3.1.1 Survey results

A total of 46 Giant Barred Frogs were recorded in spring, summer and autumn during the 2019/2020 monitoring surveys. Giant Barred Frogs were recorded at five of the six sites during spring surveys, at four sites during summer surveys and three sites in autumn surveys (Table 1). Of the 46 frogs recorded, 40 were captured, of which 12 were recaptures (30%). Frogs were recorded at three of the six sites in all seasons including Smiths Creek impact, Pipers Creek impact and Pipers Creek reference sites. A single Giant Barred Frog was recorded at Maria River impact site in spring while no Giant Barred Frogs were recorded at Cooperabung Creek impact site. The highest mean number of Giant Barred Frogs was recorded at Pipers Creek reference site.

The cumulative MNA (8 years) is highest at the Pipers Creek reference site (MNA = 178) and Smiths Creek reference site (MNA = 114). As mentioned in Section 2.4, this estimate of MNA is likely an overestimate of the population as calculation of the MNA does not take dispersal or deaths into account.

Table 1: Giant Barred Frogs recorded at each site during 2019/2020 surveys

Data set	Cooperabung Creek impact	Smiths Creek impact	Pipers Creek impact	Maria River impact	Cooperabung Creek reference	Pipers Creek reference
Spring (2019)	0	3	2	1	2	9
Summer (2020)	0	5	3	0	1	9
Autumn (2020)	0	3	1	0	0	7
Mean number of frogs	0	3.7	2	0.3	1	8.3
Standard Error (SE)	0	0	0.7	0.7	1.4	1.4
Recaptures	0	1	1	0	2	8
New captures	0	9	3	1	1	14
Uncaptured	0	1	2	0	0	3
Total	0	11	6	1	3	25
Cumulative MNA	53	114	50	93	73	178

3.1.2 Evidence of breeding

Table 2 presents records of breeding evidence. Evidence of breeding via the presence of juveniles or sub-adults, gravid females or reproductive males was observed at all sites where frogs were recorded during at least one survey event during 2019/2020.

Table 2: Breeding evidence records 2019/2020

Monitoring site	Season	Juveniles	Sub-adults	Gravid females	Nuptial pads
Cooperabung Creek impact	Spring				
	Summer				
	Autumn				
Maria River impact	Spring		1		
	Summer				
	Autumn				
Pipers Creeks impact	Spring		2		
	Summer			1 (frogs observed mating)	
	Autumn				2
Smiths Creek impact	Spring				
	Summer	3			
	Autumn			1	
Cooperabung Creek reference	Spring				
	Summer			1	
	Autumn				
Pipers Creek reference	Spring	1	3		
	Summer				
	Autumn		1		

3.1.3 Weather conditions

The prevailing weather conditions encountered during the field surveys are summarised in Table 3 (Port Macquarie Airport (BOM Station No. 060183)). Additional details of the prevailing micrometeorological conditions at the six sites during the field surveys are presented in Annex 1.

Table 3: Weather conditions: 2019/2020 surveys

Date	Min temp (˚C)	Max temp (˚C)	Humidity (%)	Rainfall 24 hours (mm)	Rainfall 7 days (mm)	Rainfall 30 days (mm)
15/10/2020	11.6	25.9	68	0	27.4	69
16/10/2020	15.3	28.1	63	0	27.4	69
17/10/2020	17.6	36.7	53	2.4	29.8	71.4
21/01/2020	19.7	32.5	30	1.8	82.2	118.1
22/01/2020	19.8	32.2	61	0	81.8	118.1
23/01/2020	23.3	35.4	64	0	81.8	116.3
17/03/2020	15.9	22.3	78	26.4	86.6	192.2
18/03/2020	16.3	24.2	61	4.6	84.8	196.8

19/03/2020	13.6	25.9	63	1.0	84.4	195.8

3.1.4 Habitat use

Habitat information collected for each site is presented in Annex 1. Microhabitat use was highly variable. Frogs were recorded on and buried within leaf litter, using flood debris as shelter, within the creeks, on rocks and under logs and vegetation. Most frogs were captured between 0-10 m from the creeks, with the furthest frog being found 25 m from the creek.

No frogs were found to have breached the frog fences at any sites (i.e. observed on the wrong side of the fence).

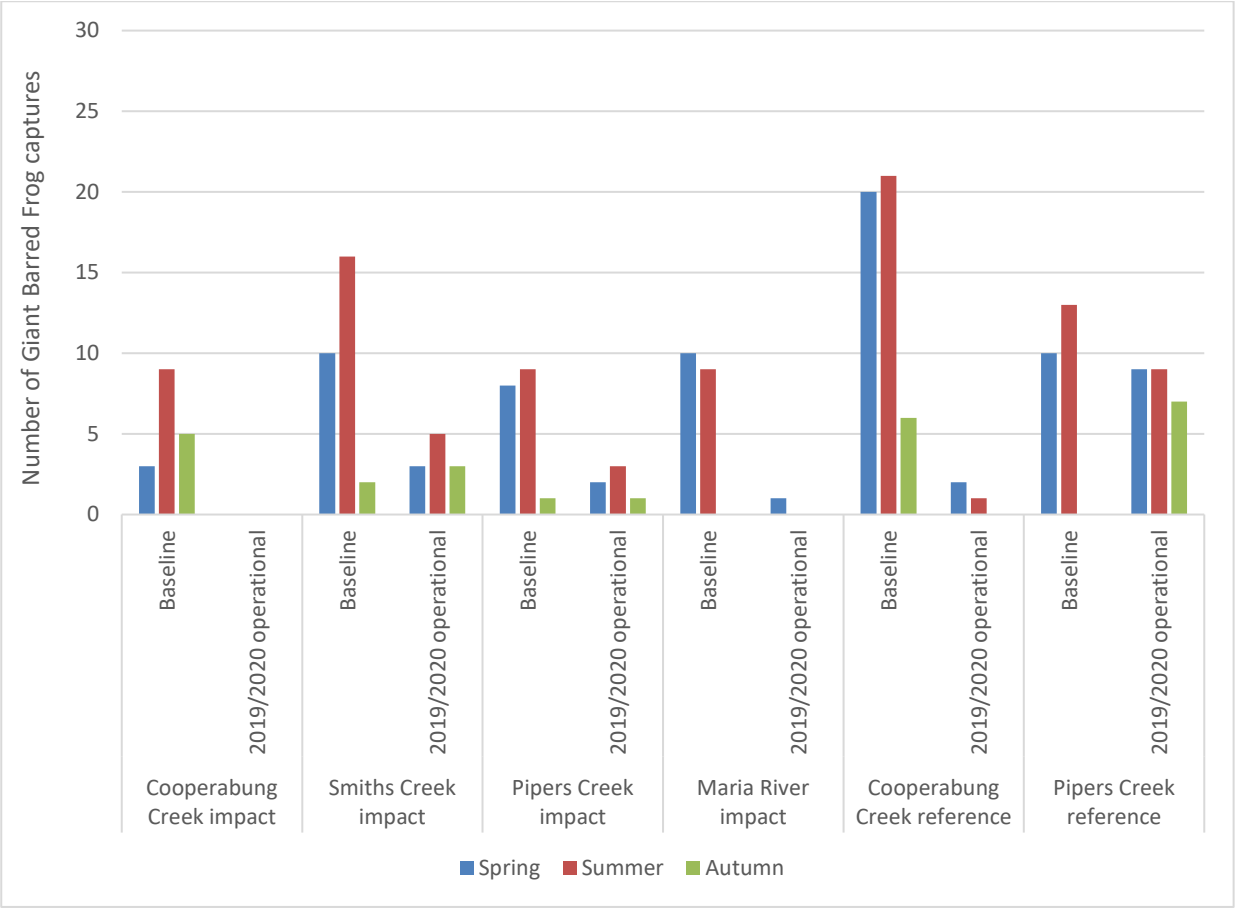
3.2 Comparison with Previous Surveys

3.2.1 Baseline and 2019/2020 surveys

Graph 1 presents the Giant Barred Frog records for baseline and the 2019/2020 operational monitoring surveys.

The Giant Barred Frog was recorded at all six monitoring sites in spring and summer and at four sites in autumn during baseline surveys. Giant Barred Frogs were not recorded at the Maria River impact site and Pipers Creek reference site during the autumn 2014 baseline survey.

Giant Barred Frogs were recorded at five of the six sites during spring, at four site during summer and three sites in autumn 2019/2020 surveys. Giant Barred Frogs were not recorded at Cooperabung Creek impact site during the 2019/2020 surveys, where it was recorded during baseline surveys. Giant Barred Frogs were also not recorded at Maria River impact site in summer and Cooperabung Creek reference site in autumn, where it was recorded during baseline surveys.



Graph 1: Giant Barred Frog records: baseline and 2019/2020 monitoring

3.2.2 Annual mean records

The mean number of records each year for each site is shown in Graph 2.

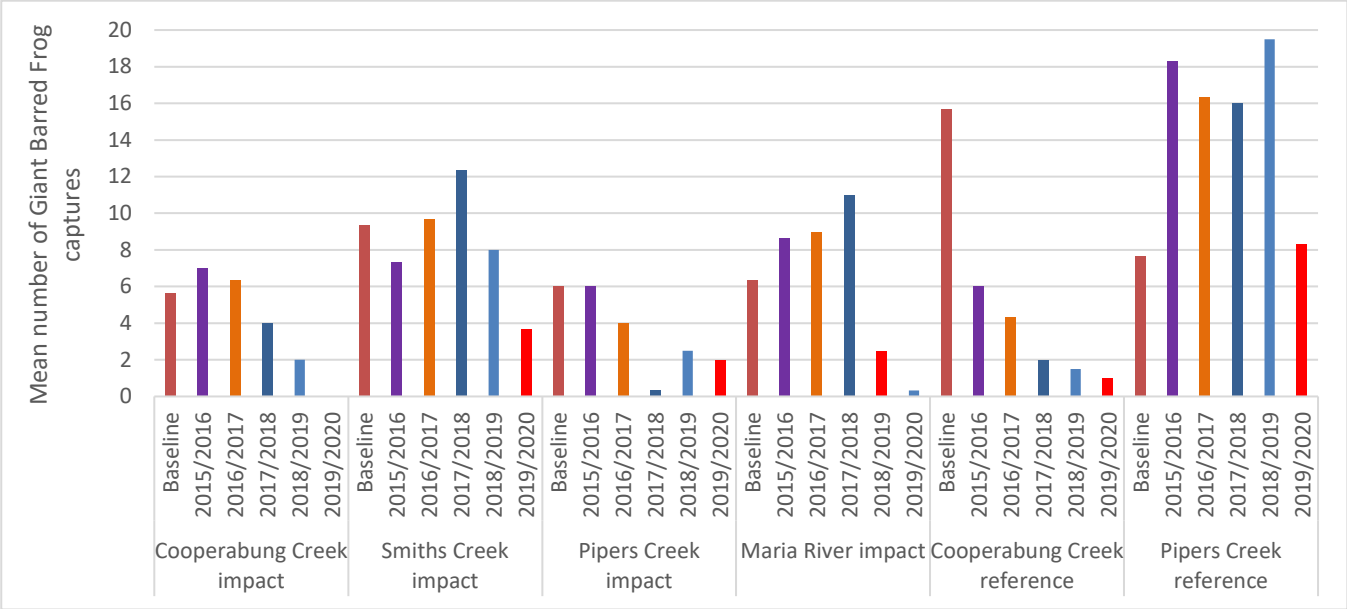
The mean number of Giant Barred Frogs recorded at Cooperabung Creek impact site and Cooperabung Creek reference site has decreased annually since 2015/2016 and baseline respectively and no Giant Barred Frogs were observed during the 2019/2020 monitoring at the Cooperabung Creek impact site. A similar annual decrease is evident at Pipers Creek impact site, however the mean number of Giant Barred Frogs recorded increased at this site in 2018/2019 and declined slightly during the current monitoring period.

The mean number of Giant Barred Frogs recorded at Smiths Creek impact site and Maria River impact site has increased annually since 2015/2016 and baseline respectively, however the mean number of Giant Barred Frogs recorded decreased substantially at both these sites in 2018/2019, declining again during the current monitoring period.

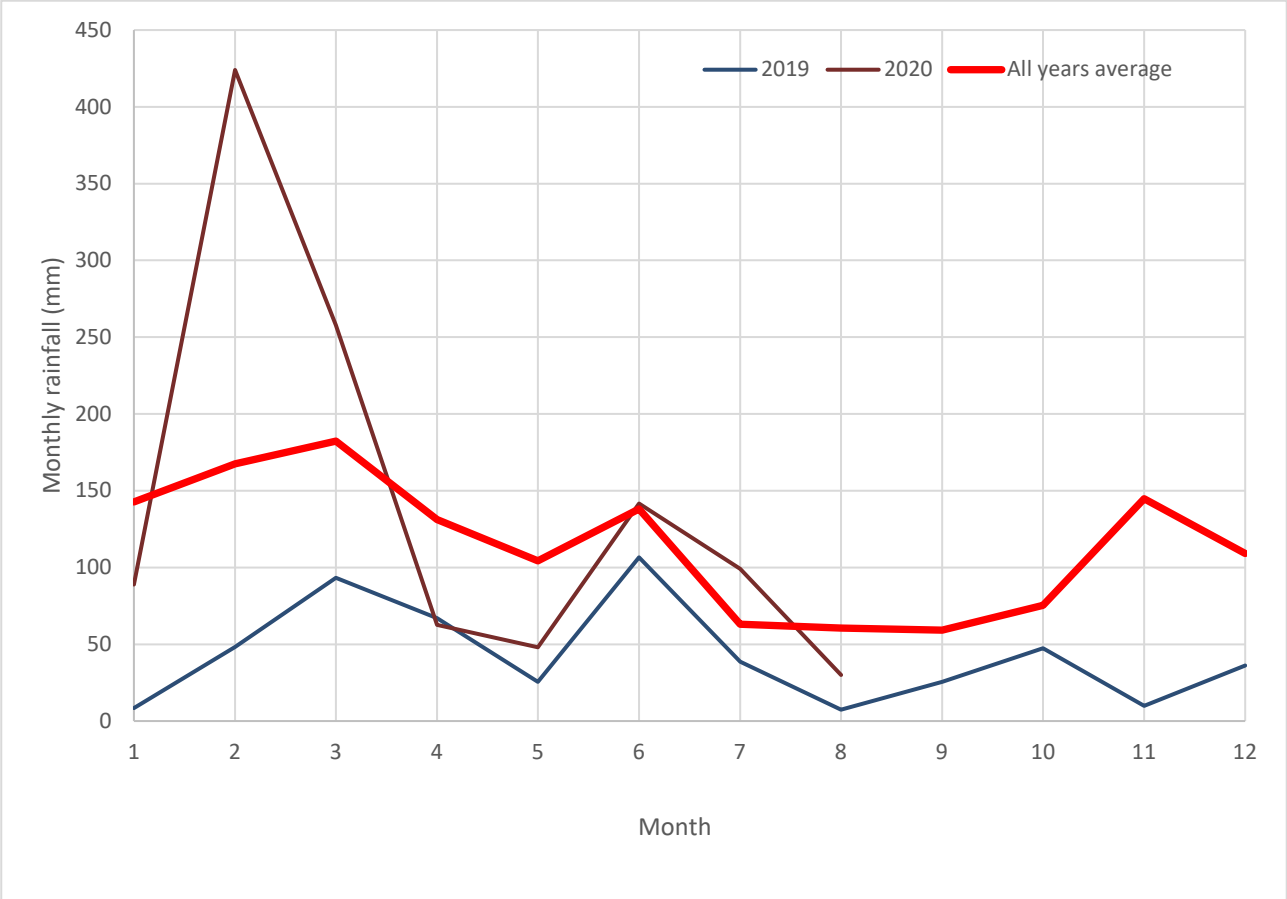
The mean number of Giant Barred Frogs recorded at Pipers Creek reference site decreased in the current monitoring period, however it is still higher than the number recorded during baseline surveys.

The mean number of Giant Barred Frogs recorded during the current monitoring period decreased from the previous monitoring event at all sites. It should be noted that 2019/2020 experienced lower than average rainfall (Graph 3), resulting in dry creek beds with the remaining water pooling rather than flowing during spring and summer surveys of the 2019/2020 monitoring period.

Given the variable nature of annual mean records among sites, the evidence of a decreasing trend at a reference site and the lack of a distinct difference between impact and reference sites, it is not possible to attribute observed changes in frog numbers to the Project.



Graph 2: Mean annual Giant Barred Frog records by site



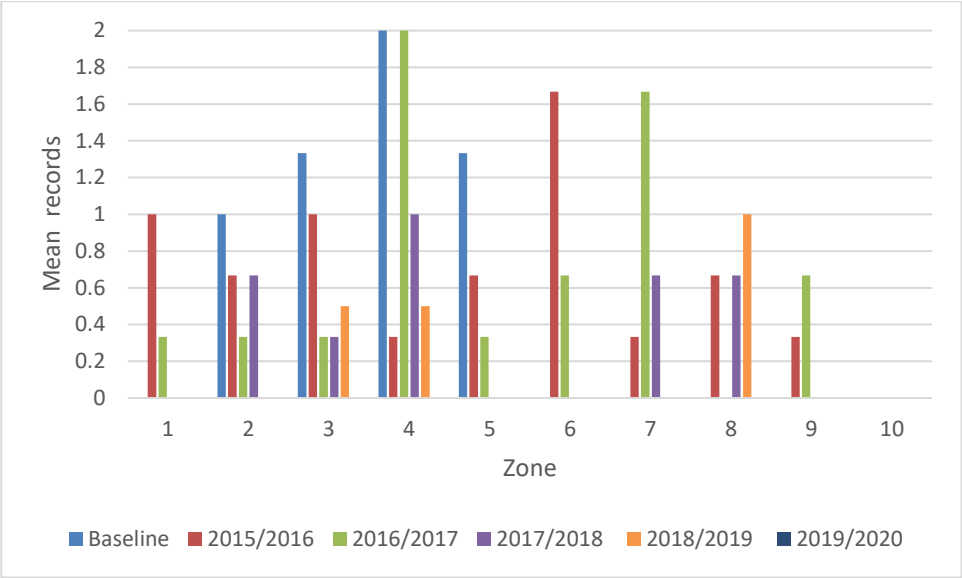
Graph 3: Monthly rainfall – All years monthly average and 2019 and 2020 monthly total rainfall

3.3 Density and Distribution

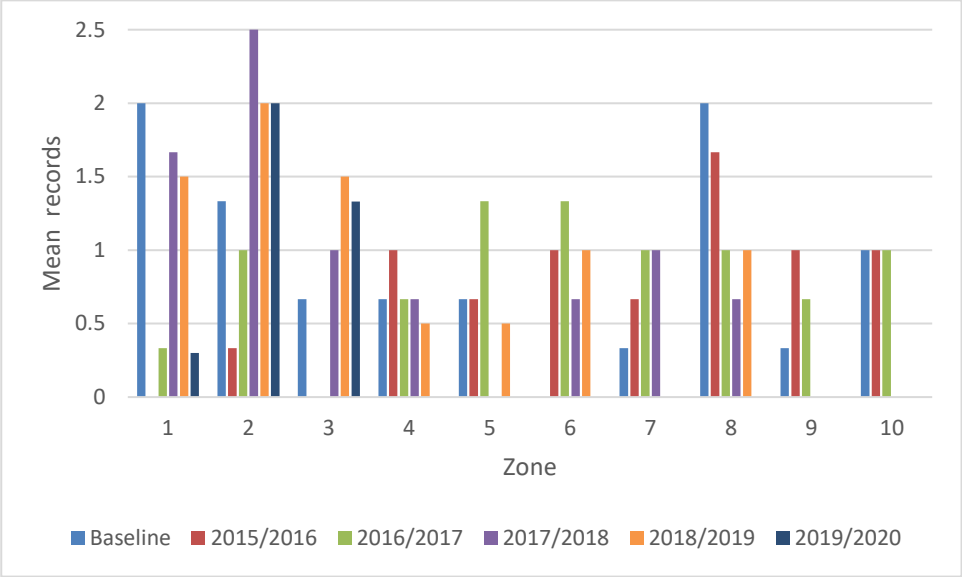
Graph 3 - Graph 8 present the density (*annual mean number of Giant Barred Frog records per zone*) and distribution of Giant Barred Frog records along the survey transect for each site and each monitoring period. Figure 8 - Figure 13 shows the total number of captures within each zone over all monitoring periods.

The density of Giant Barred Frogs has been considered as the *mean number of records per year per zone* (Graph 4 to Graph 9). While the zones may vary in size slightly due to the nature of the creek's bank formation and the non-linear nature of the creek line, the zones themselves are consistent between years. As such comparisons can be made within the same zone between years to help identify trends in changing frog numbers. There is no consistent trend evident at any site for frogs to be found in any particular zone. Density appears to be highly variable across the years and along the transect and there is no evidence of lower frog densities within zones 5 and 6, i.e. under the carriageway and immediately adjacent.

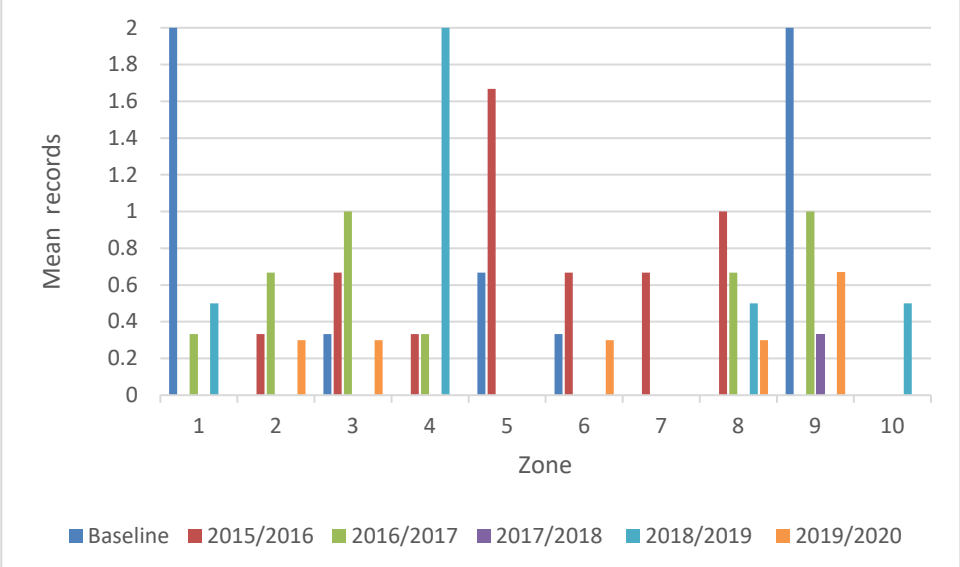
Figure 8 - Figure 13 shows all capture records (i.e. cumulative records), whereby capture records (including recaptures) are shown as count ranges, where larger circles indicate larger frog counts. While density data indicates that frog distribution along the transects varies from year to year, when considering all years, frogs mostly appear to be using the entire length of the transect and there is no evidence of frogs being recorded only in one particular zone. In addition, there is no evidence of frogs being absent from zones 5 and 6. While capture frequencies within zones directly under the carriageway consistently fall into the lower range category (1-7 frogs), the low capture frequency range occurs regularly along the transects and at all sites.



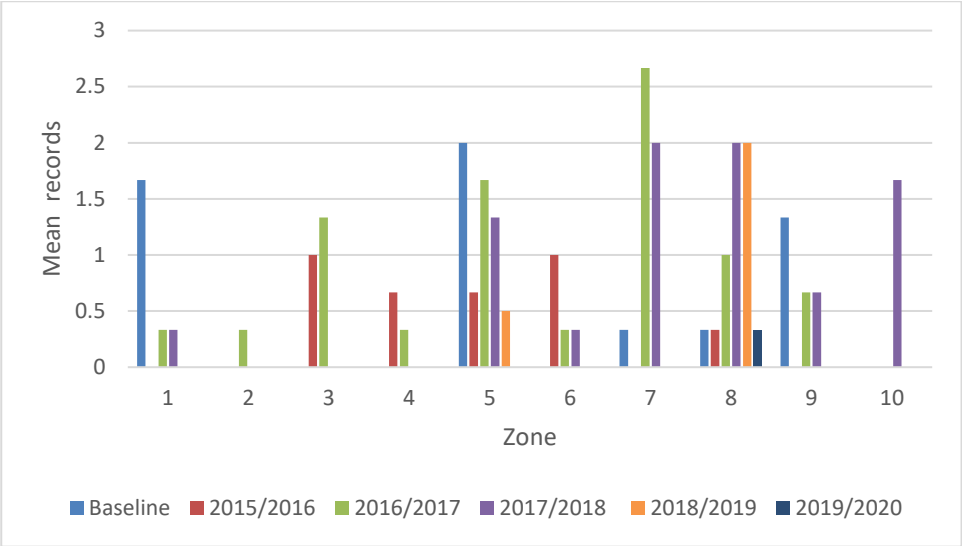
Graph 4: Cooperabung Creek impact site: mean number of Giant Barred Frogs per zone



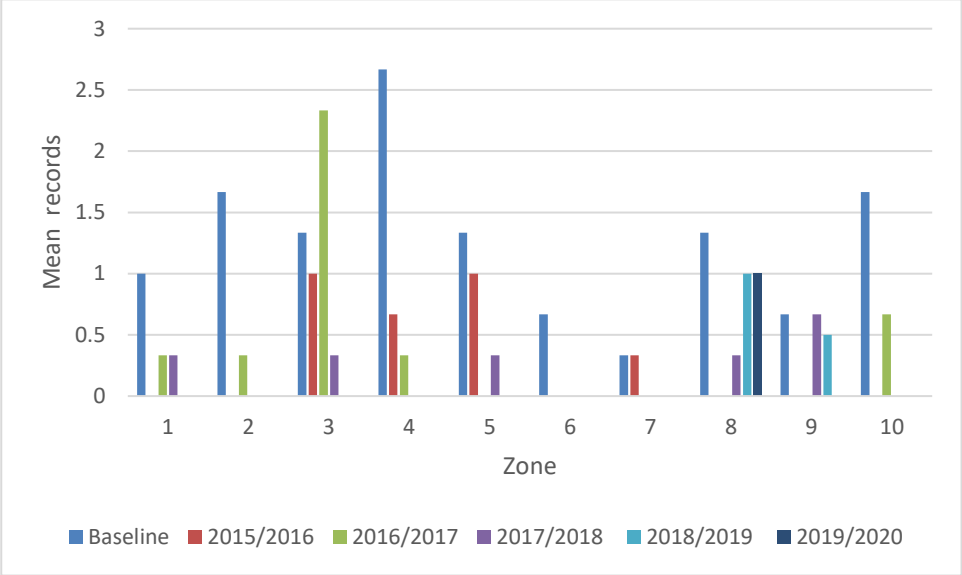
Graph 5: Smiths Creek impact site: mean number of Giant Barred Frogs per zone



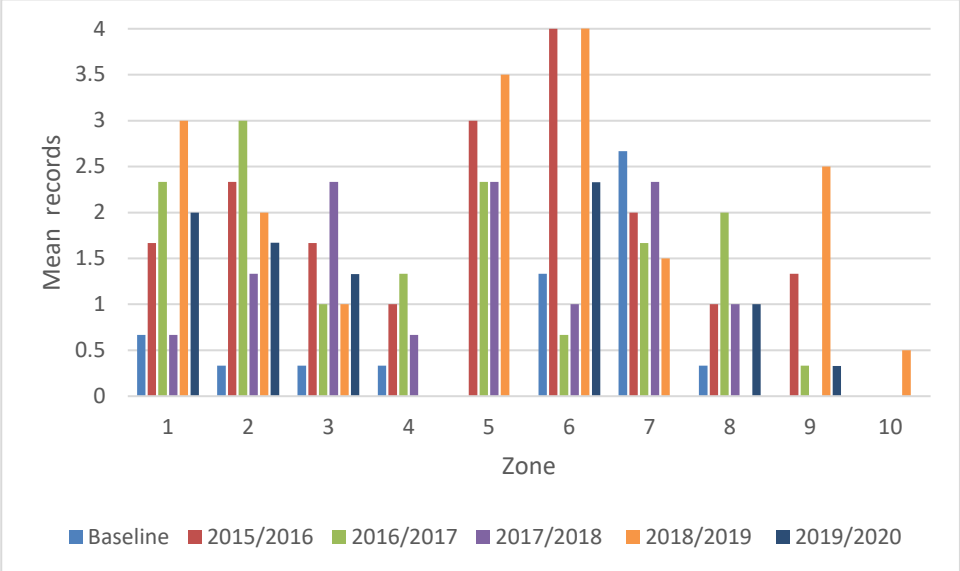
Graph 6: Pipers Creek impact site: mean number of Giant Barred Frogs per zone



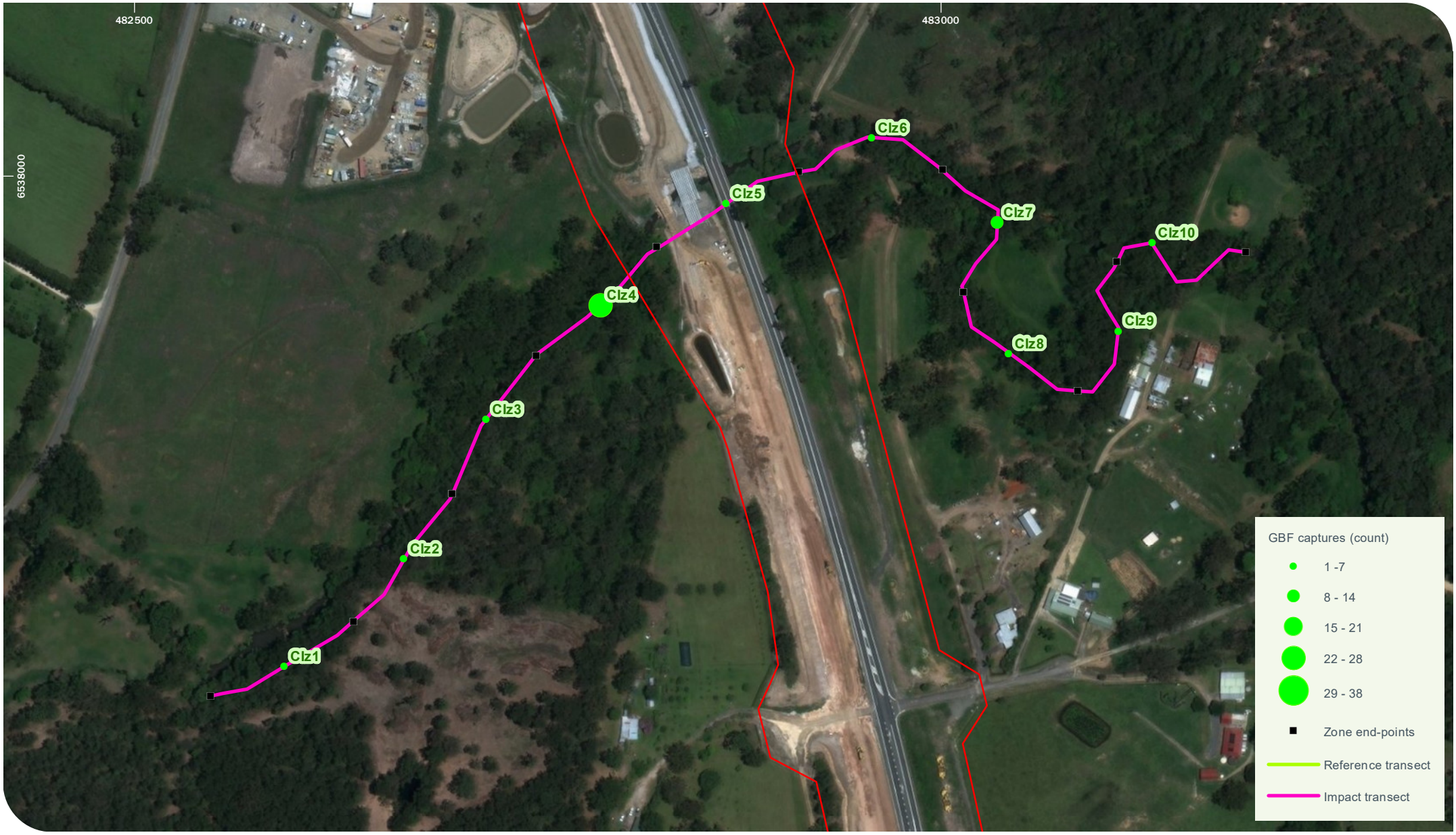
Graph 7: Maria River impact site: mean number of Giant Barred Frogs per zone



