

Pacific Highway Upgrade
Warrell Creek to Nambucca Heads

Operational Road Kill Monitoring

Transport for NSW

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Report name	Pacific Highway Upgrade Warrell Creek to Nambucca Heads Operational Road Kill Monitoring
Date	15 February 2019
Revision 1	Section 2A initial 12 week monitoring report
Revision 2	Section 2A Autumn (April) 2018 monitoring report
Revision 3	Section 2A Winter (July) 2018 monitoring report
Revision 4	Section 2B initial 12 week monitoring report
Revision 5	Spring (October) 2018 monitoring (Annual report 2018)
Revision 6	Summer (January) 2019 monitoring report
Revision 7	Autumn (April) 2019 monitoring report
Revision 8	Winter (July) 2019 monitoring report
Revision 9	Spring (October) 2019 monitoring (Annual report 2019)
Revision 10	Summer (January) 2020 monitoring report
Revision 11	Autumn (April) 2020 monitoring report
Revision 12	Winter (July) 2020 monitoring report

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Introduction

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

The aim of the monitoring program is to;

- report on any animal road kill on the project following the opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

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

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

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

Purpose of this report

The purpose of this report is to provide the monitoring data for the ongoing road monitoring following the opening of Stage 2A to traffic.

This report is updated with the results of the monitoring as Appendices as they become available.

Appendix 1 WC2NH Road Kill Monitoring Program

Timing of Monitoring

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

Table 1 – Timings and locations of road kill surveys

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

Monitoring Program Objectives

The aim of the monitoring program is to;

- report on any animal road kill on the project following the opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

Monitoring Procedure

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

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

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

- a. The provision of a qualified ecologist (shall be a recognised expert in mammal identification in coastal northern NSW) to undertake the initial phase of operational monitoring (first season) with relevant Roads and Maritime team members providing appropriate detailed training and a baseline of expert monitoring of road kills;
- b. The provision of specialist training (to be provided by an expert as above in point a) in fauna identification for Contractors and Roads & Maritime staff involved in the construction phase monitoring of road kill; and
- c. Where there is any doubt to the identification of the carcass, the provision of photographs of road kill to be sent to a qualified ecologist (an expert as above in point a) to confirm the identity of road kill and to maintain a permanent record of road kill for further comparisons, if needed.

Monitoring Methodology

1. The highway will be monitored using the method previously indicated (section 1.3) consisting of a two-person team traversing the Upgrade in a vehicle to locate and identify road kills;
2. The speed of travel will be the same in all cases to avoid confounding the data collection, and should be as slow as is safely possible;
3. The highway will be surveyed weekly for four weeks in Spring, Summer, Autumn and Winter (see Table 1);
4. Where possible, each survey shall be completed within two hours of sunrise in order to maximise the potential to record road kills before either carrion eating animals or traffic render any road kill unidentifiable;
5. if possible, each survey will be carried out on the same day of the week to remove the influence of varying environmental conditions and to ensure consistent temporal spacing;
6. For each road kill observed, the following attributes will be recorded
 - a. Geographic Coordinates of any road kill.
 - b. Whether fauna fencing was installed at/near the location.
 - c. Species of road kill where possible, however, where there is any doubt as to the identification of the carcass, photographs shall be forwarded to a qualified ecologist for identification /confirmation of the species.

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

- a. Sex and age class (juvenile or adult).
- b. Presence of pouch young (for marsupials).
- c. Presence of flightless young (for flying-foxes or other bats).
- d. Distance to a fauna connectivity structure.
- e. Distance to drop down structure.
- f. If fauna fencing was installed, is there any damage to the fence in the vicinity.
- g. Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase.
- h. If the animal is identified as a flying-fox:
 - Distance to nearest camp,
 - Distance to nearest canopy vegetation,

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

Analysis of data

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

Reporting

Quarterly reports

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

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

Annual Reports

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

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

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

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

Performance Measures

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

Adaptive Management

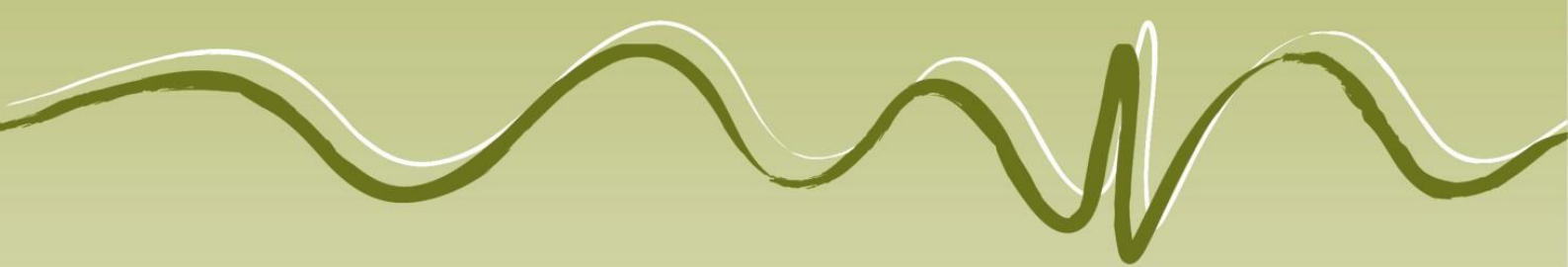
Where any annual report identifies a significant difference between the road kill numbers of the fenced and unfenced areas, DoEE and EPA shall be notified, and a meeting will be set to discuss such differences with the relevant agencies & Roads and Maritime.

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

Appendix 2 Stage 2A Initial 12 Week Monitoring Report.

Road Kill Monitoring Report

WC2NH Stage 2A



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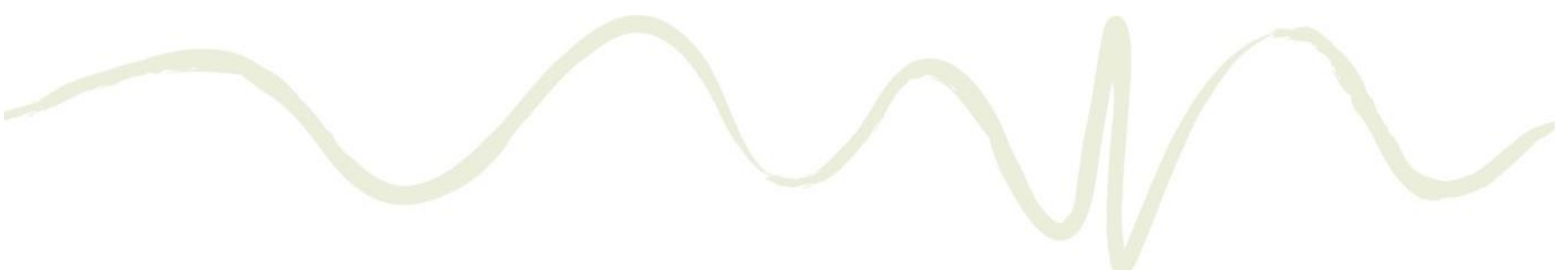


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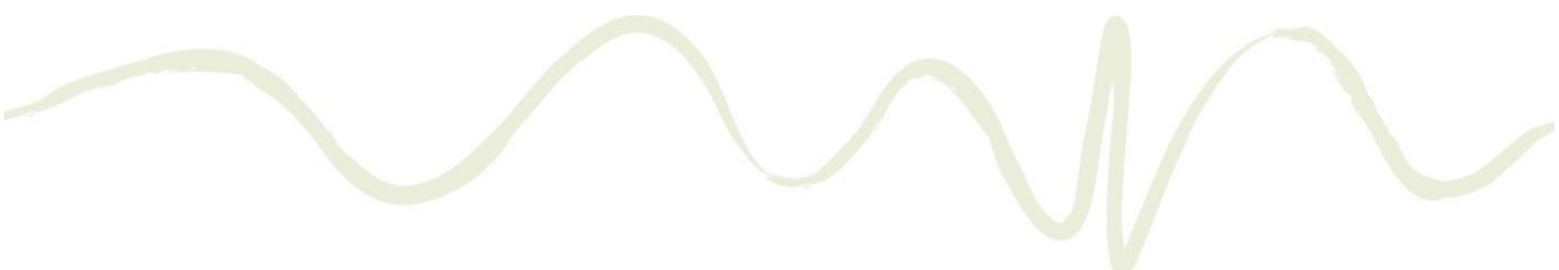
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Appendix A Stage 2A Road Kill Monitoring Results



Executive Summary

GeoLINK was engaged by NSW Roads and Maritime Services to undertake weekly Road Kill Monitoring for the first 12 weeks of the operational phase of the Stage 2A section of the Warrell Creek to Nambucca Heads Pacific Highway Upgrade (WC2NH). A number of road kill mitigation measures were implemented for WC2NH with the aim to minimise vehicle collisions with native wildlife. The types of structures which were constructed to mitigate traffic impacts to fauna consist of:

- The installation of fauna fencing to exclude fauna from the road corridor or as a guide towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including fauna culvert underpasses, bridge underpasses, rope bridges and glider poles.

The aim of the monitoring program is to:

- Report on any animal road kill within the Stage 2A section of operational highway since open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

Road kill monitoring for Stage 2A of WC2NH was undertaken weekly (each Thursday) for the first 12 weeks after the opening of Stage 2A to traffic. The Stage 2A site covers 13.3 km of dual carriageway highway extends from Scott's Heads Road in the south (Chainage 48100) to Nambucca Heads, connecting to the Nambucca Head to Urunga Pacific Highway upgrade in the north (Chainage 61250). The survey area covered the north and southbound carriageways and has a combined length of 26.6 km of road.

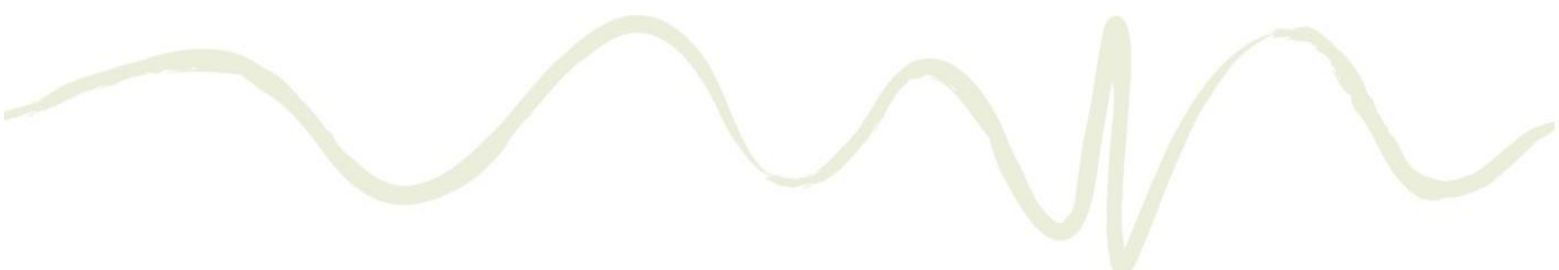
One road kill of a *Biodiversity Conservation Act 2016* (BC Act) listed species was recorded during the monitoring, which comprised a Masked Owl. No *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog.

Of the 96 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were relatively low (8) over the reporting period. No arboreal mammal road kills were recorded. Species diversity included 24 native species and five introduced species.

Three road kill hotspots were identified across Stage 2A including the Gumma Floodplain, north of the Nambucca River Bridge and to a lesser degree the section from north of Lower Warrell Creek to the Bald Hill overpass.

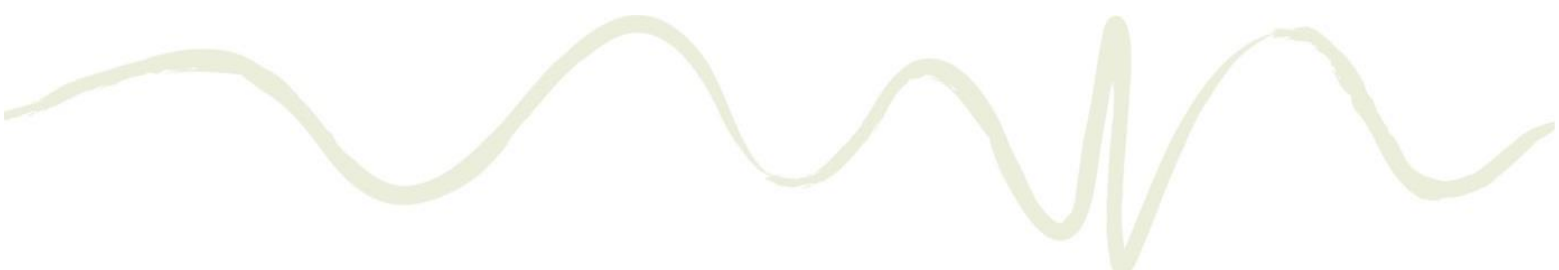
No flying-fox road kill records were made in the vicinity of the Type 4 fauna fencing (flying-fox fencing) between chainage 49700 and 50200, though the camp was not occupied during the monitoring.

The results show a declining trend in the number of road kills across the survey area for all fauna classes over time. This may be attributed to a number of factors including reduction of roadside food sources which attract fauna to the corridor, habituation of the road to fauna or local populations of certain species have temporarily declined as a direct result of vehicle collisions.



Statistical analysis to determine the effectiveness of the fauna fencing does not contain strong statistical power due to the small results data pool, particularly of relevant fauna groups (i.e. medium to large sized terrestrial mammals). This may be attributed to the effectiveness of the fencing in reducing fauna access to the roadway. The results of future monitoring should be consolidated to develop a larger data set to allow for future statistical analysis.

A number of observations and suggestions have been made as lessons learnt in preparation for the opening of Stage 2B of the WC2NH Pacific Highway Upgrade.



1. Introduction

GeoLINK was engaged by NSW Roads and Maritime Services to undertake weekly Road Kill Monitoring for the first 12 weeks of the operational phase of the Stage 2A section of the Warrell Creek to Nambucca Heads Pacific Highway Upgrade (WC2NH). A number of road kill mitigation measures were implemented for WC2NH with the aim to minimise vehicle collisions with native wildlife. The types of structures which were constructed to mitigate traffic impacts to fauna consist of:

- The installation of fauna fencing to exclude fauna from the road corridor or as a guide towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including fauna culvert underpasses, bridge underpasses, rope bridges and glider poles.

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

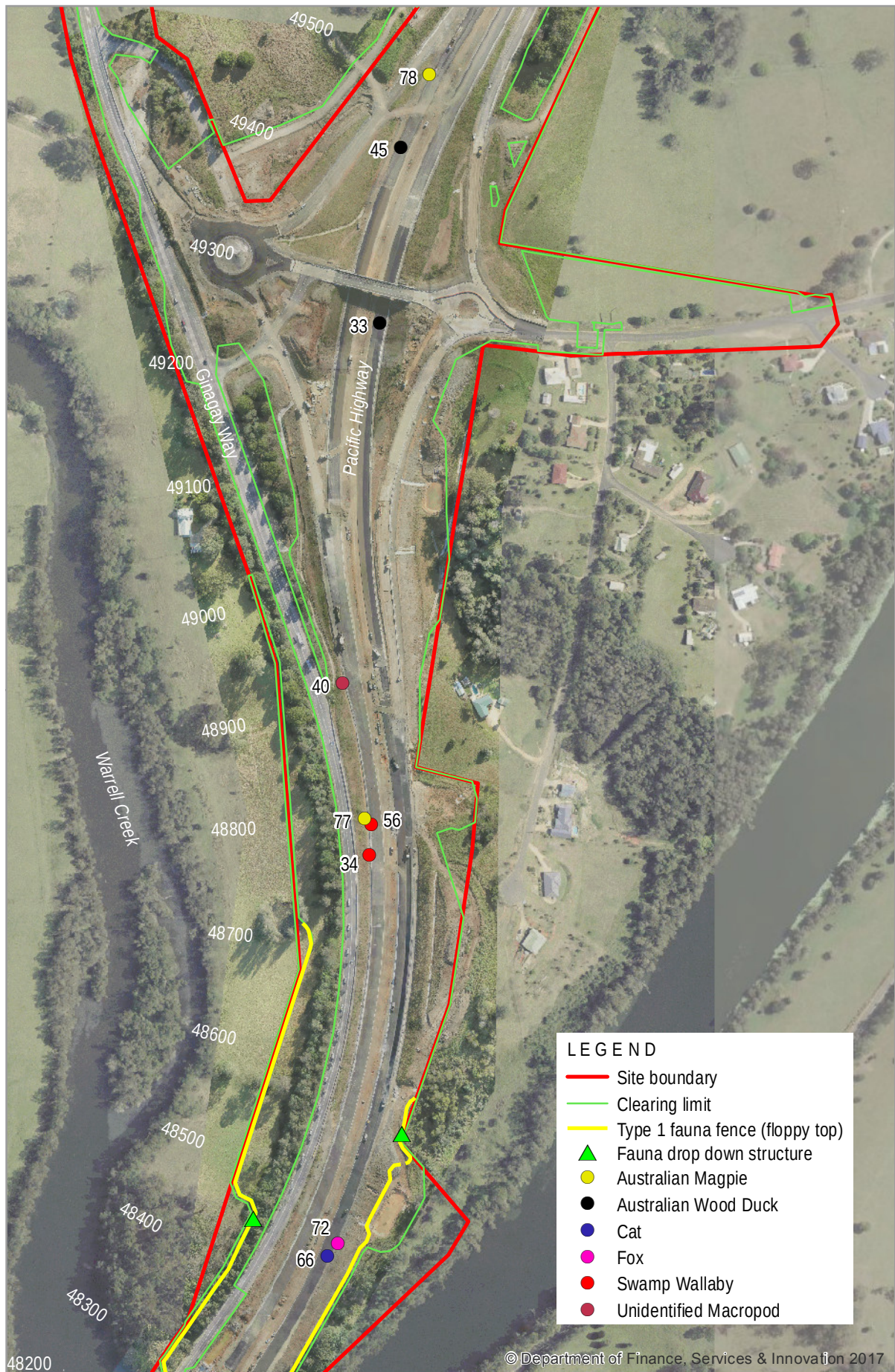
- **Type 1** - Chainmesh fence 1.8 m tall with floppy top feature which is designed to exclude a range of native mammal species such as macropods, possums, Spotted-tail Quoll (*Dasyurus maculatus*) and Koala (*Phascolarctos cinereus*). 18.03 km of this fence type occurs at the site.
- **Type 3** - Small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

The locations of fauna fences and design types are presented within **Illustration 1.1 - 1.9**.

The aim of the monitoring program is to:

- Report on any animal road kill within the Stage 2A section of operational highway since open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

This report provides the results of the first 12 weeks of road kill monitoring.



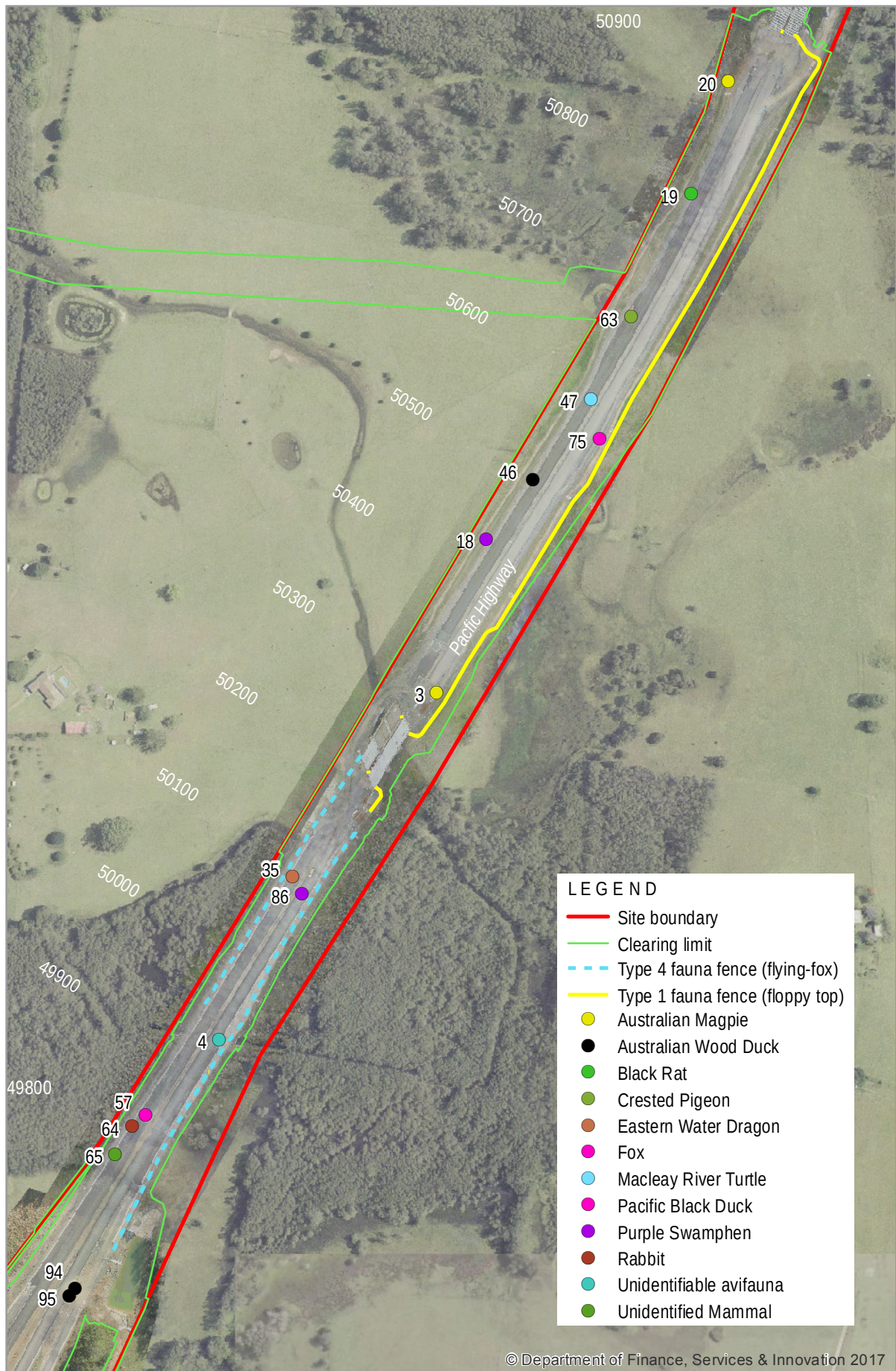
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WC2NH RMS Stage 2A Road Kill Monitoring Report
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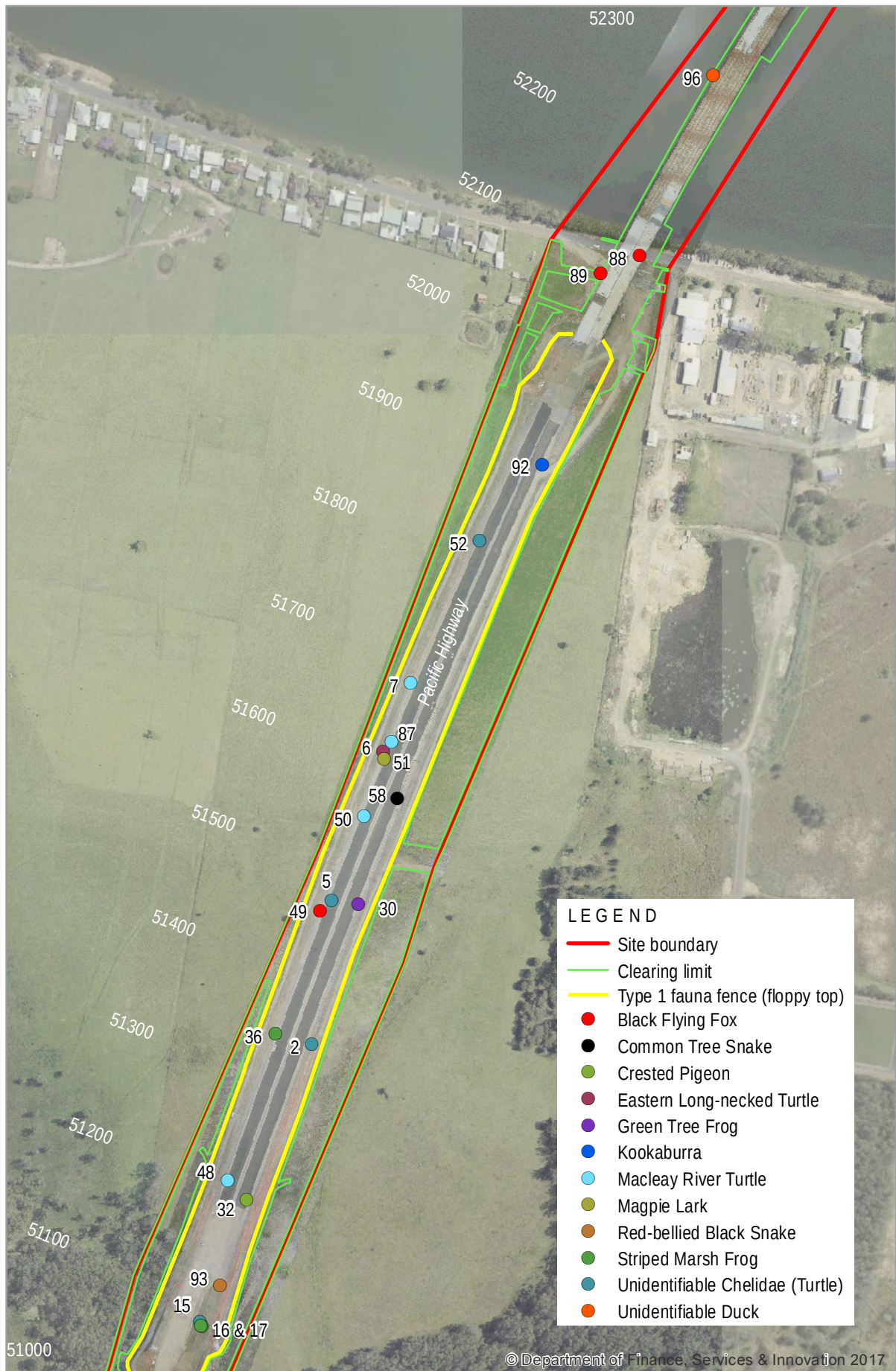
Road Kill Fauna Locations