Graph 8: Cooperabung Creek reference site: mean number of Giant Barred Frogs per zone



Graph 9: Pipers Creek reference site operational: mean number of Giant Barred Frogs per zone



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Niche PM: Jodie Danvers
Niche Proj. #: 1702 PI 5.3
Client: Transport for NSW

Giant Barred Frog capture distribution: Cooperabung Creek impact site

Pacific Highway Upgrade - Oxley Highway to Kempsey

Figure 8

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Niche PM: Jodie Danvers
Niche Proj. #: 1702 PI 5.3
Client: Transport for NSW

Giant Barred Frog capture distribution: Smiths Creek impact site

Pacific Highway Upgrade - Oxley Highway to Kempsey

Figure 9

Imagery: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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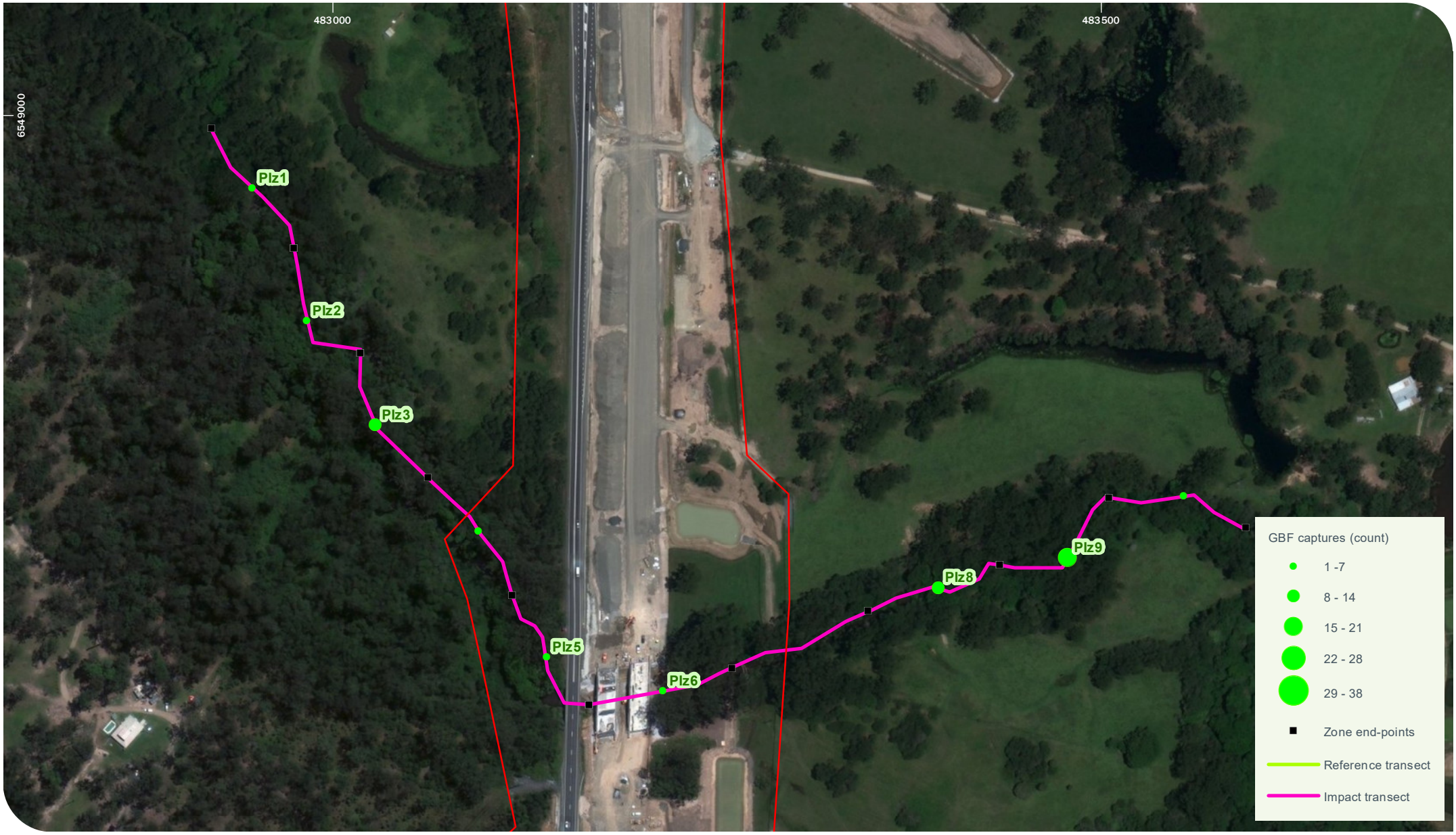

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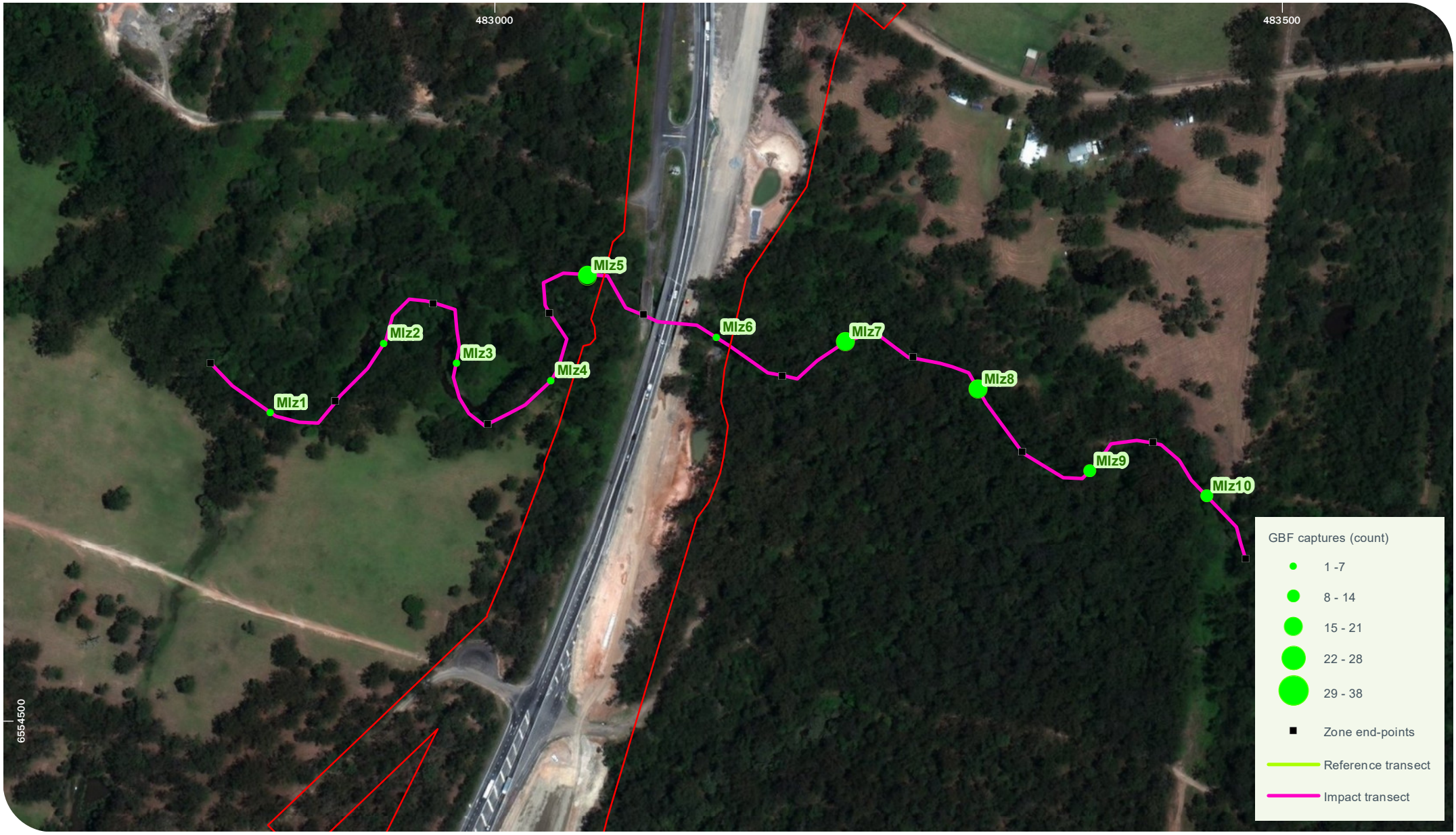
Niche Proj. #: 1702 PI 5.3
Client: Transport for NSW

Giant Barred Frog capture distribution: Pipers Creek impact site

Pacific Highway Upgrade - Oxley Highway to Kempsey

Figure 10



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Client: Transport for NSW

Giant Barred Frog capture distribution: Maria River impact site

Pacific Highway Upgrade - Oxley Highway to Kempsey

Figure 11

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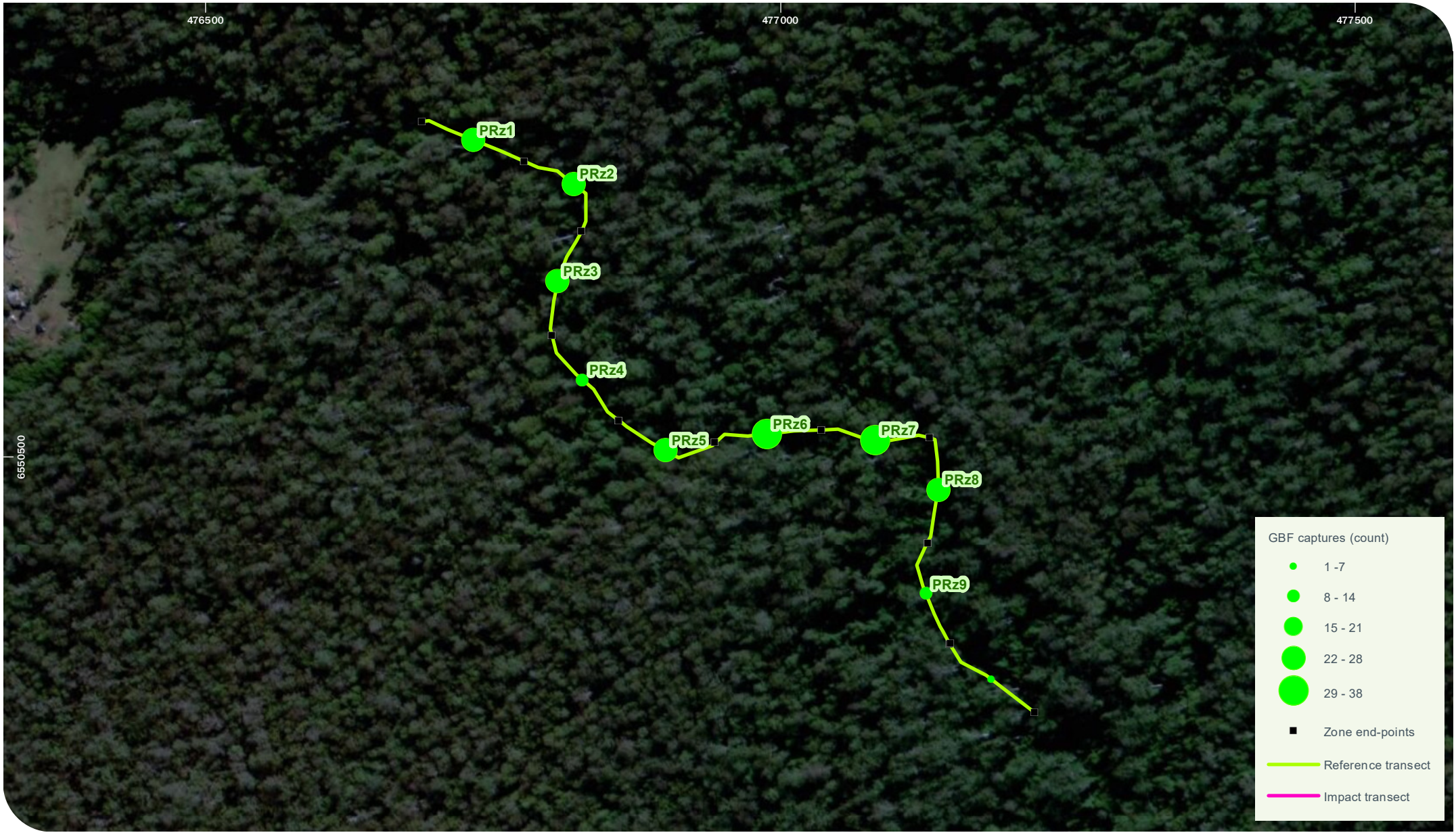
Niche Proj. #: 1702 PI 5.3
Client: Transport for NSW

Giant Barred Frog capture distribution: Cooperabung Creek reference site

Pacific Highway Upgrade - Oxley Highway to Kempsey

Figure 12



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Niche Proj. #: 1702 PI 5.3
Client: Transport for NSW

Giant Barred Frog capture distribution: Pipers Creek reference site

Pacific Highway Upgrade - Oxley Highway to Kempsey

Figure 13

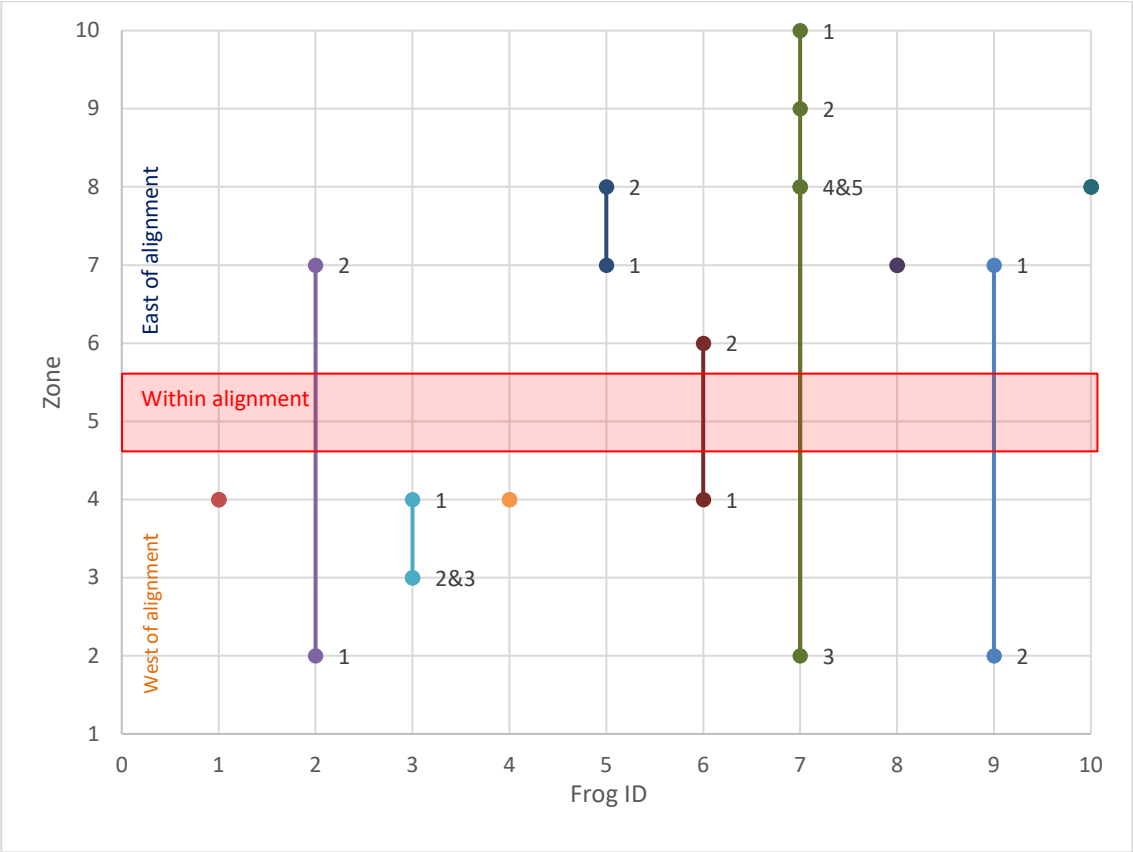
3.4 Movement

Recapture data of PIT-tagged individuals was used to determine movements along the transects, and notably, past the midpoint of the transect i.e. from one side of the carriageway to the other at the impact sites. It should be noted that this analysis does not imply that individuals that have not been found on opposite sides of the carriageway have not traversed at some time. Graph 10 - Graph 15 show the movement patterns of individual recaptured Giant Barred Frogs at each site and the data is summarised for each site below. As reference sites by their nature do not traverse the carriageway, a transect midpoint has been included to provide an indication of movements along the transects and permit comparison between reference and impact sites. The reference midpoint was chosen as the arbitrary midpoint location to provide similar recapture circumstances to the impact sites (i.e. equal zones on either side). It should however be noted that comparisons made between impact and reference sites do not take into account other potentially confounding factors such as site specific population ecology. Capture order is indicated by the numbers beside each capture point and a single capture point indicates recaptures within the same zone (order not indicated).

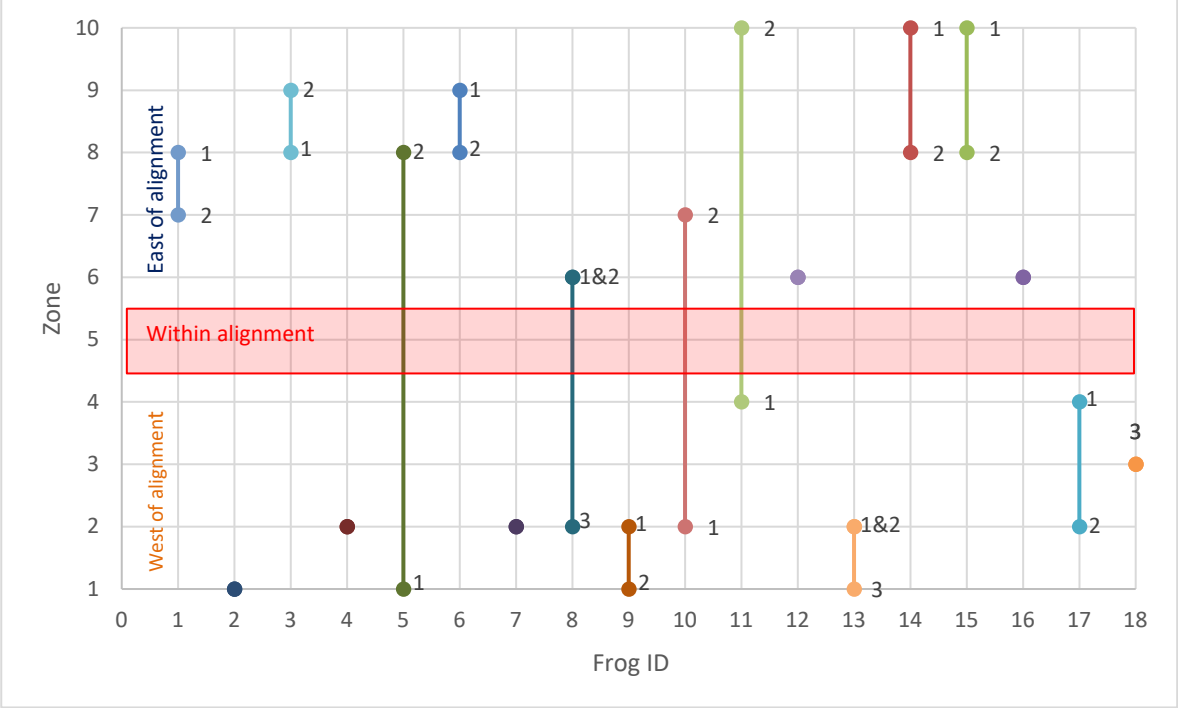
A total of 87 individuals have been recaptured on at least one occasion over all monitoring events. Of these, 49 recaptures have occurred at the impact sites. Fifteen (31%) of these individuals from impact sites have been captured on both sides of the carriageway over successive monitoring events. Of the 38 recaptures at the reference sites, 11 (29%) have been captured on both sides of the midpoint over successive monitoring events.

- *Cooperabung Creek impact site*: Ten Giant Barred Frogs have been recaptured over all monitoring periods. Of these individuals, four (40%) have been captured on both sides of the carriageway, including one individual (ID#7) that traversed on at least two occasions.
- *Smiths Creek impact site*: Eighteen frogs have been recaptured over all monitoring periods. Of these individuals, four (22%) have been captured on both sides of the carriageway.
- *Pipers Creek impact site*: Twelve Giant Barred Frogs have been recaptured over all monitoring periods. Of these individuals, three (27%) have been captured on both sides of the carriageway.
- *Maria River impact site*: Nine Giant Barred Frogs have been recaptured over all monitoring periods. Of these individuals, four (44%) have been captured on both sides of the carriageway.
- *Cooperabung Creek reference site*: Nine Giant Barred Frogs have been recaptured over all monitoring periods. Of these individuals, two (22%) have been captured on both sides of the transect midpoint.
- *Pipers Creek reference site*: Twenty-nine Giant Barred Frogs have been recaptured over all monitoring periods. Of these individuals, nine (31%) have been captured on both sides of the transect midpoint. including three individuals (ID#18, 19 and 23) that have traversed on at least two occasions.

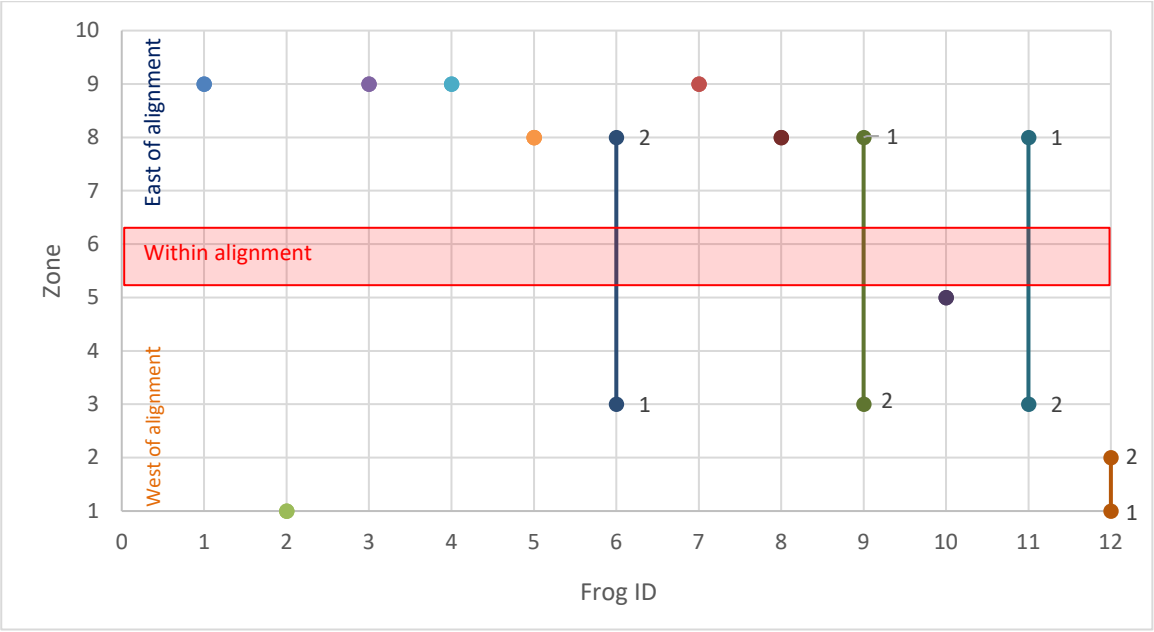
At the impact sites, while the monitored waterways continue uninterrupted under the carriageway, there is a distinct change in streamside vegetation within the area immediately under the carriageway. Under the carriageway at all impact sites, streamside vegetation ranges from completely absent to very limited, represented by small clumps of shrubs and/or *Lomandra* spp. The streamside habitat in these areas is limited to the large rocks and boulders incoporated during construction of the Project, which are part of the structure design and important for long term asset stability. Despite this abrupt change in streamside habitat immediately under the carriageway, a number of Giant Barred Frogs have been recorded traversing the carriageway. The percentage of Giant Barred Frogs found to have traversed the impact site midpoints do not appear to differ substantially from the percentage of Giant Barred Frogs found to have traversed the reference site midpoints.



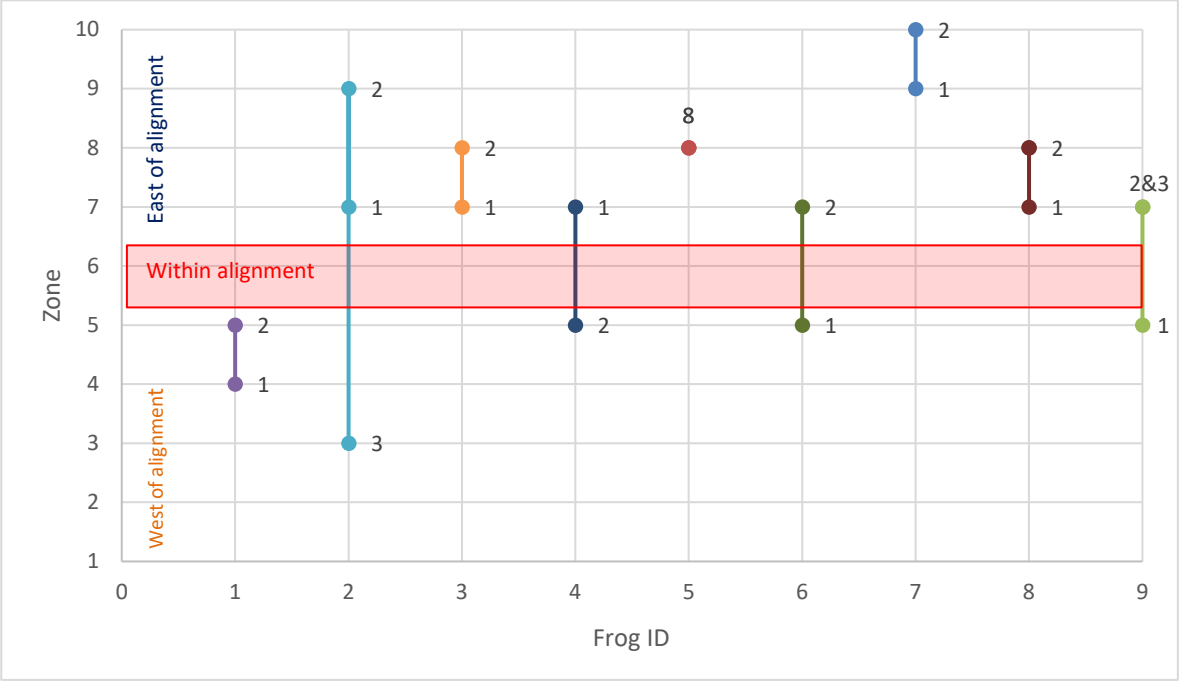
Graph 10: Cooperabung Creek impact site: recapture movement patterns



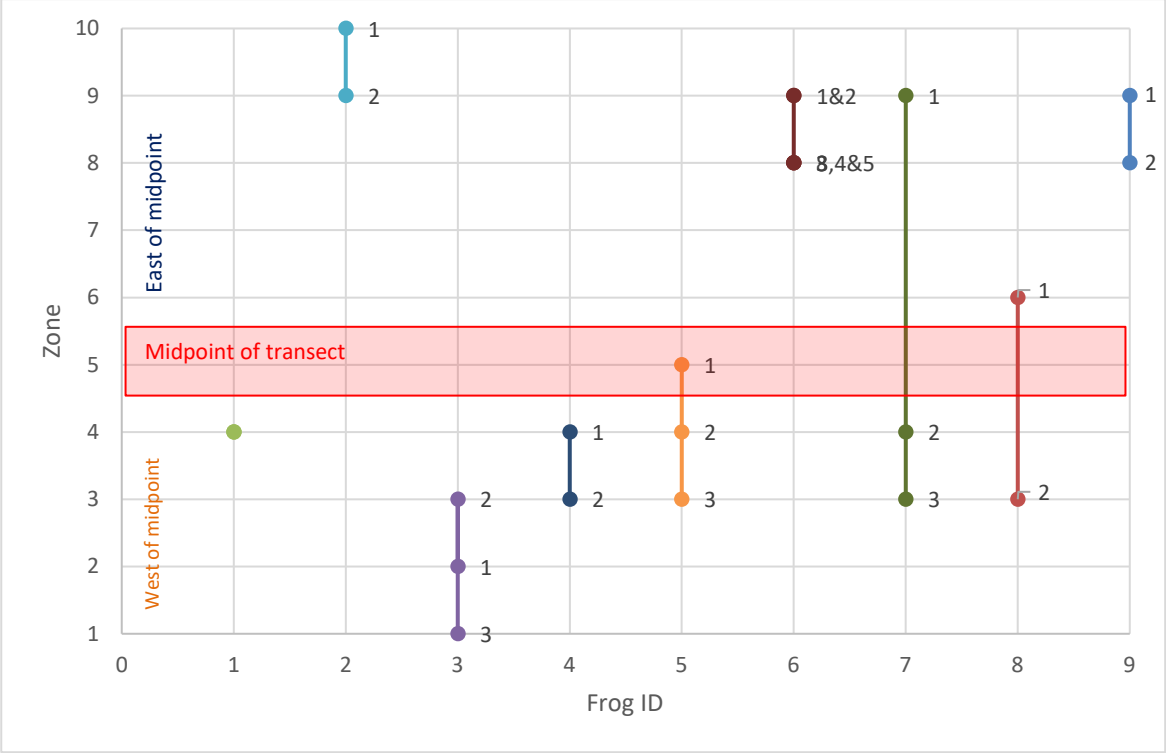
Graph 11: Smiths Creek impact site: recapture movement patterns



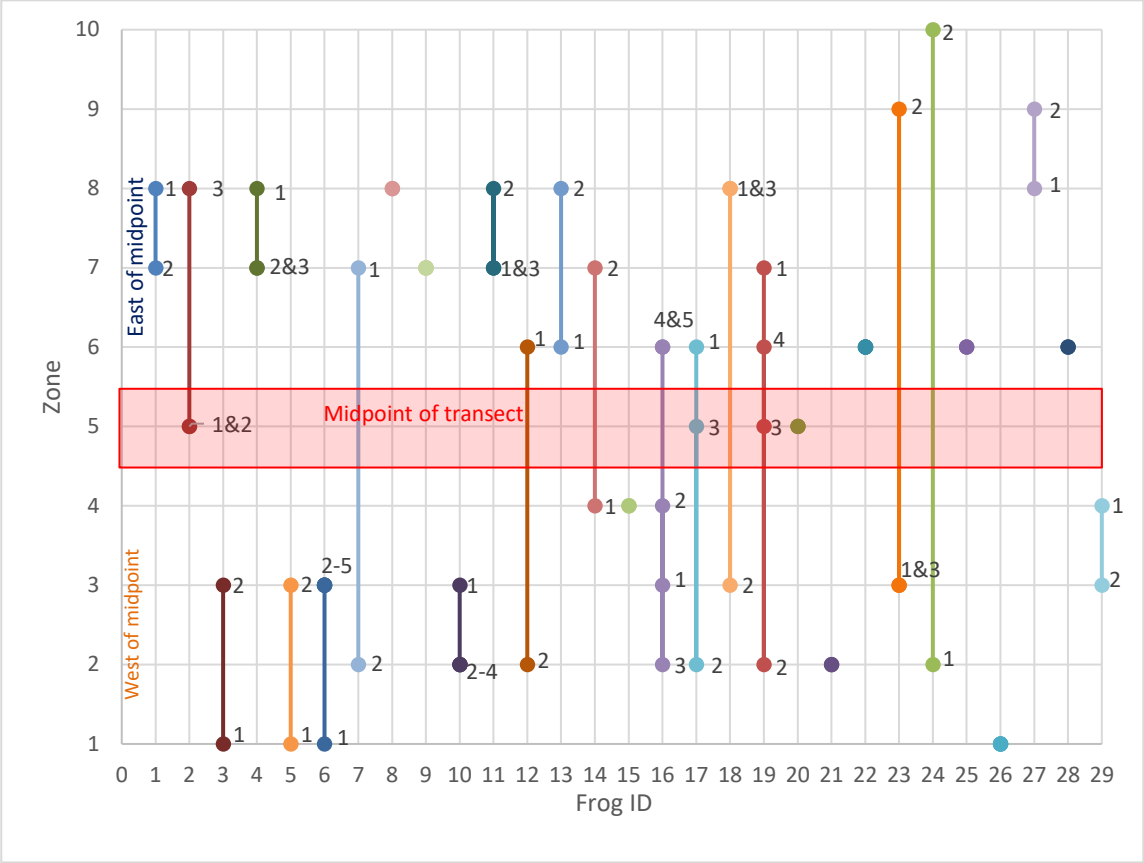
Graph 12: Pipers Creek impact site: recapture movement patterns



Graph 13: Maria River impact site: recapture movement patterns



Graph 14: Cooperabung Creek reference site: recapture movement patterns



Graph 15: Pipers Creek reference site: recapture movement patterns

3.5 Water Quality

Water quality monitoring was undertaken by TfNSW. Data included in this report represents the second operational monitoring period, from 30 March 2019 to 29 March 2020 (TfNSW 2020). Presented here is a summary of the data collected for Cooperabung Creek, Smiths Creek, Pipers Creek and Maria River, for the purpose of assessing the water quality in relation to desired parameters and the water quality performance measures specified in the EMP. Annex 3 presents data extracted from the water quality reports. It shows only those sampling results where the calculated median downstream value exceeded (was above the 80th percentile) or was below (below the 20th percentile) desired threshold values of the upstream site.

3.5.1 Parameters

Table 4 presents the number of occasions downstream median values were greater than the 80th percentile and less than the 20th percentile, and of these, the number that exceeded the ANZECC trigger value. All sites had at least one parameter for one or more monthly results, for which the median downstream value exceeded the 80th percentile of the upstream value. These are discussed below.

Electrical conductivity: Downstream median values were below or above the calculated upstream 80th and 20th percentile trigger value on one or more occasions for all sites. According to TfNSW 2020, the greater differences between upstream and downstream values occurred when there was no visible flow, sample points persisting as isolated ponds, or in some cases dry upstream conditions at the time of sampling. At Maria River, levels below the ANZECC guideline trigger values coincided with the substantial rain events in February and March 2020. At Smiths Creek the elevated levels above the ANZECC guideline trigger values were exceeded on five occasion each. TfNSW 2020 notes thats this period (ie April 2019 to January 2020) was characterised by prolonged dry conditions resulting in stagnation of these waterways and at times excessive algae growth and concluded that it is likely that a combination of agricultural activities and construction work associated with the project has contributed to elevated sediment/nutrient levels in Smiths Creek and the associated algal growth observed.

Dissolved oxygen: Downstream median values were below or above the calculated upstream 80th and 20th percentile trigger value on one or more occasions for all sites. At Cooperabung Creek and Smiths Creek the variability coincided with algae outbreaks and both these sites were noted as having little to no flow or existing as isolated ponds. TfNSW 2020 considered impacts attributable to construction to be negligible, however the removal of waterway vegetation (within and on adjacent banks) during construction may have locally reduce the waterways resilience to elevated sediment and nutrient loads.

pH: Downstream median values were generally within, or close to, the calculated upstream 80th and 20th percentile trigger values. pH levels were within the default ANZECC trigger value range for all but one instance at Pipers Creek. The water quality monitoring report considered impacts to be unrelated to construction.

Turbidity: Downstream median values were below or above the calculated upstream 80th and 20th percentile trigger value on one or more occasions for all sites. TfNSW 2020 considered impacts attributable to the Project to be negligible or minor.

Nitrogen and Phosphorus: Downstream nitrogen and phosphorus values were variable throughout the year and for sites. Levels were generally consistent within upstream and downstream ranges. Differences between upstream and downstream was generally when the sampling points persisted as isolated ponds. Elevated levels recorded at Maria River were attributed to broader land use practices.The water quality monitoring report considered impacts attributable to construction to be negligible.

Metals: There was limited variation in the level of metals with the exception of aluminium, iron, manganese and zinc. Levels were generally consistent with upstream values. Differences between upstream and downstream values was generally when the sampling points persisted as isolated ponds. The water quality monitoring report considered elevated metal parameters unlikely to be attributable to construction related activities.

The water quality monitoring report suggested that results were not inconsistent with the variability and levels experienced during the pre-construction monitoring.

Table 4: Triggered water quality parameters per site

Parameter	Number of samples where downstream median value > 80th % or < 20th % (# downstream value exceeds ANZECC trigger/range)			
	Cooperabung Creek*	Smiths Creek	Pipers Creek	Maria River
Temperature ˚C	0	0	0	1
Electrical Conductivity uS/cm	3	5 (1)	7	8 (5)
Dissolved oxygen %	1	2	2	2
pH	2	4	7 (1)	6
Turbidity (NTU)	1	5	10	7
Total suspended solids mg/L	0	4	0	0
Aluminium mg/L	1	1 (1)	2 (1)	1 (1)
Arsenic mg/L	0	0	0	0
Cadmium mg/L	0	0	0	0
Chromium mg/L	0	0	1 (1)	1 (1)
Copper mg/L	0	0	0	0
Iron mg/L	0	1	2	4
Lead mg/L	0	0	0	0
Manganese mg/L	0	4 (2)	2	2
Mercury mg/L	0	0	0	0
Nickel mg/L	0	2	0	0
Silver mg/L	0	0	0	0
Zinc mg/L	0	1 (1)	0	0
Total nitrogen mg/L	1 (1)	2 (2)	2 (1)	3
Total phosphorus mg/L	2	4 (1)	4 (1)	0

* limited sampling

4. Discussion

4.1 Performance Measures

A summary of Year 1 (2015/2016), Year 2 (2016/2017), Year 3 (2017/2018), Year 4 (2018/2019) and Year 5 (2019/2020) survey results in relation to the performance measures is provided in Table 5.

Table 5: Performance measures and discussion of results.

Performance measure	Discussion
Monitoring is undertaken during baseline surveys and Years 1 – 8 or until monitoring can demonstrate that mitigation measures are effective.	**This performance measure has been met for all years**. Giant Barred Frog monitoring has been undertaken at all six sites according to the EMP to date. Summer 2018/2019 surveys were not undertaken due to insufficient rainfall.
Monitoring during Year 1 – 8 is undertaken at the Impact and Control sites where baseline monitoring was undertaken, subject to landowner agreement.	**This performance measure has been met for all years**. Giant Barred Frog monitoring has been undertaken at all six baseline sites, where landowner agreement permitted.
Continued presence of Giant Barred Frogs during each survey event in Year 1 – 8 at sites where it was identified during baseline surveys, subject to access due to landowner agreement.	**This performance measure has been met for all sites in Year 1 (2015/2016), 5 of 6 sites in Year 2 (2016/2017), Year 3 (2017/2018), Year 4 (2018/2019) and 3 of 6 sites in Year 5 (2019/2020).** Baseline: Giant Barred Frogs were recorded at all six monitoring sites in spring and summer and at four sites in autumn. Giant Barred Frogs were not recorded at the Maria River impact site and Pipers Creek reference site during the autumn 2014 baseline survey. Year 1 (2015/2016): Giant Barred Frogs were detected at all six sites during all surveys. Year 2 (2016/2017): Giant Barred Frogs were detected at all six sites in spring and summer and five sites in autumn. Not recorded at Pipers Creek impact site during the autumn 2017 survey where it was detected during baseline surveys. Year 3 (2017/2018): Giant Barred Frogs were detected at all six sites in spring and five sites in summer and autumn. Not recorded at Pipers Creek impact site during summer and autumn 2018 where it was detected during baseline surveys. Year 4 (2018/2019): Giant Barred Frogs were detected at five sites in spring and all six sites in autumn. Not recorded at Cooperabung Creek reference site during spring 2018 where it was detected during baseline surveys. Year 5 (2019/2020): Giant Barred Frogs were not recorded at Cooperabung Creek impact site, where it was recorded during all three baseline surveys. Not recorded at Maria River impact during summer 2020, where it was recorded during baseline surveys and not recorded at Cooperabung Creek reference site during spring 2019, where it was detected during baseline surveys.
Mitigation measures are effective as defined in the EPBC approval when all monitoring events are considered at Year 8.	This performance measure is not yet applicable. Initial results (review of movement patterns of re-captured individuals showing records along the creek on either side of the carriageway) indicate that Giant Barred Frogs are moving underneath the road. It is unknown if they used the underpasses, however, no breaches of the frog fencing were observed during surveys.

Performance measure	Discussion
Median values of all downstream water quality monitoring at GBF habitat or potential habitat locations during construction and operation (Year 1 – 6) is less than the 80th percentile value of the upstream site (where 80th percentile is the value at which median values at the downstream site are above 80% of the recorded background water quality records), where this change is found to be attributable to construction or operation.	**This performance measure has been met for all parameters at all sites.** Whilst values at all sites have exceeded the 80th percentile on one or more occasion, impacts potentially attributable to construction were considered negligible or minor. Variability at some sites was a result of extensive algae outbreaks and low water flows.
No change to densities, distribution, habitat use and movement patterns compared to baseline data during monitoring in Year 1 – 8, and then when all monitoring events are considered at Year 8.	**This performance measure has not been met.** The number and location of Giant Barred Frogs recorded varied between season and year at all sites. All sites appear to show an overall decreasing trend in mean records and densities. However, as this decreasing trend is evident at both impact and reference sites, it is not possible to attribute these changes to the Project at this stage. The low number of records obtained in 2019/2020 may reflect the realtively dry conditions as a result of below average rainfall for the preceeding 10 months. Within-year movement patterns that would permit comparison between baseline and subsequent monitoring events is not possible due to lack of data (surveys and captures are too infrequent), however, assessment of movement patterns of recaptured individuals over all surveys show that 31% of recaptured frogs have been found to traverse from one side of the carriageway to the other.

5. Recommendations

5.1 Contingency Measures

The EMP lists potential problems and contingency measures for various components of the monitoring program. Those that are considered relevant to the Giant Barred Frog monitoring program are listed and discussed in Table 6.

Table 6: Contingency measures

Potential problem	Contingency measure proposed in EMP	Discussion of proposed measure
Decline in presence of target species recorded at Impact sites after the upgrade has been completed, when compared to change in Control sites.	The cause of the decline in populations at impacts sites will be investigated in consultation with EPA and DoTE within two weeks of results reported by ecologist. If the cause of decline is considered most likely attributed to the upgrade of the highway (and not another event such as bushfire), mitigation measures, such as the location and types of fauna crossings and fauna fencing will be reviewed within two months of the above consultation being completed.	The mean number of Giant Barred Frogs recorded during the current monitoring period was lower compared to the previous monitoring event at all sites. It is not possible to attribute observed changes in Giant Barred Frog presence/abundance at the sites to the Project for the following reasons: • The variable nature of annual mean records among sites • The evidence of a decreasing trend in frog numbers at reference sites • The lack of a distinct difference between frog numbers at impact and reference sites. The potential influence of environemntal variables, such as rainfall, may have contributed to the lower numbers recorded in the 2019/2020 monitoring period. The apparent reduction in Giant Barred Frog numbers, however, is noted and will be considered in future monitoring events. **This contingency measure is not yet considered relevant**.

5.2 Recommendations

A summary of those performance indicators that were not met in the 2019/2020 monitoring period, recommended corrective actions and general recommendations are provided in Table 7.

Table 7: Recommendations

Performance measure	Action
Continued presence of Giant Barred Frogs during each survey event in Year 1 – 8 at sites where it was identified during baseline surveys, subject to access due to landowner agreement.	**This performance measure has been met for 3 of 6 sites in Year 5 (2019/2020).** Giant Barred Frogs were not recorded at Cooperabung Creek impact site, where it was recorded during all three baseline surveys. Not recorded at Maria River impact during summer 2020, where it was recorded during baseline surveys and not recorded at Cooperabung Creek reference site during spring 2019, where it was detected during baseline surveys. Due to lower than average rainfall and reduced records at all sites (impact and reference) it is recommended that monitoring continue as per the EMP.
No change to densities, distribution, habitat use and movement patterns compared to baseline data during monitoring in Year 1 – 8, and then when all monitoring events are considered at Year 8.	**This performance measure has not been met.** As discussed in Table 6, all sites appear to show an overall decreasing trend in mean records and densities. However, as this decreasing trend is evident at both impact and reference sites, it is not possible to attribute these changes to the Project at this stage. The low number of records obtained in 2019/2020 may reflect the below average rainfall and relatively dry environmental conditions. It is recommended that monitoring continue as per the EMP.

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Annex 1 – 2019/2020 data summary for each monitoring site

Cooperabung Creek impact site

Table 8: Summary of surveys and prevailing abiotic variables: Cooperabung Creek impact site

Date	Time		Air temp. °C	Water temp. °C	Humidity %	Stream depth (cm)	Wind (0-3, 0= no wind)	Cloud cover %	Rain (0-3, 0= no rain)
18/10/19	Start	12:04pm	17	19	84	5	1	0	0
	Finish		14	20	91	0	0	0	0
21/01/20	Start	11:00pm	28		65	-	0	0	0
	Finish	1:30am	28		65	-	0	0	0
19/03/20	Start	9:27pm	16.3		83	100	0	0	0
	Finish	11:20pm	17		92	40	0	0	0

Table 9: Habitat details: Cooperabung Creek impact site

Zone	OS %	Sh %	G %	LL %	BE %	Cattle	Pools	Riffles	DoP (cm)	FB	EF	Frogs detected
4	75	25	10	70	0	yes	3	0	30		yes	no
3	80	5	50	30	10	yes	1		10		no	no
2	75	20	60	25	5	yes	1		50		yes	no
5	25	25	60	40	0	yes	1		40		yes	no
6	15	20	50	15	30	yes	1		30		yes	no
8	90	30	5	90	5	yes	2		40		yes	no
9	60	30	60	25	0	yes	3		5		no	no
4	75	25	10	70	0	yes	3	0	30		yes	no
3	80	5	50	30	10	yes	1		10		no	no
2	75	20	60	25	5	yes	1		50		yes	no

OS = overstorey cover, Sh = Shrub cover, G = Ground cover, LL = leaf litter cover, BE = bare earth, DoP = depth of deepest pool, FB = fence breach, EF = exotic fish

Table 10: Summary of captures: Cooperabung Creek impact site

	Spring 2019	Summer 2020	Autumn 2020
Number of frogs recorded	0	0	0
Number of adult males	0	0	0
Number of adult females	0	0	0
Number of sub-adults	0	0	0
Number of juveniles	0	0	0
Number of recaptures	0	0	0

Habitat: Microhabitat within these zones included flood debris as overhang shelter, grass and leaf litter.

Smiths Creek impact site

Table 11: Summary of surveys and prevailing abiotic variables: Smiths Creek impact site

Date	Time		Air temp. °C	Water temp. °C	Humidity %	Stream depth (cm)	Wind (0-3, 0= no wind)	Cloud cover %	Rain (0-3, 0= no rain)
16/10/19	Start	11:31pm	18.9	21	99	50	0	50	0
	Finish	1:55am	19	20	93	40	0	0	2
23/01/20	Start	11:30pm	26		76		0		0
	Finish	1:45am	29		76		0		0
18/03/20	Start	10:00pm	21		93	50	0	0	0
	Finish	1:20am	15		99	40	0	0	0

Table 12: Habitat details: Smiths Creek impact site

Zone	OS %	Sh %	G %	LL %	BE %	Cattle	Pools	Riffles	DoP (cm)	FB	EF	Frogs detected
5	70	20	80	5	20	no	2	-	-		yes	no
3	80	25	15	20	10	no	2	-	20		no	yes
2	80	10	25	85	0	no	2	-	50		yes	yes
1	70	10	70	30	0	yes	2	-	40		no	no
6	85	5	50	30	0	yes	2	-	50		yes	no
7	95	5	2	95	0	yes	1	-	50		yes	no
8	70	5	45	50	5	yes	2	-	50		yes	no
9	75	0	5	10	50	yes	1	-	60		yes	no
10	50	5	10	15	5	yes	2	1	50		yes	no
5	70	20	80	5	20	no	2	-			yes	no

OS = overstorey cover, Sh = Shrub cover, G = Ground cover, LL = leaf litter cover, BE = bare earth, DoP = depth of deepest pool, FB = fence breach, EF = exotic fish

Table 13: Summary of captures: Smiths Creek impact site

	Spring 2019	Summer 2020	Autumn 2020
Number of frogs recorded	3	5	3
Number of adult males	0	1	0
Number of adult females	2	1	3
Number of sub-adults	1	0	0
Number of juveniles	0	3	0
Number of recaptures	0	1	1

Habitat: Microhabitat within these zones included leaf litter, flood debri under log and on bare ground.

Pipers Creek impact site

Table 14: Summary of surveys and prevailing abiotic variables: Pipers Creek impact site

Date	Time		Air temp. °C	Water temp. °C	Humidity %	Stream depth (cm)	Wind (0-3, 0= no wind)	Cloud cover %	Rain (0-3, 0= no rain)
15/10/2019	Start	9:57pm	25	19	58	40	0	10	0
	Finish	1:45am	25	19	58	50	0	5	0
23/01/2020	Start	08:00pm	28		76		0		1
	Finish	11:00pm	26		76		0		0
17/03/2020	Start	07:55pm	18.3		93	100	0	100	2
	Finish	10:35pm	17.3		99	50	0	100	1

Table 15: Habitat details: Pipers Creek impact site

Zone	OS %	Sh %	G %	LL %	BE %	Cattle	Pools	Riffles	DoP (cm)	FB	EF	Frogs detected
5	80	10	1	95	5	no	1	0	100		yes	no
4	70	60	2	95	0	no	1	0	100		yes	no
3	70	90	80	10	0	yes	1	0	100		yes	no
2	30	50	5	90	5	no	1	0	100		yes	no
1	75	70	80	50	10	no	1	0	50		yes	no
6	25	5	95	5	0	yes	1	-	-		yes	no
7	15	80	1	80	20	yes	2	1	50		yes	no
8	50	5	1	80	2	yes	1	0	50		yes	no
9	75	2	2	95	5	yes	1	0	40		yes	yes
10	50	40	70	25	5	yes	1	0	40		yes	yes

OS = overstorey cover, Sh = Shrub cover, G = Ground cover, LL = leaf litter cover, BE = bare earth, DoP = depth of deepest pool, FB = fence breach, EF = exotic fish, - = unknown

Table 16: Summary of captures: Pipers Creek impact site

	Spring 2019	Summer 2020	Autumn 2020
Number of frogs recorded	2	3	1
Number of adult males	0	2	1
Number of adult females	0	1	0
Number of sub-adults	2	0	0
Number of juveniles	0	0	0
Number of recaptures	0	1	0

Habitat: Microhabitat use included leaf litter and on bare ground.

Maria River impact site

Table 17: Summary of surveys and prevailing abiotic variables: Maria River impact site

Date	Time		Air temp. °C	Water temp. °C	Humidity %	Stream depth (cm)	Wind (0-3, 0= no wind)	Cloud cover %	Rain (0-3, 0= no rain)
16/10/2019	Start	10:09pm	22	19	96	40	0	100	1
	Finish		19	19	99	0	0	100	1
22/01/2020	Start	08:40pm	28		68		1	0	0
	Finish	11:00pm	28		68		1	0	0
18/03/2020	Start	07:31pm	20		72	100	0	10	0
	Finish	10:00pm	16.8		93	100	0	0	0

Table 18: Habitat details: Maria River impact site

Zone	OS %	Sh %	G %	LL %	BE %	Cattle	Pools	Riffles	DoP (cm)	FB	EF	Frogs detected
5	50	70	25	90	10	no	2	0	40		yes	no
4	50	100	0	80	10	no	2	0	50		yes	no
3	25	90	90	15	2	no	2	0	40		yes	no
2	25	90	50	25	0	no	1	0	20		no	no
1	25	80	10	90	5	no	0	0	0		no	no
6	75	20	40	70	0	no	2	0	100		yes	no
7	70	55	5	95	0	no	-	-	-		-	no
8	90	15	35	70	0	no	-	-	-		-	yes
9	95	80	50	60	20	no	0	-	-		no	no

OS = overstorey cover, Sh = Shrub cover, G = Ground cover, LL = leaf litter cover, BE = bare earth, DoP = depth of deepest pool, FB = fence breach, EF = exotic fish

Table 19: Summary of captures: Maria River impact site

	Spring 2019	Summer 2020	Autumn 2020
Number of frogs recorded	1	0	0
Number of adult males	1	0	0
Number of adult females	0	0	0
Number of sub-adults	1	0	0
Number of juveniles	0	0	0
Number of recaptures	0	0	0

Habitat: Microhabitat within these zones included under grass and leaf litter. Lantana is very abundant along both side of the river banks and is the dominant vegetation from MIz1 to MIz5. Lantana has also increased it's dominance of the downstream side throughout all zones.

Cooperabung Creek reference site

Table 20: Summary of surveys and prevailing abiotic variables: Cooperabung Creek reference site

Date	Time		Air temp. °C	Water temp. °C	Humidity %	Stream depth (cm)	Wind (0-3, 0= no wind)	Cloud cover %	Rain (0-3, 0= no rain)
15/10/2019	Start	07:46pm	27.3	17	53	0	0	0	0
	Finish	09:38pm	22	17	53	0	0	5	0
21/01/2020	Start	08:30pm	26		78		0	0	0
	Finish	10:30pm	26		78		0	0	0
19/03/2020	Start	07:29pm	22		71	50	0	5	0
	Finish	09:10pm	20		71	40	0	0	0

Table 21: Habitat details: Cooperabung Creek reference site

Zone	OS %	Sh %	G %	LL %	BE %	Cattle	Pools	Riffles	DoP (cm)	FB	EF	Frogs detected
1	60	50	10	90	10	no	0	0	0		no	no
2	70	15	2	95	0	no	1	0	6		no	yes
3	85	65	5	90	2	yes	0	0	0		no	no
4	90	5	5	50	0	yes	0	0	0		no	no
5	95	10	2	80	5	yes	0	0	0		no	no
6	65	5	25	40	2	yes	1	0	20		no	no
7	40	2	70	10	0	yes	0	0	0		no	yes
8	25	2	15	50	20	yes	0	0	0		no	yes
9	95	5	15	80	2	yes	2	0	50		yes	no
10	98	1	2	50	20	yes	0	0	0		no	no

OS = overstorey cover, Sh = Shrub cover, G = Ground cover, LL = leaf litter cover, BE = bare earth, DoP = depth of deepest pool, FB = fence breach, EF = exotic fish

Table 22: Summary of captures: Cooperabung Creek reference site

	Spring 2019	Summer 2020	Autumn 2020
Number of frogs recorded	2	1	0
Number of adult males	0	0	0
Number of adult females	2	1	0
Number of sub-adults	0	0	0
Number of juveniles	0	0	0
Number of recaptures	1	1	0

Habitat: Microhabitat found being used included grass and lomandra.

Pipers Creek reference site

Table 23: Summary of surveys and prevailing abiotic variables: Pipers Creek reference site

Date	Time		Air temp. °C	Water temp. °C	Humidity %	Stream depth (cm)	Wind (0-3, 0= no wind)	Cloud cover %	Rain (0-3, 0= no rain)
17/10/2019	Start	07:46pm	26	21	29	30	2	0	0
	Finish	11:45pm	25	21	29	20	0	0	0
22/01/2020	Start	11:45pm	26		76				
	Finish	03:30am	24.4		81				
17/03/2020	Start	11:03pm	17.2		99	25	0	100	0
	Finish	02:50am	16.9		99	50	0	10	0

Table 24: Habitat details: Pipers Creek reference site

Zone	OS %	Sh %	G %	LL %	BE %	Cattle	Pools	Riffles	DoP (cm)	FB	EF	Frogs detected
4	80	50	15	50	50	no	1	-	50		no	yes
5	95	40	10	90	0	no	2	0	50		yes	no
3	70	10	80	25	0	no	2	0	20		yes	yes
2	85	10	5	50	20	no	2	0	50		yes	yes
1	80	5	50	25	15	no	2	-	40		yes	yes
6	85	60	10	30	40	no	0	-	2		no	yes
8	50	40	80	10	0	no	2	-	30		yes	yes
7	95	30	10	60	10	no	3	-	40		yes	no
9	30	25	15	60	0	no	1	-	20		yes	no
10	80	25	10	70	5	no	1	-	10		yes	no

OS = overstorey cover, Sh = Shrub cover, G = Ground cover, LL = leaf litter cover, BE = bare earth, DoP = depth of deepest pool, FB = fence breach, EF = exotic fish

Table 25: Summary of captures: Pipers Creek reference site

	Spring 2019	Summer 2020	Autumn 2020
Number of frogs recorded	9	9	7
Number of adult males	4	7	4
Number of adult females	1	2	2
Number of sub-adults	3	0	1
Number of juveniles	1	0	0
Number of recaptures	2	4	3

Habitat: Microhabitat within these zones included within leaf litter, sheltering under Lomandra, and on the creek bed, bank or bare ground.