Illustration 1.1



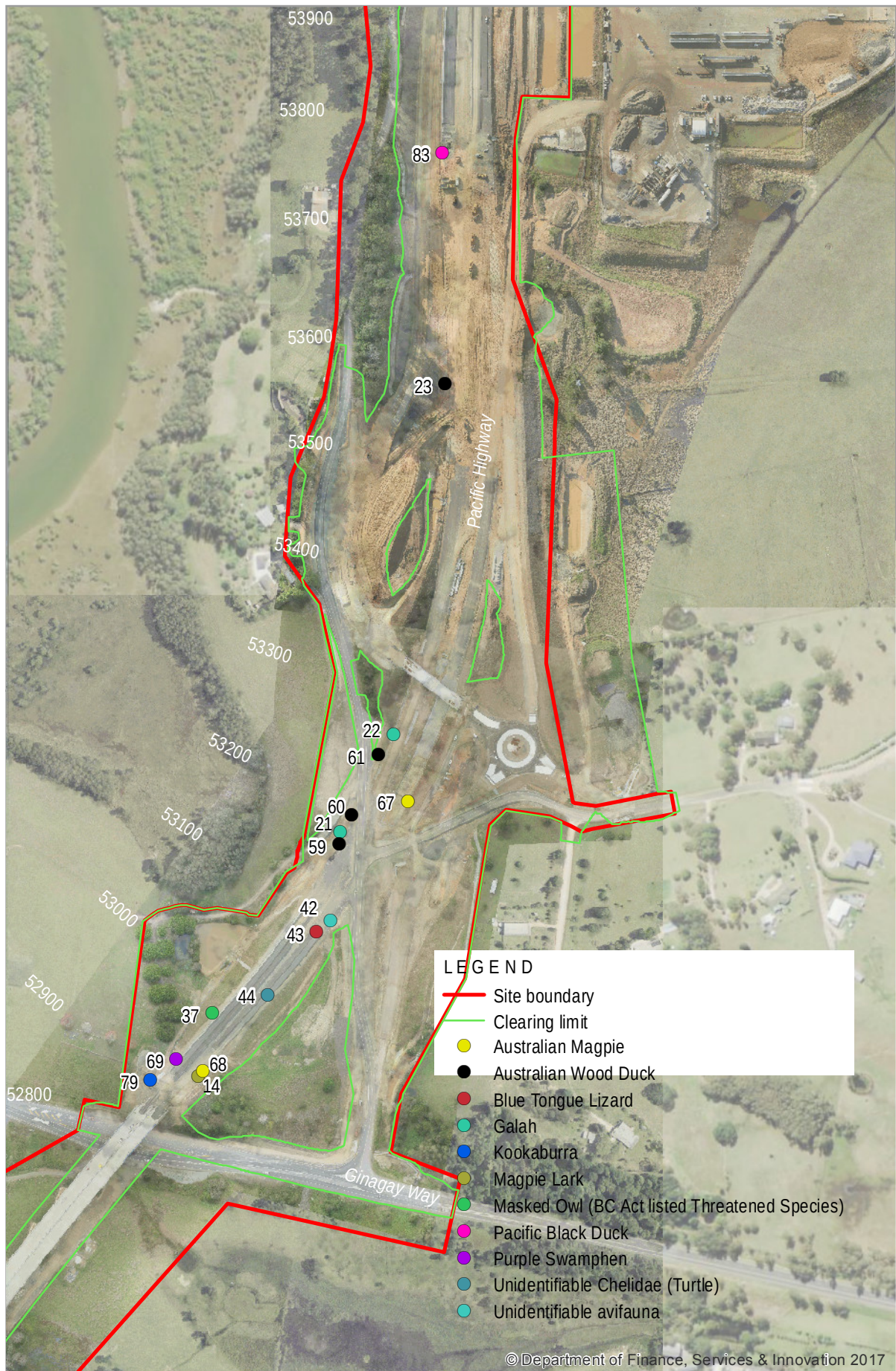
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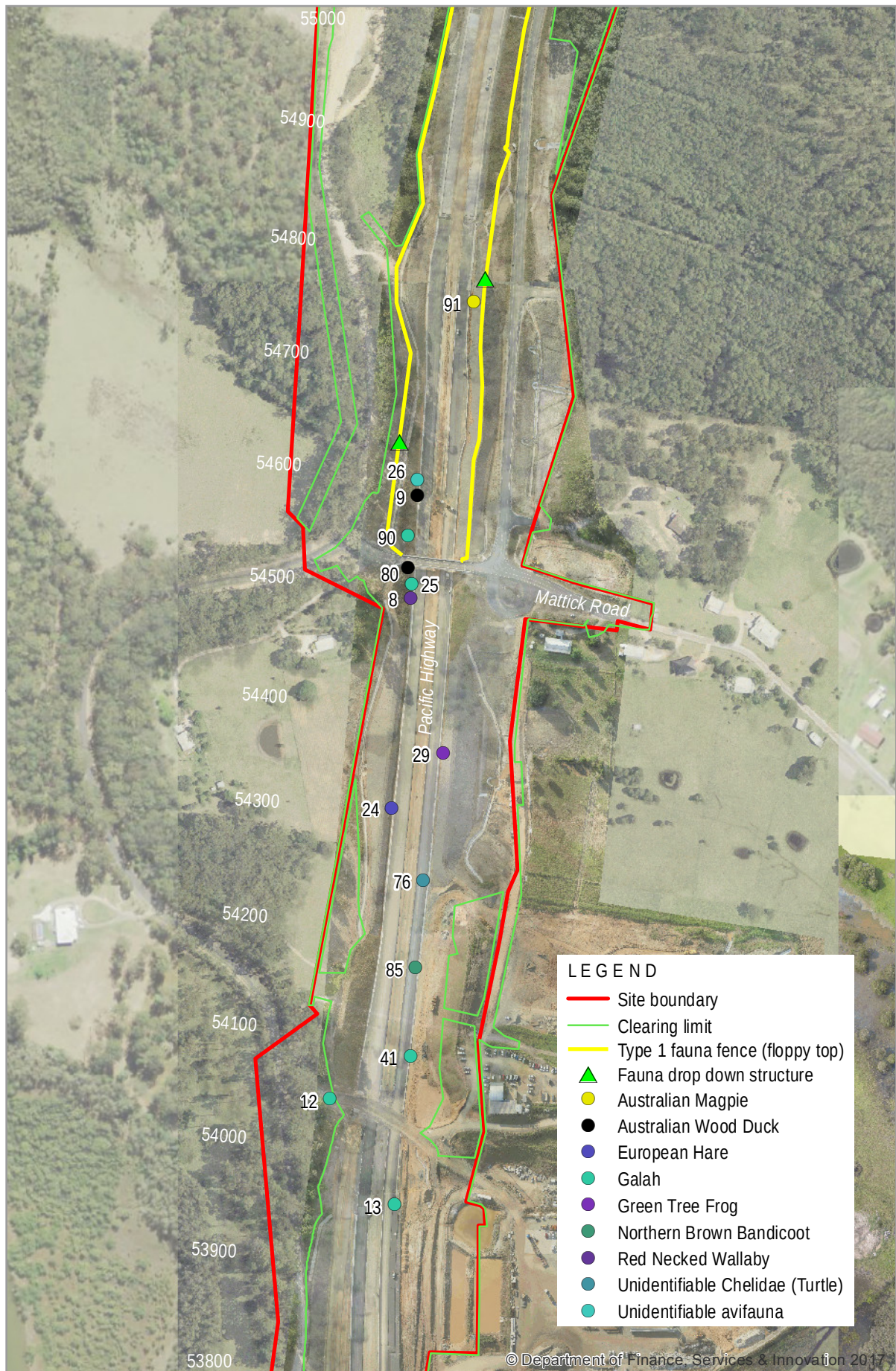
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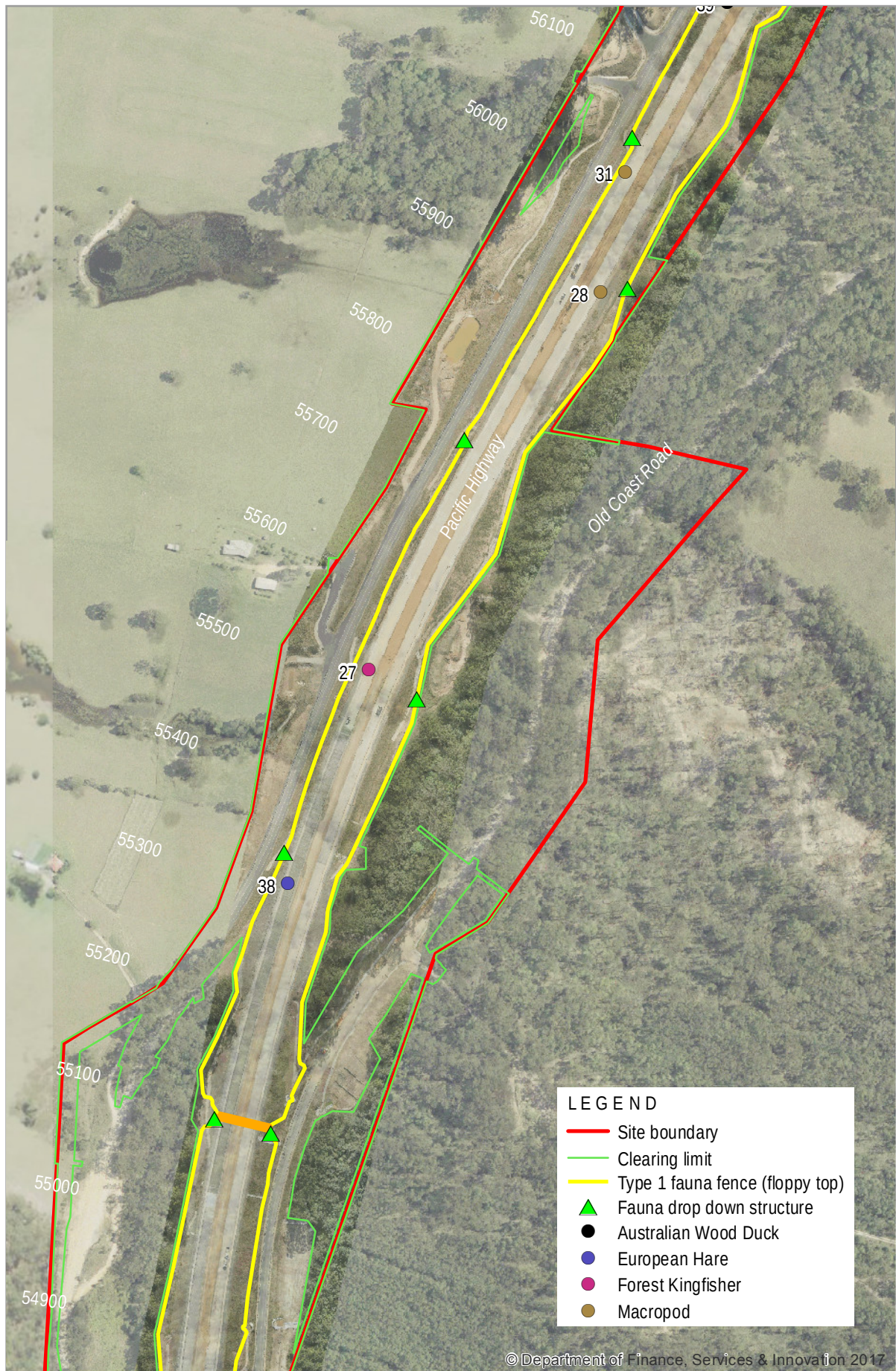
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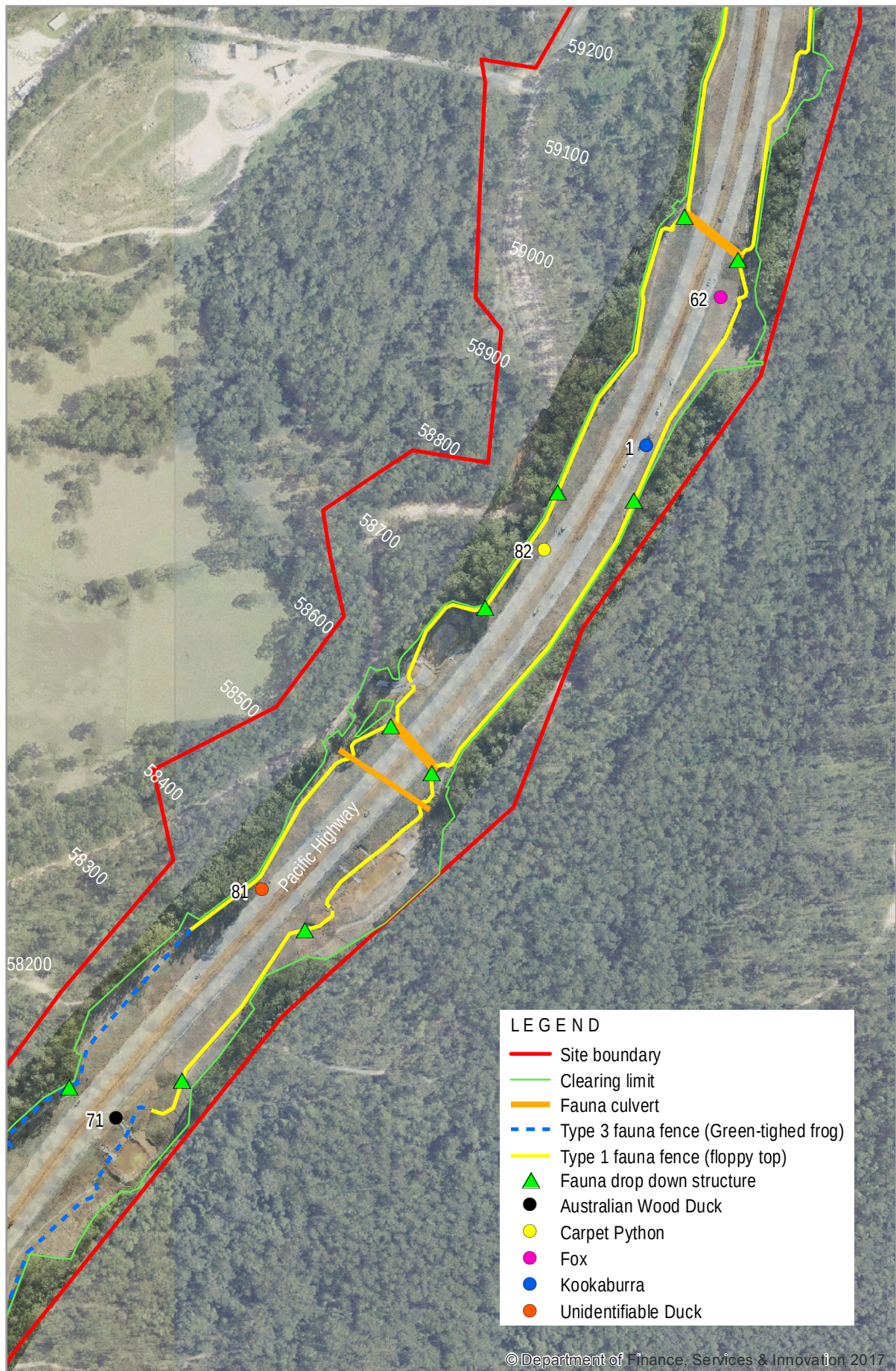
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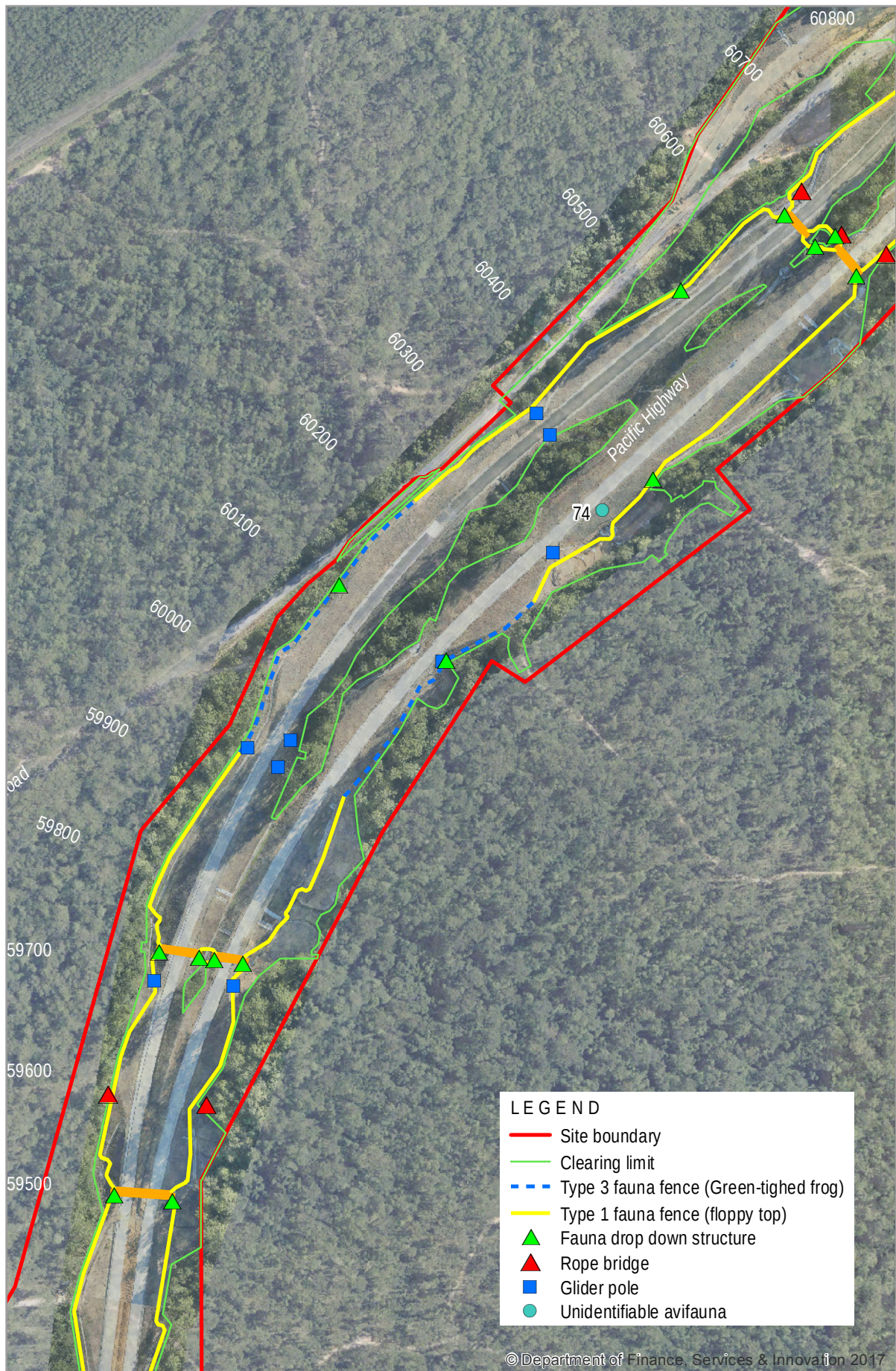


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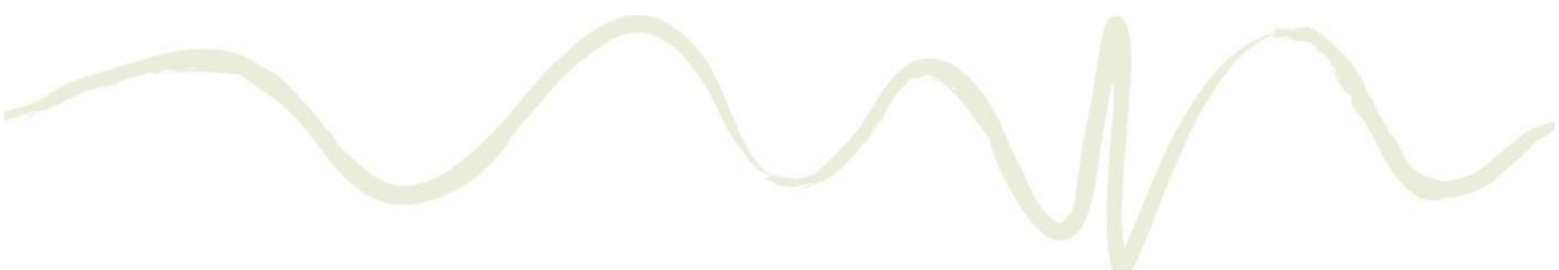
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2. Methodology

2.1 Road Kill Monitoring

Road kill monitoring for Stage 2A of WC2NH was undertaken weekly (each Thursday) for the first 12 weeks after the opening of Stage 2A to traffic. The Stage 2A site covers 13.3 km of dual carriageway highway extends from Scott's Heads Road in the south (Chainage 48100) to Nambucca Heads, connecting to the Nambucca Heads to Urunga Pacific Highway upgrade in the north (Chainage 61250). The survey area covered the north and southbound carriageways and has a combined length of 26.6 km of road (refer to **Illustration 1.1 - 1.9**). Of this, 19.04 km is fenced (71.5%) with either type 1 or type 4 fauna exclusion fencing. Type 3 fauna exclusion fencing (GTF exclusion fencing) occurs along 1.32 kms of the Type 1 fence length (GTF exclusion fencing is affixed to the bottom of the Type 1 fence).

The 12 weekly monitoring events commenced on 21 December 2017 and ended on 8 March 2018. The first pass of the survey area was undertaken within the first two hours of sunrise. The second and occasionally a third pass was undertaken to collect data not recorded during the first pass due to inaccessibility, no place to safely collect data at the time of observation or the record not being observed during the first pass.

Opportunistic road kill records were also observed on two days outside of the nominated weekly monitoring event. These records were collected on 9 January and 25 February 2018, and were grouped together with week 4 and 10 results respectively.

The following monitoring methodology was adopted:

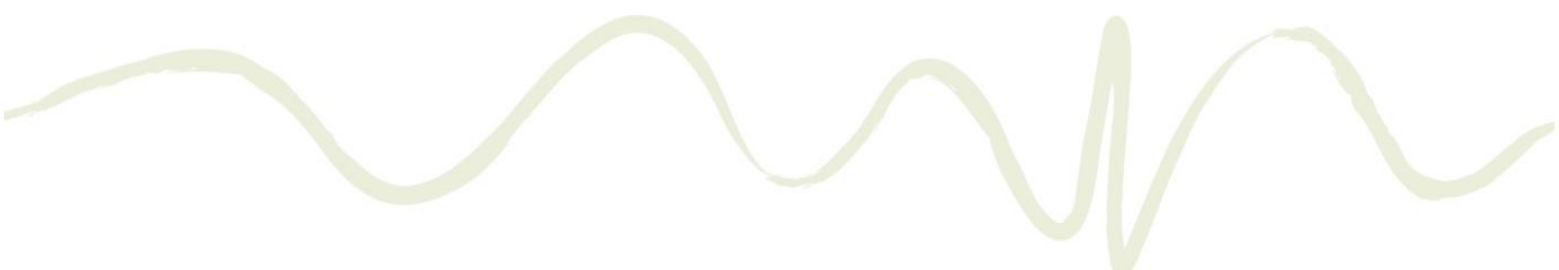
- A two-person team drove the length of Stage 2A in a vehicle to locate and identify fauna road mortalities, as a result of vehicle strike.
- The speed of travel averaged 60-70 kilometres per hour, with both the driver and ecologist visually searching for fauna road kill along the highway alignment and within 3m from the fog line.
- A minimum of two passes of the survey area was completed to ensure that all records were accurately detected and could be safely recorded.

For each road kill observed, the following attributes were recorded:

- Species of animal.
- Date of record.
- Global Positioning System (GPS) coordinates.
- Location of road kill record with in either the south or northbound carriageway.
- The presence of fauna fencing at/near to the road kill record.
- Distance to the nearest fauna fence if not installed adjacent to the road kill record.
- Photographic record of the animal.
- Comments.

If the animal was identified as an *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed threatened species, the carcass was photographed and the following information recorded:

- Sex and age class (juvenile or adult).
- Presence of pouch young (for marsupials).
- Presence of flightless young (for flying-foxes or other bats).

- 
- Distance to a fauna connectivity structure.
 - Distance to drop down structure.
 - If fauna fencing was installed, was there any damage to the fence in the vicinity.
 - Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase.
 - For flying-foxes:
 - Distance to nearest camp.
 - Distance to nearest canopy vegetation
 - Presence of flowering food trees in neighbouring median or roadside vegetation; plants identified to species and referenced with diet list.

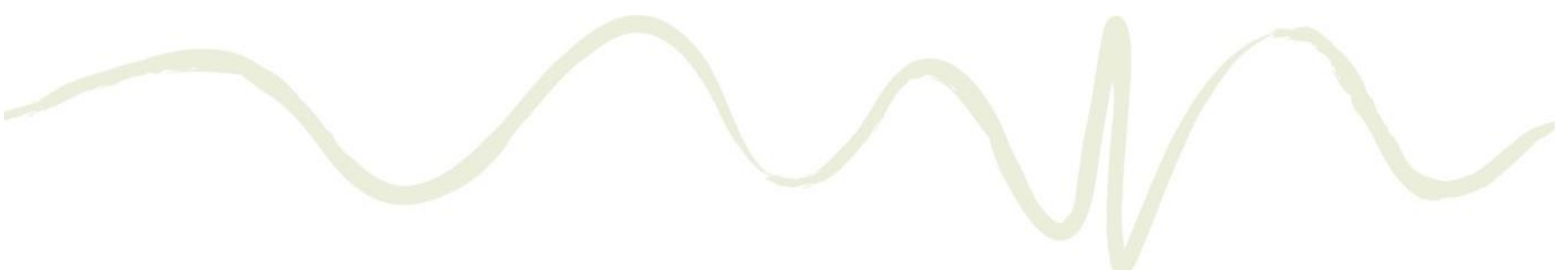
2.2 Analysis of Data

The data collected was analysed using two nonparametric tests: G-test and Kruskal-Wallis. The analysis aimed to determine:

- Whether the fenced and unfenced locations have different frequencies of road kills.
- If the amount of road kill varies through time for fenced and unfenced areas.