Annex 2 - Giant Barred Frog individual capture data

L = length (mm); W = weight (g); DW = distance to water (m); S = swabbed for Chytrid fungus; Z = Zone; U = unknown; M = male; F = female; J = juvenile

Site	Location	Season	Sex	Age	Reproductive status	L	W	DW	pit_tag_code	Capture status	Z	Activity	Microhabitat
Ref	Cooperabung Creek	Spring	F	Adult	Not Gravid	97	165	7	00076345D6	First time	9	Sitting	grass
Ref	Cooperabung Creek	Spring	F	Adult	Not Gravid	95	138	2	00077E7E2D	Recapture	9	Sitting	lomandra
Impact	Pipers Creek	Spring	Unk	Sub Adult	Immature	55	25	3	0007A385B7	First time capture	9	Sitting	leaf litter
Impact	Pipers Creek	Spring	Unk	Sub Adult	Immature	49	18	5	0007A3EDDB	First time capture	10	Sitting	leaf litter
Impact	Maria River	Spring	M	Sub Adult	Immature	61	35	20	0007A3FC27	First time capture	8	Sitting	leaf litter
Impact	Smiths Creek	Spring	Unk	Adult	n/a			15	NA	Uncaptured	3	Sitting	flood debri,under log
Impact	Smiths Creek	Spring	F	Adult	Not Gravid	97	133	20	0007A3A8C7	First time capture	2	Sitting	leaf litter
Impact	Smiths Creek	Spring	F	Adult	Not Gravid	93	130	15	0007A09A12	First time capture	2	Sitting	bare ground
Ref	Pipers Creek	Spring	M	Adult	n/a	74	64	3	900118001375092	Recapture	3	Buried	lomandra,leaf litter
Ref	Pipers Creek	Spring	Unk	Sub Adult		51	20	4	0007A11A19	First time capture	2	Sitting	leaf litter
Ref	Pipers Creek	Spring	Unk	Sub Adult	n/a	50	18	4	0007A0FA0E	First time capture	2	Sitting	tree base
Ref	Pipers Creek	Spring	Unk	Sub Adult	Immature	55	25	4	0007A0E569	First time capture	2	Sitting	leaf litter
Ref	Pipers Creek	Spring	F	Adult	Not Gravid	91	117	2	0007A3A8E7	First time capture	1	Sitting	leaf litter
Ref	Pipers Creek	Spring	M	Adult	Light Nuptial Pads	70	67	2	0007A3DCBF	Recapture	1	Sitting	leaf litter
Ref	Pipers Creek	Spring	M	Adult	Light Nuptial Pads	67	55	1	0007A11C69	First time capture	8	Buried	leaf litter
Ref	Pipers Creek	Spring	M	Adult	Light Nuptial Pads	62	44	3	00079EA4D7	First time capture	8	Sitting	leaf litter
Ref	Pipers Creek	Spring	Unk	Juvenile	Immature	40	14	1	0007A0F5E0	First time capture	8	Sitting	creek
Impact	Smiths Creek	Summer	M	Adult		72	66	1	00077E6A31	Recapture	2		leaf litter
Impact	Smiths Creek	Summer	F	Adult		99	146	10	0007A3BBFA	First time capture	2		leaf litter
Impact	Smiths Creek	Summer	Unk	Juvenile	Immature	55	25	5	0007A10FFF	First time capture	2		leaf litter
Impact	Smiths Creek	Summer	Unk	Juvenile	Immature	53	80	15	0007D23847	First time capture	3		leaf litter

Site	Location	Season	Sex	Age	Reproductive status	L	W	DW	pit_tag_code	Capture status	Z	Activity	Microhabitat
Impact	Smiths Creek	Summer	Unk	Juvenile	Immature	77	20	15	0007A0EEAB	First time capture	3		leaf litter
Ref	Cooperabung Creek	Summer	F	Adult	Possibly gravid	90	126	25	00077E7E2D	Recapture	8		grass/dirt
Ref	Pipers Creek	Summer	M	Adult		76		1	900118001375092	Recapture	3		lomandra
Ref	Pipers Creek	Summer	M	Adult		67		2	0007A10D43	First time capture	2		lomandra
Ref	Pipers Creek	Summer	M	Adult				2	0007A3500E	Recapture	2		lomandra
Ref	Pipers Creek	Summer	F	Adult	mating with frog 5			2	unkown	Uncaptured	2		lomandra
Ref	Pipers Creek	Summer	M	Adult	mating with frog 4	74	59	2.5	0007A3DCBF	Recapture	2		lomandra
Ref	Pipers Creek	Summer	M	Adult		71	57	1	000791EC31	Recapture	6		lomandra
Ref	Pipers Creek	Summer	F	Adult		69	44	0.5	00079EAEEF	First time capture	6		gravel
Ref	Pipers Creek	Summer	M	Adult		75	60	1	0007A0E2C2	First time capture	6		lomandra
Ref	Pipers Creek	Summer	M	Adult				10	unkown	Uncaptured	1		lomandra
Impact	Pipers Creek	Summer	M	Adult		52	27	10	0007A0E2E2	First time capture	8	Sitting	dirt
Impact	Pipers Creek	Summer	M	Adult						Uncaptured	7	escape	debris
Impact	Pipers Creek	Summer	F	Adult		94	132	10	0007A2e861	Recapture	2		leaf litter
Impact	Pipers Creek	Autumn	M	Adult	n/a			0		Uncaptured	3	calling	lomandra
Ref	Pipers Creek	Autumn	F	Adult	Not Gravid	76	59	3	00079206C4	Recapture	6	Sitting	bank,bare ground
Ref	Pipers Creek	Autumn	Unk	Sub Adult	Immature	62	36	2	0007A38CB4	First time capture	6	Sitting	lomandra
Ref	Pipers Creek	Autumn	F	Adult	Not Gravid	84	79	3	0007A3EB16	First time capture	7	Sitting	leaf litter
Ref	Pipers Creek	Autumn	M	Adult		68.5	48	3	0007A3E2C3	First time capture	9	Sitting	bank,bare ground
Ref	Pipers Creek	Autumn	M	Adult	Moderate Nuptial Pads	83	66		0007A0E2C2	Recapture	6	Sitting	leaf litter
Ref	Pipers Creek	Autumn	M	Adult				4		Uncaptured	3	calling	leaf litter
Ref	Pipers Creek	Autumn	M	Adult	Moderate Nuptial Pads	78	60	2.5	900118001375092	Recapture	4	Jumping	leaf litter

Site	Location	Season	Sex	Age	Reproductive status	L	W	DW	pit_tag_code	Capture status	Z	Activity	Microhabitat
Impact	Smiths Creek	Autumn	F	Adult	Not Gravid	90		10	0007A37FBE	First time capture	2	Sitting	leaf litter
Impact	Smiths Creek	Autumn	F	Adult		70	60	5	000791EBA8	First time capture	2	Sitting	leaf litter
Impact	Smiths Creek	Autumn	F	Adult	Gravid	92		3	0007023D8C	Recapture	2	Sitting	leaf litter

Annex 3 - Water Quality data (extracted from TfNSW 2020)

Table 26: Triggered water quality parameters: Cooperabung Creek

Parameter	ANZECC trigger value	Median downstream site value (Upstream 20th % - 80th % trigger range) Values in black = < 20th % Values in red = > 80th % Shaded cells = outside/above ANZECC trigger											
		April 2019	May 2019	June 2019	July 2019	August 2019	September 2019	October 2019	November 2019	December 2019	January 2020	February 2020	March 2020
Temperature ˚C	NA	DNS	DNS	DNS		DNS	DNS	DNS	DNS	DNS	DNS		
Electrical Conductivity uS/cm	125 – 2200	DNS	DNS	DNS	690.0 (206.6-456.0)	DNS	DNS	DNS	DNS	DNS	DNS	155.0 (206.6-478.2)	175.5 (189.8-478.2)
Dissolved oxygen %	85 – 110	DNS	DNS	DNS	44.7 (64.3-111.6)	DNS	DNS	DNS	DNS	DNS	DNS		
pH	6.5 – 8	DNS	DNS	DNS	6.3 (6.6-7.3)	DNS	DNS	DNS	DNS	DNS	DNS		6.1 (6.5-7.3)
Turbidity (NTU)	6 – 50	DNS	DNS	DNS	3.7 (4.7-24.6)	DNS	DNS	DNS	DNS	DNS	DNS		
Total suspended solids mg/L	-	DNS	DNS	DNS		DNS	DNS	DNS	DNS	DNS	DNS		
Aluminium mg/L	0.055	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	0.12 (0.01-0.09)	
Arsenic mg/L	0.024	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		
Cadmium mg/L	0.0002	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		
Chromium mg/L	0.001	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		
Copper mg/L	0.0014	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		
Iron mg/L	ID	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		
Lead mg/L	0.0034	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		
Manganese mg/L	1.9	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		
Mercury mg/L	0.0006	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		
Nickel mg/L	0.011	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		

Parameter	ANZECC trigger value	Median downstream site value (Upstream 20th % - 80th % trigger range) Values in black = < 20th % Values in red = > 80th % Shaded cells = outside/above ANZECC trigger											
Silver mg/L		DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		
Zinc mg/L	0.008	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS		
Total nitrogen mg/L	0.5	DNS	DNS	DNS		DNS	DNS	DNS	DNS	DNS	DNS	0.8 (0.1-0.6)	
Total phosphorus mg/L	0.05	DNS	DNS	DNS		DNS	DNS	DNS	DNS	DNS	DNS	0.03 (0.01-0.02)	0.05 (0.01-0.03)

ID = insufficient representative data (ANZECC)

Table 27: Triggered water quality parameters: Smiths Creek

Parameter	ANZECC trigger value	Median downstream site value (Upstream 20th % - 80th % trigger range) Values in black = < 20th % Values in red = > 80th % Shaded cells = outside/above ANZECC trigger											
		April 2019	May 2019	June 2019	July 2019	August 2019	September 2019	October 2019	November 2019	December 2019	January 2020	February 2020	March 2020
Temperature ˚C	NA								DNS	DNS	DNS		
Electrical Conductivity uS/cm	125 – 2200	1143.5 (192.4-323.6)	1365.5 (192.4-800.6)	5055.5 (195.8-880.0)					DNS	DNS	DNS	87.0 (807.4-8000.0)	126.5 (807.4-8000.0)
Dissolved oxygen %	85 – 110		78.5 (30.7-75.2)						DNS	DNS	DNS	84.0 (35.6-71.8)	
pH	6.5 – 8	7.6 (7.0-7.4)		6.8 (7.0-7.5)					DNS	DNS	DNS	6.8 (7.1-7.6)	6.6 (6.8-7.6)
Turbidity (NTU)	6 – 50	29.4 (10.9-26.7)	9.4 (10.8-26.7)	9.1 (10.8-26.7)			6.0 (11.1-23.8)	30.5 (11.3-26.7)	DNS	DNS	DNS		
Total suspended solids mg/L	-	11 (5-7)					10 (5-8)		15 (5-9)	38 (5-8)	DNS		
Aluminium mg/L	0.055			DNS	DNS	DNS		DNS	DNS		DNS	0.22 (0.01-0.07)	DNS
Arsenic mg/L	0.024			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Cadmium mg/L	0.0002			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Chromium mg/L	0.001			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Copper mg/L	0.0014			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Iron mg/L	ID		0.11 (0.36-1.19)	DNS	DNS	DNS		DNS	DNS		DNS		DNS
Lead mg/L	0.0034			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Manganese mg/L	1.9		0.044 (0.086-0.578)	DNS	DNS	DNS	6.920 (0.102-0.578)	DNS	DNS	3.080 (0.102-0.578)	DNS	0.019 (0.057-0.578)	DNS
Mercury mg/L	0.0006			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Nickel mg/L	0.011	0.002 (0.001-0.001)		DNS	DNS	DNS	0.002 (0.001-0.001)	DNS	DNS		DNS		DNS
Silver mg/L				DNS	DNS	DNS		DNS	DNS		DNS		DNS

Parameter	ANZECC trigger value	Median downstream site value (Upstream 20th % - 80th % trigger range) Values in black = < 20th % Values in red = > 80th % Shaded cells = outside/above ANZECC trigger											
Zinc mg/L	0.008	0.016 (0.005-0.012)		DNS	DNS	DNS		DNS	DNS		DNS		DNS
Total nitrogen mg/L	0.5						0.6 (0.3-0.5)			0.8 (0.3-0.5)	DNS		
Total phosphorus mg/L	0.05				0.06 (0.01-0.03)	0.05 (0.01-0.03)	0.05 (0.02-0.04)			0.05 (0.01-0.03)	DNS		

ID = insufficient representative data (ANZECC)

Table 28: Triggered water quality parameters: Pipers Creek

Parameter	ANZECC trigger value	Median downstream site value (Upstream 20th % - 80th % trigger range) Values in black = < 20th % Values in red = > 80th % Shaded cells = outside/above ANZECC trigger											
		April 2019	May 2019	June 2019	July 2019	August 2019	September 2019	October 2019	November 2019	December 2019	January 2020	February 2020	March 2020
Temperature ˚C	NA												
Electrical Conductivity uS/cm	125 – 2200	552.0 (210.8-441.4)	584.0 (231.2-501.0)	612.5 (247.6-544.8)						612.0 (372.0-587.4)	752.0 (461.6-592.4)	100.5 (461.6-592.4)	155.0 (425.2-592.4)
Dissolved oxygen %	85 – 110	33.5 (36.1-76.7)					76.4 (36.7-73.0)						
pH	6.5 – 8	7.8 (7.2-7.5)			7.0 (7.2-7.5)	7.8 (7.2-7.6)	7.9 (7.2-7.8)				8.1 (7.4-7.8)	6.7 (7.4-7.8)	6.4 (7.0-7.8)
Turbidity (NTU)	6 – 50	12.8 (13.7-32.7)	11.0 (13.2-28.3)	4.9 (12.6-28.3)	11.2 (12.0-26.4)	8.3 (11.4-26.4)	5.4 (9.9-23.9)	5.7 (9.7-23.9)	4.2 (8.6-23.9)	5.8 (6.9-22.3)	4.7 (6.5-20.5)		
Total suspended solids mg/L	-												
Aluminium mg/L	0.055	0.01 (0.02-0.08)		DNS	DNS	DNS		DNS	DNS		DNS	0.23 (0.01-0.14)	DNS
Arsenic mg/L	0.024			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Cadmium mg/L	0.0002			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Chromium mg/L	0.001			DNS	DNS	DNS		DNS	DNS		DNS	0.002 (0.001-0.001)	DNS
Copper mg/L	0.0014			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Iron mg/L	ID	0.15 (0.21-0.69)		DNS	DNS	DNS	0.18 (0.21-0.69)	DNS	DNS		DNS		DNS
Lead mg/L	0.0034			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Manganese mg/L	1.9			DNS	DNS	DNS	0.045 (0.066-0.263)	DNS	DNS		DNS	0.037 (0.051-0.263)	DNS
Mercury mg/L	0.0006			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Nickel mg/L	0.011			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Silver mg/L				DNS	DNS	DNS		DNS	DNS		DNS		DNS

Parameter	ANZECC trigger value	Median downstream site value (Upstream 20th % - 80th % trigger range) Values in black = < 20th % Values in red = > 80th % Shaded cells = outside/above ANZECC trigger											
Zinc mg/L	0.008			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Total nitrogen mg/L	0.5					0.1 (0.2-0.4)						0.6 (0.2-0.4)	
Total phosphorus mg/L	0.05		0.04 (0.01-0.02)							0.03 (0.01-0.02)		0.06 (0.01-0.02)	0.03 (0.01-0.02)

ID = insufficient representative data (ANZECC)

Table 29: Triggered water quality parameters: Maria River

Parameter	ANZECC trigger value	Median downstream site value (Upstream 20th % - 80th % trigger range) Values in black = < 20th % Values in red = > 80th % Shaded cells = outside/above ANZECC trigger											
		April 2019	May 2019	June 2019	July 2019	August 2019	September 2019	October 2019	November 2019	December 2019	January 2020	February 2020	March 2020
Temperature ˚C	NA			13.1 (14.1-24.3)									
Electrical Conductivity uS/cm	125 – 2200		1614.0 (166.6-1579.6)	2340.5 (164.0-1635.4)		2402.0 (164.0-1635.4)	1811.0 (187.6-1635.4)		2567.0 (172.6-1261.0)	3179.5 (172.6-1261.0)	3805.5 (172.6-1261.0)	92.5 (164.0-932.4)	
Dissolved oxygen %	85 – 110						107.1 (31.8-103.3)				31.7 (31.8-103.3)		
pH	6.5 – 8	7.8 (6.7-7.4)	7.4 (6.7-7.3)				7.8 (6.7-7.5)				7.8 (6.8-7.6)	6.3 (6.7-7.6)	6.2 (6.7-7.6)
Turbidity (NTU)	6 – 50		6.1 (7.3-42.0)	3.3 (7.3-42.0)			4.7 (6.7-42.0)		5.1 (6.7-42.0)		5.3 (6.7-42.0)	5.0 (5.7-31.5)	5.2 (5.7-18.7)
Total suspended solids mg/L	-												
Aluminium mg/L	0.055			DNS	DNS	DNS		DNS	DNS		DNS	0.36 (0.01-0.35)	DNS
Arsenic mg/L	0.024			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Cadmium mg/L	0.0002			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Chromium mg/L	0.001			DNS	DNS	DNS		DNS	DNS		DNS	0.002 (0.001-0.001)	DNS
Copper mg/L	0.0014			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Iron mg/L	ID	0.05 (0.06-0.47)	0.05 (0.06-0.47)	DNS	DNS	DNS	0.05 (0.06-0.41)	DNS	DNS	0.05 (0.06-0.41)	DNS		DNS
Lead mg/L	0.0034			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Manganese mg/L	1.9			DNS	DNS	DNS	0.008 (0.044-0.436)	DNS	DNS	1.665 (0.004-0.436)	DNS		DNS
Mercury mg/L	0.0006			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Nickel mg/L	0.011			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Silver mg/L				DNS	DNS	DNS		DNS	DNS		DNS		DNS

Parameter	ANZECC trigger value	Median downstream site value (Upstream 20th % - 80th % trigger range) Values in black = < 20th % Values in red = > 80th % Shaded cells = outside/above ANZECC trigger											
Zinc mg/L	0.008			DNS	DNS	DNS		DNS	DNS		DNS		DNS
Total nitrogen mg/L	0.5					0.1 (0.2-0.6)			0.2 (0.3-0.6)		0.2 (0.3-0.6)		
Total phosphorus mg/L	0.05												

ID = insufficient representative data (ANZECC), DNS = Did not sample

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Road Kill Monitoring 2019/2020

Oxley Highway to Kempsey, Pacific Highway Upgrade

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Illawarra
Armidale
Newcastle
Mudgee
Port Macquarie
Brisbane
Cairns

Cover photograph: Overlooking widened median showing aerial crossing and fauna fence (left) and Standard and Phascogale fauna fence (right).

Executive summary

Context

This report documents findings of the 2019/2020 road kill monitoring period, the second of four operational monitoring periods for road kill, as required by the Oxley Highway to Kempsey (OH2K) Ecological Monitoring Program (EMP, RMS 2019). Road kill monitoring has been reported in association with fauna fence monitoring for the Project (Niche 2019) and will continue to be reported in association with fauna fence monitoring. However, as the 2019/2020 road kill monitoring period occurs outside of the required fauna fence monitoring periods, this report is presented as a stand-alone report of the 2019/2020 road kill monitoring period.

Aims

The aim of the fauna fence and road kill monitoring program is to determine if purpose-built fauna fences are stopping fauna from crossing the road, thereby reducing road kill. The aims of this report are to summarise the methods and results of road kill monitoring undertaken in October 2019, January 2020 and April 2020 and determine if performance measures are being met and provide corrective actions where required, as per the EMP.

Methods

Road kill monitoring was undertaken along the entire length of the Project. Surveys involved observations made from a vehicle travelling at approximately 80 km/h. Road kill fauna observed on the road and within three metres of the road verge were recorded using a GPS.

Key Results

The key results of the 2019/2020 road kill monitoring were:

- One threatened species, the Brush-tailed Phascogale was identified as road kill during April 2020 road kill monitoring.
- There were a total of 21 road kill records in spring (October 2019), 15 in summer (January 2020) and 10 in autumn (April 2020). Large ground dwelling mammals, medium ground dwelling mammals and birds were the most commonly recorded fauna groups.
- Of the 37 road kill records (excluding birds) from the 2019/2020 monitoring period, 17 (46%) records were within and 20 (54%) records were outside fenced areas. The rate of road kill in unfenced areas (6.4 kilometres; 3.13 records/kilometre) was higher than the rate in fenced areas (30.6 kilometres; 0.56 records/kilometre).
- Of the 37 road kill records (excluding birds) there were three road kill records within 200 metres of any aerial crossing during the 2019/2020 road kill surveys. The rate of road kill within 200 metres of aerials crossings (5.2 kilometres; 0.58 records/kilometre) was substantially lower than outside this boundary (31.8 kilometres; 1.07 records/kilometre).

- Of the 37 road kill records (excluding birds), 12 occurred within 200 metres of underpasses. The rate of road kill within 200 metres of fauna underpasses/bridges (19.2 kilometres; 0.63 records/kilometre) was lower than the rate outside this boundary (17.8 kilometres; 1.40 records/kilometre).
- The overall average weekly road kill rate has decreased from baseline (2013/2014; 8.0) to 2019/2020 (3.8) for the same three seasons.

Conclusions

All performance measures for road kill monitoring were met for the 2019/2020 monitoring period:

- Rates of road kill were lower within fenced areas compared to unfenced areas
- Rates of road kill were lower in proximity to underpasses and aerial crossings
- Incidence of road kill has reduced from baseline
- Transport for NSW (TfNSW) have advised that all fauna fencing as identified in Schedule 3 of the EPBC approval has been installed.

Management Implications

Given that all performance measures were met and that contingency measures were addressed as required, there are no recommendations based on the outcomes of the 2019/2020 monitoring period.

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1. Introduction

1.1 Context

The Oxley Highway to Kempsey (OH2K) section of the Pacific Highway Upgrade Project (the Project) was approved in 2012 subject to various Ministers Conditions of Approval (MCoA) and a Statement of Commitments (SoC). A subsequent approval with additional conditions of consent (CoA) was granted in 2014 by the then Commonwealth Department of Environment (DoE) for Matters of National Environmental Significance (MNES) listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1995* (EPBC Act). The Ecological Monitoring Program (hereafter referred to as the EMP) (RMS 2019) combines these approval conditions and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project.

Fauna fences were installed to prevent fauna crossing the road surface, thereby reducing road kill and guiding animals towards safe wildlife crossing structures (underpasses and aerial crossing structures). The fauna fence and road kill are to be monitored to assess their effectiveness in reducing fauna road kill, as required by the EMP.

1.1.1 Monitoring framework

Road kill monitoring has been undertaken and reported in association with fauna fence monitoring for the Project (Niche 2019) and will continue to be reported in association with fauna fence monitoring. However, as the 2019/2020 road kill monitoring period occurs outside of the required fauna fence monitoring periods (Years 4, 6 and 8 (operational phase)), this report is presented as a stand-alone report for the 2019/2020 (Year 5) road kill monitoring period.

The design, methods and performance indicators that define the road kill monitoring program are specified in the EMP.

Road kill monitoring was required for baseline (prior to clearing), during clearing, during construction and upon completion of the Project (operational) in Years 4, 5, 6 and 8. The road kill monitoring framework provided within the EMP and the reporting status to date is shown in Table 1. The 2019/2020 monitoring period represents the second operational monitoring period and includes spring (October 2019), summer (January 2020) and autumn (April 2020). This report represents the second of four reports required for the operational phase monitoring.

Table 1: Road kill monitoring

Project phase	Monitoring event: report	Timing of survey	Location
Baseline	*spring 2013, summer 2014, autumn 2014:* Niche 2015	Weekly during October (spring), January (summer) and April (autumn) prior to commencement of construction (12 weeks).	Entire length of existing highway in Project area
During clearing operations	*November 2014- July 2015*: Niche 2015	Daily	Portion of existing highway adjacent to clearing operations
One month following clearing operations			
For the duration of construction	*8 August 2015 – 22 July 2016*: Niche 2016a *27 July 2016 – 28 July 2017*: Niche 2017a *4 August 2017 – 29 March 2018*: Niche 2018	Weekly (Note: as the opening of the Project occurred in three stages, weekly monitoring of the Project continued in the unopened sections of the Project to satisfy construction monitoring requirements.)	Entire length of existing highway in Project area

Project phase	Monitoring event: report	Timing of survey	Location
Within one month of opening of the Project	Twelve week post-opening periods were as follows: • Ku2K: from 3 November 2017 • OH2Ku Stage 1: from 17 November 2017 • OH2Ku Stage 2: from 30 March 2018 All in Niche 2018.	Weekly for 12 weeks. If this period does not coincide with the season (i.e. October (spring), January (summer) and April (autumn) in which baseline surveys were undertaken, also undertake weekly surveys during the first survey period (April, October or January) to occur after the opening of the Project (to allow for comparison to baseline results).	Entire length of completed Project
Upon completion of the Project (operation phase)	Year 4: 2018/2019 – Niche 2019 Year 5: 2019/2020 – Current Report	Weekly during October (spring), January (summer) and April (autumn (12 weeks) in Year 4, 5, 6 and 8, or until mitigation measures can be demonstrated to have been effective as defined in the EPBC approval.	Entire length of completed Project

1.1.2 Purpose of this report

This report documents findings of the 2019/2020 road kill monitoring period, the second of four operational monitoring periods for road kill. The aims of this report are to summarise the methods and results of the 2019/2020 monitoring and determine if performance measures are being met, as per the EMP.

1.2 Performance Measures

The EMP specifies the following performance measures for road kill monitoring:

- *Lower rates of road kill in proximity (i.e. areas of the main carriageways within areas adjacent to installed fauna fencing, and within 100 metres of rope bridges and fauna underpasses) to fauna fencing, rope bridges and fauna underpasses than in sections of the upgrade not near wildlife crossing structures or fauna fences in Year 1 – 6 & 8 monitoring events*
- *Reduced incidence of road kill from baseline conditions during monitoring events in Years 1-6 & 8 and when all monitoring events are considered at Year 8*
- *Fauna exclusion fencing is installed at a minimum in the locations identified in Schedule 3 of the EPBC approval at Year 4.*

1.3 Monitoring Timing

Operational road kill monitoring is required weekly for four weeks during October (spring), January (summer) and April (autumn) in Years 4, 5, 6 and 8.

1.4 Reporting

Annual reporting of monitoring results will outline:

- Detailed description of monitoring methodology employed
- Results of the monitoring period
- Discussion of results, including how the results compare against performance measures, if any modifications to timing or frequency of monitoring periods or monitoring methodology are required and any other recommendations
- If contingency measures should be implemented.

All reports prepared under the EMP will be submitted to the NSW Department of Planning, Industry and Environment (DPIE) and the NSW Environment Protection Authority (EPA).

1.5 Limitations

- Identification and detection of road kill was limited to what can be observed whilst travelling at 80km/hr as it was not considered safe to stop on the operational highway. As such:
    - Some road kill fauna were identified to the vertebrate group level only.
    - Some records were classified as 'unknown' as road kill fauna could not be identified as a result of extensive collision damage.
    - It is possible that small fauna such as frogs, snakes, small mammals and birds have been under-counted as small-sized road kill fauna have the potential to be partially or wholly removed by scavenger animals, resulting in impossible identification from the vehicle.
- Safety issues prevent the removal of road kill following each survey and therefore, despite efforts, road kill may have been recorded multiple times over the four weekly surveys resulting in double-counting and 'unknown' records as the condition of the animal deteriorated.

2. Methodology

2.1 Monitoring Sites

Road kill monitoring was undertaken along the entire length of the Project.

2.2 Survey Methods

Surveys were undertaken in accordance with the EMP and are outlined below.

Road kill surveys of the entire Project were undertaken once a week for four weeks during October 2019 (spring), January 2020 (summer) and April 2020 (autumn). These surveys involved observations made from a vehicle travelling at approximately 80 km/hr. Road kill fauna observed on the road and within three metres of the road verge were recorded by the passenger. Due to the safety issues associated with the operational highway, it was often not possible to stop the vehicle to closer inspect or remove road kill. Road kill records were grouped into general fauna groups for analysis.

2.3 Analysis

Weekly road kill rates were calculated to compare changes in rates of road kill between years. An analysis of the number of road kill events (excluding bird records) that occurred within or outside fenced sections of the Project was undertaken by calculating a *road kill per kilometre* rate. A similar analysis was undertaken to compare road kill rates within 200 metres of fauna crossings. Fauna crossing zones were created by grouping fauna crossings that occurred within 400 metres of each other (i.e. their 200 metre boundary overlapped) and included 200 metres north and south of the crossing/s. The road kill records that occurred within the zones were compared to road kill records outside of the zones. Aerial crossings and underpasses (including bridges and culverts) were analysed separately.

3. Results

Detailed field data for the 2019/2020 monitoring are presented in Annex 1. The distribution of road kill records is in shown in Figure 1.

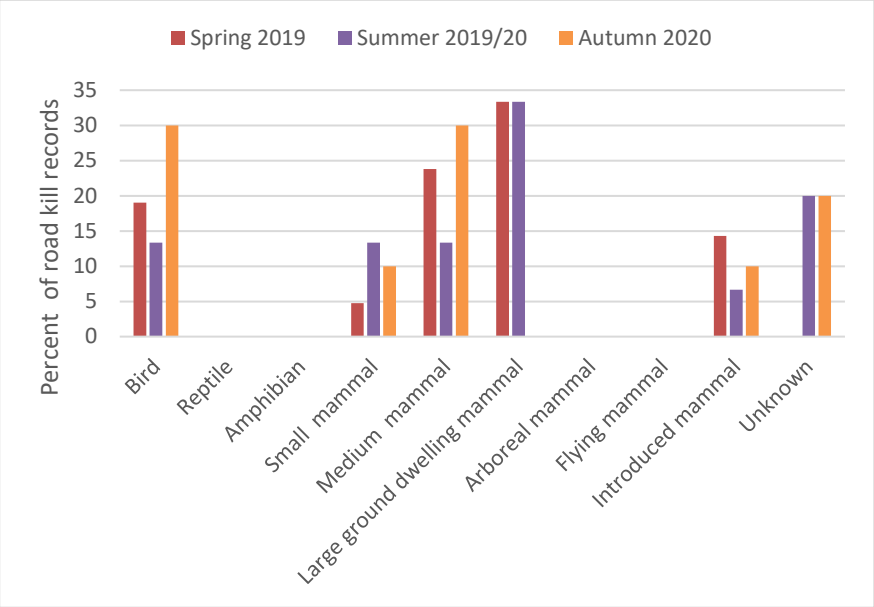
3.1 2019/2020 Road Kill Results

3.1.1 Total alignment

Fauna categories for analysis were defined as follows:

- Arboreal mammals
- Flying mammals (i.e. bats)
- Introduced mammals
- Small mammals
- Medium mammals
- Large ground dwelling mammals
- Amphibians
- Reptiles
- Birds
- Unknown

There were a total of 46 road kill records, comprising 21 in spring, 15 in summer and 10 in autumn. The percentage of road kill records for each category for the current monitoring period is presented in Graph 1. Combining spring, summer and autumn results, large ground dwelling mammals (26.1%, n = 12), medium ground dwelling mammals (21.7% of road kill, n = 10) and birds (19.6% of road kill, n = 9) were the most commonly recorded fauna groups.



Graph 1: 2019/2020 road kill records

3.1.2 Threatened fauna

There was one record of threatened fauna identified as road kill within the 2019/2020 monitoring period. A dead Brush-tailed Phascogale was observed on the 8 April 2020 in the southbound left lane on a bridge known as Wilson's River Floodplain Bridge (Bridge 7) (Figure 1, map section 5).

The EMP specifies the following:

"*If the animal is identified as a TSC Act or EPBC Act threatened species, the following information will also be recorded:*

- *Sex and age class (juvenile or adult) where possible and safety limitations permit.*
- *Presence of pouch young (for marsupials) where possible and safety limitations permit.*

In addition, for TSC Act or EPBC Act threatened species, the following information will also be recorded where possible and safety considerations permit:

- *distance to a fauna connectivity structure.*
- *distance to drop down structure.*
- *if fauna fencing was installed, is there any damage to the fence in the vicinity.*"

The individual was located on Bridge 7 in an area where it was unsafe to stop or access by foot to retrieve the animal, as such, the animal could not be inspected for physical details.

Bridge 7 traverses a flood channel lined by tall dense Swamp Oak (*Casuarina glauca*) forest surrounded by farmland. This channel provides connectivity for native fauna to move between vegetation on the West and retained riparian vegetation in the East. Fencing in that area consists of standard floppy top fauna fence adjoining the bridge and extending approximately 400 metres to the north and several kilometres to the south. The nearest Phascogale fencing starts at approximately 2.5 km to the south. Damage to the fence in the area was not evident, however, while standard floppy top fauna fence is not intended to stop Brush-tailed Phascogales, the fence appeared to be surrounded by substantial tall grassy regrowth.

While the standard floppy top fauna fence is not intended to stop Brush-tailed Phascogales, given the location of the animal in the middle of Bridge 7, it is possible and likely that the animal accessed the bridge via dense regrowth of Swamp Oak that was observed to be in contact with the bridge. Transport for NSW (TfNSW) was immediately notified of the event and vegetation control works were undertaken on 17 April, whereby trees were trimmed and lopped. It is noted that the Project was surveyed pre-construction and based on these surveys, as part of the Project approval, no Brush-tailed Phascogale mitigation measures were considered necessary in this area. The species was not previously identified in this area in any subsequent surveys conducted during or post construction.

3.1.3 Road kill rate in relation to fauna fence

A total of approximately 30,600 metres (82.7%) of the 37,000 metres of the Project is fenced with a minimum of standard fauna fence (data provided by TfNSW).

An analysis of the number of road kill events (excluding the bird records) that occurred either within or outside of fenced sections of the Project (considering those road kill observations made at the edge of a fenced area, or in an area where fencing was present on one side of the carriageway only, to be outside) was undertaken. Of the 37 road kill records (excluding birds) from the 2019/2020 monitoring period, 20 (54%) records were outside fenced areas and 17 (46%) records were within fenced areas. Considering the

data with regard to fencing along the highway, calculation of a *road kill per kilometre* rate (excluding birds) showed the rate of road kill in unfenced areas (20 records over 6.4 kilometres; 3.13 records/kilometre) to be substantially higher than the rate in fenced areas (17 records over 30.6 kilometres; 0.56 records/kilometre).

3.1.4 Road kill rate in relation to fauna crossings

The performance indicator for road kill refers to lower rates of road kill "*within 100 metres of rope bridges and fauna underpasses"*. However, the EMP identifies "*high rates of fauna road strike mortality within 200 metres of fauna underpasses*" as a potential problem for fauna fences for which contingency measures have been provided. An analysis of road kill within 200 metres each side of fauna crossings has therefore been undertaken in order to address the trigger for contingency measures. It is considered that this analysis is sufficient to address the performance indicator, as it extends the range within which road kill rates should be lower. As discussed in Section 2.3 fauna crossing zones were created by grouping fauna crossings that occurred within 400 metres of each other (i.e. their 200 metre boundary overlapped). The road kill records that occurred within these zones were compared to road kill records outside of the zones. Aerial crossings and underpasses (including bridges and culverts) were analysed separately.

Aerial crossings

There are 18 aerial crossings along the entire length of the Project that fall into nine separate zones. Both rope bridges and glider pole crossings were considered in this analysis. The Project consists of 5,176 metres that fall within 200 metres either side of an aerial crossing, and therefore 31,824 metres outside of these zones. Of the 37 road kill records (excluding birds) from the 2019/2020 monitoring period there were three road kill records (none of which were identified to be arboreal) within 200 metres of any aerial crossing during the 2019/2020 road kill surveys. Calculation of a *road kill per kilometre* rate (excluding birds) showed the rate of road kill within 200 metres either side of aerial crossings (5.2 kilometres; 0.58 records/kilometre) to be lower than outside this boundary (31.8 kilometres; 1.07 records/kilometre).

Underpasses

There are 42 culverts and 12 bridges throughout the Project that are considered to provide fauna passage under the carriageway, which fall into 39 separate zones. The Project consists of 19,175 metres that fall within 200 metres of an underpass/bridge, and therefore 17,825 metres outside of these zones. Of the 37 road kill records (excluding birds) from the 2019/2020 monitoring period, 12 occurred within 200 metres of underpasses, while the remaining 25 occurred outside this boundary. Calculation of a *road kill per kilometre* rate (excluding birds) found the rate of road kill within 200 metres of fauna underpasses/bridges (19.2 kilometres; 0.63 records/kilometre) to be lower than the rate outside this boundary (17.8 kilometres; 1.40 records/kilometre).

3.2 Comparison with Baseline Surveys and Previous Monitoring

3.2.1 Total alignment

The average weekly road kill for all monitoring periods is presented in Table 2.

Baseline surveys were undertaken prior to the commencement of construction for 12 weeks in spring 2013, summer 2014 and autumn 2014. Monitoring took place weekly for four weeks in each of the seasons as required by the EMP. Baseline surveys recorded 96 animals as road kill during the three monitoring events, representing 33 species and an average weekly road kill for spring, summer and autumn of 9.5, 11.8 and 3.3 respectively.

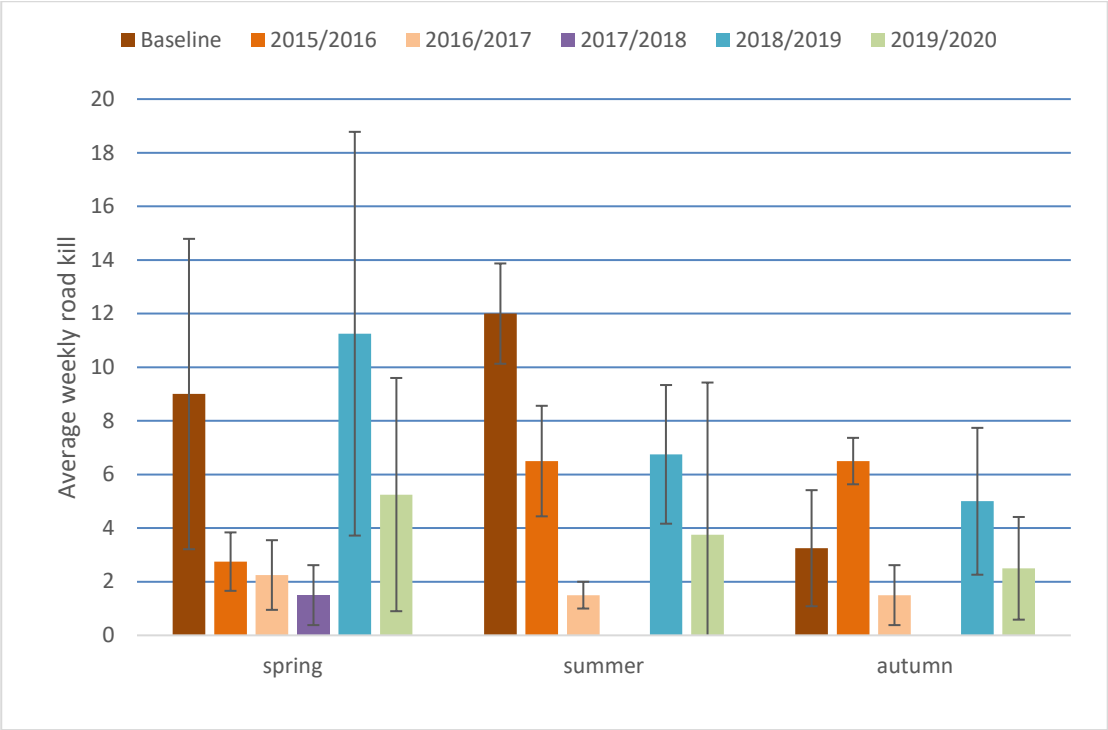
In order to compare the results of the baseline surveys with that of subsequent monitoring periods, the average weekly road kill for the four survey weeks undertaken in each season of the baseline surveys (spring (October), summer (January), autumn (May)), was compared to the same four weeks of each subsequent monitoring event. All weekly road kill rates were lower in the 2019/2020 monitoring period than during baseline surveys. The overall average weekly road kill rate decreased from baseline of 8.0 to 3.8 for the same three seasons.

Graph 2 shows the seasonal average weekly road kill for each of the same four week periods for all monitoring events. Winter has been excluded from the graph as winter surveys were not undertaken during baseline surveys and do not form part of the operational road kill monitoring.

Table 2: Weekly road kill rates for monitoring undertaken along the entire Project alignment

Monitoring period		Spring (n)	Summer (n)	Autumn (n)	Winter (n)	Annual (n)
Baseline	**2013/2014**	9.5 (4)	11.8 (4)	3.3 (4)	No surveys	8.0 (12)
Construction phase	**2015/2016 (all surveys)**	4.2 (13)	5.8 (14)	6.7 (13)	4.1 (12)	5.0 (52)
	2015/2016 (4 weeks)	2.75 (4)	6.5 (4)	6.5 (4)	3.0 (4)	
	2016/2017 (all surveys)	3.3 (13)	2.6 (13)	2.0 (12)	2.2 (14)	2.3 (52)
	2016/2017 (4 weeks)	4.0 (4)	1.5 (4)	1.5 (4)	2.5 (4)	
	2017/2018 (all surveys)	2.9 (9)	No surveys*	No surveys*	3.3 (4)	3.0 (13)
	2017/2018 (4 weeks)	1.5 (4)	No surveys*	No surveys*	3.3 (4)	
12-week post-opening	**2017/2018 (all sections combined)**					4.5 (12)
Operational	**2018/2019**	11.3 (4)	6.8 (4)	5.0 (4)	No surveys	7.7 (12)
Operational	**2019/2020**	5.3 (4)	3.8 (4)	2.5 (4)	No surveys	3.8 (12)

n = number of survey weeks; * = construction partially complete



Graph 2: Average (±SD, n = 4) weekly road kill in spring, summer and autumn

3.2.2 Threatened species

Table 3 lists the threatened species identified as road kill throughout the Project to date. The baseline monitoring report (Lewis 2014) states that, based on baseline Koala road kill records, "*the baseline count for road kill should be set at 1 individual per 8 weeks*". Koala road kill has therefore not increased from the baseline count.

Table 3: Threatened species road kill

Monitoring type (report)	Monitoring period	Threatened species identified as road kill (number recorded)
Baseline (Lewis 2014)	2013-2014	Koala (1*) Grey-headed Flying Fox (2)
Clearing (Niche 2015)	2014-2015	Koala (4) Grey-headed Flying Fox (1) Masked Owl (2) Spotted-tail Quoll (1)
Construction (Niche 2016b)	2015-2016	Koala (1)
Construction (Niche 2017b)	2016-2017	Koala (2)
Construction (Niche 2018)	2017-2018	Nil
Operational (Niche 2019)	2018-2019	Koala (1)
Operational (current)	2019-2020	Brush-tailed Phascogale (1)

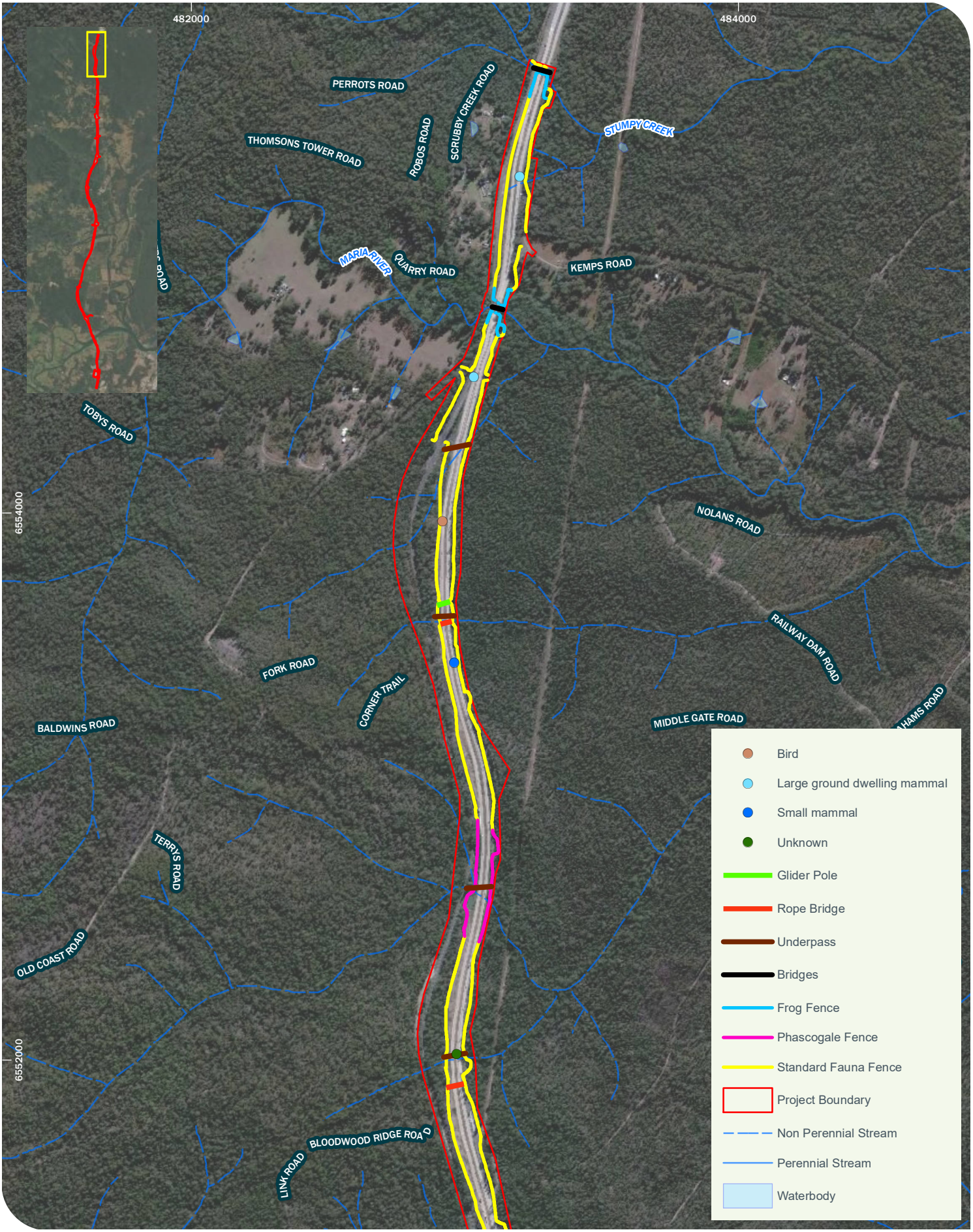
* = An additional three Koala road kill were recorded between August 2013 and February 2014, outside of the monitoring period.

3.2.3 Road kill in relation to fauna fence and crossings

The *road kill per kilometre* rate (excluding birds) for sections of the Project alignment within or outside of fenced sections or within 200 metres of a fauna crossing has been calculated for operational monitoring. These results are provided in Table 4. Road kill rates are lower in fenced sections than unfenced sections during both 2018/2019 and 2019/2020 monitoring periods. Similarly, the road kill rates within 200 metres of either aerial crossings or underpasses are lower than rates outside of the 200 metre boundaries in both monitoring periods. In addition, rates have decreased for all categories in 2019/2020.

Table 4: Operational road kill rates in relation to fauna fence and crossings

	Road kill per kilometre	
Treatment within Project area	**2018/2019**	**2019/2020**
Fenced	0.85	0.56
Unfenced	5.16	3.13
Within 200 m of aerial Crossings	0.77	0.58
Outside 200 m of aerial crossing	1.73	1.07
Within 200 m of underpass	1.25	0.63
Outside 200 m of underpass	1.96	1.40



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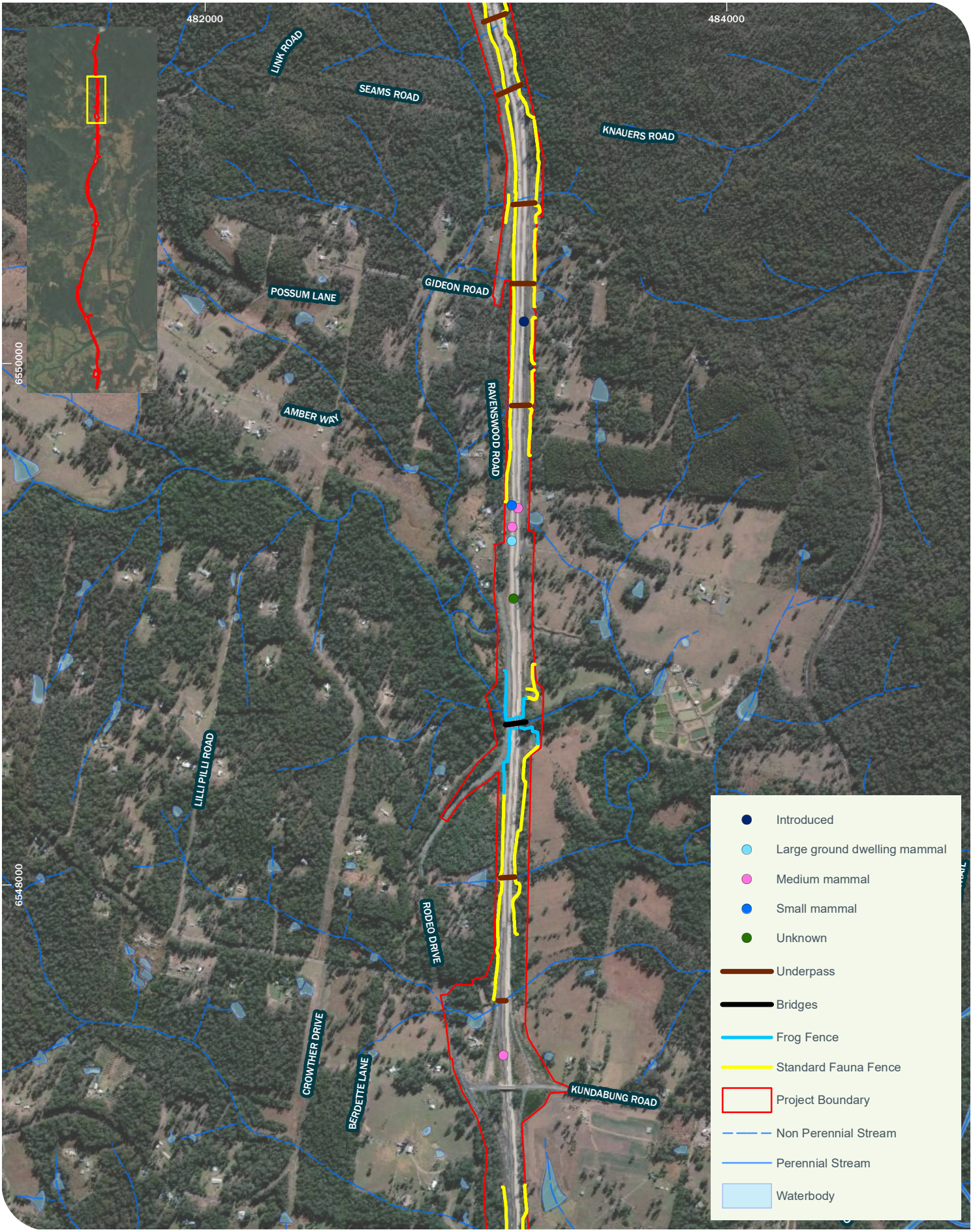
GDA 1994 MGA Zone 56

Road Kill Monitoring 2019/2020 - Map Section 1

Oxley Highway to Kempsey Pacific Highway Upgrade

Niche PM: Radika Michniewicz
Niche Proj. #: 1702 PI 8.1
Client: TfNSW

Figure 1.1



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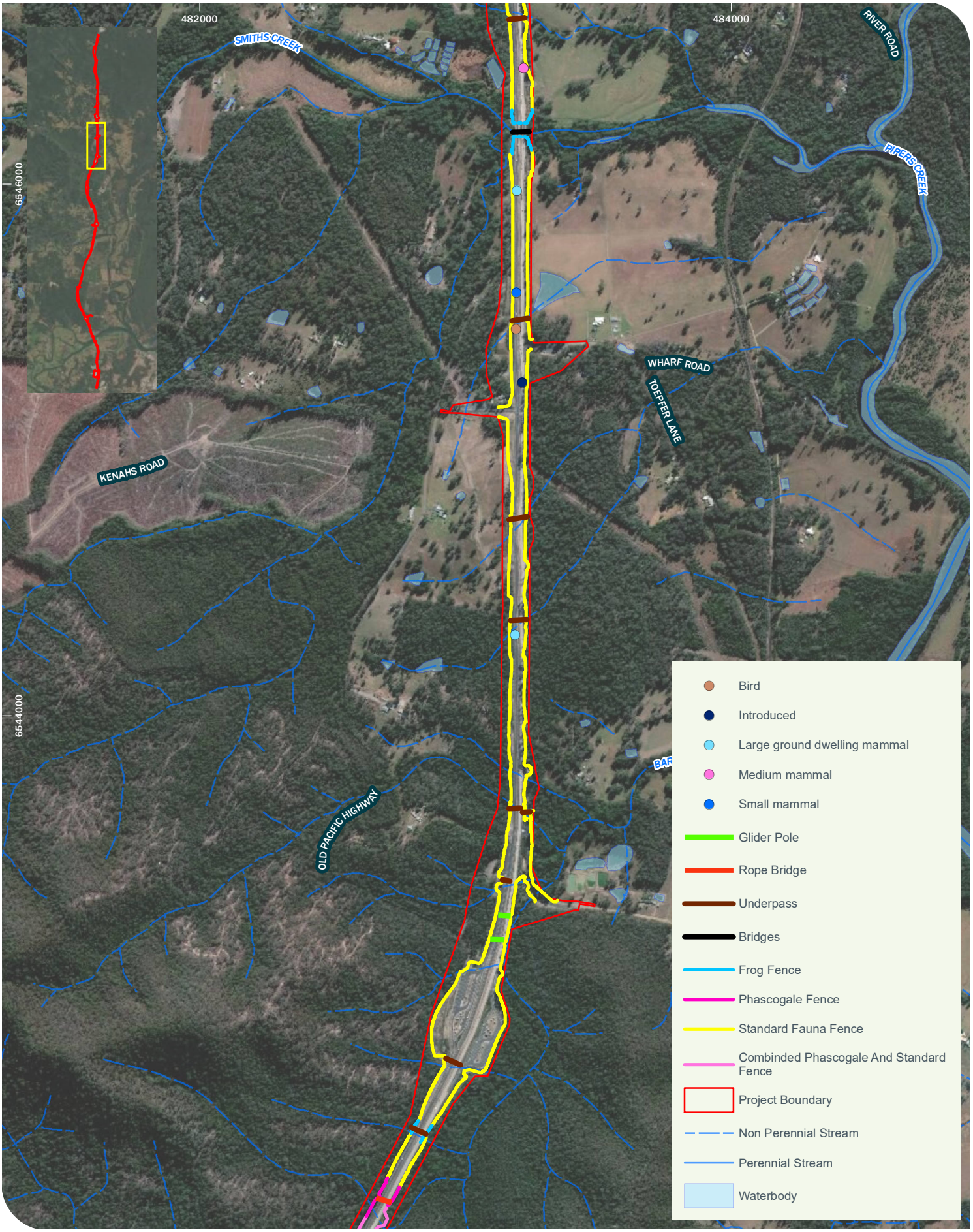
Road Kill Monitoring 2019/2020 - Map Section 2

Oxley Highway to Kempsey Pacific Highway Upgrade

Niche PM: Radika Michniewicz
Niche Proj. #: 1702 PI 8.1
Client: TfNSW

Figure 1.2



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Road Kill Monitoring 2019/2020 - Map Section 3

Oxley Highway to Kempsey Pacific Highway Upgrade

Niche PM: Radika Michniewicz
Niche Proj. #: 1702 PI 8.1
Client: TfNSW

Figure 1.3

Imagery: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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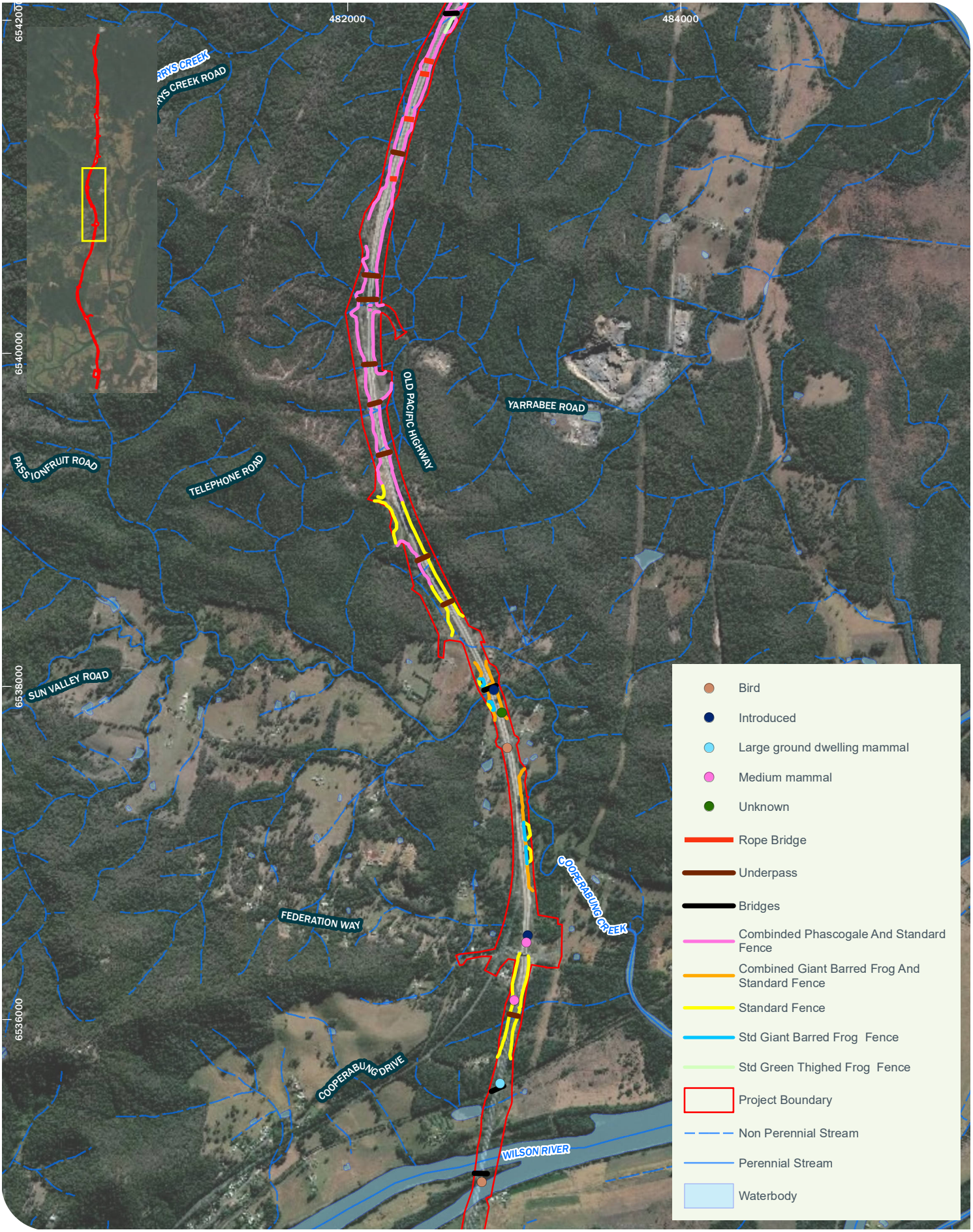

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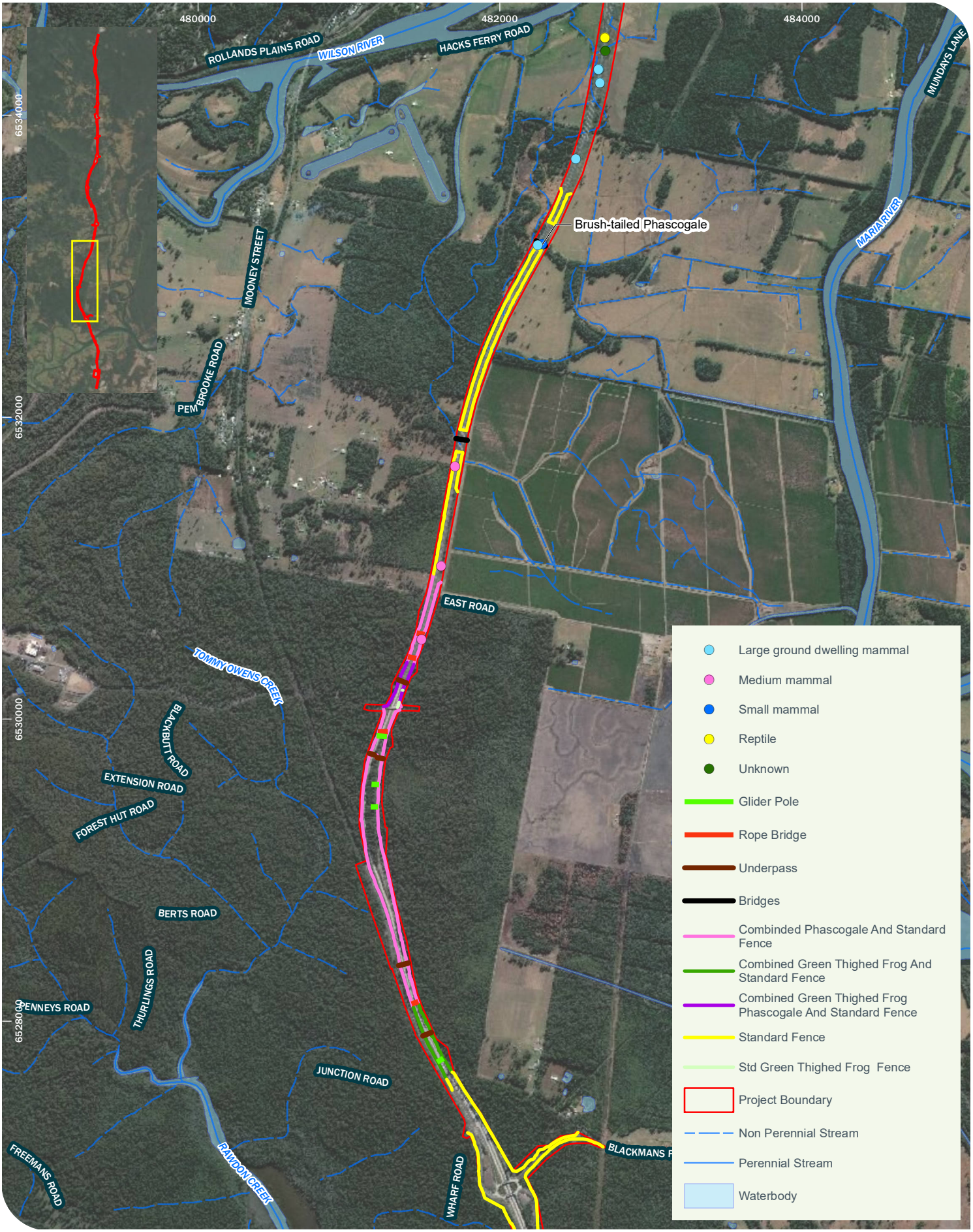
Road Kill Monitoring 2019/2020 - Map Section 4

Oxley Highway to Kempsey Pacific Highway Upgrade

Niche PM: Radika Michniewicz
Niche Proj. #: 1702 PI 8.1
Client: TfNSW

Figure 1.4



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Road Kill Monitoring 2019/2020 - Map Section 5

Oxley Highway to Kempsey Pacific Highway Upgrade

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Niche Proj. #: 1702 PI 8.1
Client: TfNSW

Figure 1.5

Imagery: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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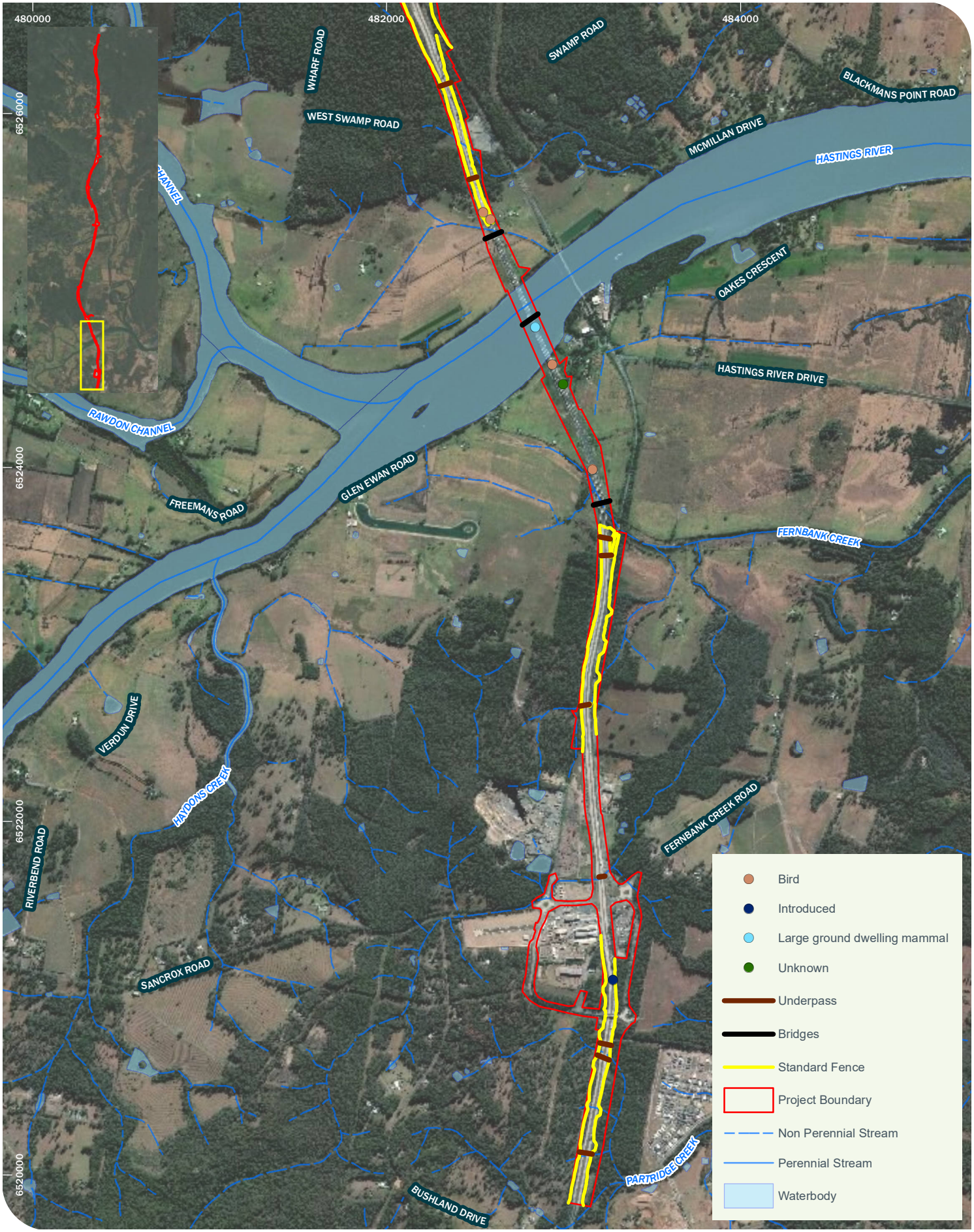

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GDA 1994 MGA Zone 56

Road Kill Monitoring 2019/2020 - Map Section 6

Oxley Highway to Kempsey Pacific Highway Upgrade

Niche PM: Radika Michniewicz
Niche Proj. #: 1702 PI 8.1
Client: TfNSW

Figure 1.6

4. Discussion

4.1 Performance Measures

A summary of 2019/2020 survey results in relation to the road kill performance measures is provided in Table 5.