The G-test has been shown to be superior to the Chi-squared test for comparing frequency data where the expected proportions were not derived from the data. The G-test is a non-parametric log-likelihood test that conforms to a Chi-squared distribution. It tests the null hypothesis that the observed and expected frequencies do not differ (Dytham 2003). A G-test was applied to frequency data by pooling monitoring periods for both fenced and non-fenced areas. Expected proportions were taken from the proportion of total highway length (26.6 km) that was fenced (76.5%) versus unfenced (23.5%). A two-tailed G-test was conducted by programming the G-test into an Excel spreadsheet.

A Kruskal-Wallis (KW) test is a non-parametric equivalent of the one-way ANOVA. It is used when the assumptions of an ANOVA are violated (e.g. normality). The KW is a rank test that uses the null hypothesis that the samples are taken from populations with the same median (Dytham 2003). The KW test was used to compare the number of road kill over time by pooling fenced and non-fenced sites. Twelve monitoring periods were available for analysis. A two-tailed KW test using K independent samples was undertaken in SPSS.



3. Results

3.1 Number and Species of Fauna Road Kills

The results of the road kill surveys during the first 12 weeks of Stage 2A being operational are provided in **Appendix A**. A total of 94 fauna road mortalities were recorded during the 12 weekly monitoring events. Species diversity included 24 native species and five introduced species. The road kill recordings included:

- Fifty-five (59%) native avifauna (birds) comprising a minimum 11 confirmed species/species groups. This included one *Biodiversity Conservation Act 2016* (BC Act) listed threatened species, the Masked Owl (*Tyto novaehollandiae*) (refer to **Plates 1.1** and **1.2**).
- Nine (10%) native mammal comprising a minimum of four confirmed species/species groups including six macropod (including Red-necked Wallaby (*Macropus rufogriseus*) and Swamp Wallaby (*Wallabia bicolor*)), three Black Flying-Fox (*Pteropus alecto*) and one Northern Brown Bandicoot (*Isodon macrourus*) records.
- Eight (9%) introduced mammals comprising five species including three European Foxes (*Vulpes vulpes*), one cat (*Felis catus*), two European Hares (*Lepus europaeus*), a Rabbit (*Oryctolagus cuniculus*) and a Black Rat (*Rattus rattus*) record.
- Sixteen (17%) native reptiles comprising seven confirmed species, including 11 records of two turtle species, one record of two lizard species and one record of three snake species.
- Six (6%) frogs comprising two confirmed species (Striped March Frog (*Limnodynastes peronii*) and Green Tree Frog (*Litoria cerulea*)) and one record that was unidentifiable.

Two additional opportunistic road kill mortalities were recorded on two occasions with the following recordings:

- Macropod (9/01/2018).
- Black-flying Fox (25/02/2018).

Figures 3.1 and **3.2** shows the number of fauna road kills recorded each monitoring event over the 12 week monitoring period. The number of fauna mortality records peaked during week 2 of Stage 2A being operational with 20 road kill fauna records observed. Results indicate a general trend with the number of fauna road kill records declining over time. The last monitoring event of week 12 was the only monitoring event where no fauna mortalities were recorded. Heavy rainfall at the site during the week preceding this monitoring event is likely to have contributed to this result.

No road kill recordings of EPBC Act listed threatened species occurred during the monitoring.



Plate 1.1
Masked Owl road kill recorded 4 January 2018



Plate 1.2
Close up photo of Masked Owl road kill recorded 4 January 2018

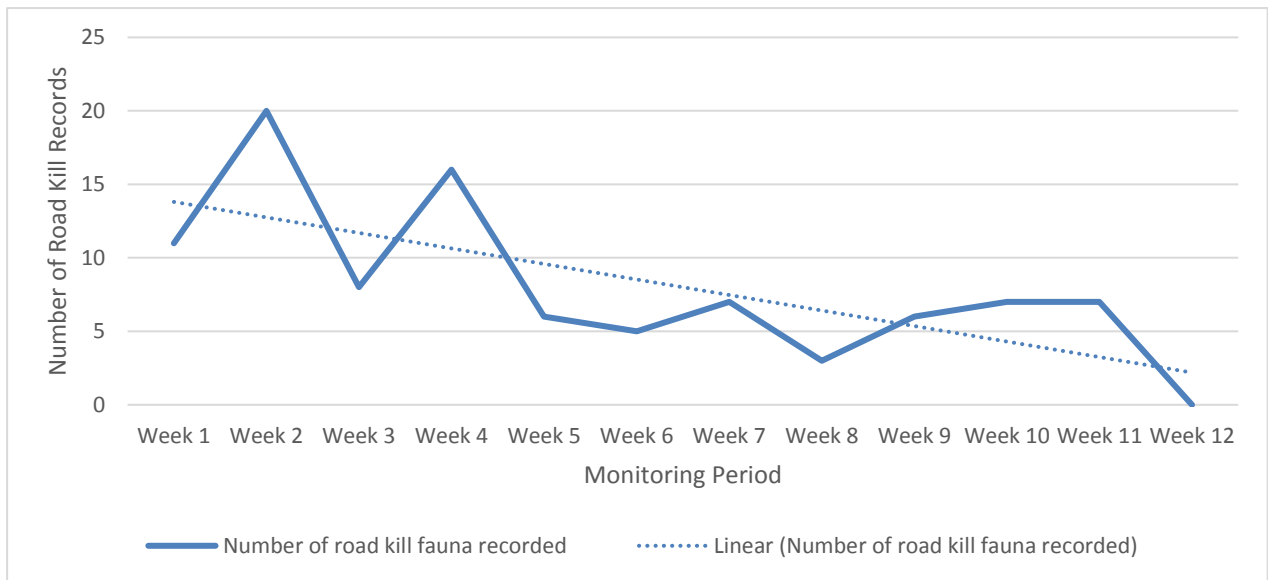


Figure 3-1

Number of fauna road kills recorded during each monitoring event and trend line

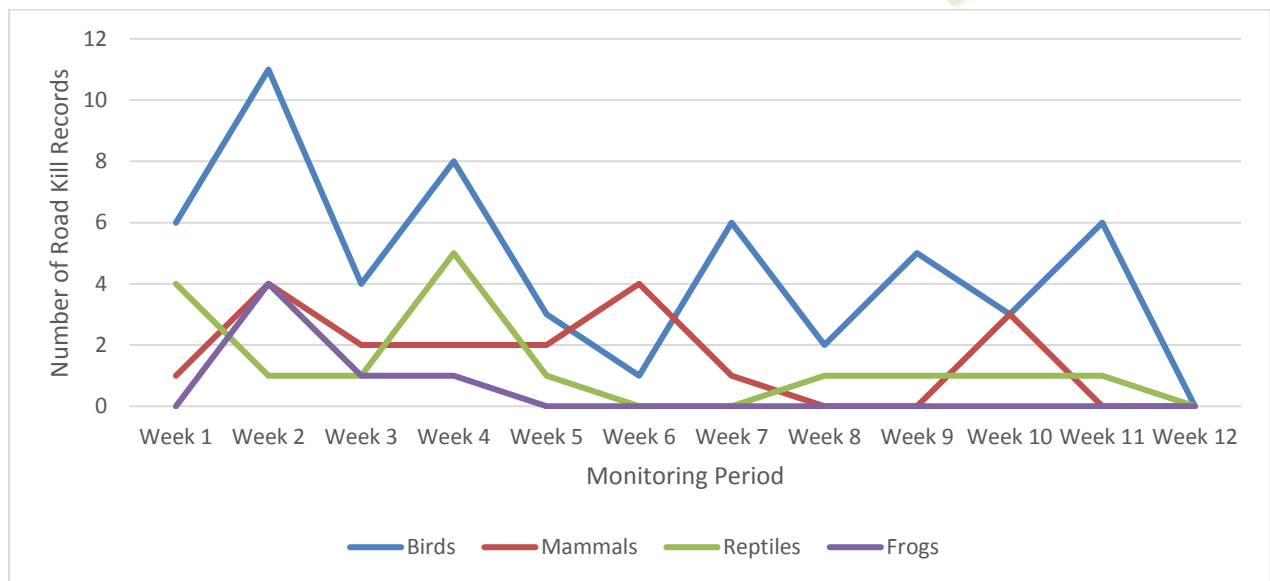


Figure 3-2

Number of road kill chordate class recorded over time

3.2 Distribution of Fauna Road Kill Records

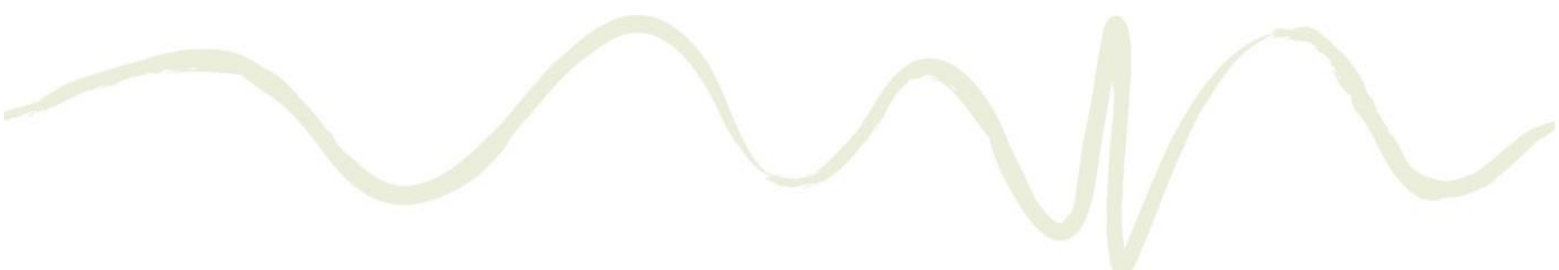
Illustration 1.1 - 1.9 shows the location of the road kill recording, including opportunistic results. Three main concentrations of road kill records were observed:

- Chainages 48300 to 49000 north from Lower Warrell Creek to the Macksville off-ramp at Bald Hill Road, where the majority of records were mammal species both native and introduced.
- Chainages 49700 and 52000 throughout the Gumma Floodplain. The majority of records were reptile and bird species.
- Chainages 52800 to 54900 from the north abutment of the Nambucca River Bridge to approximately 200 m north of the Mattick Road overpass, where the majority of records were birds particularly Galah and Australian Wood Duck.

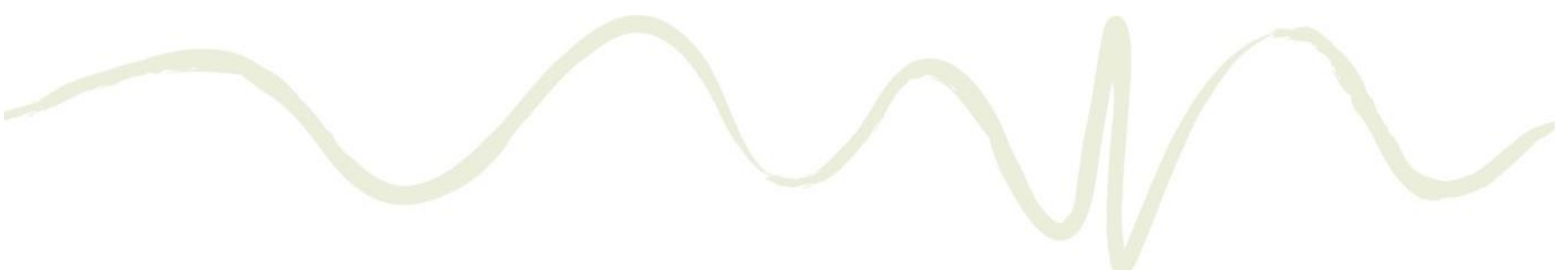
Of the 96 road kill fauna records (including opportunistic recordings), 58 records (60%) were located along the highway carriageway where fauna exclusion fence is installed. Twenty-nine of the 58 records (50%) were birds which are not prevented from entering the road corridor by fauna exclusion fencing due to their ability to fly. Thirty-eight (40%) of road kill records were located where no fauna exclusion fencing was installed, of which 26 records (68%) were birds.

A number of road kill fauna such as lizards, amphibians and snakes were also located within an area where fauna fencing is installed, outside the Type 3 (frog exclusion) fauna fenced area. The fauna fencing where these species were recorded comprised chainmesh fence holes and therefore would not restrict these species from accessing the road corridor. As with birds, the fencing does not restrict flying-foxes from flying over the fence, with three road kill records being observed (Black Flying-fox *Pteropus alecto*).

No flying-fox road kill records were made in the vicinity of the Type 4 fauna fencing (flying-fox fencing) between chainage 49700 and 50200. Flying-foxes were not recorded roosting in the adjacent swamp sclerophyll forest during the monitoring period (GeoLINK 2017/ 2018).



A concentration of turtle road kill records were observed within the Gumma Floodplain area which has fauna exclusion fencing installed the entire length from chainage 49650 to the southern abutment of the Nambucca River Bridge at chainage 52000).



4. Discussion

4.1 Discussion

One road kill of a BC Act listed species was recorded during the monitoring, which comprised a Masked Owl. No EPBC Act listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog.

Of the 96 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were relatively low (7) over the reporting period. No arboreal mammal road kills were recorded.

The majority of animals impacted by traffic have been bird species (55 individuals or 57%). Fauna exclusion fencing does not effectively mitigate against vehicle strike to birds due to their ability to fly over fauna fencing and into the road corridor. The recent application of hydroseed and hand seed to the newly topsoiled batters has attracted birds that consume seeds to the roadside (including ducks and Galah), particularly between Chainages 52800 to 54900. This area has recorded the largest concentration of birds which feed on grain and seeds initially attracted to the roadside.

The high number of turtles recorded within the Gumma Floodplain area compared to elsewhere on the project is likely attributable to suitable habitat on either side of the alignment, the source of the turtle population. Additionally, it is expected that the turtles affected by vehicle strike were located within the vegetation and low lying areas adjacent to the road when the fauna exclusion fence was installed, effectively trapping the turtles within the road side of the fenced highway corridor. A recommendation to undertake a pre-clearing walkthrough prior to opening roads to traffic in similar habitats has been suggested (refer to **Section 4.4**).

Results indicate that over the 12 week monitoring period numbers of recorded road kill fauna have reduced. This may be attributed to:

- Some species habituating to the presence of the road and associated traffic.
- Local population declines. This mainly applies to species with low mobility/small home range sizes. For example, the population of turtles within the fencing is likely to have reduced.
- Reductions in roadside food resources (e.g. recently applied seed mix germinating).

Several recommendations have been suggested (refer to **Section 4.4**) with the aim to further reduce fauna road kills in preparation for opening of Stage 2B to operational traffic.

4.2 Comparison with Construction Road Kill Monitoring

The road kill monitoring during February 2015 and February 2017 (25 months) undertaken during construction by the WC2NH contractor recorded 62 road kill mortalities. One EPBC Act listed road kill was recorded. It is not possible to make a meaningful comparison between this construction monitoring data and the subject operational monitoring data due to:

- Differences in survey methodologies, data collected and personnel skill levels.

- Construction monitoring targeting different locations (i.e. subject sections of WC2NH follows a different alignment to the old Pacific Highway).

Notwithstanding, when pooling the 52 construction phase roadkill monitoring results where chainages were recorded into 1km segments, the data anecdotally shows roadkill 'hotspots' at:

- Chainage 41001-42000 (Upper Warrell Creek locality): 6 roadkill recordings
- Chainage 44001-45000 (Rosewood Creek locality): 8 roadkill recordings.
- Chainage 49001-50000 (Warrell Creek locality): 7 roadkill recordings.

4.3 Analysis of Data

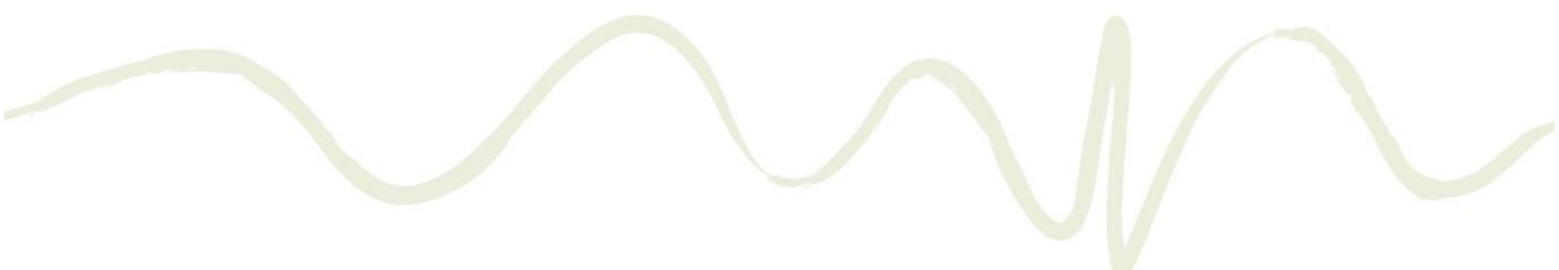
As few data were available, native and non-native non-flying mammals were pooled to increase sample size. Small ground mammals, such as rodents, were excluded because the exclusion mesh fencing does not provide a barrier to their movement. The data shown in **Table 4.1** was available for analysis.

Table 4.1 Summary of Road Kill Data Used in the Analyses

Survey Date	No. Mammal Road Kill (Fauna Fence)	No. Mammal Road Kill (No Fauna Fence)
21/12/2017	0	1
28/12/2017	2	1
4/01/2018	1	1
11/01/2018	0	0
18/01/2018	1	1
25/01/2018	3	0
1/02/2018	1	0
8/02/2018	0	0
15/02/2018	0	0
22/02/2018	0	1
1/03/2018	0	0
8/03/2018	0	0
Total	8	5

The G-test comparing fenced versus unfenced road kill frequencies produced $\chi^2 = 1.44$, $df = 1$, $p = 0.22$. The KW examining whether the amount of road kill changed over time for fenced and unfenced areas produced $\chi^2 = 14.44$, $df = 11$, $p = 0.21$. Thus, for both tests, the null hypothesis was accepted – that there was no difference between road kill numbers between fenced and non-fenced sections of the carriageway.

However, while the null hypothesis was accepted, this does not necessarily mean that there was no difference between fence and non-fenced areas or no change over time. Few road kill data were available for analysis and the test results could simply be an artefact of low statistical power. This could be remedied if more data were able to be collected, or to use additional data from other highway monitoring sites in a meta-analysis. To demonstrate that there is truly no difference in the data, the burden of proof is reversed and an equivalence test using the null hypothesis that there is a difference due to fencing or a change over time would be required. Equivalence tests use two one-tailed tests to determine whether the data fall within specific bounds that are assumed to indicate that there is no

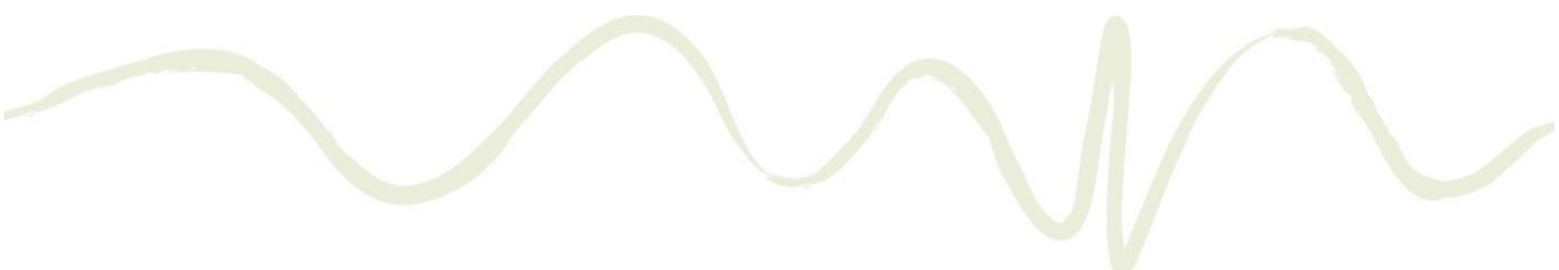


true difference (Quertemont 2011). The few road kill results may be attributed to the effectiveness of the fencing in preventing fauna access to the road way.

4.4 Observations

The following observations are provided to further augment road kill mitigations on WC2NH (including the upcoming Stage 2B opening) or to incorporate into future road kill mitigation strategies:

- Should the trend of mammal road kill records continue at Lower Warrell Creek continue a review of the fauna fence and fauna drop down structure configuration on the south-eastern side of the Lower Warrell Creek Bridge northern abutment is suggested. The design could be improved by:
 - Constructing an additional fauna drop down structure on the south-eastern side of the Lower Warrell Creek Bridge northern abutment. This will allow fauna which access the road corridor a second more accessible option to escape into adjoining vegetation and away from the road corridor; and/or
 - Extend fauna fence on western side to chainage 49000.
- In response to relatively high levels of bird strike north of the Nambucca river bridge allow sufficient time for seed applications in proximity to the roadway to grow prior to opening WC2NH Stage 2B to public traffic.
- To reduce the potential for road kill records similar to the Gumma Floodplain, it is suggested that an ecologist inspection would be undertaken to capture and relocate any fauna contained within the fauna fencing prior to opening the highway. This would include salvage of turtles in aquatic habitats contained within the fencing to reduce similar incidences of turtle mortalities as observed throughout the Gumma Floodplain area.



5. Summary and Conclusion

One road kill of a BC Act listed species was recorded during the monitoring, which comprised a Masked Owl. No EPBC Act listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog.

Of the 96 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were relatively low (7) over the reporting period. No arboreal mammal road kills were recorded.

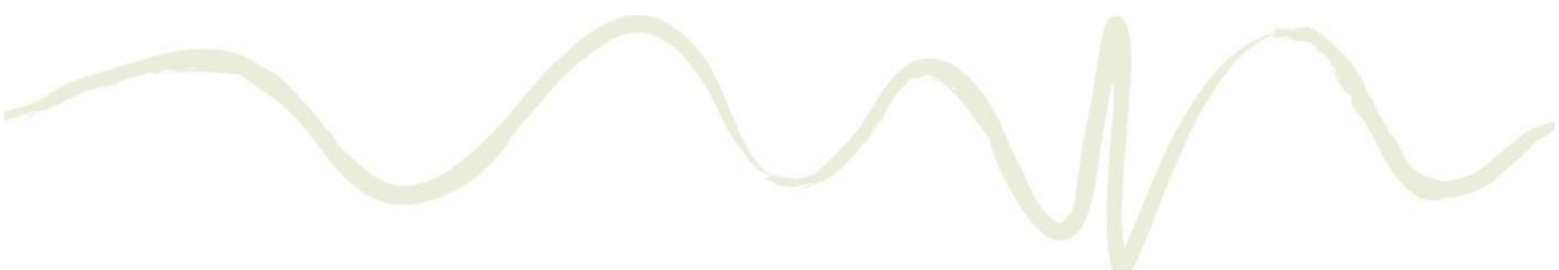
Three road kill hotspots were identified across Stage 2A including the Gumma Floodplain, north of the Nambucca River Bridge and to a lesser degree the section from north of Lower Warrell Creek to the Bald Hill overpass.

No flying-fox road kill records were made in the vicinity of the Type 4 fauna fencing (flying-fox fencing) between chainage 49700 and 50200, though the camp was not occupied during the monitoring.

The results show a declining trend in the number of road kills across the survey area for all fauna classes over time. This may be attributed to a number of factors including reduction of roadside food sources which attract fauna to the corridor, habituation of the road to fauna or local populations of certain species have temporarily declined as a direct result of vehicle collisions.

Statistical analysis to determine the effectiveness of the fauna fencing does not contain strong statistical power due to the small results data pool, particularly of relevant fauna groups (i.e. medium to large sized terrestrial mammals). The results of future monitoring should be consolidated to develop a larger data set to allow for future statistical analysis.

A number of recommendations have been suggested as lessons learnt in preparation for the opening of Stage 2B of the WC2NH Pacific Highway Upgrade.