Table 5: Performance measures for road kill monitoring

Performance measure	Discussion
Lower rates of road kill in proximity (i.e. areas of the main carriageways within areas adjacent to installed fauna fencing, and within 100m of rope bridges and fauna underpasses) to fauna fencing, rope bridges and fauna underpasses than in sections of the upgrade not near wildlife crossing structures or fauna fences in Year 1 – 6 & 8 monitoring events.	**This performance measure has been met.** As discussed in 3.1.3 and 3.1.4, road kill adjacent to fencing and within 200 metres of fauna crossings was analysed. *Fauna fence*: Of the 37 road kill records (excluding birds) 17 (46%) records were within and 20 (54%) records were outside fenced areas. The rate of road kill in unfenced areas (3.13 records/kilometre) was higher than the rate in fenced areas (0.56 records/kilometre). *Aerial crossing 200 metre boundary*: Of the 37 road kill records (excluding birds) there were three road kill records within 200 metres of any aerial crossing during the 2019/2020 road kill surveys. The rate of road kill within 200 metres of aerial crossings (0.58 records/kilometre) was substantially lower than outside this boundary (1.07 records/kilometre). *Underpass 200 metre boundary*: Of the 37 road kill records (excluding birds) 12 occurred within 200 metres of underpasses, while the remaining 25 occurred outside. The rate of road kill within 200 metres of fauna underpasses/bridges (0.63 records/kilometre) was lower than the rate outside this boundary (1.4 records/kilometre).
Reduced incidence of road kill from baseline conditions during monitoring events in Years 1- 6 & 8 and when all monitoring events are considered at Year 8.	**This performance measure has been met.** The overall average weekly road kill rate has decreased from baseline (8.0) to 2019/2020 (3.8) for the same three seasons.
Fauna exclusion fencing is installed at a minimum in the locations identified in Schedule 3 of the EPBC approval at Year 4.	**This performance measure has been met.** TfNSW have advised that all fauna fencing as identified in Schedule 3 of the EPBC approval has been installed.

5. Recommendations

5.1 Contingency Measures and Recommendations

The EMP lists potential problems and contingency measures for the Project's mitigation measures. Those that are related to the fauna fence monitoring program are listed and discussed in Table 6.

Given that all performance measures were met and that contingency measures were addressed as required, there are no recommendations based on the outcomes of the 2019/2020 monitoring period.

Table 6: Contingency measures for fauna fencing

Potential problems	Contingency measure	Discussion of proposed measure
Breach in fauna fencing. High rates of fauna road strike mortality within 200 metres of fauna underpasses.	Commence review/modification of fauna exclusion fencing design, location or extent depending on species struck by vehicles within two weeks of results reported by ecologist.	Road kill rates were lower in proximity to underpasses. One threatened species road kill (Brush-tailed Phascogale) was recorded within a standard fenced area during autumn 2020. While the standard floppy top fauna fence is not intended to stop Brush-tailed Phascogales, given the location of the animal in the middle of Bridge 7, it is possible and likely that the animal accessed the bridge via dense regrowth of Swamp Oak that was observed to be in contact with the bridge. TfNSW was immediately notified of the event and vegetation control works were undertaken on 17 April, whereby trees were trimmed and lopped. It is noted that the Project was surveyed pre-construction and based on these surveys, as part of the Project approval, no Brush-tailed Phascogale mitigation measures were considered necessary in this area. The species was not identified in this area in any subsequent surveys conducted during and post construction. The bridge itself provides a means for animals to pass under the carriageway. Future road kill monitoring in years 6 and 8 will determine if this road kill record was a one off event and if modification of fence design is required in this area. **At this stage, this contingency measure is not considered relevant.**
	Inspect fence for breaches and inform maintenance as necessary within two weeks of results reported by ecologist. Any damage to fauna fencing will be temporarily repaired within one week of a breach being identified.	**This contingency measure was relevant and addressed during the 2019/2020 monitoring period.** TfNSW were immediately notified of the Brush-tailed Phascogale road kill record and maintenance was undertaken within nine days of the event.
	Permanent repair to occur as soon as possible and within two months of the breach being identified.	**This contingency measure was relevant and addressed during the 2019/2020 monitoring period.** TfNSW were immediately notified of the Brush-tailed Phascogale road kill record and maintenance was undertaken within nine days of the event.

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RMS (2019). Oxley Highway to Kempsey Pacific Highway Upgrade Ecological Monitoring Program. Roads and Maritime Update to report prepared by SMEC Hyder Joint Venture, August 2016.

Annex 1 – Road kill survey data

Table 7: 2019/2020 road kill monitoring results

Season	Date	Latitude	Longitude	Species	Native/Introduced	Assigned vertebrate group
Spring	3/10/2019	-31.330892	152.81609	Kangaroo	native	Large ground dwelling mammal
Spring	3/10/2019	-31.325538	152.8177	Kangaroo	native	Large ground dwelling mammal
Spring	3/10/2019	-31.323661	152.81812	Red-belly Black Snake	native	Reptile
Spring	3/10/2019	-31.295541	152.82093	Bird	unknown	Bird
Spring	3/10/2019	-31.235321	152.82345	Kangaroo	native	Large ground dwelling mammal
Spring	3/10/2019	-31.223707	152.82352	Small mammal	unknown	Small mammal
Spring	3/10/2019	-31.220237	152.82354	Kangaroo	native	Large ground dwelling mammal
Spring	3/10/2019	-31.313726	152.82043	Kangaroo	native	Large ground dwelling mammal
Spring	3/10/2019	-31.326368	152.81776	Kangaroo	native	Large ground dwelling mammal
Spring	3/10/2019	-31.359616	152.80527	Echidna	native	Medium mammal
Spring	3/10/2019	-31.405881	152.81682	Bird of prey	native	Bird
Spring	10/10/2019	-31.418634	152.82286	Galah	native	Bird
Spring	10/10/2019	-31.309236	152.82135	Bandicoot	native	Medium mammal
Spring	10/10/2019	-31.189587	152.82343	Medium Mammal	unknown	Medium mammal
Spring	10/10/2019	-31.18894	152.82368	Echidna	native	Medium mammal
Spring	10/10/2019	-31.305722	152.82221	Rabbit	introduced	Introduced
Spring	10/10/2019	-31.319072	152.81926	Bird of prey	native	Bird
Spring	17/10/2019	-31.226755	152.82374	Rabbit	introduced	Introduced
Spring	17/10/2019	-31.306097	152.82212	Bandicoot	native	Medium mammal
Spring	17/10/2019	-31.444691	152.82403	Dog	introduced	Introduced
Spring	24/10/2019	-31.136736	152.82378	Kangaroo	native	Large ground dwelling mammal
Summer	2/01/2020	-31.411356	152.81946	Kangaroo	native	Large ground dwelling mammal
Summer	2/01/2020	-31.405488	152.81637	Bird of Prey	native	Bird
Summer	2/01/2020	-31.336048	152.81341	Kangaroo	native	Large ground dwelling mammal
Summer	2/01/2020	-31.325548	152.81767	Kangaroo	native	Large ground dwelling mammal
Summer	2/01/2020	-31.224939	152.8235	Purple Swamp Hen	native	Bird
Summer	2/01/2020	-31.188839	152.82343	Small Mammal	unknown	Small mammal
Summer	2/01/2020	-31.129685	152.82578	Medium Mammal	unknown	Medium mammal
Summer	2/01/2020	-31.152768	152.82122	Rodent	unknown	Small mammal
Summer	2/01/2020	-31.165696	152.82131	Unknown	unknown	Unknown
Summer	2/01/2020	-31.182485	152.82393	Fox	introduced	Introduced
Summer	2/01/2020	-31.293647	152.82058	Unknown	unknown	Unknown
Summer	2/01/2020	-31.324466	152.81815	Unknown	unknown	Unknown
Summer	9/01/2020	-31.207881	152.82306	Bandicoot	native	Medium mammal
Summer	9/01/2020	-31.190078	152.82341	Kangaroo	native	Large ground dwelling mammal
Summer	9/01/2020	-31.14335	152.822	Red-necked Wallaby	native	Large ground dwelling mammal
Autumn	8/04/2020	-31.349261	152.80763	Echidna	native	Medium Mammal

Season	Date	Latitude	Longitude	Species	Native/Introduced	Assigned vertebrate group
Autumn	8/04/2020	-31.148106	152.82079	Magpie	native	Bird
Autumn	8/04/2020	-31.335999	152.81374	Brushtail Phascogale	native	Small Mammal
Autumn	8/04/2020	-31.414277	152.82112	Unknown	unknown	Unknown
Autumn	22/04/2020	-31.413265	152.82049	Bird	native	Bird
Autumn	22/04/2020	-31.216087	152.82381	Tawny Frogmouth	native	Bird
Autumn	22/04/2020	-31.216087	152.82381	Echidna	native	Medium Mammal
Autumn	22/04/2020	-31.292415	152.8201	Fox	introduced	Introduced
Autumn	29/04/2020	-31.192077	152.82348	Unknown	unknown	Unknown
Autumn	29/04/2020	-31.355228	152.80666	Echidna	native	Medium Mammal

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Spotted-tailed Quoll Monitoring 2020

Oxley Highway to Kempsey, Pacific Highway Upgrade

Prepared for Transport for NSW

August 2020

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Jodie Danvers	D1	Radika Michniewicz	10/08/2020
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Radika Michniewicz	R0		20/08/2020
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Locations

Sydney
Central Coast
Illawarra
Armidale
Newcastle
Mudgee
Port Macquarie
Brisbane
Cairns

Cover photograph: Fauna captured on camera: Koala recorded in Cooperabung Creek Nature Reserve (left); Swamp Wallaby recorded in Ballengarra State Forest (middle).

Executive summary

Context

This report documents findings of the 2020 monitoring period, the second of three monitoring periods, for the Spotted-tailed Quoll (*Dasyurus maculatus*), as required for the Oxley Highway to Kempsey (OH2K) Pacific Highway upgrade project (the Project) and specified in the Oxley Highway to Kempsey (OH2K) Ecological Monitoring Program (EMP, RMS 2019). Transport for NSW (TfNSW) is required to manage and monitor the effectiveness of biodiversity mitigation measures implemented as part of the Project. The Spotted-tailed Quoll is one of the threatened species identified as requiring mitigation and monitoring during the operational phase of the Project.

Aim

The aim of the Spotted-tailed Quoll monitoring program is to determine whether the Project is meeting the performance indicators for the species, and provide corrective actions where required.

Method

Monitoring was undertaken in accordance with the EMP, in three broad areas of Cairncross State Forest, Ballengarra State Forest and Maria River State Forest. Three different site types: reference, impact with mitigation and impact without mitigation, were monitored within each area. This design was replicated three times for each area, resulting in a total of nine, 100 hectare plots for each area. Within each plot there were four camera monitoring locations, resulting in 36 camera monitoring locations per area and 12 cameras per site type. Remotely triggered Scout Guard cameras were installed at the camera locations, positioned facing a bait station and left for a minimum of 21 consecutive nights. Bait stations were baited with a mixture of fish, flour and fish oil. Any changes in the environment since the previous monitoring were noted.

Key results

The Spotted-tailed Quoll was not recorded during the 2020 monitoring period and has not been recorded during either of two previous survey/monitoring events undertaken to date. These results are consistent with baseline findings. There were a total of 307 photo records, including 238 (77.3%) with native fauna (including the threatened Koala), 68 with (22.1%) introduced predators (including Domestic Dogs), and 2 (0.6%) with non-predatory introduced fauna.

As part of the analogous underpass monitoring program undertaken as part of the OH2K EMP, a Spotted-tailed Quoll was previously recorded during the 2018 underpass monitoring traversing underpass C36.40 immediately to the west of plot MM1 (Maria River impact with mitigation site). No Spotted-tailed Quolls were recorded during 2020 underpass monitoring.

Conclusion

Performance measures for the 2020 monitoring period have been met; the second round of monitoring was undertaken as per the EMP in year 6 (2020) at impact and control sites where monitoring was undertaken during baseline surveys.

Management implications

Given that no Spotted-tailed Quolls were recorded during the baseline, 2018 or 2020 Spotted-tailed Quoll monitoring events, there are no current recommendations based on the outcomes of the 2020 monitoring period.

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1. Introduction

1.1 Context

The Oxley Highway to Kempsey (OH2K) section of the Pacific Highway Upgrade Project (the Project) was approved in 2012 subject to various Ministers Conditions of Approval (MCoA) and a Statement of Commitments (SoC). A subsequent approval with additional conditions of consent (CoA) was granted in 2014 by the Commonwealth Department of Environment (DoE) for Matters of National Environmental Significance (MNES) listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1995* (EPBC Act). The Ecological Monitoring Program (hereafter referred to as the EMP) (RMS 2019) combines these approval conditions and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project. The Spotted-tailed Quoll (*Dasyurus maculatus*) was one threatened species identified as requiring monitoring following the completion of the Project's construction, during the operational phase.

1.1.1 Legal status

The Spotted-tailed Quoll is listed as vulnerable under the New South Wales *Biodiversity Conservation Act 2016* (BC Act) and endangered under the Commonwealth EPBC Act. Monitoring of the species is required under the Project's approval.

1.1.2 Monitoring framework

The survey design, methodology and performance indicators that define the Spotted-tailed Quoll monitoring program are specified in the EMP. The EMP requires monitoring of the Spotted-tailed Quoll on three occasions in total: in autumn or winter (preferably between March and Mid-July) in Year 4, 6 and 8 (operational phase of the Project). The 2020 monitoring represents the second of the three monitoring periods – Year 6, autumn - winter 2020.

1.1.3 Baseline data

No Spotted-tailed Quoll were recorded during baseline surveys conducted by Lewis Ecological in August 2013 (Lewis 2014).

1.1.4 Purpose of this report

This report details the findings obtained from the second monitoring event for the Spotted-tailed Quoll.

The aims of this report are to summarise the methods and results of the 2020 monitoring and determine if performance measures are being met, as per the EMP.

1.2 Performance Measures

The EMP specifies the following performance measures for the Spotted-tailed Quoll:

- *Monitoring is undertaken in Year 4, 6 and 8 or until monitoring can demonstrate that mitigation measures are effective.*
- *Monitoring during Year 4, 6 & 8 is undertaken at the Impact and Control sites where monitoring was undertaken during baseline surveys, subject to ongoing landowner agreement.*

1.3 Monitoring Timing

Monitoring is to be undertaken during autumn or winter, but preferably March – mid-July.

1.4 Reporting

As per the EMP, annual reporting of monitoring results will include:

- Detailed description of monitoring methodology employed.
- Results of the monitoring period.
- Discussion of results, including how the results compare against performance measures, if any modifications to timing or frequency of monitoring periods or monitoring methodology are required and any other recommendations.
- If contingency measures should be implemented.

All reports prepared under the EMP will be submitted to the NSW Department of Planning, Industry and Environment (DPIE) and the NSW Environment Protection Authority (EPA).

2. Methodology

2.1 Monitoring Sites

Monitoring was undertaken in the three broad areas identified in the EMP and included Cairncross State Forest, Ballengarra State Forest and Maria River State Forest. Three different site types (treatments) were monitored within each area:

- Reference: located greater than five kilometres from the project corridor and considered likely to be unaffected by the Project.
- Impact without mitigation: located where no specific Spotted-tailed Quoll mitigation has been proposed, i.e. no combined or dedicated fauna underpasses within 500 metres.
- Impact with mitigation: located within 500 metres of combined or dedicated fauna underpasses.

This design was replicated three times for each area, resulting in a total of nine 100 hectare plots for each area. Within each plot, four camera monitoring locations were established during baseline surveys, resulting in 36 camera monitoring locations per area and a total of 12 cameras per site type. Table 1 details the monitoring design and Figures 1 to 4 show the location of all monitoring camera locations along with bridges and underpasses in the area.

It should be noted that monitoring sites were established prior to the finalisation of the box culvert locations. This has resulted in a number of 'impact without mitigation' sites being located within 500 metres of a crossing structure. As such, they no longer conform to the original classification of 'impact without mitigation'. While the original classification established in the baseline study will be retained for the purpose of continuity and clarity within the current report, if any comparison to detect difference between treatments (mitigation and no mitigation sites) were required, these two site types would need to be re-classified as all sites no longer fulfil their original classification criteria.

Table 1: Monitoring sites and treatment

Area	Site type	Plot ID	Camera ID
Cairncross	Reference	CREF1	CREF1A, CREF1B, CREF1C, CREF1D
		CREF2	CREF2A, CREF2B, CREF2C, CREF2D
		CREF3	CREF3A, CREF3B, CREF3C, CREF3D
	Impact-no mitigation	CNM1	CNM1A, CNM1B, CNM1C, CNM1D
		CNM2	CNM2A, CNM2B, CNM2C, CNM2D
		CNM3	CNM3A, CNM3B, CNM3C, CNM3D
	Impact-mitigation	CM1	CM1A, CM1B, CM1C, CM1D
		CM2	CM2A, CM2B, CM2C, CM2D
		CM3	CM3A, CM3B, CM3C, CM3D
Ballengarra	Reference	BREF1	BREF1A, BREF1B, BREF1C, BREF1D
		BREF2	BREF2A, BREF2B, BREF2C, BREF2D
		BREF3	BREF3A, BREF3B, BREF3C, BREF3D
	Impact-no mitigation	BNM1	BNM1A, BNM1B, BNM1C, BNM1D
		BNM2	BNM2A, BNM2B, BNM2C, BNM2D
		BNM3	BNM3A, BNM3B, BNM3C, BNM3D
		BM1	BM1A, BM1B, BM1C, BM1D

Area	Site type	Plot ID	Camera ID
	Impact-mitigation	BM2	BM2A, BM2B, BM2C, BM2D
		BM3	BM3A, BM3B, BM3C, BM3D
Maria River	Reference	MREF1	MREF1A, MREF1B, MREF1C, MREF1D
		MREF2	MREF2A, MREF2B, MREF2C, MREF2D
		MREF3	MREF3A, MREF3B, MREF3C, MREF3D
	Impact-no mitigation	MNM1	MNM1A, MNM1B, MNM1C, MNM1D
		MNM2	MNM2A, MNM2B, MNM2C, MNM2D
		MNM3	MNM3A, MNM3B, MNM3C, MNM3D
	Impact-mitigation	MM1	MM1A, MM1B, MM1C, MM1D
		MM2	MM2A, MM2B, MM2C, MM2D
		MM3	MM3A, MM3B, MM3C, MM3D

2.2 Survey Method

In accordance with the EMP, remotely triggered Scout Guard cameras were installed at the camera locations established during baseline surveys. Each camera location was approximately 500 metres apart, covering the 100 hectare plot. Cameras were positioned facing a bait station (PVC tubing pegged to the ground with bait cache located inside) and left operating continuously for a minimum of 21 consecutive nights. Stations were baited with a mixture of fish, flour and fish oil, with fish oil dripped on the ground directly surrounding the station as an additional attractant.

In accordance with the EMP, the following habitat attributes were recorded during the first monitoring period in 2018 at each camera station (Annex 2):

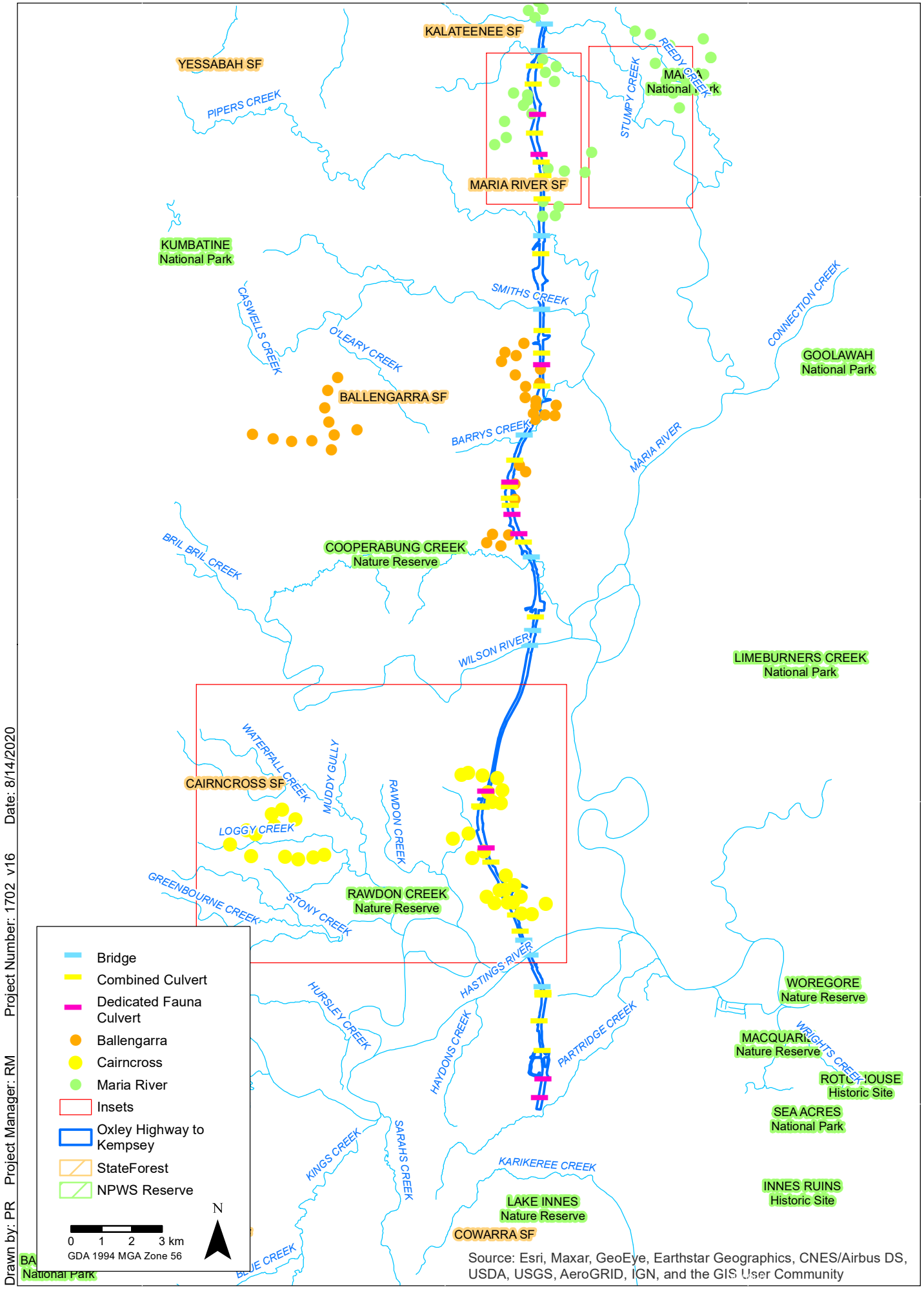
- Structure and floristics of vegetation, including dominant species of each vegetation stratum, height and per cent cover.
- Presence and type of hydrological features and surface drainage features.
- Presence and type of rocky features.
- Abundance and type of tree and log hollows.

Any changes to the habitat attributes were noted during the 2020 monitoring.

2.3 Analysis

Analysis of camera records was undertaken as for the baseline surveys (Lewis 2014). Namely, the maximum abundance or activity levels for any species within a given one hour period was one. The only exception to this was where the individuals could clearly be distinguished from another within that one hour period.

Monitoring results were analysed in accordance with the performance measures specified within the EMP. In the case of the Spotted-tailed Quoll, performance measures are based on survey completion only; they do not specifically relate to the detection of this species and statistical analysis of data is not required. However, the current assessment considers presence/absence results.



Drawn by: PR Project Manager: RM Project Number: 1702 v16 Date: 8/14/2020

[redacted]

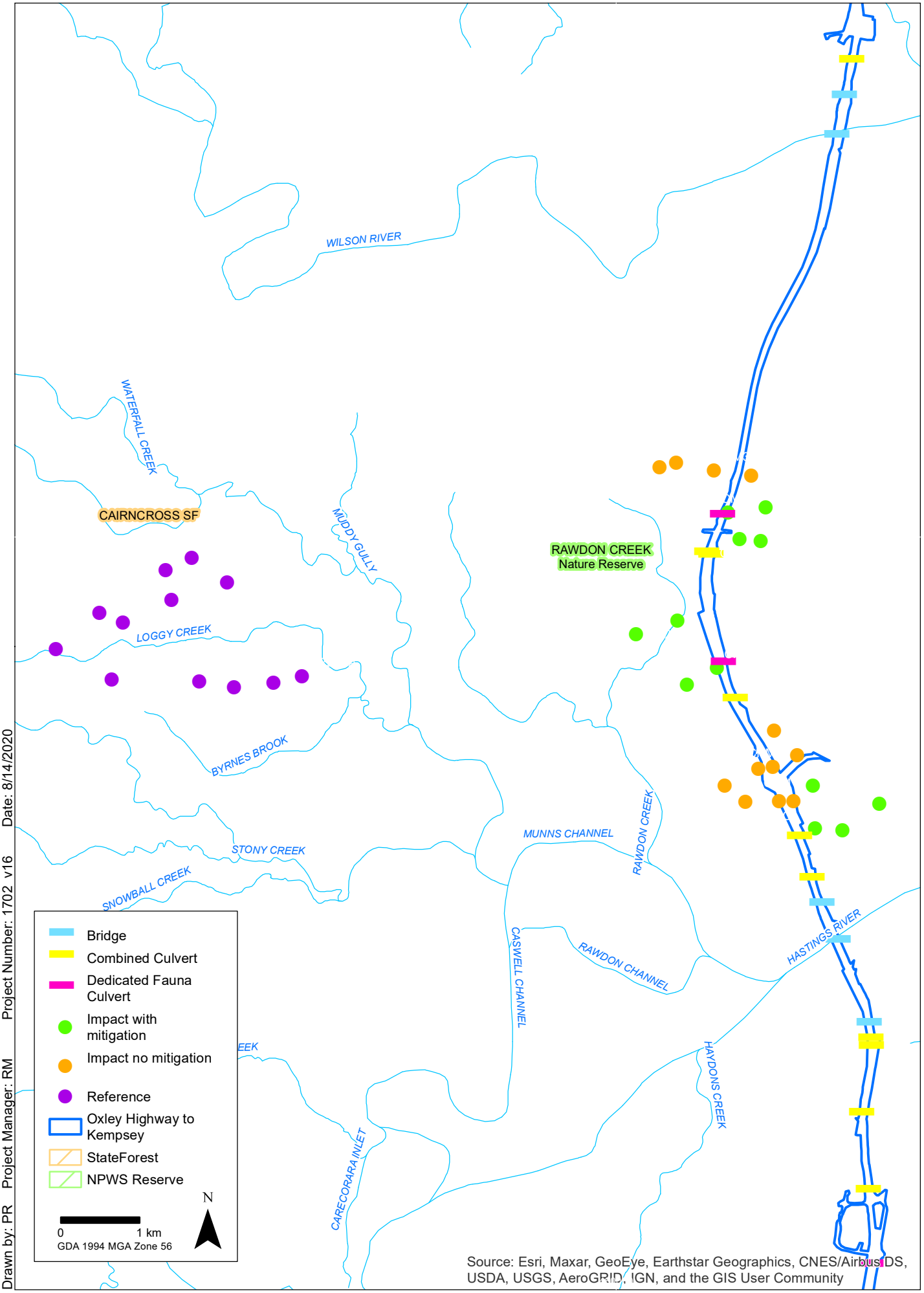
Overview of monitoring sites

Oxley Highway to Kempsey - Spotted-tailed Quoll Monitoring sites

Imagery: (c) LPI NSW 2014-10-06

FIGURE 1

Path: T:\spatial\projects\a1700\a1702_OH2K_Ecology\Maps\PI_5_Ecology_OH2K\PI_52_Quoll\1702_PI52_Quoll_20180312_Fig1_Overview.mxd



Drawn by: PR Project Manager: RM Project Number: 1702 v16 Date: 8/14/2020

[redacted]