References

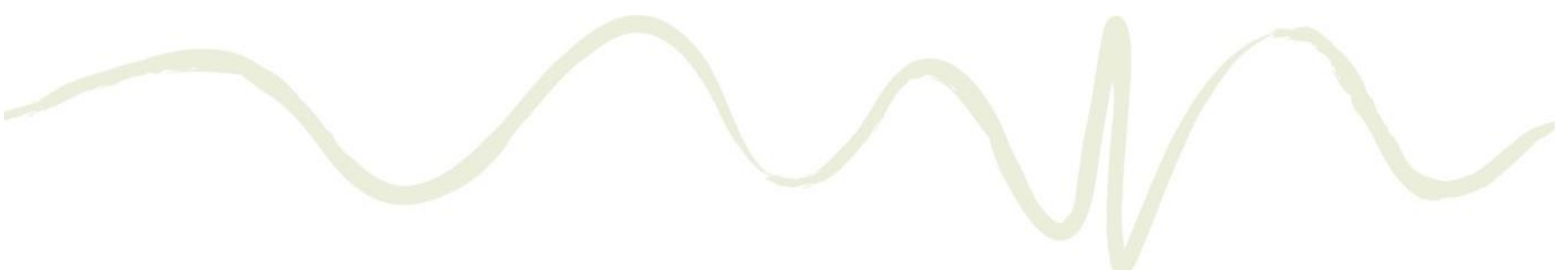
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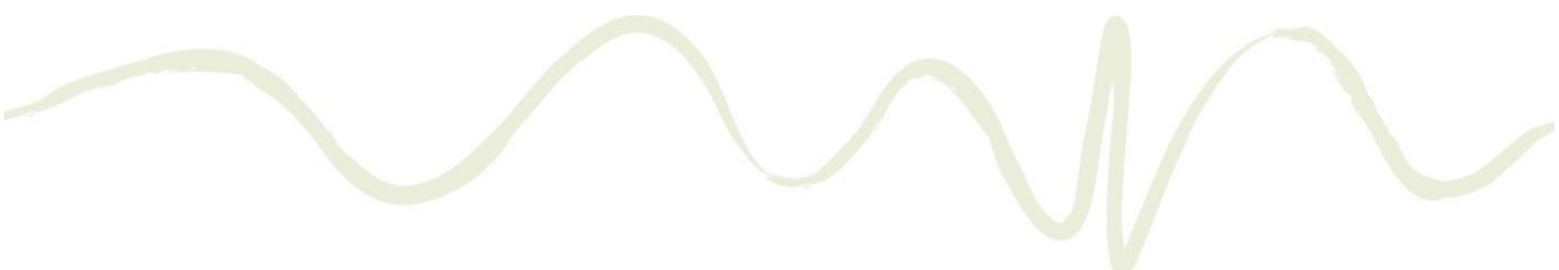
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Appendix A

Stage 2A Road Kill Monitoring Results

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
Week 1	1	Kookaburra (<i>Dacelo novaeguineae</i>)	Bird	21/12/2017	496419	6608561	South	Near old Gate 17	Yes	-	
	2	Unidentifiable <i>Chelidae</i> (Turtle) species (<i>Emydura macquarii</i> subsp. <i>dharra</i>) or (<i>Chelodina longicollis</i>)	Reptile	21/12/2017	493414	6601843	South	Gumma Floodplain sth of NR Bridge	Yes	-	-
	3	Australian Magpie (<i>Cracticus tibicen</i>)	Bird	21/12/2017	492952	6600885	South	Gumma Floodplain north of southbound Bald Hill off ramp	Yes	-	
	4	Unidentifiable black avifauna	Bird	21/12/2017	492759	6600577	South	Flying Fox Swamp Forest Community	Yes	-	Very damaged and inaccessible due to location in the fast lane
	5	Unidentifiable <i>Chelidae</i> (Turtle) species (<i>Emydura macquarii</i> subsp. <i>dharra</i>) or (<i>Chelodina longicollis</i>)	Reptile	21/12/2017	493431	6601971	North	Gumma Floodplain	Yes	-	Very damaged shell fragments only
	6	Eastern Long-necked Turtle (<i>Chelodina longicollis</i>) (probable)	Reptile	21/12/2017	493477	6602102	North	Gumma Floodplain	Yes	-	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	East ing	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	7	Macleay River Turtle (<i>Emydura macquarii subsp.dharra</i>) (possible)	Reptile	21/12/2017	4935 01	6602 163	North	Gumma Floodplain	Yes	-	-
	8	Red Necked Wallaby (<i>Macropus rufogriseus</i>)	Mammal	21/12/2017	4944 38	6604 735	North	Beneath Mattick Road overpass	No	50m	Adult male
	9	Australian Wood Duck (<i>Chenonetta jubata</i>)	Bird	21/12/2017	4944 45	6604 826	North	North of Mattick Road overpass	Yes	-	-
	10	Australian Wood Duck	Bird	21/12/2017	4950 82	6606 572	North	Near Sheather property	Yes	-	-
	11	Australian Wood Duck (possible)	Bird	21/12/2017	4950 97	6606 594	North	Near Sheather property	Yes		-
Week 2	12	Galah (<i>Eolophus roseicapilla</i>)	Bird	28/12/2017	4943 67	6604 291	South	North Compound	No	>100 m n/a to birds	-
	13	Galah	Bird	28/12/2017	4944 24	6604 196	South	North Compound	No	>100 m n/a to birds	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	East ing	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	14	Magpie Lark (<i>Grallina cyanoleuca</i>)	Bird	28/12/2017	494168	6603197	South	North of Nambucca River Bridge	No	>100 m n/a to birds	-
	15	Unidentifiable <i>Chelidae</i> (Turtle) species (<i>Emydura macquarii</i> subsp.dharra) or (<i>Chelodina longicollis</i>)	Reptile	28/12/2017	493314	6601597	South	Near Floodplain Bridge 2 Gumma Floodplain	Yes	-	Very damaged fragments remain
	16 & 17	Two x Striped Marsh Frog (<i>Limnodynastes peronii</i>)	Amphibian	28/12/2017	493316	6601593	South	Near Floodplain Bridge 2 Gumma Floodplain	Yes	-	-
	18	Purple Swamphen (<i>Porphyrio porphyrio</i>)	Bird	28/12/2017	492996	6601021	south	Gumma Floodplain near Flying Fox camp	Yes	-	-
	19	Black Rat (<i>Rattus rattus</i>)	Mammal*	28/12/2017	493177	6601328	North	Gumma Floodplain	Yes	-	-
	20	Australian Magpie	Bird	28/12/2017	493211	6601427	North	Near Floodplain Bridge 2 Gumma Floodplain	Yes	-	-
	21	Galah	Bird	28/12/2017	494295	6603413	North	South of Old Coast Road Overpass	No	>100 m n/a to birds	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	East ing	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	22	Galah	Bird	28/12/2017	4943 41	6603 499	North	South of Old Coast Road Overpass	No	>100 m n/a to birds	-
	23	Australian Wood Duck (likely)	Bird	28/12/2017	4943 87	6603 811	North	Macksville north facing on ramp	No	>100 m n/a to birds	Smeared feathers consistent colours with Wood Duck
	24	European Hare (<i>Lepus europaeus</i>)	Mammal*	28/12/2017	4944 22	6604 549	North	South of Mattick Road	No	>100 m	-
	25	Australian Wood Duck	Bird	28/12/2017	4944 37	6604 762	North	Beneath Mattick Road overpass	No	~10m	-
	26	Unidentifiable avifauna	Bird	28/12/2017	4944 45	6604 839	North	North Mattick Road overpass	Yes	-	Only a wing fragment remains
	27	Forest Kingfisher (<i>Todiramphus macleayii</i>)	Bird	28/12/2017	4946 34	6605 718	North	Near Hartman property	Yes	-	-
	28	Macropod (likely, large blood stain)	Mammal	28/12/2017	4948 40	6606 053	North	South of Sheather property	Yes	-	Fauna Drop Down Structure approximately 15 m from record (eastern side). Fauna drop down structure

Monitoring Week	No. of Records	Species	Class of Chordate	Date	East ing	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
											on the western side of highway was not open and functioning at time of monitoring
	29	Green Tree Frog (<i>Litoria caerulea</i>)	Amphibian	28/12/2017	4944 67	6604 598	South	South of Mattick Road	No	>100 m n/a to frogs not applicable	-
	30	Green Tree Frog	Amphibian	28/12/2017	4934 55	6601 967	South	Gumma Floodplain	Yes	-	-
	31	Macropod (likely, large blood stain)	Mammal	28/12/2017	4948 62	6606 159	South	South of Sheather property	Yes	-	Fauna Drop Down Structure approximately 20 m from record however not open and functioning at time of monitoring

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easti ng	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
Week 3	32	Crested Pigeon (<i>Ocyphaps lophotes</i>)	Bird	4/01/2018	4933 56	6601 705	South	Near Floodplain Bridge 2 Gumma Floodplain	Yes	-	-
	33	Australian Wood Duck	Bird	4/01/2018	4924 76	6600 014	South	Bald Hill Road overpass	No	>100 m and n/a to birds	-
	34	Swamp Wallaby (<i>Wallabia bicolor</i>)	Mammal	4/01/2018	4924 67	6599 542	North	South of Bald Hill Road overpass	No	~100 m	-
	35	Eastern Water Dragon (<i>Intellagama lesueurii</i>)	Reptile	4/01/2018	4928 24	6600 722	North	Gumma Floodplain near Flying Fox camp	Yes	-	-
	36	Striped Marsh Frog	Amphibian	4/01/2018	4933 81	6601 852	North	South of Nambucca River Bridge	Yes	-	-
	37	Masked Owl (<i>Tyto novaehollandiae</i>)	Bird	4/01/2018	4941 81	6603 252	North	Near Mrs. Woods north of Nambucca River Bridge	No	>100 m n/a to birds	Listed as Vulnerable in NSW
	38	European Hare	Mammal*	4/01/2018	4945 63	6605 528	North	South of Hartman Property	Yes	-	-

Monitor ing Week	No. of Records	Species	Class of Chordate	Date	Easti ng	North ing	North or south bound d lane	Location Description	Fauna fence install ed adjace nt Y/N	Dista nce to neare st fauna fence	Comments
	39	Australian Wood Duck	Bird	4/01/2018	4949 52	6606 310	North	Nambucca State Forest	Yes	-	-
Opportu nistic	40	Macropod	Mammal	9/01/2018	4924 43	6599 694	North	Macksville off ramp 300 m south of Bald Hill overpass	No	>100 m to LWC fauna fence	Badly damaged likely hit over the weekend
Week 4	41	Galah	Bird	11/01/2018	4944 39	6604 328	South	North Compound	No	>100 m	-
	42	Unidentifiable black and white avifauna	Bird	11/01/2018	4942 86	6603 334	South	South of Nambucca River Bridge	No	>100 m	-
	43	Blue Tongue Lizard (<i>Tiliqua sp.</i>)	Reptile	11/01/2018	4942 74	6603 324	South	South of Nambucca River Bridge	No	>100 m	-
	44	Unidentifiable <i>Chelidae</i> (Turtle) species (<i>Emydura macquarii</i> subsp. <i>dharra</i>) or (<i>Chelodina longicollis</i>)	Amphibian	11/01/2018	4942 30	6603 269	South	Southern abutment of Nambucca River Bridge	No	>100 m	Badly damaged skin fragments only
	45	Australian Wood Duck	Bird	11/01/2018	4924 95	6600 170	North	North of Bald Hill on ramp	No	>100 m	-
	46	Australian Wood Duck	Bird	11/01/2018	4930 37	6601 074	Centr e of media n	Gumma Floodplain	Yes	-	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easti ng	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	47	Macleay River Turtle (<i>Emydura macquarii subsp.dharra</i>) possible	Reptile	11/01/2018	493088	6601146	South	Gumma Floodplain south of Flood Plain Bridge 2	Yes	-	Inaccessible within the fast lane
	48	Macleay River Turtle (<i>Emydura macquarii subsp.dharra</i>) possible	Reptile	11/01/2018	493339	6601722	Centre of median	Gumma Floodplain south of Flood Plain Bridge 2	Yes	-	
	49	Black Flying Fox (<i>Pteropus alecto</i>)	Mammal	11/01/2018	493421	6601962	North	Gumma Floodplain	Yes	-	Inaccessible within the centre median
	50	Macleay River Turtle (<i>Emydura macquarii subsp.dharra</i>) (possible)	Reptile	11/01/2018	493460	on6602045	North	Gumma Floodplain 200 m south of Nambucca River Bridge	Yes	-	-
	51	Magpie Lark possible	Bird	11/01/2018	493478	6602096	North	Gumma Floodplain 200 m south of Nambucca River Bridge	Yes	-	-
	52	Unidentifiable <i>Chelidae</i> (Turtle) species (<i>Emydura macquarii subsp.dharra</i>) or (<i>Chelodina longicollis</i>)	Reptile	11/01/2018	493563	6602290	North	Gumma Floodplain 100m south of Nambucca River Bridge	Yes	-	-
	53	Australian Wood Duck	Bird	11/01/2018	495071	6606557	North	Near Sheather property	Yes	-	-

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easti ng	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	54	Australian Wood Duck (possible)	Bird	11/01/2018	4950 78	6606 545	North	Near Sheather property	Yes	-	Not clearly visible although waterbird feet are discernible
	55	Australian Wood Duck (possible)	Bird	11/01/2018	4950 97	6606 589	North	Near Sheather property	Yes	-	Not clearly visible although waterbird feet are discernible
Week 5	56	Swamp Wallaby (possible)	Mammal	18/01/2018	4924 68	6599 568	North	South of Bald Hill off ramp	No	100 m to the south west	Very badly damaged skin, fur and feet remain.
	57	Fox (<i>Vulpes vulpes</i>)	Mammal*	18/01/2018	4926 93	6600 511	North	Flying Fox Swamp Forest Community	Yes	-	Badly damaged and dry and flat
	58	Common Tree Snake (<i>Dendrelaphis punctulatus</i>)	Reptile	18/01/2018	4934 90	6602 061	South	Gumma 200m south of Nambucca River Bridge	yes	n/a	-
	59	Australian Wood Duck (possible)	Bird	18/01/2018	4942 94	6603 402	North	North of Nambucca River Bridge	No	>100 m n/a to birds	Very flat/ damaged

Monitoring Week	No. of Records	Species	Class of Chordate	Date	East ing	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	60	Australian Wood Duck (possible)	Bird	18/01/2018	4943 04	6603 428	North	North of Nambucca River Bridge	No	>100 m n/a to birds	Very flat/damaged
	61	Australian Wood Duck (possible)	Bird	18/01/2018	4943 28	6603 482	North	North of Nambucca River Bridge	No	>100 m n/a to birds	Very flat/damaged
Week 6	62	Fox	Mammal*	25/01/2018	4964 85	6608 693	South bound	Nambucca State Forest	Yes	-	Flat Fox
	63	Crested Pigeon	Bird	25/01/2018	4931 24	6601 219	North bound	Gumma south of Flood Plain Bridge 2	Yes	-	-
	64	Rabbit (<i>Oryctolagus cuniculus</i>) (possible)	Mammal*	25/01/2018	4926 82	6600 500	North bound	Flying Fox Swamp Forest Community	Yes	-	Very damaged possible Rabbit
	65	Unidentifiable terrestrial mammal	Mammal	25/01/2018	4926 67	6600 476	North bound	Flying Fox Swamp Forest Community	Yes	-	Very badly damaged undiscernible mammal species
	66	Cat (<i>Felis catus</i>)	Mammal*	25/01/2018	4924 30	6599 185	South bound	Lower Warrell Creek northern abutment	Yes	-	-

<i>Monitoring Week</i>	<i>No. of Records</i>	<i>Species</i>	<i>Class of Chordate</i>	<i>Date</i>	<i>Easti ng</i>	<i>North ing</i>	<i>North or south bound lane</i>	<i>Location Description</i>	<i>Fauna fence installed adjacent Y/N</i>	<i>Distance to nearest fauna fence</i>	<i>Comments</i>
Week 7	67	Australian Magpie	Bird	1/02/2018	494354	6603440	South bound	200 m north of northern abutment of Nambucca River Bridge	No	>100 m n/a to birds	3m east of fog line
	68	Australian Magpie	Bird	1/02/2018	494173	6603201	South bound	North abutment Nambucca River Bridge	No	>100 m n/a to birds	-
	69	Purple Swamphen	Bird	1/02/2018	494149	6603211	North bound	Near Mrs Woods house	No	>100 m n/a to birds	-
	70	Australian Wood Duck	Bird	1/02/2018	495228	6606818	North bound	North of Sheather property	Yes	-	-
	71	Australian Wood Duck	Bird	1/02/2018	495949	6607964	South bound	State forest near perm basin	Yes	-	-
	72	Fox	Mammal*	1/02/2018	492439	6599197	South bound	North of Lower Warrell Creek	Yes	-	Also very damaged but reddish fur and back feet shape indicate Fox
	73	Australian Wood Duck (possible)	Bird	1/02/2018	495197	6606689	South bound	Old Selection Drive property	Yes	-	Very damaged but feather colour indicates

Monitoring Week	No. of Records	Species	Class of Chordate	Date	East ing	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
											Australian Wood Duck
Week 8	74	Unidentifiable avifauna	Bird	8/02/2018	4969 64	6609 797	South bound	State forest near widened median	Yes	-	Not accessible due to location at edge of southbound fast lane. Badly damaged dark brown feathers with tan barring. Possibly bird of prey (e.g. brown falcon) or tawny frogmouth
	75	Pacific Black Duck (<i>Anas superciliosa</i>)	Bird	8/02/2018	4930 96	6601 110	South bound/ Centre median	Gumma Flood Plain 300 m north of Flying Fox Swamp Forest Community	Yes	-	Not accessible due to position within the centre median
	76	Unidentifiable <i>Chelidae</i> (Turtle) species (<i>Emydura macquarii</i>)	Reptile	8/02/2018	4944 50	6604 485	South bound	Near the North Compound	No	>100 m n/a to birds	Very badly damaged shell remains

Monitoring Week	No. of Records	Species	Class of Chordate	Date	East ing	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
		subsp.dharra) or (Chelodina longicollis)									
Week 9	77	Australian Magpie	Bird	15/02/2018	4924 62	6599 574	North bound	200 m south of Bald Hill Road overpass	No	~100 m and n/a to birds	-
	78	Australian Magpie	Bird	15/02/2018	4925 20	6600 235	North bound	150 m north of Bald Hill Road overpass	No	n/a to birds	-
	79	Kookaburra	Bird	15/02/2018	4941 26	6603 193	North bound	South abutment of Nambucca River Bridge	No	>100 m n/a to birds	Not accessible due to location at edge of northbound fast lane
	80	Galah	Bird	15/02/2018	4944 39	6604 747	North bound	10 m south of Mattcik Road Overpass	No	~10m n/a to birds	Not accessible due to location at edge of northbound fast lane
	81	Unidentifiable duck	Bird	15/02/2018	4960 78	6608 168	North bound	100 m south of old Gate 13 access	Yes	-	-
	82	Carpet Python (Morelia spilota)	Reptile	15/02/2018	4963 29	6608 469	North bound	Nambucca State Forest	Yes	n/a to snakes	-
Week 10	83	Pacific Black Duck	Bird	22/02/2018	4943 85	6604 016	North bound	Old Coast Road on ramp	No	>100 m n/a to birds	In drain grate washed in from pavement

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easti ng	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
	84	Tawny Frogmouth (<i>Podargus strigoides</i>)	Bird	22/02/2018	4950 46	6606 441	South bound	Near Sheather property	Yes	-	Quite fresh 1-2 days old
	85	Northern Brown Bandicoot (<i>Isoodon macrourus</i>)	Mammal	22/02/2018	4944 43	6604 407	South bound	North Compound	No	>100 m	Identified by toe arrangement, and fur colouration otherwise very damaged carcass
	86	Purple Swamphen	Bird	22/02/2018	4928 32	6600 707	South bound	Fying Fox Swamp Forest Community	Yes	-	Quite fresh 1-2 days old
	87	Macleay River Turtle (<i>Emydura macquarii subsp.dharra</i>) (possible)	Reptile	22/02/2018	4934 84	6602 111	North bound	Gumma Floodplain 200m south of Nambucca River Bridge	Yes	-	-
	88	Black Flying Fox	Mammal	22/02/2018	4937 04	6602 543	South bound	Southern abutment of Nambucca River Bridge	No	>100 m n/a to Flying-fox	No pic due to location not safe to stop
Opportunistic	89	Black Flying Fox	Mammal	25/02/2018	4936 70	6602 527	North bound	Southern abutment of Nambucca River Bridge	No	~100 m n/a to Flying-fox	Appeared to be juvenile, no pic due to location not safe to stop

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easti ng	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
Week 11	90	Galah	Bird	1/03/2018	4944 36	6604 790	North bound	10 m north of Mattick Road overpass	Yes	-	Clear Galah record
	91	Australian Magpie	Bird	1/03/2018	4944 95	6604 998	South bound	200 m north of Mattick Road O/P	Yes	-	Clear Magpie record, no access to remove carcass due to location at edge of fast lane
	92	Kookaburra	Bird	1/03/2018	4936 18	6602 357	South bound	100 m south of south abutement of Nambucca River Bridge	Yes	-	Very damaged record
	93	Red-bellied Black Snake (<i>Pseudechis porphyriacus</i>)	Reptile	1/03/2018	4933 32	6601 629	South bound	50 m north of Flood Plain Bridge 2 Gumma Floodplain	Yes	n/a to snakes	Younger animal, approximately <1m long
	94	Australian Wood Duck	Bird	1/03/2018	4926 31	6600 356	South bound	400 m north of Bald Hill Road overpass	No	>50m n/a to birds	No access, carcass in middle of the traffic lane
	95	Australian Wood Duck	Bird	1/03/2018	4926 26	6600 350	North bound	395 m north of Bald Hill Road overpass	No	>50m n/a to birds	Smear of feathers likely to be Duck species. No access carcass in

Monitoring Week	No. of Records	Species	Class of Chordate	Date	East ing	North ing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
											middle of the traffic lane
	96	Unidentifiable duck	Bird	1/03/2018	4937 70	6602 703	North bound	Crest of Nambucca River Bridge	No	>100 m n/a to birds	No access or stopping on the bridge
Week 12	No new road kill records during this monitoring event (8/03/2018). Heavy rainfall occurred during the week preceding the week 12 monitoring event.										

Appendix 3 Section 2A Autumn (April) 2018 Monitoring Report.

21 May 2018
Ref No: 2692-1103

Roads and Maritime Services
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Kris Hincks

Road Kill Monitoring Summary Report – Autumn (April) 2018

GeoLINK was engaged by NSW Roads and Maritime Services to undertake stage 2A operational phase road kill monitoring during Autumn (April) 2018 for the Warrell Creek to Nambucca Heads Pacific Highway Upgrade project (WC2NH). This constitutes the second seasonal roadkill monitoring event for the Stage 2A section.

The aim of the road kill monitoring program is to:

- Report on any animal road kill within the Stage 2A section of operational highway since open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH upgrade.

Details of the road kill mitigation measures implemented as part of WC2NH and being assessed are detailed in *Road Kill Monitoring Report WC2NH Stage 2A* (GeoLINK 2018a). This report provides the results of the Stage 2A Autumn (April) 2018 road kill monitoring event.

Methodology

Details of the Stage 2A site and road kill monitoring methodology are provided in GeoLINK (2018a). During the subject 2A Autumn (April) 2018 road kill monitoring event, the 13.3 km Stage 2A section of dual carriageway highway (26.6 km of roadway) was surveyed for four weekly monitoring events on 5, 12, 19 and 26 April 2018. The following monitoring methodology was adopted:

- A two-person team drove the length of Stage 2A in a vehicle to locate and identify fauna road mortalities, as a result of vehicle strike. The first pass of the survey area was undertaken within the first two hours of sunrise.
- The speed of travel averaged 60-70 km per hour, with both the driver and ecologist visually searching for fauna road kill along the highway alignment and within three metres from the fog line.
- A minimum of two passes of the survey area was completed to ensure that all records were accurately detected and could be safely recorded.

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Opportunistic road kill records would also be recorded if observed outside of the nominated weekly monitoring event.

For each road kill observed, the following attributes were recorded:

- Species of animal;
- Date of record;
- Global Positioning System (GPS) coordinates;
- Location of road kill record with in either the south or northbound carriageway;
- The presence of fauna fencing at/near to the road kill record;
- Distance to the nearest fauna fence if not installed adjacent to the road kill record;
- Photographic record of the animal; and
- Comments.

If the animal was identified as an *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed threatened species, the carcass was photographed and the following information recorded:

- Sex and age class (juvenile or adult).
- Presence of pouch young (for marsupials).
- Presence of flightless young (for flying-foxes or other bats).
- Distance to a fauna connectivity structure.
- Distance to drop down structure.
- If fauna fencing was installed, was there any damage to the fence in the vicinity.
- Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase.
- For flying-foxes:
 - Distance to nearest camp
 - Distance to nearest canopy vegetation
 - Presence of flowering food trees in neighbouring median or roadside vegetation; plants identified to species and referenced with diet list.

Results

Number and species of Fauna Road Kills

The results of the Autumn (April) 2018 Stage 2A operational road kill monitoring are provided in **Appendix A**. A total of 12 fauna road mortalities were recorded during the four weekly monitoring events. Species diversity included five confirmed native species, three unidentifiable birds and one introduced mammal species. The road kill recordings included:

- Six (50 per cent) avifauna (birds) recordings comprising three Tawny Frogmouths (*Podargus strigoides*) and three unidentifiable birds.
- Two (16.5 per cent) native mammals recordings comprising a Black Flying Fox (*Pteropus alecto*) and a Swamp Wallaby (*Wallabia bicolor* – possible).
- One (8.5 per cent) introduced mammal recordings comprising a European Fox (*Vulpes vulpes*).
- Three (25 per cent) native reptile recordings comprising two Common Tree Snakes (*Dendrelaphis punctulatus*) and one Macleay River Turtle (*Emydura macquarii subsp.dharra*).

No *Biodiversity Conservation Act 2016* (BC Act) or EPBC Act listed threatened species road kills were recorded. No opportunistic road kill mortalities were recorded outside of the weekly monitoring events.

Figures 1.1 and 1.2 shows the number of fauna road kills recorded during each weekly monitoring event over the initial Summer 2017/18 (12 week) and subject Autumn 2018 (four week) monitoring events for WC2NH Stage 2A. The number of fauna mortality records peaked during week 2 of Stage 2A being operational with 20 road kill fauna records observed. Results indicate a general trend with the number of fauna road kill records declining over time. The mean weekly road kill rate has reduced from 7.8 road kills/ week (SD: 5.3) during the Summer 2017/12 monitoring event to three road kills/ week (SD: 1.4) during the Autumn (April) 2018 monitoring event (excludes opportunistic recordings)).

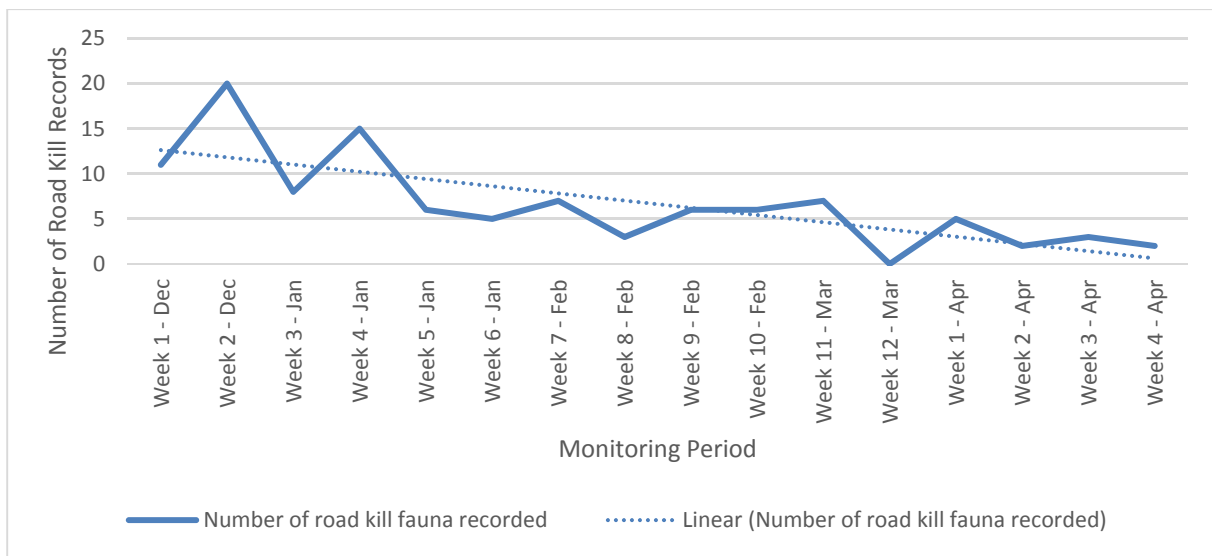


Figure 1-1 Number of fauna road kills recorded during each monitoring event and trend line for WC2NH Stage 2A

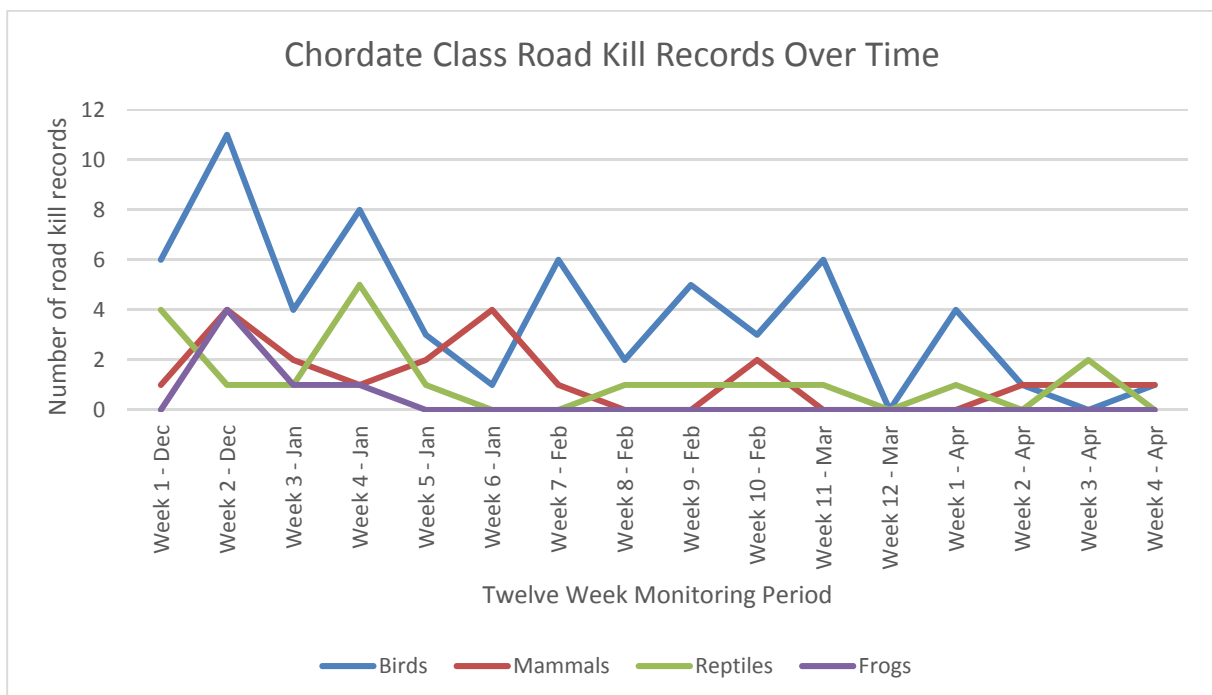


Figure 1-2 Number of road kill chordate class recorded over time for WC2NH Stage 2A



Distribution of Fauna Road Kill Records

Illustration 1.1 - 1.6 shows the location of the road kill records for the Autumn (April) 2018 monitoring event. One main concentration of road kills (four records) was recorded between chainage 49550 and 49900, and included two Common Tree Snakes, an unidentifiable bird and a European Fox. This overlaps with the Summer 2017/18 road kill identified concentration between chainages 49700 and 52000 throughout the Gumma Floodplain (GeoLINK 2018a).

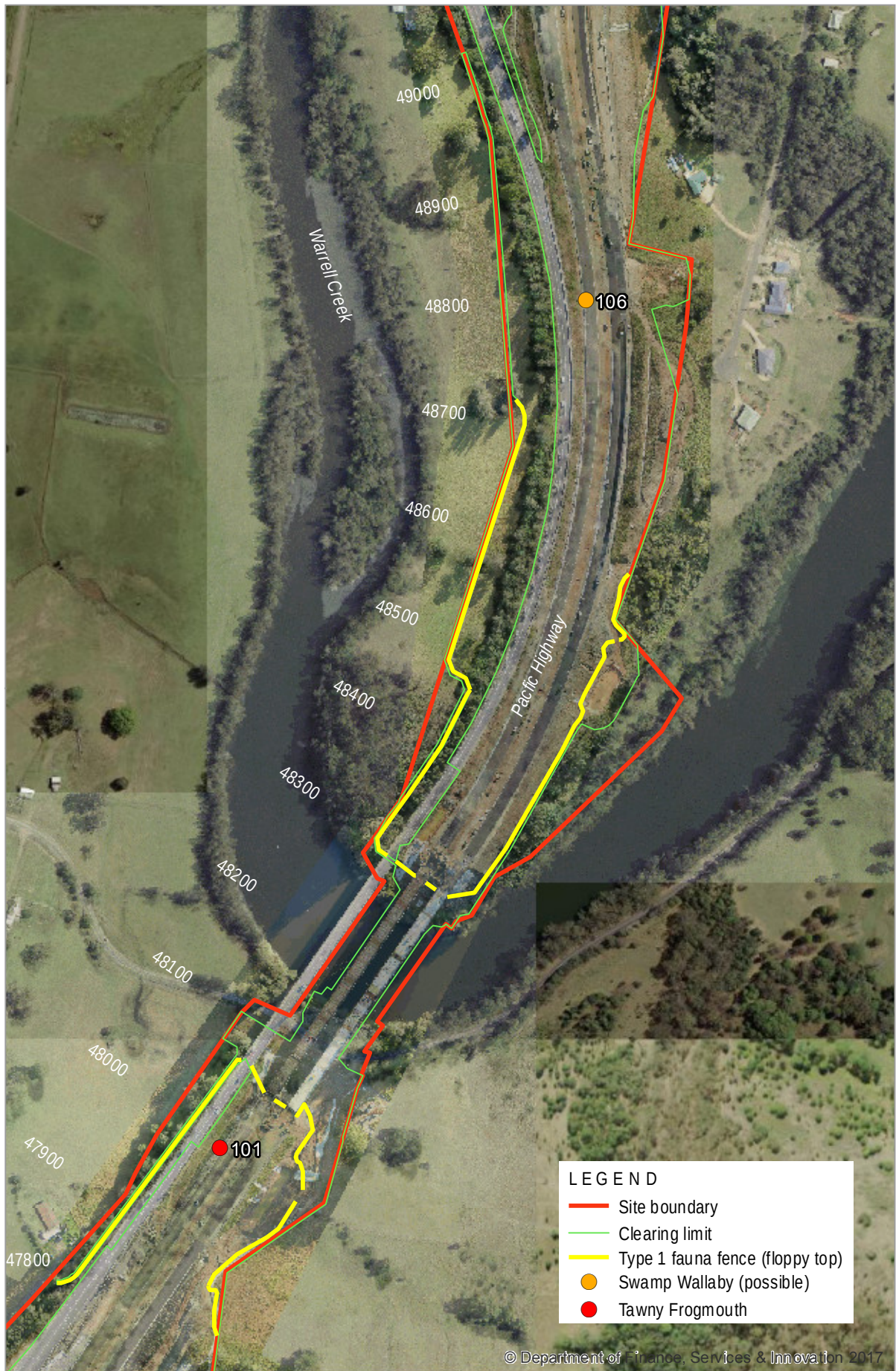
Two road kill recordings (one Black Flying-fox and one Tawny Frogmouth) were recorded on the Nambucca River Bridge at chainages 52200 and 52400 respectively. No other concentrations of road kills were recorded.

Of the other two main road kill concentrations recorded during the Summer 2017/18 monitoring at chainages 48300-49000 and 52800-54900, only one road kill was recorded at these locations during the Autumn 2018 monitoring event. Specifically, a Swamp Wallaby (possible species identification) road kill was recorded at chainage 49200, which corresponds with the previously identified road kill concentration between chainages 48300 to 49000 (north from Lower Warrell Creek to the Macksville off-ramp at Bald Hill Road). This area has recorded the largest number of macropod road kills within the monitoring footprint to date.

Of the 12 road kill recordings from the subject monitoring event:

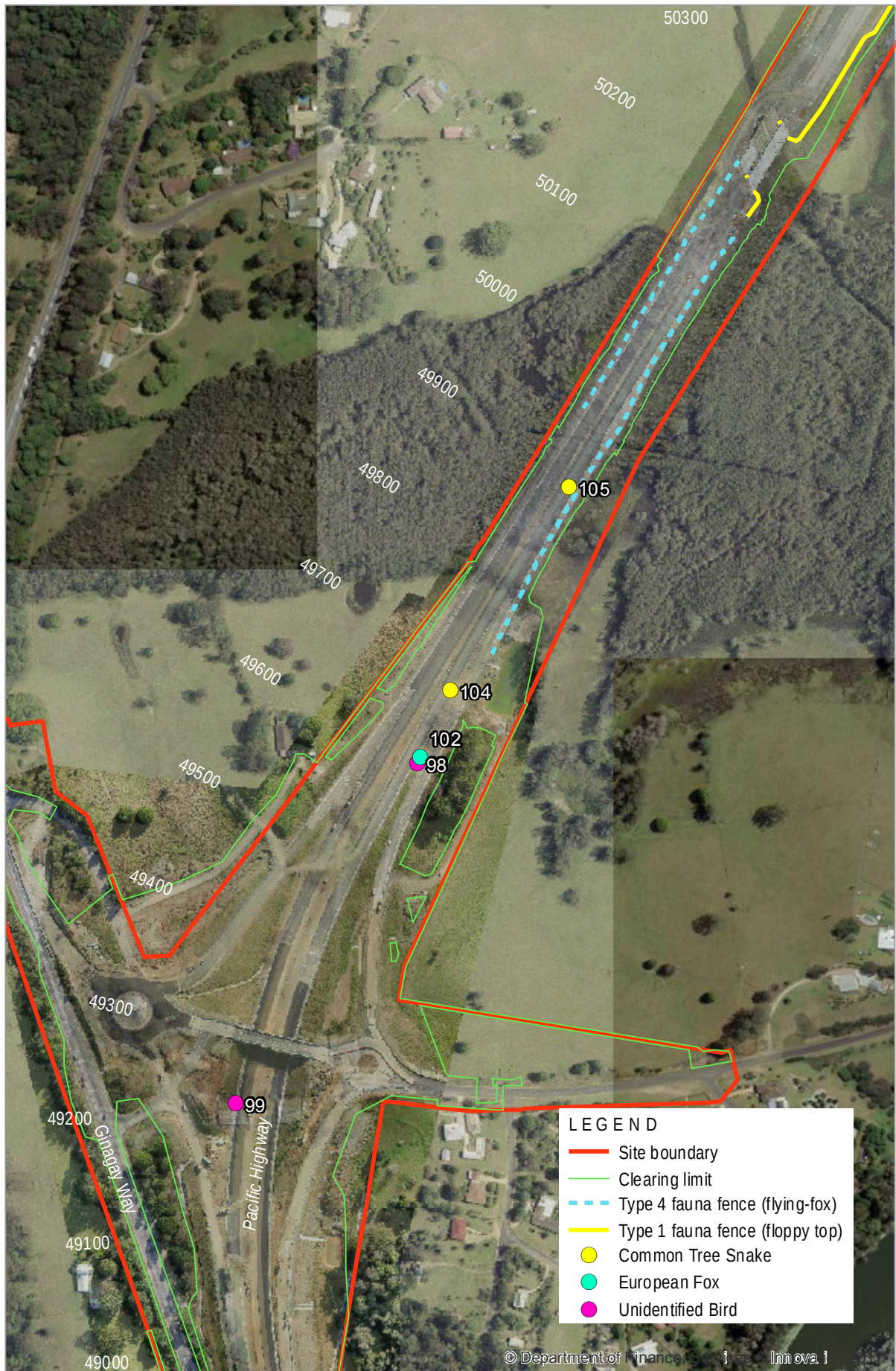
- Six records (50 per cent) were located along the highway carriageway where fauna exclusion fence is present. Only one of these records comprised a species that the fencing may provide a barrier for (i.e. Macleay River Turtle).
- Six records (50 per cent) were located where fauna exclusion fencing is not present. Only two of these records comprised species that exclusion fencing may provide a barrier for (i.e. one European Fox and one Swamp Wallaby).
- Three records (25 per cent) were of species whose ability to enter the roadway is potentially inhibited by the exclusion fencing (i.e. one Macleay River Turtle, one European Fox and one Swamp Wallaby)
- Nine records (75 per cent) were of species whose ability to enter the roadway is not inhibited by the exclusion fencing (i.e. birds, flying-foxes {recorded outside of the Flying-fox exclusion fencing area} or snakes).

No flying-fox road kill records were made in the vicinity of the Type 4 fauna fencing (flying-fox fencing) between chainage 49700 and 50200. Flying-foxes were not recorded roosting in the adjacent swamp sclerophyll forest during the monitoring period (GeoLINK 2018b).

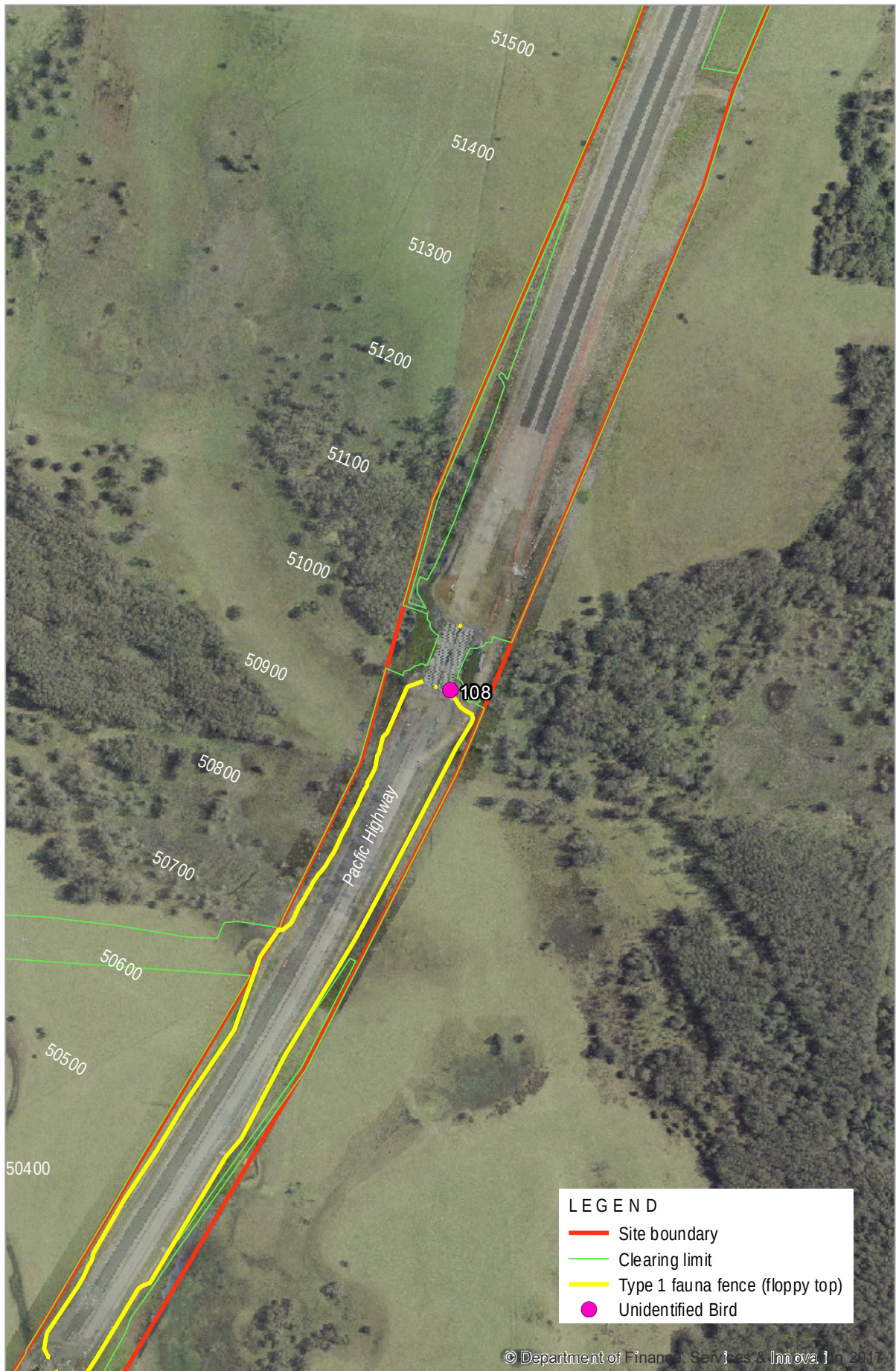


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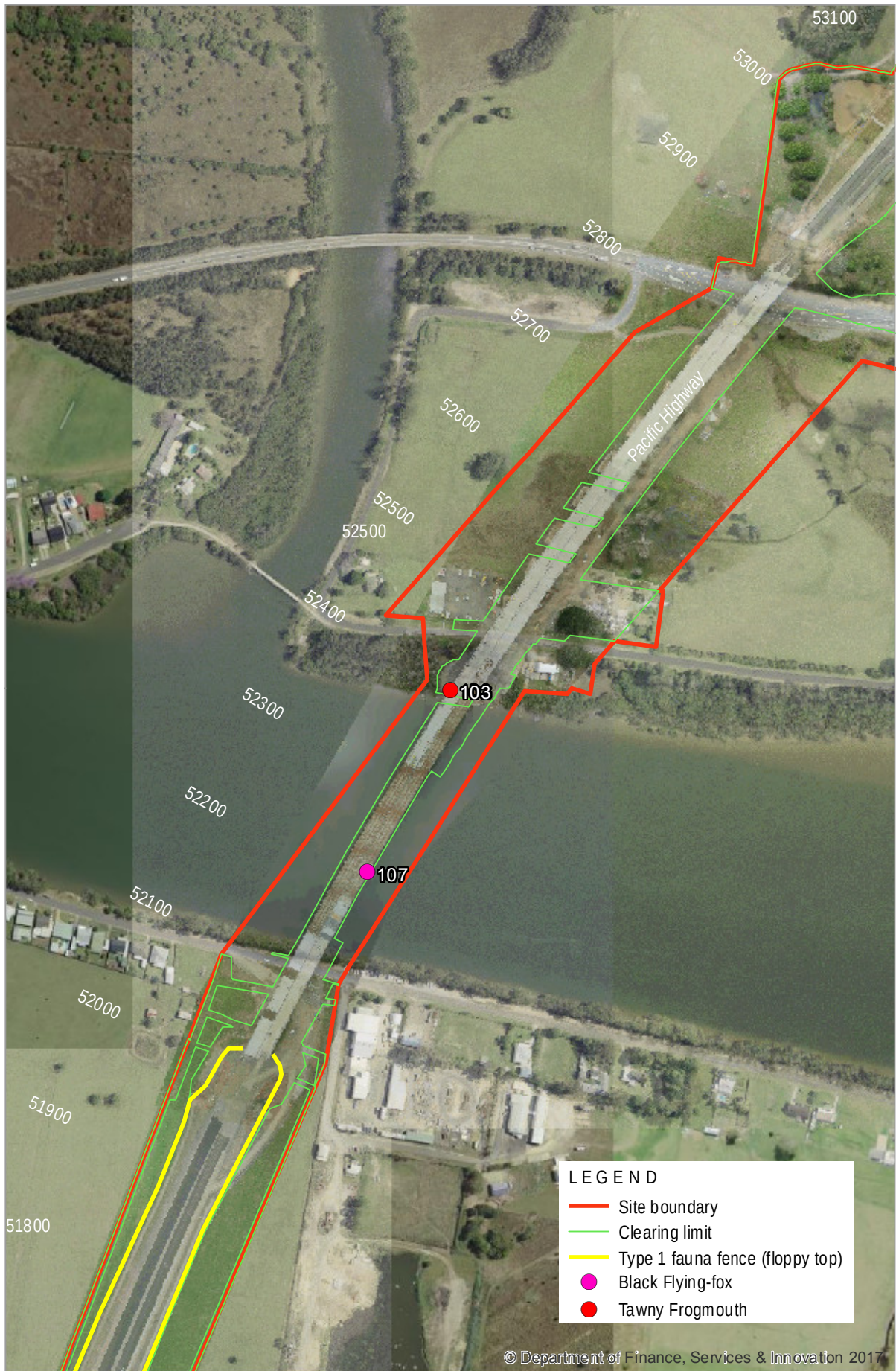


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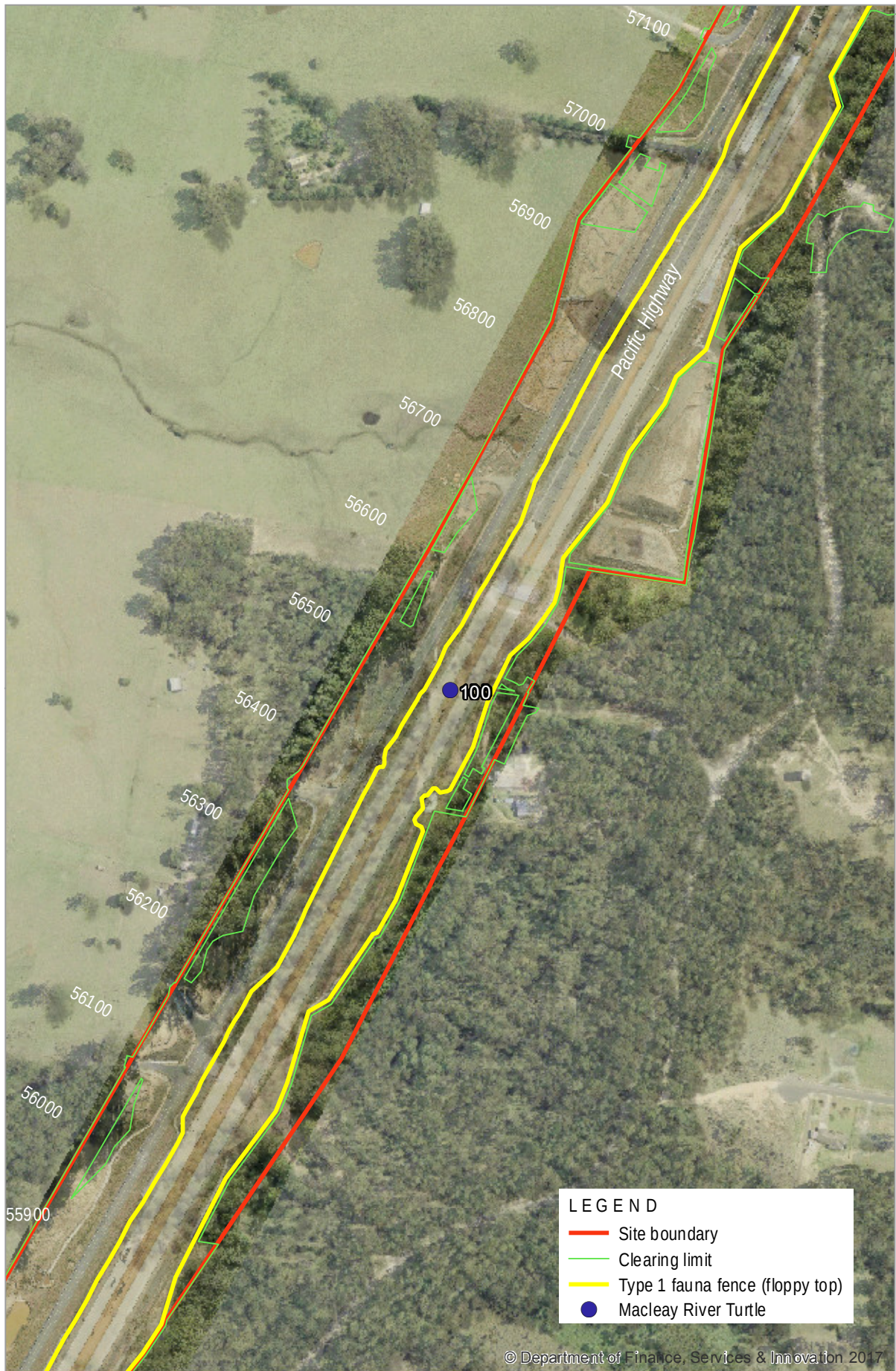
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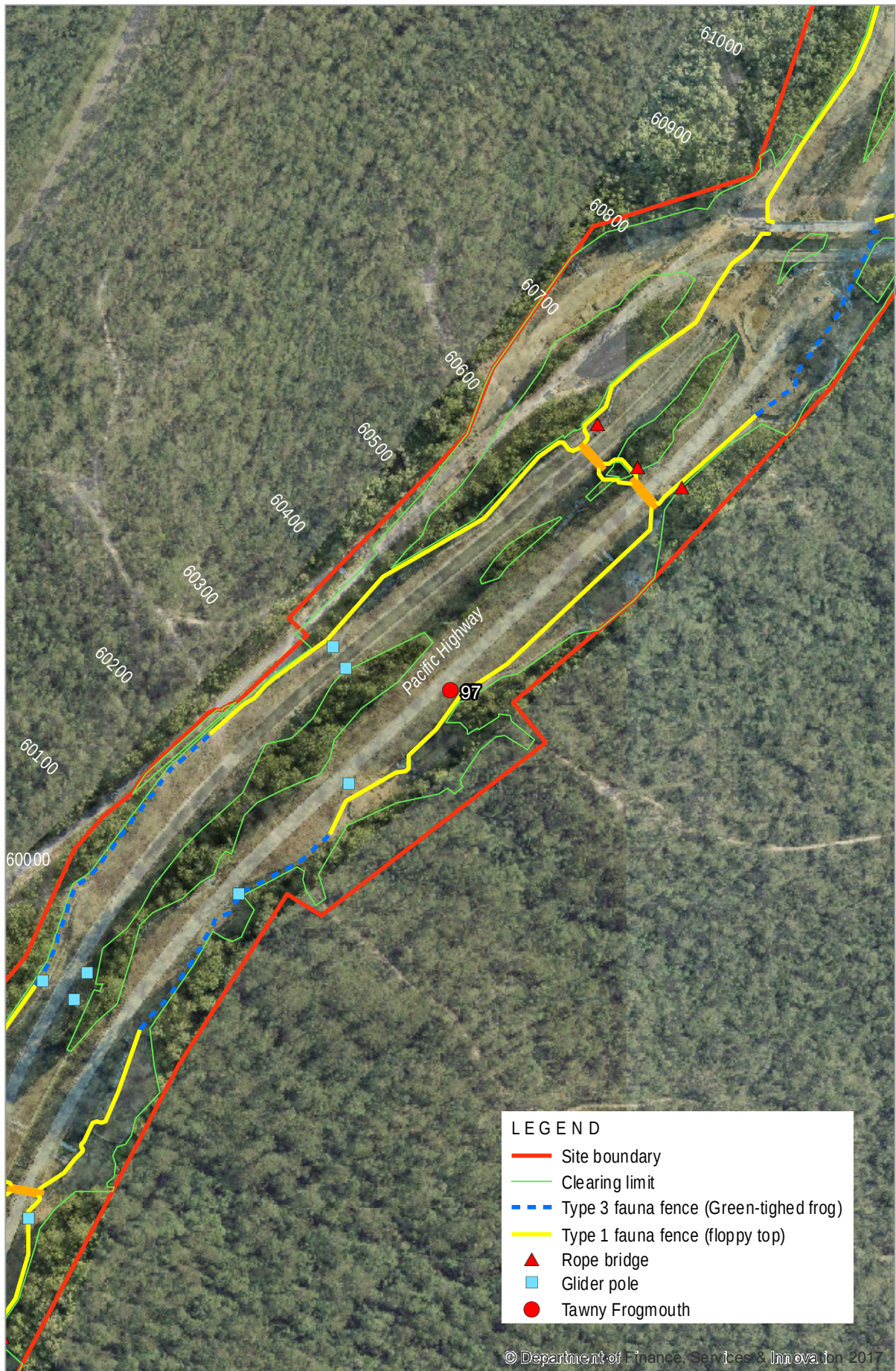
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Discussion

In relation to threatened species:

- No BC Act or EPBC Act listed species road kills were recorded during the Autumn (April) 2018 monitoring event.
- No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog.