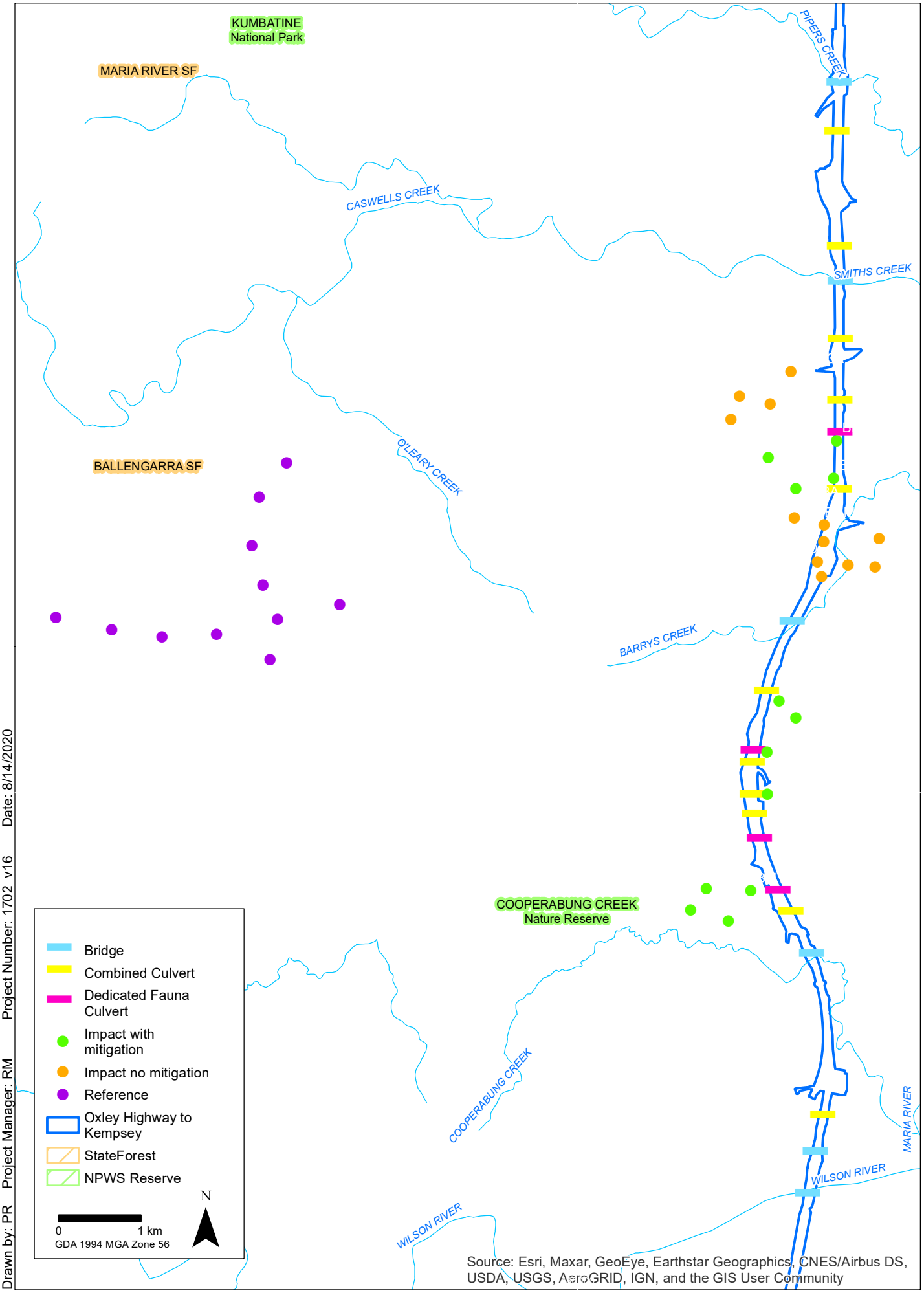
Cairncross State Forest camera locations

Oxley Highway to Kempsey - Spotted-tailed Quoll Monitoring sites

Imagery: (c) LPI NSW 2014-10-06

FIGURE 2

Path: T:\spatial\projects\a1700\a1702_OH2K_Ecology\Maps\PI_5_Ecology_OH2K\PI_52_Quoll\1702_PI52_Quoll_20180312_Fig2_Caircross.mxd



Drawn by: PR Project Manager: RM Project Number: 1702 v16 Date: 8/14/2020

[redacted]

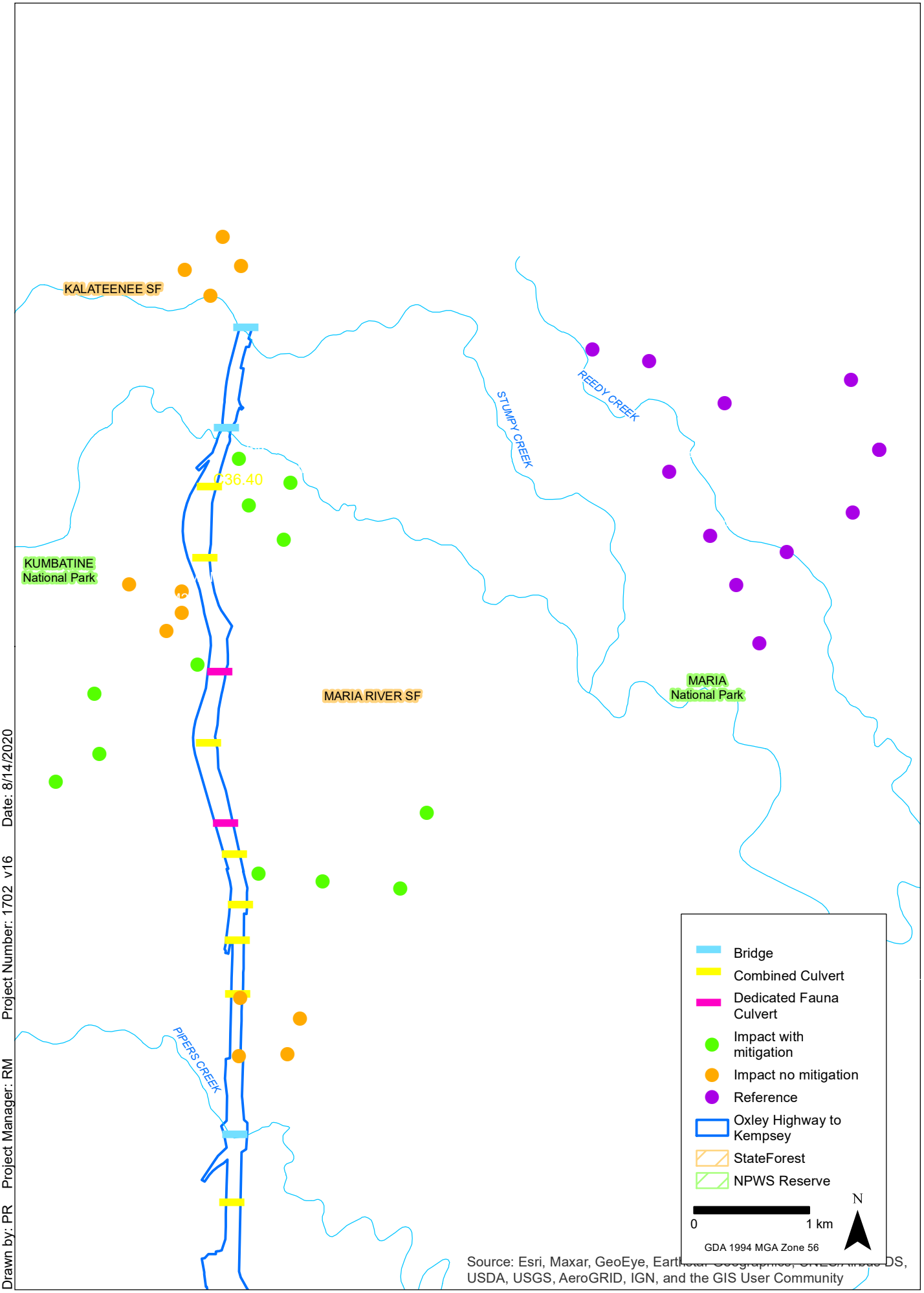
Ballengarra State Forest camera locations

Oxley Highway to Kempsey - Spotted-tailed Quoll Monitoring sites

Imagery: (c) LPI NSW 2014-10-06

FIGURE 3

Path: T:\spatial\projects\a1700\a1702_OH2K_Ecology\Maps\PI_5_Ecology_OH2K\PI_52_Quoll\1702_PI52_Quoll_20180312_Fig3_Ballengar.mxd



Drawn by: PR Project Manager: RM Project Number: 1702 v16 Date: 8/14/2020

Maria River State Forest camera locations

Oxley Highway to Kempsey - Spotted-tailed Quoll Monitoring sites

[redacted]

Imagery: (c) LPI NSW 2014-10-06

FIGURE 4

Path: T:\spatial\projects\a1700\a1702_OH2K_Ecology\Maps\PI_5_Ecology_OH2K\PI_52_Quoll\1702_PI52_Quoll_20180312_Fig4_MariaRiver.mxd

3. Results

3.1 2020 Monitoring Results

Results of the 2020 monitoring are provided in Annex 1 and a summary is provided in Table 2. There were a total of 307 photo records, including 237 (77.3%) with native fauna, 68 (22.1%) with introduced predators (including domestic dogs) and 2 (0.6%) with non-predatory introduced or domestic fauna. Graph 1 to Graph 3 show the number of records for the different fauna groups. Three cameras (location BREF1A, BREF1D and BREF2A) were stolen or damaged during the surveys. Surveys were undertaken during the following periods:

- Cairncross: 8 April 2020 – 29 April 2020 (22 survey nights)
- Ballengarra: 5 May 2020 – 1 June 2020 (27 survey nights)
- Maria River: 3 June 2020 – 6 July 2020 (35 survey nights).

3.1.1 Habitat attributes

Habitat attribute data from 2018 are included in Annex 2 for reference, with changes observed during 2020 monitoring included. No changes to habitat attributes were observed in Maria River or Cairncross monitoring areas. Ballengarra State Forest was in the process of being logged at the time of surveys, resulting in substantial habitat changes at Ballengarra reference sites and in surrounding habitat. In addition, site BNM3 is located in a forestry plantation that was subject to recent logging and subsequent reduction burning, which removed the majority of vegetation except for that along creek lines.

3.1.2 Spotted-tailed Quoll

No Spotted-tailed Quoll were recorded at any of the monitoring sites during the 2020 monitoring.

As part of monitoring of mitigation measures for the Project, remotely triggered Scout Guard cameras were deployed in a number of selected combined and dedicated fauna underpasses. One Spotted-tailed Quoll was previously recorded during the 2018 underpass monitoring traversing underpass C36.40 (combined culvert C36.40) in a westerly direction (Niche 2018b). This underpass is immediately to the west of plot MM1 (Maria River impact with mitigation site 1, Figure 4). No Spotted-tailed Quolls were recorded during the 2020 underpass monitoring.

3.1.3 Other fauna

Native fauna

The most frequently recorded fauna from all sites except the Ballengarra reference sites were macropods, representing 46.1% of all records. Arboreal mammals and medium ground-dwelling mammals were the next most frequently recorded fauna, representing 8.1% and 7.8% of all records respectively. Of note was the detection of Koalas (vulnerable, BC Act and EPBC Act) at one Ballengarra mitigation site (BM1), Cairncross reference site (CREF1) and Maria River reference site (MREF1).

Introduced predatory fauna

Introduced predatory fauna, which may compete with the Spotted-tailed Quoll, included the European Red Fox (*Vulpes vulpes*), Cat (*Felis catus*), Wild (including Dingoes) and Domestic Dogs (*Canis familiaris*), and represented 22.1% of all records (of which 73.5% were Fox and Cat). All sites except the Maria River reference sites recorded predators on more than one occasion, with the Maria River impact area representing 38.2% of the predator records across all site types. High visitation by predators may be considered to be where visitation by exotic predators equates to greater than 25% of visitations or as visitations by exotic predators on more than 25% of the days monitored (Niche 2018a). This is relevant for 16 of the 27 sites (CM1, CM2, CM3,

CNM1, CNM2, CNM3, CREF1, BM2, BNM2, BNM3, BREF2, MM1, MM3, MNM1, MNM2, MNM3), where predator records account for 25-100% of fauna records at one or more cameras within these sites.

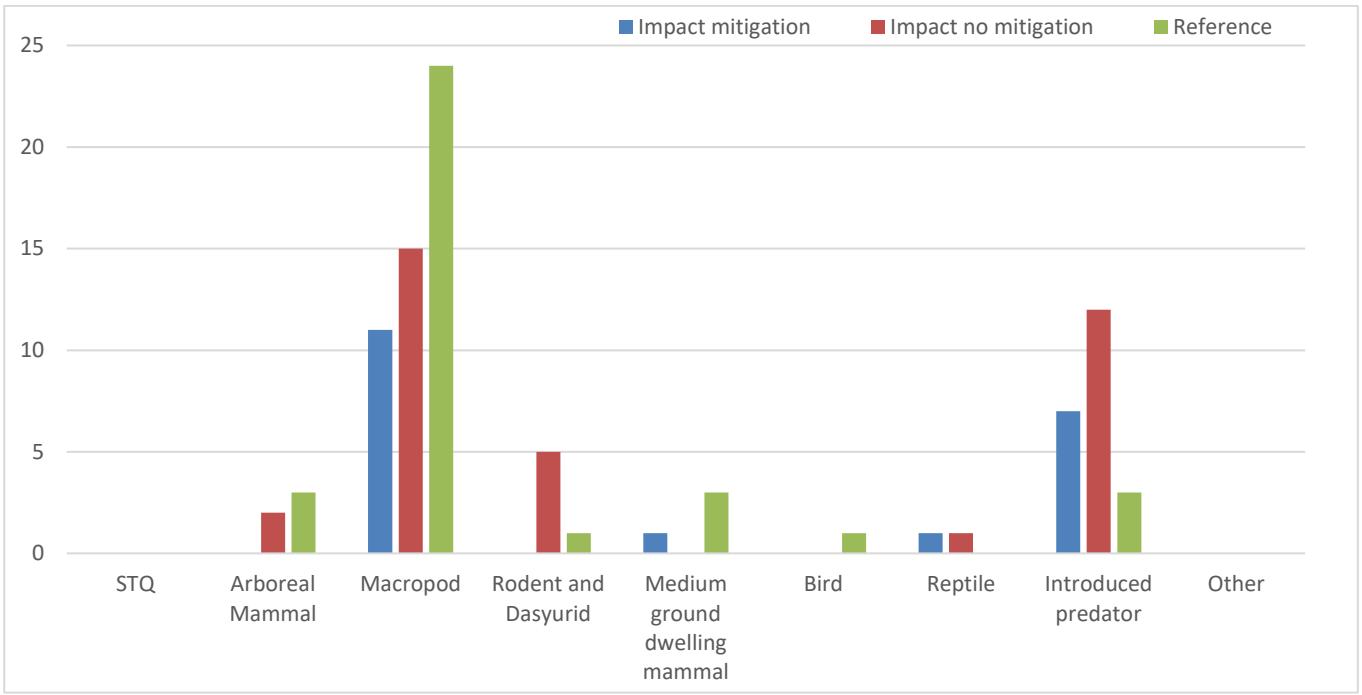
3.1.4 Native fauna record rate

The number of native fauna records per trap night was calculated for each area and treatment (Table 2). Impact sites had higher native fauna detection rates within the Ballengarra and Maria River areas, while the Cairncross area had a slightly higher detection rate at the reference sites. Ballengarra and Cairncross areas both recorded similarly higher native fauna detection rates than Maria River.

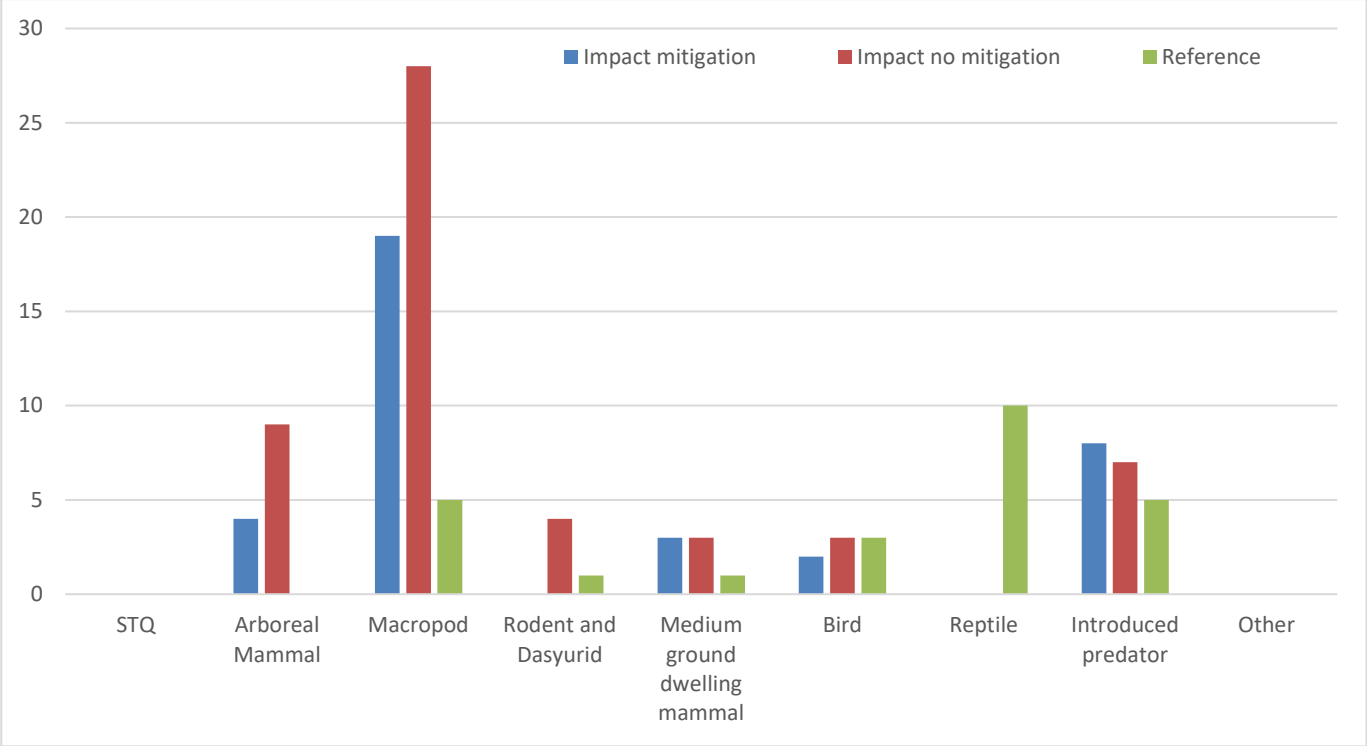
Table 2: Summary of fauna records

Area	Site Type	STQ	AM	M	R&D	MGD	Bird	R	IP	Other	R/CN
Cairncross	Impact mitigation	0	0	11	0	1	0	1	7	0	0.59
	Impact no mitigation	0	2	15	5	0	0	1	12	0	1.05
	Reference	0	3	24	1	3	1	0	3	0	1.45
	Total										3.09
Ballengarra	Impact mitigation	0	4	19	0	3	2	0	8	0	1.04
	Impact no mitigation	0	9	28	4	3	3	0	7	0	1.74
	Reference	0	0	5	1	1	3	10	5	0	0.74
	Total										3.52
Maria	Impact mitigation	0	2	17	2	10	2	0	8	0	0.94
	Impact no mitigation	0	3	20	5	2	5	0	18	2	1.00
	Reference	0	2	3	0	1	0	0	0	0	0.14
	Total										2.09
	total	0	25	142	18	24	16	12	68	2	

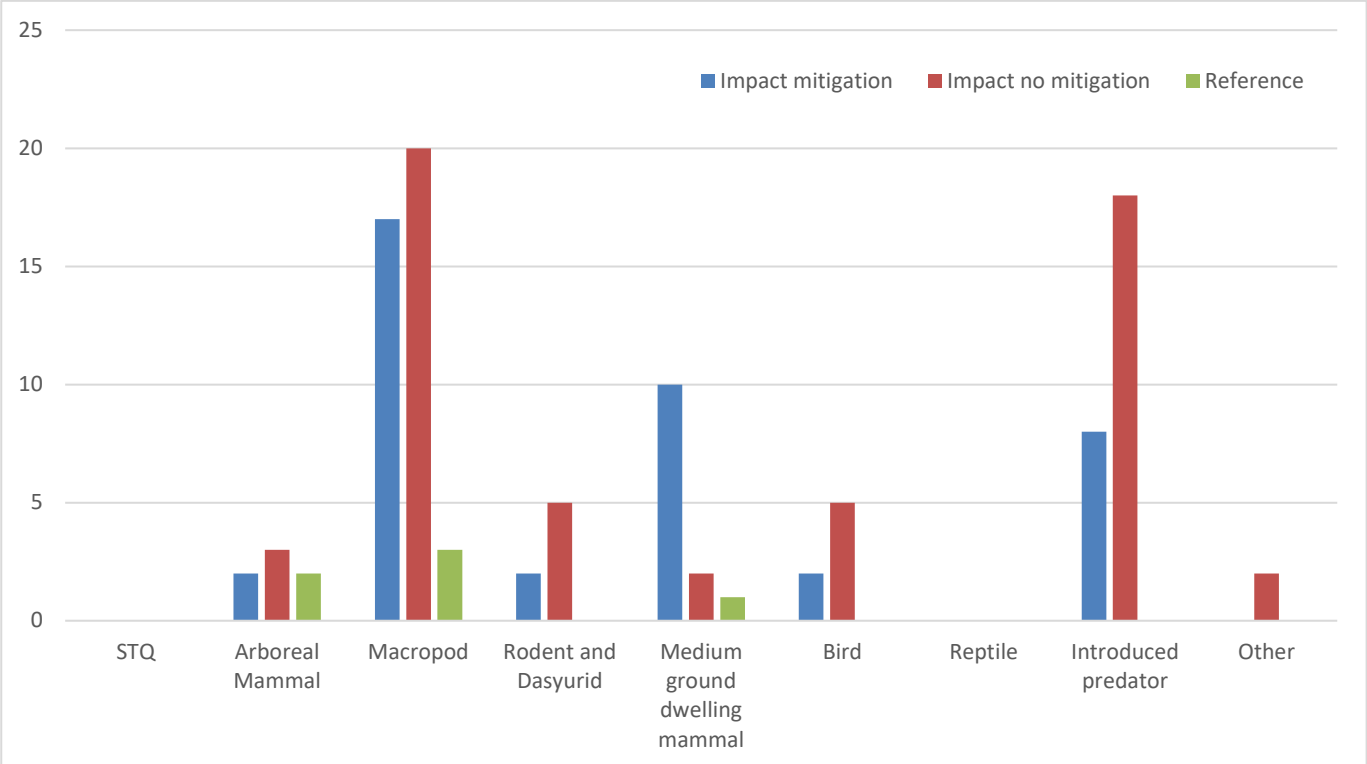
STQ = Spotted-tailed Quoll; AM = arboreal mammals (Possums and Koala); M = macropods; R&D = rodents and dasyurids; MGD = medium ground dwelling mammals (Echidna, Bandicoot); R = reptile; IP = Introduced predator (Fox, Cat, Wild and Domestic Dog); Other= non-native and non-fauna categories such as people, cars, cows, pigs, hares and horses; R/CN = records/camera night.



Graph 1: Cairncross area grouped records



Graph 2: Ballengarra area grouped records



Graph 3: Maria River area grouped records

3.2 Cumulative Results

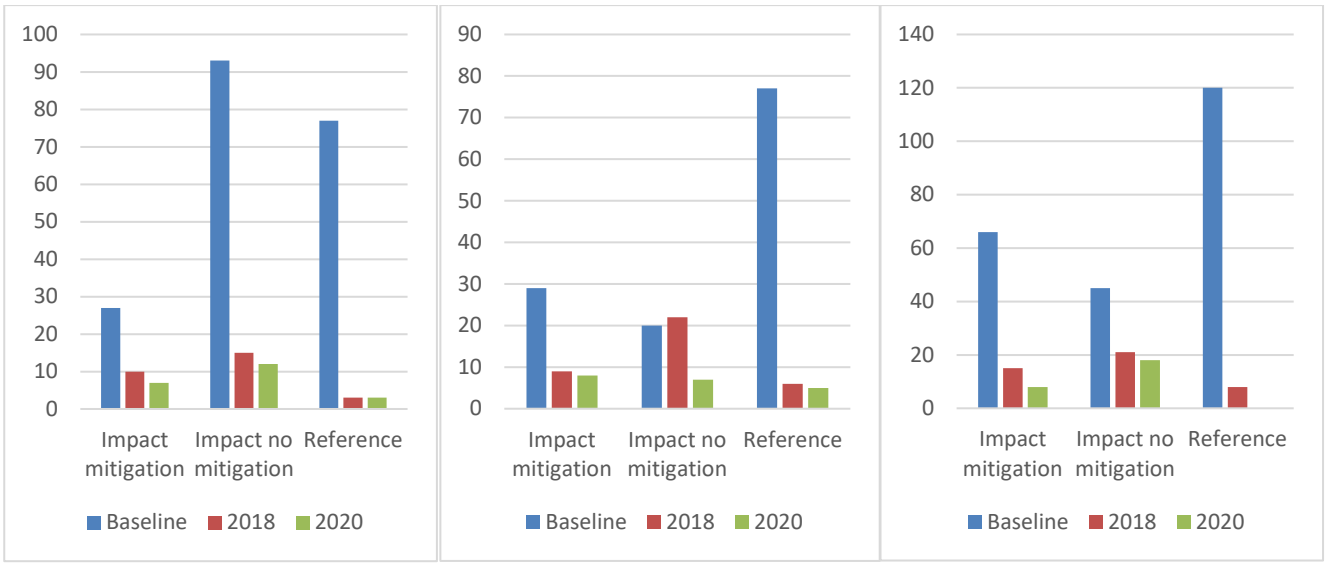
3.2.1 Record summary

As for the baseline and 2018 surveys, the Spotted-tailed Quoll was not recorded at any of the monitoring sites during the 2020 monitoring.

Table 3 highlights the difference in record type between the baseline, 2018 and 2020 monitoring events. 2020 monitoring resulted in a much higher false trigger rate, mostly due to sunlight and vegetation movements at Maria River sites, and fewer images from the 'other' category than baseline and 2018 monitoring. Whilst 2020 monitoring recorded a much higher number of native fauna records than baseline records, this was lower than 2018 surveys. The number of introduced predators detected was also lower in 2020 than during baseline and 2018 monitoring. Contrary to baseline results, introduced predator records within the reference sites were lower than impact sites for each area. Introduced predator records for each area are shown in Graph 4.

Table 3: Comparison with baseline

	Baseline	2018	2020
Total triggers	28,270	12,329	34,837
Total records	1,540	688	308
Native fauna records	46 (3.0%)	578 (84.0%)	238 (77.3%)
Introduced predator records	554 (36.0%)	79 (11.5%)	68 (22.1%)
Other	940 (61.0%)	31 (4.5%)	2 (0.6%)



a) **b)** **c)**

Graph 4: Introduced predator records within a) Cairncross, b) Ballengarra and c) Maria River areas

3.2.2 Native fauna record rates

The number of native fauna recorded per trap night was calculated for each area and treatment and is shown in Table 4. There is no consistent, evident trend or relationship between detection rates at impact and reference sites or between areas. Maria River has had consistently the lowest detection rates and Ballengarra has had consistently the highest detection rates over the three monitoring events.

Table 4: Native fauna recorded per trap night

		Baseline			2018			2020		
		# NF records	# camera nights	Record rate	# NF records	# camera nights	Record rate	# NF records	# camera nights	Record rate
Cairncross	Impact mitigation	8	23	0.35	50	28	1.79	13	22	0.59
	Impact no mitigation	2	23	0.09	87	28	3.11	23	22	1.05
	Reference	4	22	0.18	106	28	3.79	32	22	1.45
	TOTAL	**14**	**22.67**	**0.62**	**243**	**28**	**8.68**	**68**	**22**	**3.09**
Ballengarra	Impact mitigation	8	24	0.33	224	27	8.30	28	27	1.04
	Impact no mitigation	12	23	0.52	75	27	2.78	47	27	1.74
	Reference	4	24	0.17	98	27	3.63	20	27	0.74
	TOTAL	**24**	**23.67**	**1.01**	**397**	**27**	**14.70**	**95**	**27**	**3.52**
Maria	Impact mitigation	4	23	0.17	49	34	1.44	33	35	0.94
	Impact no mitigation	1	24	0.04	23	34	0.68	35	35	1.00
	Reference	3	26	0.12	46	42	1.10	5	35	0.14
	TOTAL	**8**	**24.33**	**0.33**	**118**	**36.67**	**3.22**	**73**	**35**	**2.09**

NF = native fauna

4. Discussion

4.1 Performance Measures

A summary of the 2020 survey results in relation to the performance measures are provided in Table 5.

Table 5: Summary of performance measures for the 2020 monitoring period.

Performance measure	Discussion
Monitoring is undertaken in Year 4, 6 and 8 or until monitoring can demonstrate that mitigation measures are effective.	**This performance measure has been met for 2020.** Monitoring has been undertaken in year 6 (2020) as per the EMP. The species was detected moving through underpass C36.40 (combined culvert C36.40) in a westerly direction. This underpass is immediately to the west of plot MM1 (Maria River impact with mitigation site 1,
Monitoring during Year 4, 6 & 8 is undertaken at Impact and Control sites where monitoring was undertaken during baseline surveys, subject to ongoing landowner consent.	**This performance measure has been met for 2020.** Impact and Control sites used in baseline surveys were monitored.

5. Recommendations

5.1 Contingency Measures

The EMP lists potential problems and contingency measures for various components of the monitoring program. Those relevant to the Spotted-tailed Quoll monitoring program are listed and discussed in Table 6.

Table 6: Contingency measures

Potential problem	Contingency measure	Discussion of proposed measure
Decline in presence of target species recorded at Impact sites after the upgrade has been complete, compared to change in Control sites.	The cause of decline in populations at impact sites will be investigated in consultation with EPA and DOTE within two weeks of results reported by ecologist. If the cause of decline is considered most likely attributed to the upgrade of the highway (and not another event such as bushfire), mitigation measures, such as the location and types of fauna crossings and fauna fencing will be reviewed within two months of the above consultation being completed.	Spotted-tailed Quolls were not recorded during baseline surveys or the 2018 or 2020 monitoring events at any sites. **These contingency measures are not considered relevant at this stage**

5.2 Recommendations

The design of the Spotted-tailed Quoll monitoring program indicates an intention to compare record frequency between reference and impact sites before and after construction (Before After Control Impact (BACI) design). In order to undertake such comparisons specifically for the Spotted-tailed Quoll, a reasonable frequency of Spotted-tailed Quoll records would be required, more so if statistical analyses were expected/required. Given the Spotted-tailed Quoll is a species that occurs in low densities, especially in the coastal region of the OH2K project, and is notoriously cryptic, the record frequency required to render the monitoring approach/method useful is highly unlikely to be achieved. In addition, baseline (before construction) surveys did not record the Spotted-tailed Quoll at either impact or reference sites, and furthermore the species has not been detected during the subsequent two monitoring periods. As such, the current monitoring program is unable to fulfill its intended objective and adds no information regarding the success of implemented mitigation measures for this species (fencing, fauna underpasses/culverts).

As such, a number of recommendations have been made:

- It is recommended that the current monitoring program be discontinued.
- It is recommended that camera monitoring resources be redirected to mitigation structures as follows:
  - In order to capture the acknowledged movement periods for the species, monitoring of underpasses should occur
  - In order to link with the original monitoring program fauna underpasses/culverts in the vicinity of the three monitoring areas should be targeted, notably those occurring along creek lines and connecting expanses of suitable habitat

- In order the encapsulate the key movement periods for this species, monitoring should occur from May – August
- For efficiency, camera monitoring may be continued from the autumn underpass monitoring component of the Project, where the underpasses are suitable
- Bridges may also be considered for monitoring to demonstrate passage under the highway for the target, and other, species.

- As a Spotted-tailed Quoll has been confirmed using underpass 36.4, thus already demonstrating the functionality and use of underpasses in the Project by this species, it is recommended that performance measures reflect general fauna use of underpasses and the data collected is value adding data to the current fauna underpass monitoring component of the Project.

TfNSW, working in consultation with the EPA, will update the current EMP (version 4 – August 2019) to include specifics relating to the revised monitoring program, which will be submitted to DPIE and DAWE for approval.