A reduction in the weekly rate of fauna road kills has been observed between Summer 2017/18 and Autumn 2018, with an overall decreasing trend in the number of road kills recorded over time being recorded. This may be attributed to:

- Reductions in roadside food resources for some species (e.g. applied seed mix for batter stabilisation).
- Some species habituating to the presence of the road and associated traffic.
- The seasonal changes in species behaviour.
- Potential local population declines (e.g. turtles potentially within the fencing).

Of the 12 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species was low (one record) over the reporting period. No arboreal mammal, amphibian or lizard road kills were recorded during April 2018 monitoring.

The majority of animals impacted by traffic continue to be bird species (six individuals or 50 per cent). Fauna exclusion fencing does not effectively mitigate against vehicle strike to birds due to their ability to fly over fauna fencing and into the road corridor. The reduction in records of Galah and Australian Wood Duck compared to the previous monitoring may be as a result of the hydrospray and hand application of seed for batter stabilisation having sprouted and reduced available suitable food resources for these species. Instead Tawny Frogmouths dominated the bird species count with three mortalities of this species recorded within the April 2018 monitoring event.

The lack of turtle records throughout the Gumma Floodplain area compared to the summer monitoring period may be due to the local turtle population which were fenced into the highway corridor being reduced as a result of vehicle strike impacts or season variations in activity (i.e. cooler temperatures starting to reduce the movements of turtles).

A potential emerging trend is Black-flying fox road kills on the Nambucca River Bridge, in the vicinity of the riparian zone. Three of the four Black-flying Fox road kill recordings to date are located at the bridge. Flying-foxes are known to use waterways and other landscape features as navigational tools and flight paths when moving across the landscape.

Please feel free to contact me if you require any additional information.

Yours sincerely

GeoLINK



Jessica O'Leary
Ecologist



PR	Description	Date issued	Issued By
2692-1103	First issue	21/05/2018	Jessica O'Leary

References

GeoLINK, (2018a). *Road Kill Monitoring Report – WC2NH (ref. 2692-1092)*. Unpublished report for Roads and Maritime Services, NSW.

GeoLINK, (2018). *Flying-fox Monitoring Report April 2018 (ref. 2692-1105)* for Warrell Creek to Nambucca Heads Pacific Highway Upgrade. Unpublished report for Roads and Maritime Services, NSW.



Appendix A

Stage 2A Road Kill Monitoring Results – Autumn (April) 2018

Table A1 Autumn (April) 2018 Stage 2A Road Kill Monitoring Results

<i>Monitoring Week</i>	<i>Road Kill Fauna Reference</i>	<i>Species</i>	<i>Class of Chordate</i>	<i>Date</i>	<i>Easting</i>	<i>Northing</i>	<i>North or south bound lane</i>	<i>Location Description</i>	<i>Fauna fence installed adjacent Y/N</i>	<i>Distance to nearest fauna fence</i>	<i>Comments</i>
Week 1	97	Tawny Frogmouth	Bird	05/04/2018	497010	6609846	Southbound		Yes	N/A	Nil
	98	Unidentifiable Bird	Bird	05/04/2018	492599	6600295	Southbound	Adjacent Bald Hill Road off ramp	No	100 m to the north	Badly damaged unidentifiable
	99	Unidentifiable Bird	Bird	05/04/2018	492437	6599992	Northbound	50 m south of Bald Hill Road overpass	No	>300 m to the southeast	Badly damaged unidentifiable
	100	Macleay River Turtle	Reptile	05/04/2018	495105	6606575	Northbound	Opposite Donnelly-bonnet residence	Yes	N/A	Nil
	101	Tawny Frogmouth	Bird	05/04/2018	492145	6598817	Northbound	Adjacent to southern abutment of Lower Warrell Creek	Yes	N/A	No access to capture photo
Week 2	102	Fox	Mammal*	12/04/2018	492601	6600300	Southbound	South of Bald Hill Road 250m	No		Very damaged skin and fur only
	103	Tawny Frogmouth	Bird	12/04/2018	493829	6602792	Northbound	On the NBR	No	N/A	Tawny Frogmouth identified by feathers and shape of beak



<i>Monitoring Week</i>	<i>Road Kill Fauna Reference</i>	<i>Species</i>	<i>Class of Chordate</i>	<i>Date</i>	<i>Easting</i>	<i>Northing</i>	<i>North or south bound lane</i>	<i>Location Description</i>	<i>Fauna fence installed adjacent Y/N</i>	<i>Distance to nearest fauna fence</i>	<i>Comments</i>
Week 3	104	Common Tree Snake	Reptile	19/04/2018	492628	6600360	Southbound	Approx. 300m north of Bald Hill Road overpass at the separation point of off ramp from highway	Yes	N/A	Nil
	105	Common Tree Snake	Reptile	19/04/2018	492733	6600540	Southbound	Approx. 350m north of Bald Hill Road overpass.	Yes	N/A	Nil
	106	Swamp Wallaby (possible)	Mammal	19/04/2018	492469	6599570	Northbound	Approx. 300m south of Bald Hill overpass	No	100 m to the south-west	Very damaged skin and fur remains
Week 4	107	Black Flying-fox	Mammal	26/04/2018	493755	6602630	Southbound	On Nambucca River Bridge	No	N/A	Appears to be juvenile not adult size
	108	Unidentified Bird	Bird	26/04/2018	493271	6601470	Northbound	Floodplain bridge 1 or 2 need to check this	Yes	N/A	Very degraded unidentified bird in centre median, no access.

Table A1 Autumn (April) 2018 Stage 2A Road Kill Monitoring Results

Species		Summer 2017/18 (Initial 12 Week Monitoring)													Autumn (April) 2018					Grand Total
	Opportunistic	Week 01	Week 02	Week 03	Week 04	Week 05	Week 06	Week 07	Week 08	Week 09	Week 10	Week 11	Week 12	TOTAL	Week 01	Week 02	Week 03	Week 04	TOTAL	
Australian Magpie		1	1					2		2		1		7						7
Australian Wood Duck		3	2	2	5	3		3				2		20						20
Black Flying-fox	1				1						1			3				1	1	4
Black Rat*			1											1						1
Blue Tongue Lizard					1									1						1
Carpet Python										1				1						1
Cat*							1							1						1
Common Tree Snake						1								1			2		2	3
Crested Pigeon				1			1							2						2
Eastern Long Neck Turtle		1												1						1
Eastern Water Dragon				1										1						1
European Fox*						1	1	1						3		1			1	4
Forest Kingfisher			1											1						1
Galah			4		1					1		1		7						7
Green Tree Frog			2											2						2
Hare*			1	1										2						2
Kookaburra										1		1		2						2
Kookaburra		1												1						1
Macleay River Turtle		1			3						1			5	1				1	6
Magpie Lark			1											1						1
Magpie Lark					1									1						1
Masked Owl				1										1						1
Northern Brown Bandicoot											1			1						1



Species		Summer 2017/18 (Initial 12 Week Monitoring)													Autumn (April) 2018					Grand Total
	Opportunistic	Week 01	Week 02	Week 03	Week 04	Week 05	Week 06	Week 07	Week 08	Week 09	Week 10	Week 11	Week 12	TOTAL	Week 01	Week 02	Week 03	Week 04	TOTAL	
Pacific Black Duck									1		1			2						2
Purple Swamphen			1					1			1			3						3
Rabbit*							1							1						1
Red Necked Wallaby		1												1						1
Red-bellied Black Snake												1		1						1
Striped Marsh Frog			2	1										3						3
Swamp Wallaby				1		1								2			1		1	3
Tawny Frogmouth											1			1	2	1			3	4
Unidentifiable bird		1	1		1				1	1		1		6	2			1	3	9
Unidentified Chelidae (Turtle) species		2	1		2				1					6						6
Unidentified Macropod	1		2											3						3
Unidentified Mammal							1							1						1
Grand Total	2	11	20	8	15	6	5	7	3	6	6	7	0	96	5	2	3	2	12	108

* denotes feral species.

Appendix 4 Road Kill Monitoring Report – Section 2A Winter (July) 2018 monitoring.

09 August 2018
Ref No.: 2692-1133

Roads and Maritime Services
124 Albert Drive
DONNELLYVILLE NSW 2447

Attention: Kris Hincks

Winter (July) 2018

GeoLINK was engaged by NSW Roads and Maritime Services to undertake Stage 2A operational phase road kill monitoring during winter (July) 2018 for the Warrell Creek to Nambucca Heads Pacific Highway upgrade project (WC2NH). This constitutes the third seasonal road kill monitoring event for the Stage 2A section.

The aim of the road kill monitoring program is to:

- Report on any animal road kill within the Stage 2A section of operational highway since being open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH upgrade.

Details of the road kill mitigation measures implemented as part of WC2NH upgrade being assessed are detailed in *Road Kill Monitoring Report WC2NH Stage 2A* (GeoLINK 2018a). This report provides the results of the Stage 2A winter (July) 2018 road kill monitoring event.

Methodology

Details of the Stage 2A site and road kill monitoring methodology are provided in GeoLINK 2018a. During the subject 2A winter (July) 2018 road kill monitoring event, the 13.3 km Stage 2A section of dual carriage highway (26.6 km of roadway) was surveyed weekly for four monitoring events on 5, 12, 19 and 26 July 2018. The following monitoring methodology was adopted:

- A two-person team drove the length of Stage 2A in a vehicle to locate and identify fauna road mortalities, as a result of vehicle strike. The first pass of the survey area was undertaken within the first two hours of sunrise.
- The speed of travel averaged 60-70 km per hour, with the ecologist visually searching for fauna road kill along the highway alignment and within three metres from the fog line.
- A minimum of two passes of the survey area was completed to ensure that all records were accurately detected and could be safely recorded.

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Opportunistic road kill records were also recorded if observed outside of the nominated weekly monitoring event.

For each road kill observed, the following attributes were recorded:

- Species of animal
- Date of record
- Global Positioning System (GPS) coordinates
- Location of road kill record; within either the south or northbound carriageway
- The presence of fauna fencing at/near the road kill record
- Distance to the nearest fauna fence if not installed adjacent to the road kill record
- Photographic record of the road kill
- Comments.

If the road kill was identified as an *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed species, the carcass was photographed, and the following information recorded:

- Sex and age class (juvenile or adult)
- Presence of pouch young (for marsupials)
- Presence of flightless young (for flying-foxes or other microbats)
- Distance to a fauna connectivity structure
- Distance to a drop-down structure
- If fauna fencing was installed, was there any damage to the fence in the vicinity
- Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase
- For flying-foxes:
 - Distance to nearest camp
 - Distance to nearest canopy vegetation
 - Presence of flowering food trees in neighbouring median or roadside vegetation; plants identified to species and referenced with diet list.

Results

Number and Species of Fauna Road Kills

The results of the winter (July) 2018 Stage 2A operational road kill monitoring are provided in **Appendix A**. A total of 16 fauna road mortalities were recorded during the four weekly monitoring event. Species diversity included six confirmed native species, one unidentifiable bird and one introduced mammal species. The road kill recordings included:

- Fourteen (87.5 per cent) avifauna (birds) comprising two Tawny Frogmouths (*Podargus strigoides*), two Purple Swamphens (*Porphyrio porphyrio*), two Laughing Kookaburras (*Dacelo novaeguineae*), one Grey Butcherbird (*Cracticus torquatus*), six Barn Owls (*Tyto alba*) and one unidentifiable bird
- One (six per cent) native mammal comprising a macropod which was too badly decomposed to be identified to species level
- One (six per cent) introduced mammal comprising a European Fox (*Vulpes vulpes*).

No *Biodiversity Conservation Act 2016* (BC Act) or EPBC Act listed threatened species road kills were recorded. No road kill recordings of target threatened species (Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog) known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded.

One opportunistic road kill mortality, a Brahminy Kite (*Haliastur indus*) was also recorded outside of the weekly monitoring event.

Figures 1.1 and 1.2 show the number of fauna road kills recorded during each weekly monitoring event over the initial summer 2017/18 (12 weeks from December 2017 to March 2018), autumn 2018 (four weeks in April) and subject winter 2018 (four weeks in July) monitoring events for WC2NH Stage 2A. The number of fauna mortality records peaked during week 2 of Stage 2A being operational with 20 road kill records observed. Results indicate a general declining trend with the number of fauna road kill records decreasing over time. The mean weekly road kill rate has reduced from 7.8 road kills/ week (SD: 5.3) during the summer 2017/18 monitoring event to three road kills/ week (SD: 1.4) during the autumn (April) 2018 with a slight increase to four road kills/ week (SD: 1.4) during the winter (July) 2018 monitoring event (excludes opportunistic recordings)).

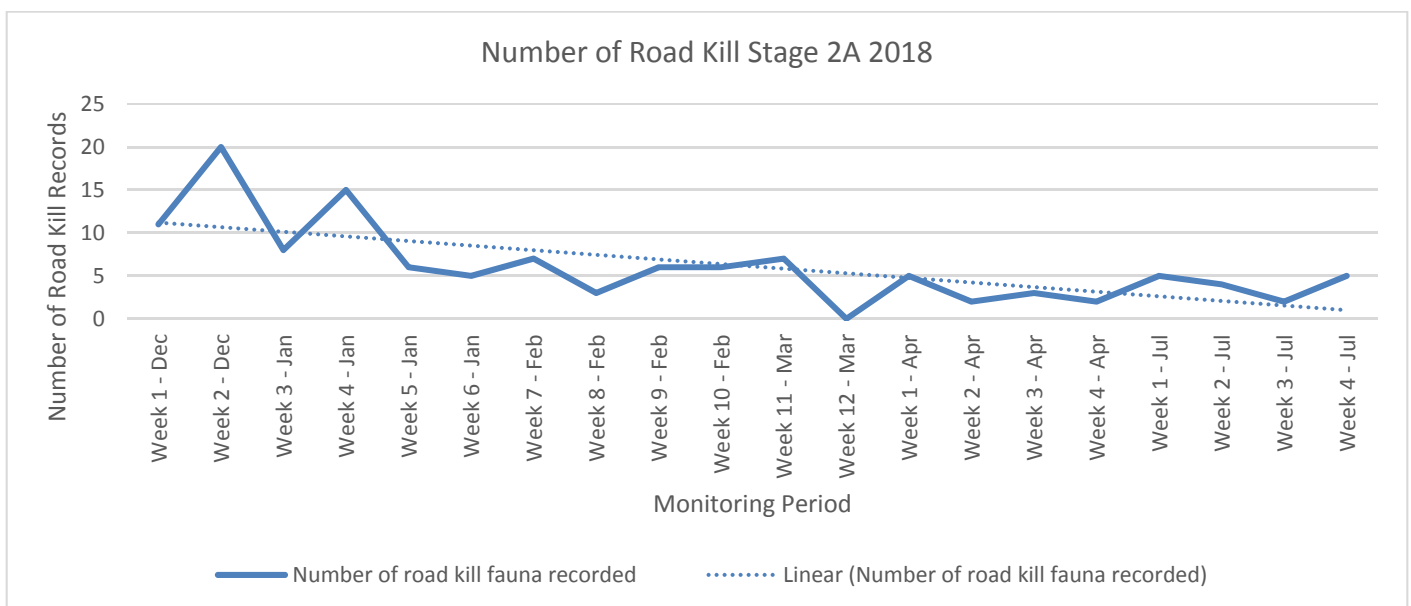


Figure 1.1 Number of road kills recorded during each monitoring event and trend line for WC2NH Stage 2A 2018.

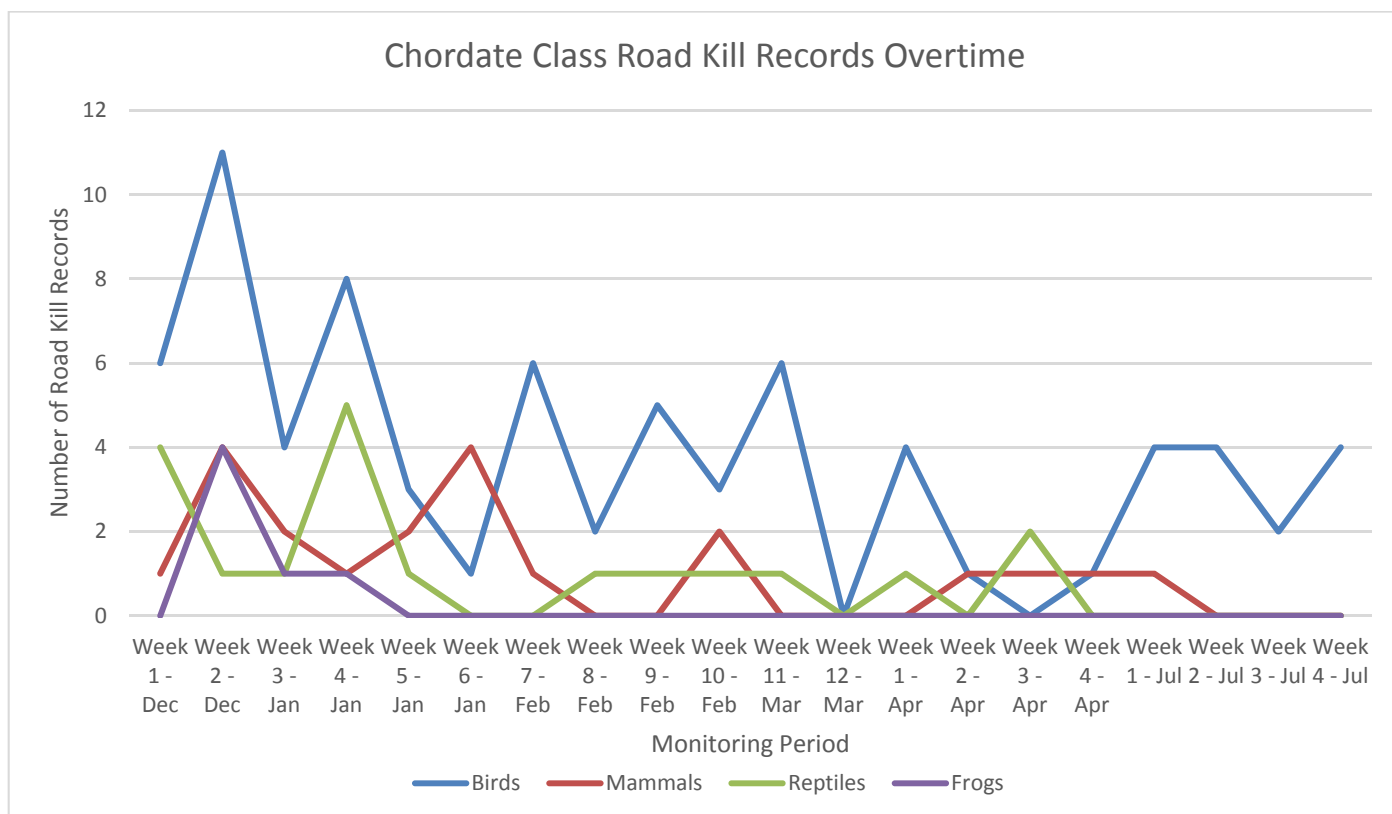


Figure 1.2 Number of road kill per chordate class recorded over time for WC2NH Stage 2A

Distribution of Fauna Road Kill Records

Illustrations 1.1 - 1.7 show the location of the road kill records for the winter (July) 2018 monitoring event. A small grouping of road kills was recorded over a 180 m section between chainages 53080 and 53260 and included one Grey Butcherbird (*Cracticus torquatus*), one Barn Owl (*Tyto alba*) and a possible juvenile Barn Owl. Two more road kills were observed to the north at chainages 53600 and 53830 respectively. This overlaps with the summer 2017/18 road kill identified concentration between chainages 52800 and 54900 from the northern abutment of the Nambucca River Bridge to the Mattick Road overpass (GeoLINK 2018a).

The remaining road kill records across Stage 2A were predominantly spaced at a minimum distance of 200 m apart across the monitoring footprint. This includes the six records between 50300 and 52000 which overlaps with the summer 2017/2018 road kill identified concentration between chainages 49700 and 52000.

Of the other main road kill concentration recorded during the summer 2017/18 monitoring at chainages 48300-49000, only one road kill, a Laughing Kookaburra, was recorded at this location during the winter 2018 monitoring event. No macropod records were recorded at this location which previously recorded the largest number of macropod road kills within the monitoring footprint to date.

One road kill recording (one Brahminy Kite) was recorded on the Nambucca River Bridge at chainage 52250.



Of the 16 road kill recordings from the subject monitoring event:

- Eight records (50 per cent) were located where fauna exclusion fence is present. Only one of these records comprised a species that the exclusion fencing may provide a barrier for (i.e. European Fox)
- Eight records (50 per cent) were located where fauna exclusion fencing is not present. Only one of these records comprised species that exclusion fencing may provide a barrier for (i.e. one macropod)
- Two records (12.5 per cent) were of species whose ability to enter the roadway is potentially inhibited by the exclusion fencing (i.e. one European Fox and one macropod)
- Fourteen records (87.5 per cent) were of species whose ability to enter the roadway is not inhibited by the exclusion fencing (i.e. birds).

A potential emerging trend of Black Flying-fox road kills on the Nambucca River Bridge, in the vicinity of the riparian zone was observed during April 2018 monitoring however no Flying-fox road kills records were observed at this location during the subject monitoring period. No flying-fox road kill records made in the vicinity of the Type 4 fauna fencing (flying-fox fencing) between chainage 49700 and 50200. Flying-foxes were not recorded roosting in the adjacent swamp sclerophyll forest during the monitoring period (GeoLINK 2018b).



LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Purple Swamphen

0 100



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Information shown is for illustrative purposes only



LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Type 1 fauna fence (floppy top)

- ▲ Fauna drop down structure
- Barn Owl likely
- Laughing Kookaburra

0 100



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Stage 2A Road Kill Monitoring Report – Winter (July) 2018
2692-1134

Road Kill Fauna Locations

Illustration 1.2

Information shown is for illustrative purposes only



LEGEND

- | | |
|---|---|
| — Site boundary | ● Barn Owl likely |
| — Clearing limit | ● Laughing Kookaburra |
| — Fauna culvert | ● Purple Swampphen |
| - - - Type 4 fauna fence (flying-fox) | ● Unidentified Bird |
| — Type 1 fauna fence (floppy top) | |

0 100



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Stage 2A Road Kill Monitoring Report – Winter (July) 2018
2692-1134

Road Kill Fauna Locations

Illustration 1.3

Information shown is for illustrative purposes only



LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Type 1 fauna fence (floppy top)
- Barn Owl likely
- Brahminy Kite
- European Fox

0 100

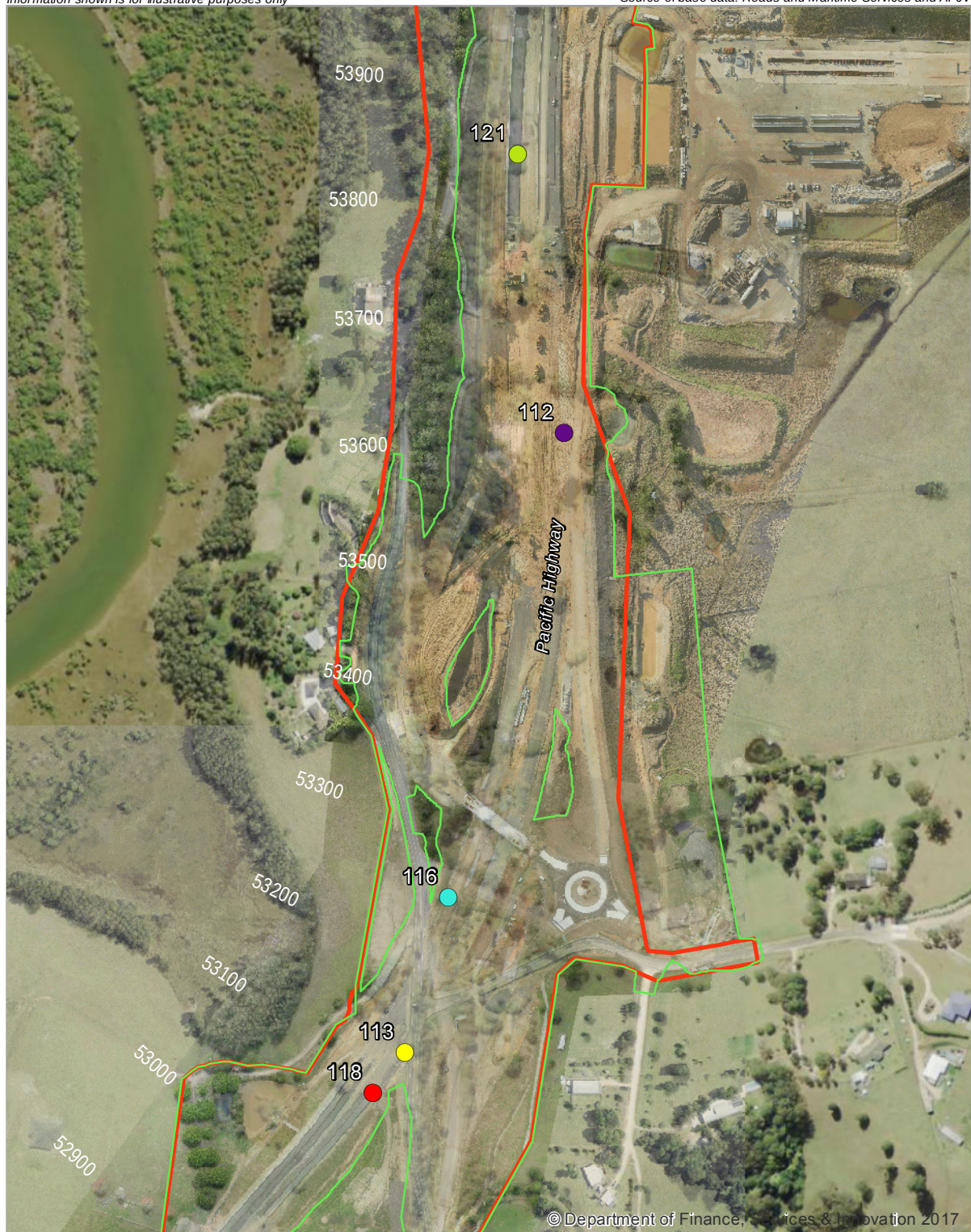


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Stage 2A Road Kill Monitoring Report – Winter (July) 2018
2692-1134

Road Kill Fauna Locations

Illustration 1.4



LEGEND

- | | |
|---|--|
| — Site boundary | ● Barn Owl |
| — Clearing limit | ● Grey Butcherbird |
| — Fauna culvert | ● Possible juvenile Barn Owl |
| | ● Tawny Frogmouth |
| | ● Unidentified Macropod |

0 100



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LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Type 1 fauna fence (floppy top)

- ▲ Fauna drop down structure
- Barn Owl likely

0 100





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LEGEND

- Site boundary
- Clearing limit
- Fauna culvert
- Type 1 fauna fence (floppy top)
- ▲ Fauna drop down structure
- Barn Owl

0 100



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Discussion

In relation to threatened species:

- No BC Act or EPBC Act listed species road kills were recorded during the winter (July) 2018 monitoring event.
- No road kill recordings of target threatened species (Koala, Spotted-tailed Quoll, Grey Headed Flying-fox or Green-thighed Frog) known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded.

A reduction in the weekly rate of fauna road kills has been observed between summer 2017/18 and autumn 2018 although a slight increase from autumn 2018 to winter 2018 monitoring was observed. An overall decreasing trend in the number of road kills recorded over time has been recorded. This may be attributed to:

- Reductions in roadside food resources for some species (e.g. applied seed mix for batter stabilisation)
- Some species habituating to the presence of the road and associated traffic
- Seasonal changes in species behaviour
- Potential local population declines.

Medium to large terrestrial native mammals comprise the main species group to which the fauna exclusion fence design provides a barrier for. Recordings of these species was low (two records; one native and one introduced species) over the reporting period. No arboreal mammal, amphibian or reptile road kills were recorded during July 2018 monitoring.

The majority of animals impacted by traffic continue to be bird species (14 individuals, 87.5 per cent). Fauna exclusion fencing does not effectively mitigate against vehicle strike to birds due to their ability to fly over fauna fencing and into the road corridor. The reduction in records of Galah and Australian Wood Duck compared to the summer 2017/18 monitoring event may be as a result of the hydrospray and hand application of seed for batter stabilisation having sprouted and reduced available suitable food resources for these species. Instead, Barn Owls dominated the bird species count with seven mortalities of this species recorded within the winter (July) 2018 monitoring event. One record was observed on 5 July, two records on 12 July and four records on 26 July. One Tawny Frogmouth road kill was recorded during July 2018, a decrease from three records during April 2018.

The increase of Barn Owl records may be attributable to a current or a recent breeding event which has increased the numbers of owls which are present and active locally. Barn Owls can breed year-round and raise successive broods if food resources are abundant, although typically two broods are raised in a year (Morcombe, 2004). It is not known if these Owls are from a local population or have dispersed from elsewhere in search of food resources during the winter period.

Please feel free to contact me if you require any additional information.

Yours sincerely

GeoLINK



Jessica O'Leary
Ecologist



UPR	Description	Date issued	Issued By
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GeoLINK, (2018b). *Road Kill Monitoring Report Autumn (April) 2018 – WC2NH (ref. 2692-1092)*. Unpublished report for Roads and Maritime Services, NSW.

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Morcombe, M. (2004). *Field Guide to Birds of Australia*. Pascal Press, Australia.



Appendix A

Stage 2A Road Kill Monitoring Results – Winter (July) 2018

Table A1 Winter (July) 2018 Stage 2A Road Kill Monitoring Results

Monitoring Week	No. of Records	Species Common Name	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
Opportunistic	109	Brahminy Kite	Brahminy Kite (Haliastur indus)	Bird	25/05/2018	493758	6602679	Northbound	Middle of Nambucca River Bridge	No	N/A for birds	Record provided by RMS could not get photo but distinctive description of solid rusty brown colour of body of bird of prey with solid white head.
Week 1	110	Purple Swamphen	Purple Swamphen	Bird	5/07/2018	492939	6600920	Northbound	100 m north of Gumma Floodplain Bridge 1	Yes	N/A for birds	n/a
	111	European Fox	European Fox	Mammal*	5/07/2018	493405	6601900	Center median	Centremedian 350m south of Nambucca River Bridge	Yes	within fauna fence	Badly amaged record
	112	Tawny Frogmouth	Tawny Frogmouth	Bird	5/07/2018	494433	6603863	Southbound	200 m north of Old Coast Road Overpass	No	N/A for birds	n/a
	113	Possible juvenile Barn Owl	Tawny Frogmouth	Bird	5/07/2018	494302	6603355	Southbound	300 m north of Nambucca River Bridge	No	N/A for birds	Very degraded wings only remain with possible rat scats deposit on and adjacent to the body.
	114	Purple Swamphen	Purple Swamphen	Bird	5/07/2018	490860	6596833	Southbound	250 m north of Rosewood Road Overpass	No	N/A for birds	n/a
Week 2	115	Laughing Kookaburra	Laughing Kookaburra	Bird	12/07/2018	492469	6599557	Northbound	1 km south Bald Hill Overpass	No	N/A for birds	n/a
	116	Grey Butcherbird	Grey Butcherbird (Cracticus torquatus)	Bird	12/07/2018	494338	6603482	Northbound	50 m south of Old Coast Road Overpass	No	N/A for birds	n/a
	117	Barn Owl	Barn Owl	Bird	12/07/2018	494595	6605636	Northbound	50 m south of	Yes	N/A for	Quite old carcass

Monitoring Week	No. of Records	Species Common Name	Species	Class of Chordate	Date	Easting	Northing	North or south bound lane	Location Description	Fauna fence installed adjacent Y/N	Distance to nearest fauna fence	Comments
		likely	(Tyto alba)						the Hartman property		birds	
	118	Barn Owl	Barn Owl (Tyto alba)	Bird	12/07/2018	494276	6603322	Southbound	Northern of the northern abutment of the Nambucca River Bridge	No	N/A for birds	n/a
Week 3	119	Laughing Kookaburra	Laughing Kookaburra	Bird	19/07/2018	493313	6601661		100 m north of Gumma Floodplain Bridge 2	Yes	N/A for birds	n/a
	120	Unidentified Bird	Unidentified Bird	Bird	19/07/2018	493093	6601122	Center median	300 m north of Gumma Floodplain Bridge 1	Yes	N/A for birds	Too badly damaged to identify species.
Week 4	121	Unidentified Macropod	Unidentified Macropod	Mammal	26/07/2018	494395	6604091	Southbound	300 m north of Old Coast Road overpass	No	250 m	Very damaged fur and skin remains, species identification not possible.
	122	Barn Owl likely	Barn Owl likely	Bird	26/07/2018	493235	6601447	Northbound	20 m south of Gumma Floodplain Bridge 2	Yes	N/A for birds	n/a
	123	Barn Owl likely	Barn Owl likely	Bird	26/07/2018	492474	6599958	Southbound	50 m south of Bald Hill overpass	No	N/A for birds	n/a
	124	Barn Owl likely	Barn Owl likely	Bird	26/07/2018	493522	6602141	Southbound	Gumma Floodplain 400 m south of Nambucca River Bridge southern abutment	Yes	N/A for birds	n/a
	125	Barn Owl	Barn Owl	Bird	26/07/2018	495147	6606611	Southbound	100 m north of Bonnett-Donnelly property	Yes	N/A for birds	n/a

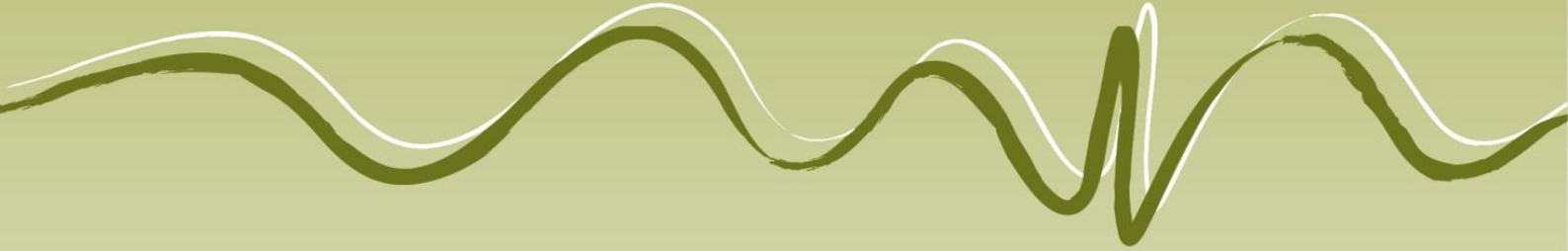
Table A1 Autumn (April) 2018 Stage 2A Road Kill Monitoring Results

Species	Summer 2017/18(Initial 12 weeks)												Total	Autumn (April) 2018					Total	Winter (July) 2018					Total	Grand Total
	Opportunistic	Week 01	Week 02	Week 03	Week 04	Week 05	Week 06	Week 07	Week 08	Week 09	Week 10	Week 11		Week 01	Week 02	Week 03	Week 04	Opportunistic		Week 01	Week 02	Week 03	Week 04			
Australian Magpie		1	1					2		2		1	7													
Australian Wood Duck		3	2	2	5	3		3				2	20													
Barn Owl																			1	2			4	7	7	
Black Flying-fox	1				1						1		3				1	1								
Black Rat			1										1													
Blue Tongue Lizard					1								1													
Brahminy Kite																		1						1	1	
Carpet Python										1			1											1		
Cat							1						1													
Common Tree Snake						1							1			2		2								
Crested Pigeon				1									2													
Eastern Long Neck Turtle		1											1													
Eastern Water Dragon				1		1							1													
European Fox						1	1	1					3		1			1		1				1	5	
Forest Kingfisher			1										1													
Galah			4		1					1		1	7													
Green Tree Frog			2										2													
Grey Butcherbird																				1				1	1	
Hare			1	1									2											7		
Kookaburra		1								1		1	3								1	1		2	5	
Macleay River Turtle		1			3						1		5	1				1								
Magpie Lark			1										1													
Magpie Lark					1								1													
Masked Owl				1									1													
Northern Brown Bandicoot											1		1											1		
Pacific Black Duck									1		1		2													
Purple Swamphen			1					1			1		3							2				2	5	
Rabbit							1						1											2		
Red Necked Wallaby		1											1													
Red-bellied Black Snake												1	1											1		
Striped Marsh Frog			2	1									3											1		
Swamp Wallaby				1		1							2			1		1						1		
Tawny Frogmouth											1		1	2	1			3		1				1	5	

Species	Summer 2017/18(Initial 12 weeks)												Total	Autumn (April) 2018					Winter (July) 2018					Total	Grand Total
	Opportunistic	Week 01	Week 02	Week 03	Week 04	Week 05	Week 06	Week 07	Week 08	Week 09	Week 10	Week 11		Week 01	Week 02	Week 03	Week 04	Total	Opportunistic	Week 01	Week 02	Week 03	Week 04		
Unidentifiable bird		1	1		1				1	1		1	6	2			1	3						1	10
Unidentified Chelidae (Turtle) species		2	1		2				1				6								1				
Unidentified Macropod	1		2										3										1	1	4
Unidentified Mammal							1						1											1	
Grand Total	2	11	20	8	15	6	5	7	3	6	6	7	96	5	2	3	2	12	1	5	4	2	5	17	125

Appendix 5 Stage 2B Initial 12 Week Monitoring Report.

Road Kill Monitoring Report – Initial 12 weeks WC2NH Stage 2B



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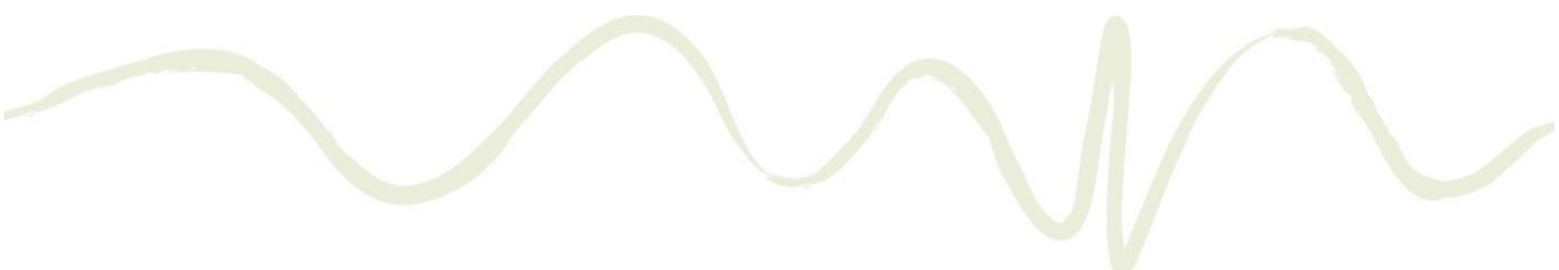


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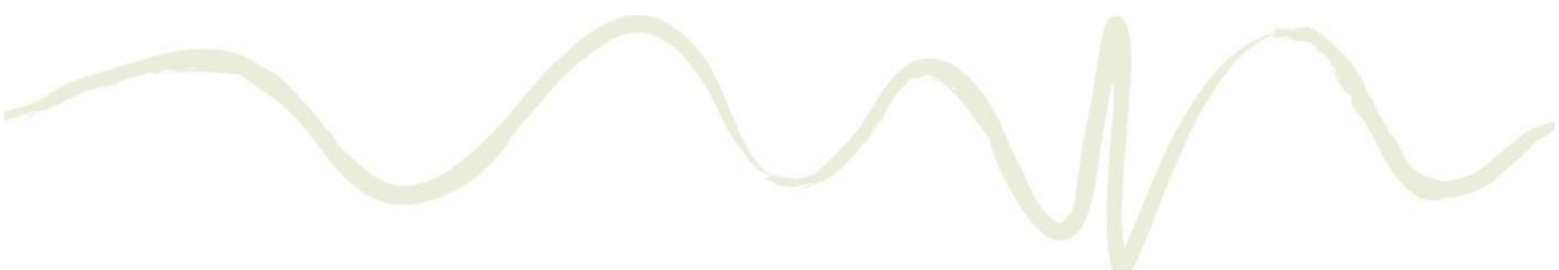
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Appendices

Appendix A Stage 2B Road Kill Monitoring Results



Executive Summary

GeoLINK was engaged by NSW Roads and Maritime Services to undertake weekly Road Kill Monitoring for the first 12 weeks of the operational phase of the Stage 2B section of the Warrell Creek to Nambucca Heads Pacific Highway Upgrade (WC2NH). A number of road kill mitigation measures were implemented for WC2NH with the aim to minimise vehicle collisions with native wildlife. The types of structures which were constructed to mitigate traffic impacts to fauna consist of:

- The installation of fauna fencing to exclude fauna from the road corridor or as a guide towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including fauna culvert underpasses, bridge underpasses, rope bridges and glider poles.

The aim of the monitoring program is to:

- Report on any animal road kill within the Stage 2B section of operational highway since open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Pacific Highway Upgrade.

Road kill monitoring for Stage 2B of WC2NH was undertaken weekly (each Thursday) for the first 12 weeks after the opening of Stage 2B to traffic. The Stage 2B site covers 6.6 km of dual carriageway highway extending from Browns Crossing Road (Chainage 41700) in the south to Scott's Heads Road in the north (Chainage 48100). The survey area covered the north and southbound carriageways and has a combined length of 13.2 km of road

No BC or EPBC Act listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll or Giant Barred Frog.

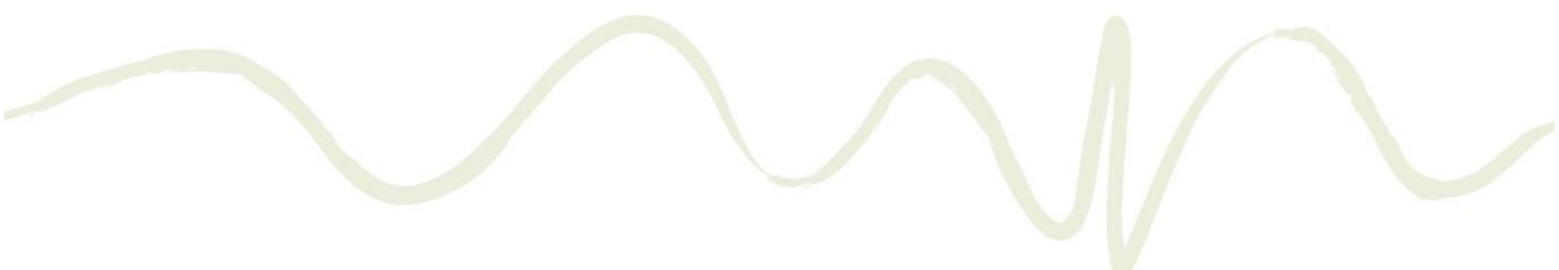
Of the 27 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were moderate (44.5 per cent of records) over the reporting period.

Two road kill hotspots were identified across Stage 2B including the Rosewood Creek to Rosewood Tributary and to a lesser degree to the north of Rosewood Road overpass.

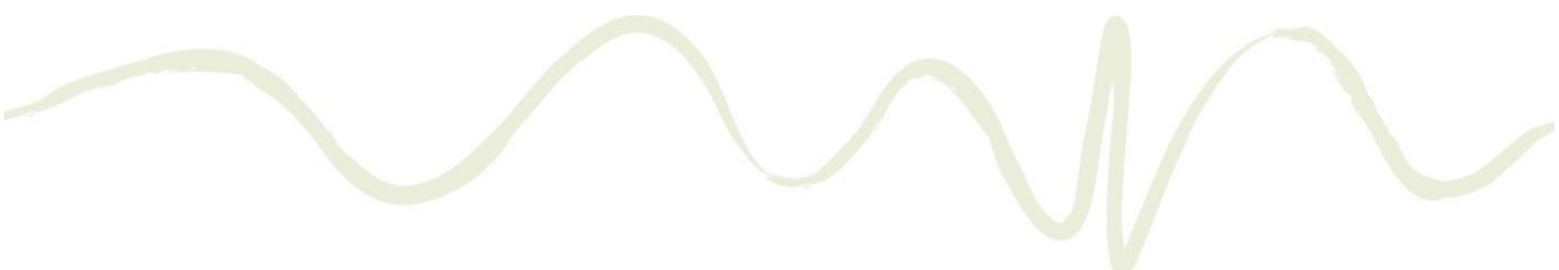
No Giant Barred Frog road kill records were made in the vicinity of the Type 2 fauna fencing (Giant Barred Frog fencing) between chainage 42550 and 43400.

Results indicate a general trend with the number of fauna road kill records increasing slightly over time. Week 5 of the 12 weeks of monitoring was the only monitoring event where no fauna mortalities were recorded.

Statistical analysis to determine the effectiveness of the fauna fencing does not contain strong statistical power due to the small results data pool, particularly of relevant fauna groups (i.e. medium to large sized terrestrial mammals). The results of future monitoring should be consolidated to develop a larger data set to allow for future statistical analysis.



A recommendation to review the fauna fence and drop down structure configuration within the Rosewood Creek to Rosewood Tributary area has been suggested should the trend of mammal road kill records at this location continue.



1. Introduction

GeoLINK was engaged by NSW Roads and Maritime Services to undertake weekly Road Kill Monitoring for the first 12 weeks of the operational phase of the Stage 2B section of the Warrell Creek to Nambucca Heads Pacific Highway Upgrade (WC2NH). A number of road kill mitigation measures were implemented for WC2NH with the aim to minimise vehicle collisions with native wildlife. The types of structures which were constructed to mitigate traffic impacts to fauna consist of:

- Fauna fencing to exclude fauna from the road corridor and guide fauna towards connectivity structures.
- Fauna Drop Down Structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including fauna culvert underpasses, bridge underpasses, vegetated widened medians, rope bridges and glider poles.

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

- **Type 1** - Chainmesh fence 1.8 m tall with floppy top feature which is designed to exclude a range of native mammal species such as macropods, possums, Spotted-tail Quoll (*Dasyurus maculatus*) and Koala (*Phascolarctos cinereus*). A total of 1.16 km of this fence type occurs at the site, located on one side of the highway only.
- **Type 2** – Comprises Type 1 fence as described above, with Giant Barred Frog (GBF) (*Mixophyes iteratus*) exclusion at the bottom. The GBF exclusion comprises small gauge mesh fence with sheet metal return angled away from the highway. A total of 1.74 km of Type 2 fauna fence occurs at the site, located on both sides of the highway for a stretch of approximately 520 m and one side of the highway for a stretch of approximately 350 m. Approximately 870 km of highway is covered by Type 2 fauna fencing.