References

Lewis (2014). Pacific Highway Upgrade: Oxley Highway to Kempsey Pre-construction Spring and Summer Baseline Monitoring. Report prepared for RPS-RMS by Lewis Ecological Surveys.

Niche (2018a). Fauna Underpass and Associated Fauna Fence Monitoring 2016/2017. Frederickton to Eungai Pacific Highway Upgrade. Prepared by Niche Environment and Heritage Pty Ltd for Roads and Maritime Services, Port Macquarie, NSW.

Niche (2018b). Spotted-tailed Quoll Monitoring 2018. Oxley Highway to Kempsey Pacific Highway upgrade. Prepared by Niche Environment and Heritage Pty Ltd for Roads and Maritime Services, Port Macquarie, NSW.

RMS (2019). Oxley Highway to Kempsey Pacific Highway Upgrade Ecological Monitoring Program. Roads and Maritime Update to report prepared by SMEC Hyder Joint Venture, August 2019.

Annex 1. Field Data – 2020 Camera Results

Table 7: Cairncross area 2020 camera results

Site	Nights	Total images	Spotted-tailed Quoll	Wallaby	Kangaroo	Koala	Brushtail Possum	Ringtail Possum	Echidna	Bandicoot	Rodent_Dasyurid	Bird	Reptile	Wild Dog/dingo	Domestic_Dog	Red Fox	Feral Cat	Feral Pig	Hare
CM1A	22	19		2															
CM1B	22	20		1										2					
CM1C	22	13		3	1					1									
CM1D	22	14		2	1														
CM2A	22	4,701																	
CM2B	22	4																	
CM2C	22	16														2			
CM2D	22	2											1						
CM3A	22	20														3			
CM3B	22	0																	
CM3C	22	10		1															
CM3D	22	2																	
CNM1A	22	3																	
CNM1B	22	16		1							4					1			
CNM1C	22	16		3			1									2			
CNM1D	22	2																	
CNM2A	22	30		6							1					1			
CNM2B	22	40																	
CNM2C	22	8																	
CNM2D	22	234													1				
CNM3A	22	24					1									1			
CNM3B	22	10											1			4			

Site	Nights	Total images	Spotted-tailed Quoll	Wallaby	Kangaroo	Koala	Brushtail Possum	Ringtail Possum	Echidna	Bandicoot	Rodent_Dasyurid	Bird	Reptile	Wild Dog/dingo	Domestic_Dog	Red Fox	Feral Cat	Feral Pig	Hare
CNM3C	22	28		2										1		1			
CNM3D	22	26		3															
CREF1A	22	12		1								1				1			
CREF1B	22	18			2	1													
CREF1C	22	24		2			2							1					
CREF1D	22	9		2															
CREF2A	22	16		2															
CREF2B	22	16		5															
CREF2C	22	41		6										1					
CREF2D	22	12		2															
CREF3A	22	0																	
CREF3B	22	2																	
CREF3C	22	6		1						1									
CREF3D	22	20		1						2	1								

Table 8: Ballengarra area 2020 camera results

Site	Nights	Total images	Spotted-tailed Quoll	Wallaby	Kangaroo	Koala	Brushtail Possum	Ringtail Possum	Echidna	Bandicoot	Rodent_Dasyurid	Bird	Reptile	Wild Dog/dingo	Domestic Dog	Red Fox	Feral Cat	Feral Pig	Hare
BM1A	27	6				1	1												
BM1B	27	6																	
BM1C	27	78		9	1														
BM1D	27	8		1						1									
BM2A	27	8			1														
BM2B	27	0																	
BM2C	27	102					1					1				3			
BM2D	27	12		1			1									1			
BM3A	27	16		1								1				1			
BM3B	27	20			1									1		1			
BM3C	27	54		4						1									
BM3D	27	12								1				1					
BNM1A	27	42		8												2			
BNM1B	27	36		4			2					1							
BNM1C	27	8		2															
BNM1D	27	54		8										2					
BNM2A	27	5,418					1					1				1			
BNM2B	27	6			1														
BNM2C	27	4,945																	
BNM2D	27	29		3			5				4								
BNM3A	27	4																	
BNM3B	27	22												1					
BNM3C	27	15					1		2	1		1							
BNM3D	27	22			2												1		
BREF1A	27	0																	
BREF1B	27	16		1						1									

Site	Nights	Total images	Spotted-tailed Quoll	Wallaby	Kangaroo	Koala	Brushtail Possum	Ringtail Possum	Echidna	Bandicoot	Rodent_ Dasyurid	Bird	Reptile	Wild Dog/dingo	Domestic Dog	Red Fox	Feral Cat	Feral Pig	Hare
BREF1C	27	88																	
BREF1D	27	0																	
BREF2A	27	0																	
BREF2B	27	17																	
BREF2C	27	10		1												1	2		
BREF2D	27	19		1											1	1			
BREF3A	27	0																	
BREF3B	27	215		1									10						
BREF3C	27	6										2							
BREF3D	27			1							1	1							

Table 9: Maria River area 2020 camera results.

Site	Nights	Total Images	Spotted-tailed Quoll	Wallaby	Kangaroo	Koala	Brushtail Possum	Ringtail Possum	Echidna	Bandicoot	Rodent_ Dasyurid	Bird	Reptile	Wild Dog/ dingo	Domestic_Dog	Red Fox	Feral Cat	Feral Pig	Hare
MM1A	35	44		4						1						2			
MM1B	35	6		3															
MM1C	35	242		4						2									
MM1D	35	14		4															
MM2A	35	456																	
MM2B	35	3,367					2				2								
MM2C	35	1,554							1			1							
MM2D	35	10							4	1									
MM3A	35	5																	
MM3B	35	70		2						1		1		1		1	3		
MM3C	35	2																	
MM3D	35	3												1					
MNM1A	35	45			1						5								
MNM1B	35	5,700										1							
MNM1C	35	14														4			
MNM1D	35	20		2										1		1		1	
MNM2A	35	10														2			
MNM2B	35	5,976																	
MNM2C	35	22														3			
MNM2D	35	22		1			2		2			4				1			
MNM3A	35	290														3			
MNM3B	35	4		1															
MNM3C	35	80			12										3				
MNM3D	35	26		3			1												1
MREF1A	35	4		1		2													

Site	Nights	Total Images	Spotted-tailed Quoll	Wallaby	Kangaroo	Koala	Brushtail Possum	Ringtail Possum	Echidna	Bandicoot	Rodent_ Dasyurid	Bird	Reptile	Wild Dog/ dingo	Domestic_Dog	Red Fox	Feral Cat	Feral Pig	Hare
MREF1B	35	0																	
MREF1C	35	23		1					1										
MREF1D	35	64																	
MREF2A	35	4																	
MREF2B	35	4																	
MREF2C	35	4.699																	
MREF2D	35	5																	
MREF3A	35	12																	
MREF3B	35	0																	
MREF3C	35	0																	
MREF3D	35	6		1															

Annex 2. 2018 Field Data - Habitat Attributes

Table 10: Cairncross area habitat attributes

Site	Canopy dominant species	Canopy % cover	Canopy Height (m)	Midstorey dominant species	Midst % cover	Midst Height (m)	Ground dominant species	Ground % cover	Ground Height (m)	Hydrology (present/absent and type)	Rocky features (present/absent and type)	Tree and log Hollows (type and abundance)	2020 changes in environment
CM1A	Ironbark sp.	30	20	*Melaleuca* spp.	60	8	*Entolasia stricta*	70	0.4	Absent	Absent	Substantial log hollows and woody debris.	
CM1B	*Eucalyptus eugenioides*	40	25	*Melaleuca linariifolia*	40	10	*Entolasia stricta*	70	0.4	Absent	Absent	Substantial log hollows and woody debris.	
CM1C	*Eucalyptus pilularis*	50	25	*Melaleuca quinquenervia*	40	15	*Lomandra longifolia*	70	0.6	Adjacent drainage line	Absent	Occasional log hollows, some woody debris	
CM1D	*Eucalyptus pilularis*	60	30	*Melaleuca sieberi*	20	12	*Entolasia stricta*	20	0.3	Absent	Absent	Substantial logs with hollows	
CM2A	*Eucalyptus pilularis*	60	30	Mixed rainforest species	40	8	*Gahnia* sp.	40	1	Adjacent wet creek	Absent	Occasional log hollows	
CM2B	*Eucalyptus pilularis*	40	25	*Allocasuarina littoralis*	80	15	*Pteridium esculentum*	50	0.8	Absent	Absent	Occasional log hollows	
CM2C	*Corymbia intermedia*	60	25	*Allocasuarina littoralis*	80	12	*Lomandra* spp.	30	0.4	Absent	Absent	Absent	
CM2D	*Eucalyptus pilularis*	40	25	*Allocasuarina littoralis*	80	15	*Lomandra* spp.	40	0.6	Adjacent wet creek	Absent	Occasional log hollows	
CM3A	*Corymbia intermedia*	40	25	*Syncarpia glomulifera*	40	15	*Lomandra* spp.	90	0.5	Absent	Absent	Occasional log hollows	
CM3B	*Eucalyptus pilularis*	40	35	*Melaleuca quinquenervia*	60	15	*Lomandra* spp.	90	0.7	Absent	Absent	Occasional log hollows	
CM3C	*Eucalyptus pilularis*	70	30	*Allocasuarina littoralis*	40	15	*Imperata cylindrica*	70	0.5	Absent	Absent	Abundant logged timber frequent hollows.	
CM3D	*Eucalyptus pilularis*	60	35	*Melaleuca linariifolia*	60	10	*Imperata cylindrica*	10	0.4	Absent	Absent	Substantial log hollows	
CNM1A	*Eucalyptus pilularis*	20	25	*Eucalyptus saplings*	60	10	*Lomandra* sp.	80	0.6	Absent	Absent	Occasional log hollows and substantial woody debris.	

Site	Canopy dominant species	Canopy % cover	Canopy Height (m)	Midstorey dominant species	Midst % cover	Midst Height (m)	Ground dominant species	Ground % cover	Ground Height (m)	Hydrology (present/absent and type)	Rocky features (present/absent and type)	Tree and log Hollows (type and abundance)	2020 changes in environment
CNM1B	*Eucalyptus pilularis*	30	30	*Allocasuarina littoralis*	80	12	*Pteridium esculentum*	90	0.9	Absent	Absent	Occasional log hollows and woody debris.	
CNM1C	*Eucalyptus propinqua*	50	25	*Allocasuarina littoralis*	70	12	*Imperata cylindrica*	70	0.6	Absent	Absent	Occasional log hollows and woody debris.	
CNM1D	*Eucalyptus pilularis*	30	25	*Allocasuarina littoralis*	80	15	*Lomandra longifolia*	15	0.6	Absent	Absent	Occasional log hollows	
CNM2A	*Corymbia intermedia*	30	25	*Allocasuarina torulosa*	60	10	*Entolasia stricta*	60	0.4	Absent	Absent	Occasional log hollows	
CNM2B	*Eucalyptus eugeniodes*	60	30	*Eucalyptus saplings*	30	8	*Lomandra longifolia*	70	0.7	Absent	Absent	Substantial log hollows	
CNM2C	*Corymbia gummifera*	40	25	*Allocasuarina torulosa*			*Imperata cylindrica*	60	0.6	Absent	Absent	Absent	
CNM2D	*Eucalyptus pilularis*	40	30	*Allocasuarina littoralis*	60	12	*Pteridium esculentum*	80	1	Absent	Absent	Absent	
CNM3A	*Eucalyptus pilularis*	60	30	*Eucalyptus tereticornis*	40	20	*Lomandra* spp.	60	0.6	Absent	Absent	Occasional log hollows	
CNM3B	*Eucalyptus robusta*	50	25	*Allocasuarina littoralis*	50	20	*Gahnia* sp.	90	1.5	Absent	Absent	Absent	
CNM3C	*Corymbia intermedia*	60	25	*Allocasuarina littoralis*	80	15	*Imperata cylindrica*	40	0.4	Absent	Absent	Absent	
CNM3D	*Eucalyptus pilularis*	80	25	*Melaleuca* sp.	40	10	*Pteridium esculentum*	80	0.8	Absent	Absent	Absent	
CREF1A	*Eucalyptus microcorys*	80	30	*Melaleuca quinquenervia*	40	15	*Lomandra* sp.	10	0.3	Adjacent wet creek	Absent	Substantial log hollows	
CREF1B	*Corymbia intermedia*	40	25	*Melaleuca quinquenervia*	30	15	*Lomandra longifolia*	30	0.3	Adjacent wet creek	Absent	Substantial log hollows	
CREF1C	*Corymbia intermedia*	20	25	*Allocasuarina torulosa*	15	10	*Lomandra longifolia*	10	0.3	20m from drainage	Absent	Abundant felled trees and logs	
CREF1D	*Eucalyptus grandis*	60	35	*Allocasuarina torulosa*	30	10	*Lomandra longifolia*	30	0.3	Adjacent intermittent drainage line	Absent	Abundant felled trees and logs	

Site	Canopy dominant species	Canopy % cover	Canopy Height (m)	Midstorey dominant species	Midst % cover	Midst Height (m)	Ground dominant species	Ground % cover	Ground Height (m)	Hydrology (present/absent and type)	Rocky features (present/absent and type)	Tree and log Hollows (type and abundance)	2020 changes in environment
CREF2A	*Eucalyptus grandis*	60	30	*Persoonia sp.*	50	80	*Lomandra longifolia*	40	0.2	Adjacent intermittent creek	Absent	Occasional log hollows	
CREF2B	*Eucalyptus propinqua*	60	35	*Lophostemon confertus*	20	20	*Lomandra longifolia*	50	0.5	Adjacent intermittent creek	Absent	Occasional log hollows	
CREF2C	*Eucalyptus siderophloia*	50	30	*Allocasuarina torulosa*	20	20	*Lomandra longifolia*	15	0.3	Absent	Absent	Minimal hollows	
CREF2D	Ironbark sp.	60	30	*Lophostemon confertus*	50	20	*Blechnum* sp.	20	0.2	Adjacent intermittent creek	Absent	Occasional log hollows	
CREF3A	*Eucalyptus grandis*	40	35	*Allocasuarina torulosa*	40	15	*Lomandra longifolia*	10	0.3	Adjacent intermittent creek	Absent	Occasional log hollows	
CREF3B	*Eucalyptus grandis*	80	30	*Lophostemon confertus*	30	20	*Blechnum* sp.	10	0.2	Adjacent wet creek	Absent	Substantial fallen logs with occasional hollows	
CREF3C	Mahogany sp.	40	25	*Eucalyptus teretecornis*	40	10	*Imperata cylindrica*	60	0.5	Absent	Absent	Occasional log hollows	
CREF3D	*Eucalyptus grandis*	60	25	*Eucalyptus teretecornis*	60	15	*Pteridium esculentum*	70	0.4	Absent, low area possible pooling	Absent	Substantial fallen logs with occasional hollows	

Table 11: Ballengarra area habitat attributes

Site	Canopy dominant species	Canopy % cover	Canopy Height (m)	Midstorey dominant species	Midst % cover	Midst Height (m)	Ground dominant species	Ground % cover	Ground Height (m)	Hydrology (present/absent and type)	Rocky features (present/absent and type)	Tree and log Hollows (type and abundance)	2020 changes in environment
BM1A	*Eucalyptus propinqua*	70	25	*Lophostemon confertus*	70	10	*Lomandra longifolia*	30	0.6	Adjacent wet creek	Absent	Substantial fallen timber and log hollows	
BM1B	*Eucalyptus microcorys*	60	20	*Allocasuarina torulosa*	80	12	*Imperata cylindrica*	30	0.3	Adjacent dry drainage line	Absent	Substantial fallen timber and log hollows	
BM1C	*Eucalyptus microcorys*	70	25	*Melaleuca quinquenervia*	80	12	*Gahnia* spp.	60	0.7	Absent	Absent	Occasional fallen timber and log hollow	
BM1D	*Eucalyptus microcorys*	40	20	*Lophostemon confertus*	70	12	*Imperata cylindrica*	20	0.3	Absent	Absent	Occasional fallen timber and log hollow	
BM2A	*Eucalyptus propinqua*	70	25	*Melaleuca sieberi*	60	8	*Entolasia stricta*	10	0.2	Adjacent dry drainage line	Absent	Abundant fallen timber and occasional hollow. Litter/dumping.	
BM2B	*Eucalyptus microcorys*	80	25	*Eucalyptus microcorys*	65	5	*Lomandra* sp., *Gahnia* sp.	15	0.7	Adjacent dry drainage line	Absent	Occasional fallen timber /logs	
BM2C	*Eucalyptus propinqua*	60	20	*Lophostemon confertus, Allocasuarina* sp.	40	8	*Lomandra* sp., *Imperata cylindrica*	40	0.5	Adjacent dry drainage line	Absent	Substantial fallen limbs and logs.	
BM2D	*Eucalyptus microcorys*	40	18	*Allocasuarina* sp., Euc saplings	30	5	*Lomandra* sp.	10	0.4	Absent	Absent	Abundant logs and hollows	
BM3A	*Eucalyptus microcorys*	50	20	*Lophostemon confertus*	70	10	*Lomandra longifolia*	10	0.8	Adjacent dry drainage line	Absent	Occasional fallen log hollows	
BM3B	*Eucalyptus pilularis*	60	20	*Lophostemon confertus*	60	8	*Imperata cylindrica*	10	0.4	Adjacent moist gully	Absent	Minimal fallen timber no hollows	
BM3C	*Eucalyptus pilularis*	60	15	*Lophostemon confertus*	60	8	*Imperata cylindrica*	70	0.8	Adjacent dry drainage line	Absent	Minimal fallen timber no hollows	
BM3D	*Eucalyptus pilularis*	50	20	*Allocasuarina littoralis*	80	10	*Lomandra longifolia*	80	0.9	Adjacent dry drainage line	Absent	Minimal fallen timber no hollows	

Site	Canopy dominant species	Canopy % cover	Canopy Height (m)	Midstorey dominant species	Midst % cover	Midst Height (m)	Ground dominant species	Ground % cover	Ground Height (m)	Hydrology (present/absent and type)	Rocky features (present/absent and type)	Tree and log Hollows (type and abundance)	2020 changes in environment
BNM1A	*Eucalyptus siderophloia*	60	20	*Allocasuarina littoralis*	50	10	*Gahnia* spp.	60	0.7	Adjacent dry drainage line	Absent	Abundant fallen timber no log hollows evident	
BNM1B	*Eucalyptus microcorys*	70	22	*Melaleuca quinquenervia*	60	12	*Entolasia stricta*	50	0.2	Adjacent moist gully and dry drainage line	Absent	Substantial fallen old logs and hollows	
BNM1C	*Syncarpia glomulifera*	60	30	*Allocasuarina littoralis*	70	10	*Pteridium esculentum*	80	0.8	Adjacent dry drainage line	Absent	Occasional fallen timber and limited hollows	
BNM1D	*Corymbia gummifera*	50	20	*Allocasuarina littoralis*	50	8	*Lomandra* spp.	60	0.5	Absent	Absent	Numerous log hollows	Logging adjacent
BNM2A	*Eucalyptus propinqua*	60	20	*Lophostemon confertus*	60	10	*Imperata cylindrica*	70	0.3	Absent	Absent	Abundant fallen timber and log hollows available	
BNM2B	*Eucalyptus siderophloia*	40	17	*Lophostemon confertus*	40	8	*Entolasia stricta*	60	0.3	Absent	Absent	Occasional fallen timber, log hollows	
BNM2C	*Eucalyptus saligna*	50	25	*Melaleuca* spp.	60	10	*Lomandra longifolia*	80	1	Absent	Absent	Minimal fallen timber, one log hollow	
BNM2D	*Syncarpia glomulifera*	70	25	Mixed rainforest species	80	10	*Lomandra* spp.	30	1	Adjacent wet creek	Absent	Numerous log hollows	
BNM3A	*Eucalyptus paniculata*	30	20	*Allocasuarina* spp.	80	8	*Lomandra longifolia*	0.5	15	Absent	Absent	Minimal fallen timber, one log hollow	Site subject to extensive logging/clearing and fire
BNM3B	*Eucalyptus grandis*	80	30	*Melaleuca quinquenervia*	80	10	*Gahnia* spp.	50	1	Adjacent dry drainage line	Absent	Occasional fallen timber and log hollows	Site subject to extensive logging/clearing and fire
BNM3C	*Eucalyptus pilularis*	60	30	*Acacia* spp.	60	8	*Imperata cylindrica*	60	0.8	Absent	Absent	Substantial fallen logs and hollows	Site subject to extensive logging/clearing and fire
BNM3D	*Eucalyptus pilularis*	60	30	Mixed rainforest species	80	8	*Pteridium esculentum*	70	0.9	Adjacent moist gully	Absent	Occasional log hollow	Site subject to extensive

Site	Canopy dominant species	Canopy % cover	Canopy Height (m)	Midstorey dominant species	Midst % cover	Midst Height (m)	Ground dominant species	Ground % cover	Ground Height (m)	Hydrology (present/absent and type)	Rocky features (present/absent and type)	Tree and log Hollows (type and abundance)	2020 changes in environment
													logging/clearing and fire
BREF1A	*Eucalyptus microcorys*	60	25	*Allocasuarina torulosa*	40	12	*Imperata cylindrica*	30	0.4	Absent	Absent	Substantial fallen timber and hollow logs	Logging
BREF1B	*Allocasuarina torulosa*	60	25	*Lantana camara*	70	2	*Imperata cylindrica*	10	0.3	Adjacent gully drainage	Absent	Occasional fallen timber, large log hollow	Logging
BREF1C	*Corymbia gummifera*	50	20	*Allocasuarina torulosa*	60	12	*Lomandra* spp.	30	0.4	Absent	Absent	One hollow under burnt stag	Logging
BREF1D	*Eucalyptus carnea*	50	25	*Acacia* spp.	70	6	*Imperata cylindrica*	50	0.4	Absent	Absent	Occasional fallen log no hollows	Logging
BREF2A	*Eucalyptus propinqua*	60	30	*Melaleuca sieberi*	8	12	*Lomandra longifolia*, *Gahnia* sp.	30	0.4	Adjacent wet creek	Absent	Minimal fallen timber no hollows	Logging
BREF2B	*Eucalyptus grandis*	70	35	*Melaleuca quinquenervia*	80	13	*Lantana camara*	50	2	Adjacent wet creek	Absent	Occasional fallen timber no hollows	Logging
BREF2C	Mahogany spp.	50	25	*Allocasuarina littoralis*	60	10	*Entolasia stricta*	60	0.5	Absent	Absent	Substantial fallen timber no hollows	Logging
BREF2D	*Eucalyptus propinqua*	70	30	*Melaleuca quinquenervia*	70	12	*Gahnia* spp.	40	0.6	Absent	Absent	Abundant fallen timber and hollow logs	Logging
BREF3A	*Corymbia intermedia*	60	25	*Allocasuarina torulosa*	70	15	*Imperata cylindrica*	40	0.3	Absent	Absent	Substantial fallen timber and hollow logs	Logging
BREF3B	*Eucalyptus carnea*	40	20	Eucalyptus saplings	40	8	*Lomandra longifolia*	40	0.4	Absent	Absent	Substantial fallen timber and hollow logs	Logging
BREF3C	*Corymbia intermedia*	60	30	*Allocasuarina torulosa*	70	12	*Lomandra* spp.	30	0.4	Absent	Absent	Substantial fallen timber and hollow logs	Logging
BREF3D	*Syncarpia glomulifera*	70	25	Eucalyptus saplings	80	8	*Imperata cylindrica*	10	0.3	Absent	Absent	Occasional fallen timber no hollows	Logging

Table 12: Maria River area habitat attributes

Site	Canopy dominant species	Canopy % cover	Canopy Height (m)	Midstorey dominant species	Midst % cover	Midst Height (m)	Ground dominant species	Ground % cover	Ground Height (m)	Hydrology (present/absent and type)	Rocky features (present/absent and type)	Tree and log Hollows (type and abundance)	2020 changes in environment
MM1A	*Eucalyptus microcorys*	40	25	Eucalyptus saplings	60	8	*Lomandra longifolia*	60	0.6	Adjacent wet drainage	Absent	Absent	
MM1B	*Eucalyptus pilularis*	30	30	Eucalyptus saplings	60	8	*Imperata cylindrica*	90	0.7	Absent	Absent	Absent	
MM1C	Stringybark	20	20	Eucalyptus saplings	50	10	*Imperata cylindrica*	90	0.4	Absent	Absent	Absent	
MM1D	*Eucalyptus microcorys*	30	22	Eucalyptus saplings	40	10	*Imperata cylindrica*	80	0.4	Absent	Absent	Absent	
MM2A	*Eucalyptus pilularis*	20	20	Eucalyptus saplings	40	8	Mixed native grasses	70	0.5	Absent	Absent	Occasional hollow log	
MM2B	*Syncarpia glomulifera*	50	25	*Allocasuarina littoralis*	70	10	*Imperata cylindrica*	40	0.4	Absent	Absent	Numerous hollow logs	
MM2C	*Corymbia gummifera*	10	25	*Allocasuarina littoralis*	20	8	*Lomandra* sp.	60	0.2	Absent	Absent	Substantial hollow logs	
MM2D	*Eucalyptus paniculata*	30	20	*Lophostemon confertus*	60	8	Mixed native grasses	40	0.7	Absent	Absent	Occasional hollow log	
MM3A	Mahogany sp.	30	20	Eucalyptus saplings	40	8	*Xanthorrhoea* sp.	80	0.8	Absent	Absent	Occasional hollow log	
MM3B	*Eucalyptus pilularis*	40	22	*Melaleuca* sp.	50	10	*Imperata cylindrica*	90	0.5	Adjacent wet drainage	Absent	Substantial hollow logs	
MM3C	Stringybark	15	22	Eucalyptus saplings	10	10	*Imperata cylindrica*	60	0.7	Absent	Absent	Occasional hollow log	
MM3D	Stringybark	10	20	Eucalyptus saplings	60	12	*Xanthorrhoea* sp.	80	0.9	Adjacent wet drainage	Absent	Absent	
MNM1A	*Eucalyptus propinqua*	20	18	*Allocasuarina littoralis*	70	8	*Imperata cylindrica*	20	0.4	Adjacent wet drainage and swampy area	Absent	Absent	
MNM1B	*Eucalyptus pilularis*	40	28	*Allocasuarina littoralis*	50	8	Mixed native grasses	80	0.6	Absent	Absent	Occasional hollow log	
MNM1C	*Eucalyptus propinqua*	30	22	*Melaleuca* spp.	70	15	Mixed native grasses	90	0.2	General wet area	Absent	Substantial hollow logs	

Site	Canopy dominant species	Canopy % cover	Canopy Height (m)	Midstorey dominant species	Midst % cover	Midst Height (m)	Ground dominant species	Ground % cover	Ground Height (m)	Hydrology (present/absent and type)	Rocky features (present/absent and type)	Tree and log Hollows (type and abundance)	2020 changes in environment
MNM1D	*Syncarpia glomulifera*	60	30	*Melaleuca stypheloides*	80	12	*Lomandra* spp.	60	0.3	Adjacent wet Stumpy Creek	Absent	Occasional hollow log	
MNM2A	*Eucalyptus pilularis*	70	25	*Allocasuarina littoralis*	10	8	*Imperata cylindrica*	10	0.3	Absent	Absent	Absent	
MNM2B	Mahogany sp.	30	22	*Allocasuarina littoralis*	30	8	Mixed native grasses	50	0.4	Absent	Absent	Occasional hollow log	
MNM2C	*Eucalyptus pilularis*	60	30	Eucalyptus saplings	10	8	Mixed native grasses and *Pteridium esculentum*	10	0.6	Absent	Absent	Absent	
MNM2D	*Eucalyptus pilularis*	50	20	*Allocasuarina littoralis*	30	8	*Entolasia stricta*	15	0.3	Absent	Absent	Numerous hollow logs	
MNM3A	Mahogany sp.	20	20	*Allocasuarina torulosa*	40	8	*Entolasia stricta*	60	0.4	Absent	Absent	Absent	
MNM3B	Mahogany sp.	10	22	*Allocasuarina littoralis*	5	6	*Imperata cylindrica*	40	0.4	Adjacent dam	Absent	Absent	
MNM3C	*Eucalyptus pilularis* plantation	60	20	Burnt *Allocasuarina littoralis*	5	8	*Imperata cylindrica*	80	0.7	Absent	Absent	Absent	
MNM3D	*Eucalyptus propinqua*	60	25	*Melaleuca* spp.	70	8	Mixed native forbs and grasses	90	0.2	Adjacent dry creek	Absent	Occasional hollow log	
MREF1A	*Eucalyptus pilularis*	50	25	*Allocasuarina littoralis*	60	10	*Entolasia stricta*	70	0.5	Adjacent drainage	Absent	Occasional hollow log	
MREF1B	*Eucalyptus racemosa*	30	20	*Syncarpia glomulifera*	80	20	*Entolasia stricta*	60	0.5	Absent	Absent	Occasional hollow log	
MREF1C	*Eucalyptus racemosa*	30	25	*Leptospermum* sp.	30	8	*Xanthorrhoea* sp.	80	0.6	Absent	Absent	Occasional hollow log	
MREF1D	*Corymbia gummifera*	50	25	*Allocasuarina torulosa*	30	12	*Xanthorrhoea* sp.	70	0.7	Absent	Absent	Occasional hollow log	
MREF2A	*Eucalyptus racemosa*	60	25	*Allocasuarina torulosa*	80	10	*Imperata cylindrica*	30	0.3	Absent	Absent	Occasional hollow log	
MREF2B	Mahogany sp.	60	25	*Allocasuarina torulosa*	80	10	*Xanthorrhoea* sp.	80	0.6	Absent	Absent	Occasional hollow log	

Site	Canopy dominant species	Canopy % cover	Canopy Height (m)	Midstorey dominant species	Midst % cover	Midst Height (m)	Ground dominant species	Ground % cover	Ground Height (m)	Hydrology (present/absent and type)	Rocky features (present/absent and type)	Tree and log Hollows (type and abundance)	2020 changes in environment
MREF2C	*Corymbia gummifera*	15	22	*Allocasuarina littoralis*	30	8	Mixed native grasses	80	0.4	Absent	Absent	Occasional hollow log	
MREF2D	*Eucalyptus racemosa*	40	22	*Allocasuarina littoralis*	80	10	*Xanthorrhoea* sp.	90	0.6	Absent	Absent	Occasional hollow log	
MREF3A	*Eucalyptus pilularis*	50	25	*Melaleuca stypheloides*	80	10	*Lomandra longifolia*	20	0.6	Wet creek	Absent	Absent	
MREF3B	*Eucalyptus racemosa*	20	22	*Allocasuarina torulosa*	70	8	*Xanthorrhoea* sp.	80	0.6	Absent	Absent	Occasional hollow log	
MREF3C	*Corymbia gummifera*	15	22	*Allocasuarina littoralis*	30	8	*Xanthorrhoea* sp.	80	0.6	Absent	Absent	Occasional hollow log	
MREF3D	*Eucalyptus racemosa*	30	22	*Allocasuarina torulosa*	70	12	*Xanthorrhoea* sp.	70	0.6	Absent	Absent	Occasional hollow log	

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