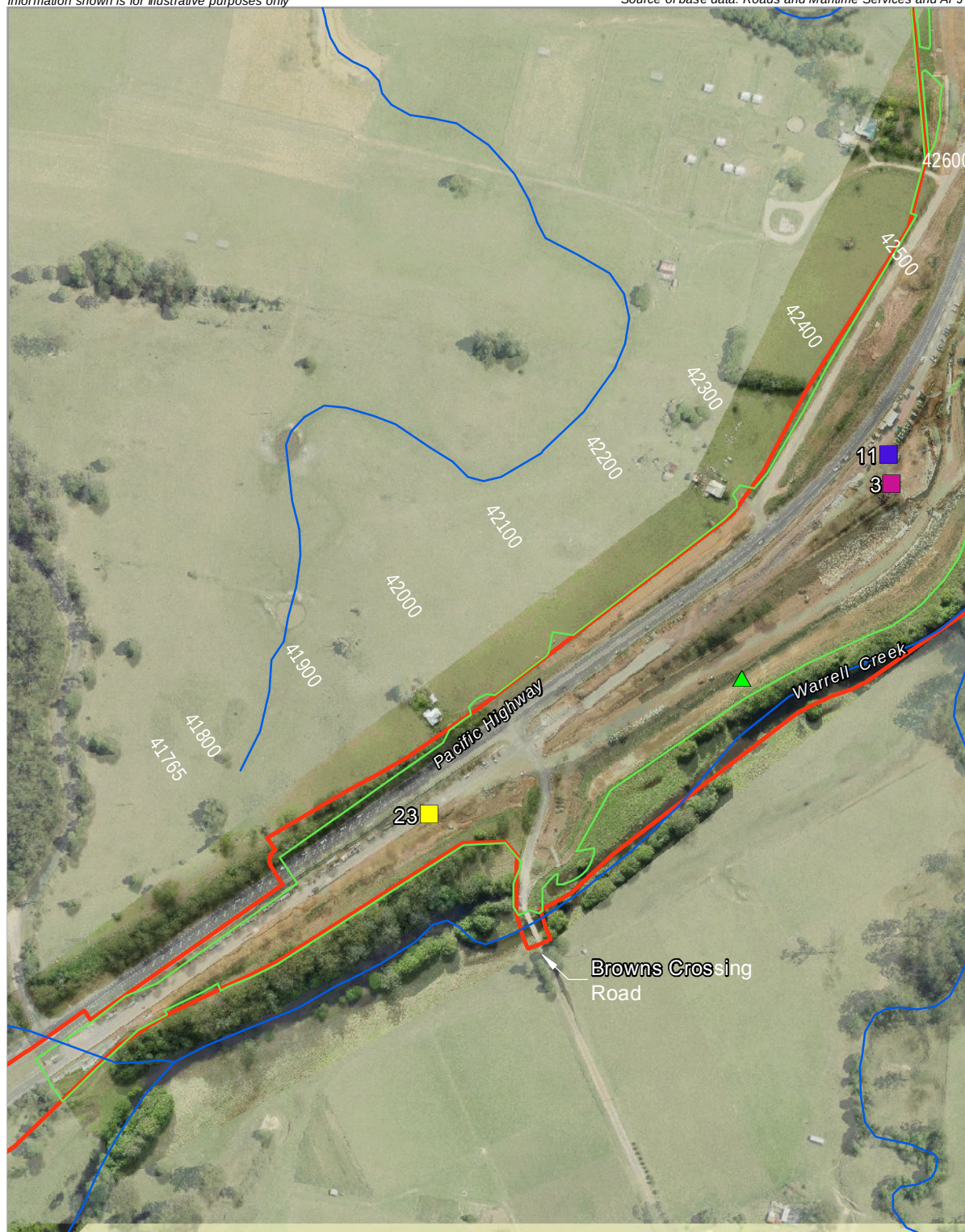
The locations of fauna fences and design types are presented within **Illustration 1-1 to Illustration 1-7**.

The aim of the monitoring program is to:

- Report on any animal road kill within the Stage 2B section of operational highway since open to traffic; and
- Assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

This report provides the results of the first 12 weeks of road kill monitoring since Stage 2B became operational to traffic on 29 June 2018.

Information shown is for illustrative purposes only



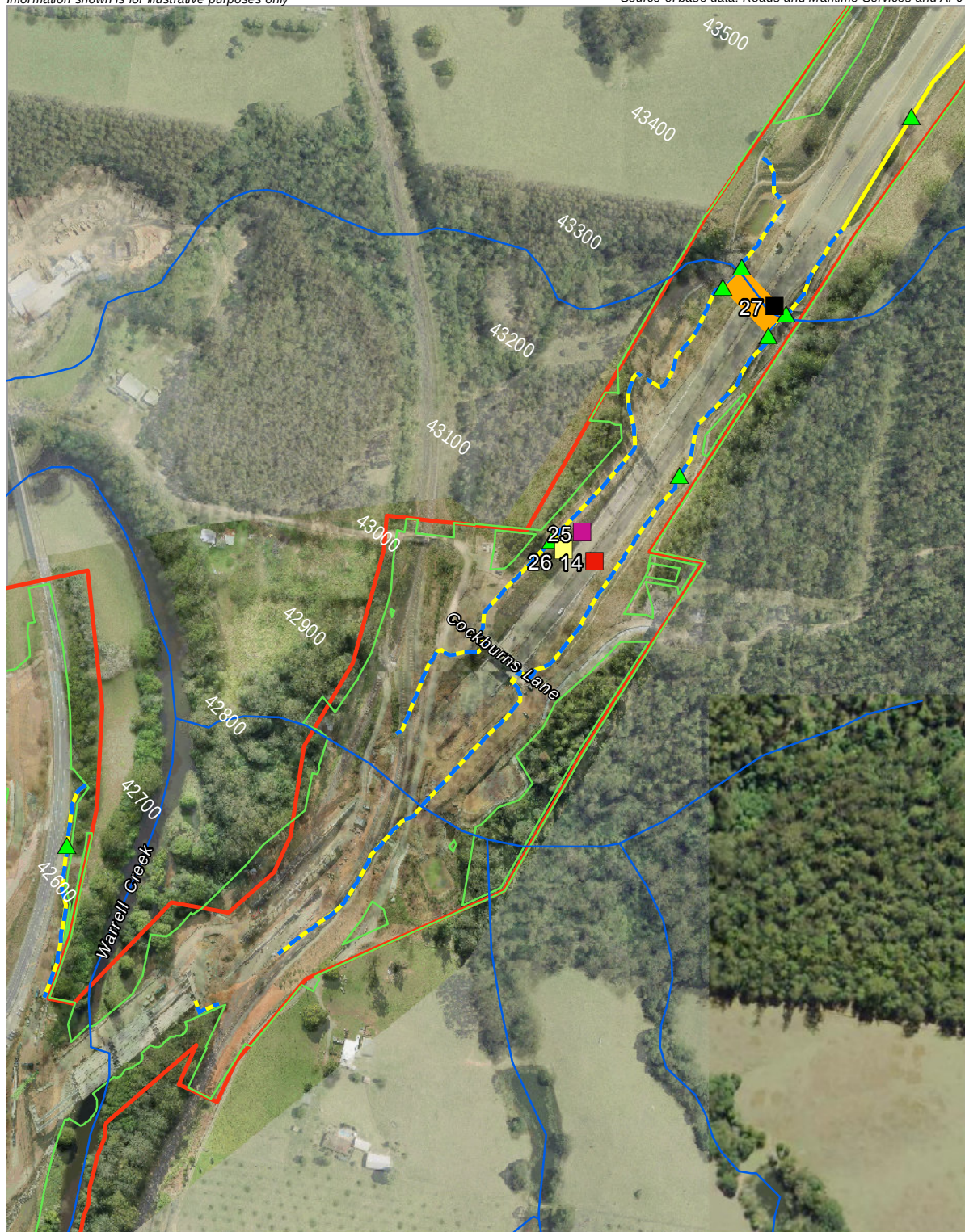
LEGEND

- | | |
|---|--|
| — Site boundary | ▲ Fauna drop down structure |
| — Clearing limit | ■ Australian Magpie |
| — Fauna culvert | ■ Australian White Ibis |
| — Watercourse | ■ Common Brushtail Possum |

0 100



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LEGEND

- | | |
|--|--|
| — Site boundary | ▲ Fauna drop down structure |
| — Clearing limit | ■ Barn Owl |
| — Fauna culvert | ■ Common Brushtail Possum |
| — Watercourse | ■ Short-beaked Echidna |
| — Type 1 fauna fence (floppy top) | ■ Tawny Frogmouth |
| — Type 2 fauna fence (Giant Barred Frog) | |

0 100



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LEGEND

- | | |
|-----------------------------------|------------------------------------|
| — Site boundary | ▲ Fauna drop down structure |
| — Clearing limit | ■ Barn Owl |
| — Fauna culvert | ■ Common Brushtail Possum (likely) |
| — Watercourse | ■ European Fox |
| — Type 1 fauna fence (floppy top) | ■ Northern Brown Bandicoot |
| | ■ Red-necked Wallaby |
| | ■ Unidentified Macropod |

0 100



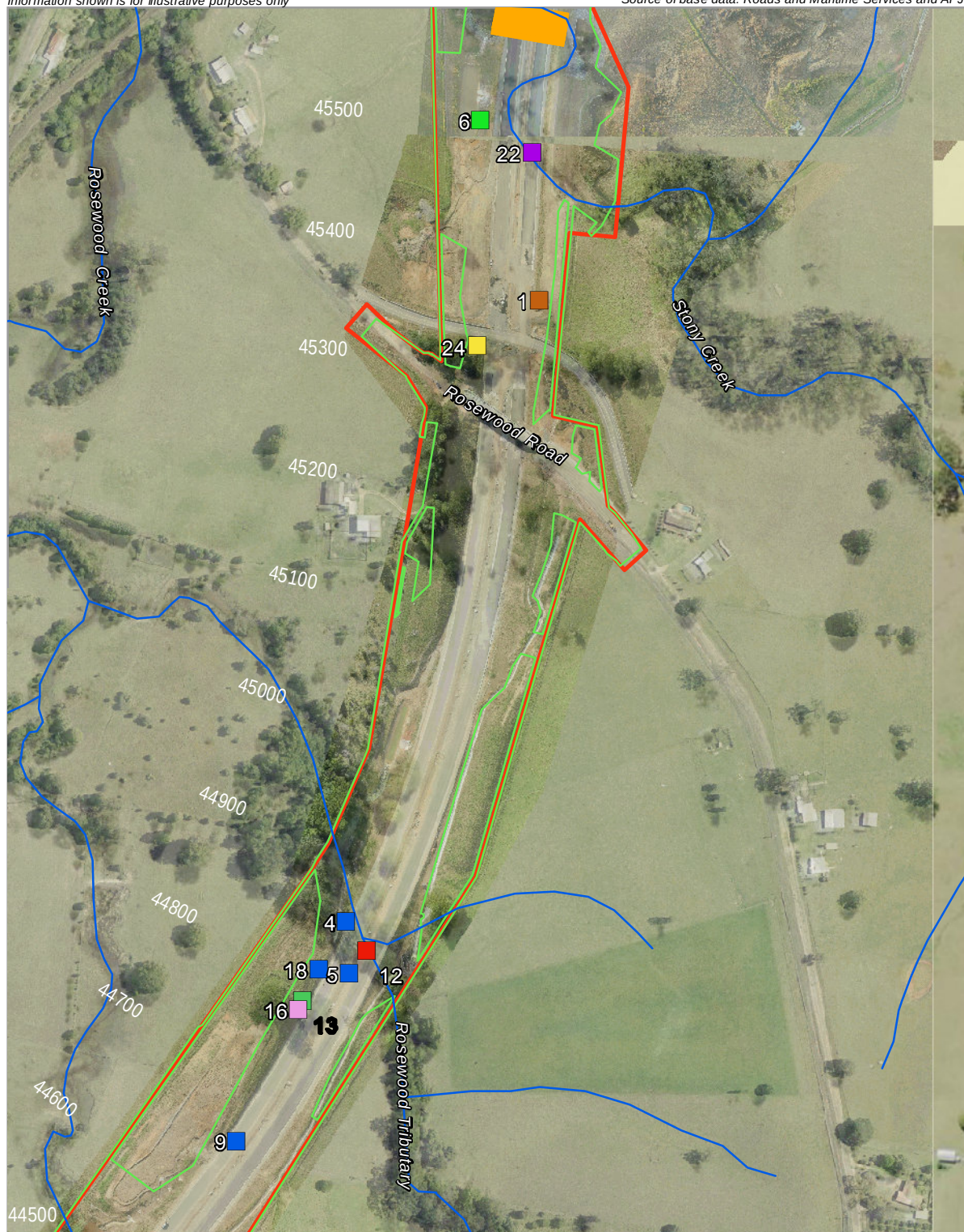
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Stage 2B Road Kill Monitoring Report – Initial 12 Weeks 2018
2692-1147

Road Kill Fauna Locations

Sheet 3 of 7

Information shown is for illustrative purposes only



LEGEND

- | | |
|------------------|----------------------------|
| — Site boundary | ■ Australian Wood Duck |
| — Clearing limit | ■ Barn Owl |
| — Fauna culvert | ■ Blue or Pink Tongue Sink |
| — Watercourse | ■ Northern Brown Bandicoot |
| | ■ Pacific Black Duck |
| | ■ Purple Swampphen |
| | ■ Red-necked Wallaby |
| | ■ Unidentified Macropod |

0 100



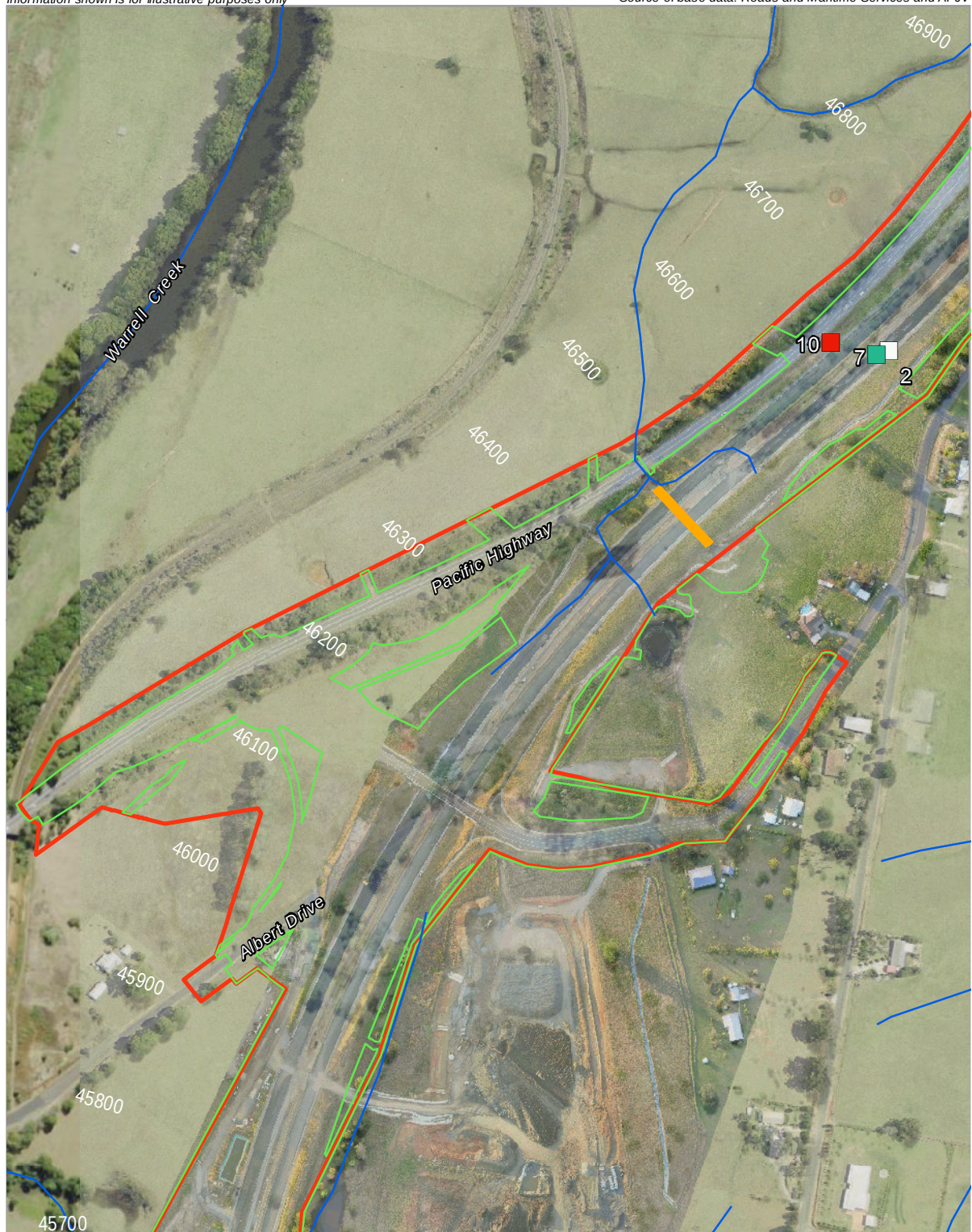
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Stage 2B Road Kill Monitoring Report – Initial 12 Weeks 2018
2692-1147

Road Kill Fauna Locations

Sheet 4 of 7

Information shown is for illustrative purposes only



LEGEND

- | | |
|------------------|----------------------|
| — Site boundary | ■ Barn Owl |
| — Clearing limit | ■ Red-necked Wallaby |
| — Fauna culvert | □ Magpie-lark |
| — Watercourse | |

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Information shown is for illustrative purposes only



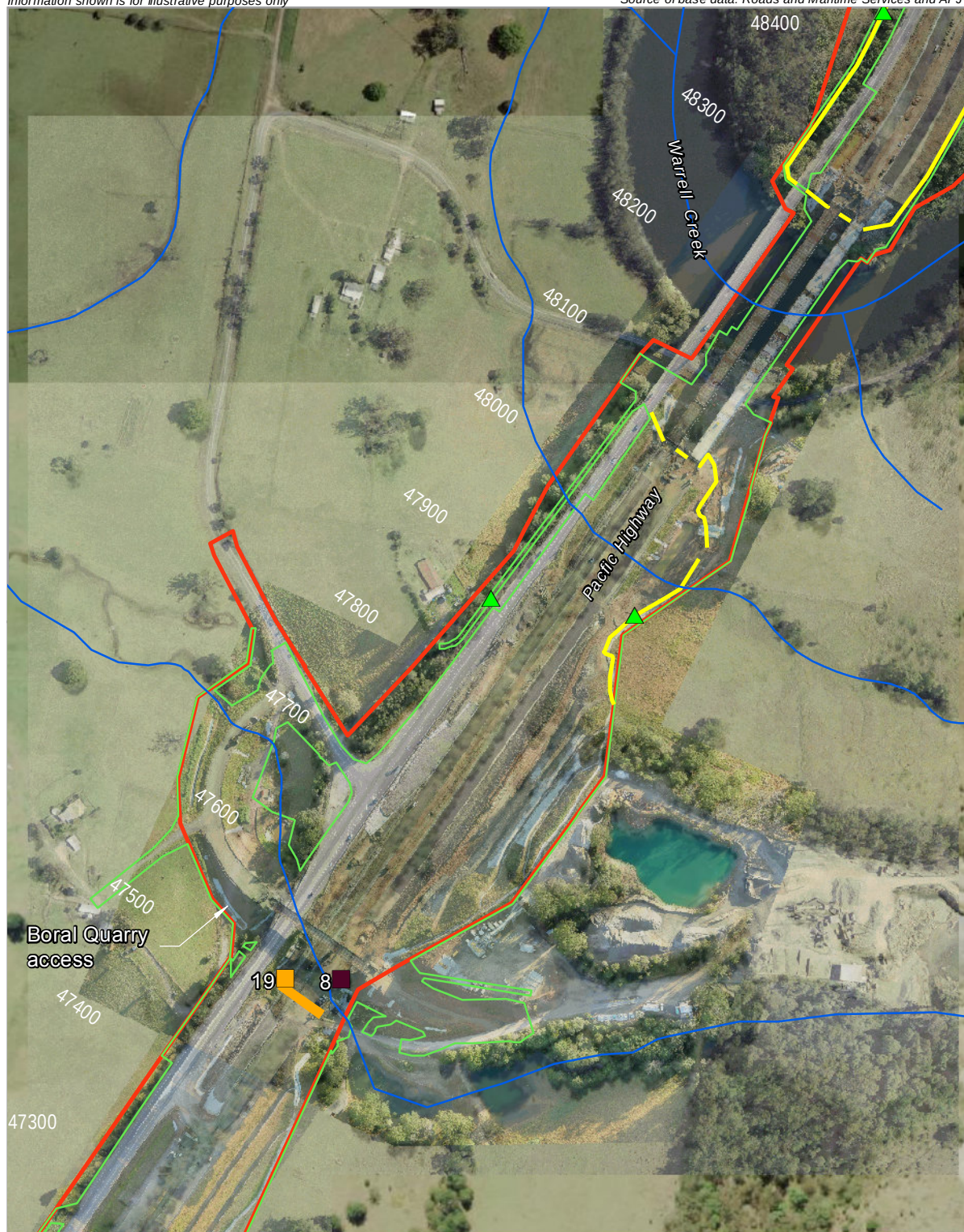
LEGEND

- | | |
|------------------|----------------------|
| — Site boundary | ■ Barn Owl |
| — Clearing limit | ■ Red-necked Wallaby |
| — Fauna culvert | ■ Feral Pigeon |
| — Watercourse | ■ Magpie-lark |
| | ■ Southern Boobook |

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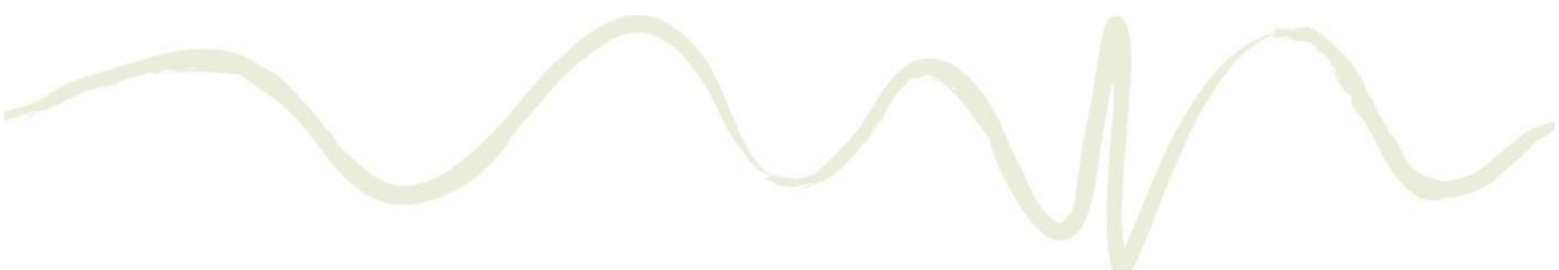


LEGEND

- | | |
|---|--|
| — Site boundary | ▲ Fauna drop down structure |
| — Clearing limit | ■ Feral Pigeon |
| — Fauna culvert | ■ Southern Boobook |
| — Watercourse | |
| — Type 1 fauna fence (floppy top) | |

0 100





2. Methodology

2.1 Road Kill Monitoring

Road kill monitoring for Stage 2B of WC2NH was undertaken weekly (each Thursday) for the first 12 weeks after the opening of Stage 2B to traffic. The Stage 2B site covers 6.6 km of dual carriageway highway extending from Browns Crossing Road (Chainage 41700) in the south to Scott's Heads Road in the north (Chainage 48100). The survey area covered the north and southbound carriageways and has a combined length of 13.2 km of road (refer to **Illustration 1-1 to Illustration 1-7**). In total, 1.9 km (29 per cent) of the 6.6 km of dual carriageway contains fauna exclusion fencing (Type 1 or 2) on one or both sides of the highway. Of this, Type 2 fauna exclusion fencing (with GBF exclusion) covers 870 m (13 per cent) of the highway.

The 12 weekly monitoring events commenced on 5 July 2018 and ended on 20 September 2018. No opportunistic road kill records were observed outside of the nominated weekly (Thursday) monitoring events for Stage 2B. The following monitoring methodology was adopted:

- A two-person team drove the length of Stage 2B in a vehicle to locate and identify fauna road mortalities, as a result of vehicle strike.
- The speed of travel averaged 60-70 km per hour, with both the ecologist visually searching for fauna road kill along the highway alignment and within three metres from the fog line.
- A minimum of two passes of the survey area was completed to ensure that all records were accurately detected and could be safely recorded. The first pass of the survey area was undertaken within the first two hours of sunrise. Occasionally a third pass was undertaken to collect data not recorded during the first two pass due to inaccessibility or no place to safely collect data at the time of observation.

For each road kill observed, the following attributes were recorded:

- Species of animal.
- Date of record.
- Global Positioning System (GPS) coordinates.
- Location of road kill record within either the south or northbound carriageway.
- The presence of fauna fencing at/near to the road kill record.
- Distance to the nearest fauna fence if not installed adjacent to the road kill record.
- Photographic record of the animal.
- Comments.

If the animal was identified as an *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed threatened species, the carcass was photographed, and the following information recorded:

- Sex and age class (juvenile or adult).
- Presence of pouch young (for marsupials).
- Presence of flightless young (for flying-foxes or other bats).
- Distance to a fauna connectivity structure.
- Distance to drop down structure.
- If fauna fencing was installed, was there any damage to the fence in the vicinity.
- Weather conditions at the time of the monitoring (from the Bureau of Meteorology) – including temperature, rainfall in the last 24 hours, moon phase.

- For flying-foxes:

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

2.2 Analysis of Data

Mammals are the main targets of exclusion fencing; therefore, mammal data was analysed to determine whether there was any difference in the number of road kill between fenced and unfenced section of the site. Count data was available for the analysis. Each road kill was nominated as being either within or outside a fauna fenced area. The within fencing category applied regardless of whether the fencing was on one or both sides of the highway at the road kill site. Insufficient data was available to test whether time, since fence installation, affected the number of road kill (e.g. using a Kruskal-Wallis analysis). No frog road kill recordings were made; therefore an analysis of the effectiveness of the Type 2 fauna exclusion fencing (with GBF exclusion) in relation to frogs was not undertaken.

The G-test has been shown to be superior to the Chi-squared test for comparing frequency data where the expected proportions were not derived from the data. The G-test is a non-parametric log-likelihood test that conforms to a Chi-squared distribution. It tests the null hypothesis that the observed and expected frequencies do not differ (Dytham 2003). A G-test was applied to frequency data by pooling monitoring periods for both fenced and non-fenced areas. Expected proportions were taken from the proportion of total highway length (6.6 km) that was fenced (29 per cent) versus unfenced (71 per cent). A two-tailed G-test was conducted by programming the G-test into an Excel spreadsheet.

3. Results

3.1 Number and Species of Fauna Road Kills

The results of the road kill surveys during the first 12 weeks of Stage 2B being operational are provided in **Appendix A**. A total of 27 fauna road mortalities were recorded. Species diversity included 16 native species and two introduced species. The road kill recordings included:

- Twelve (44.5 per cent) native avifauna (birds) comprising nine confirmed species/species groups.
- One (3.7 per cent) introduced avifauna species; a Feral Pigeon (*Columba livia*).
- Twelve (44.5 per cent) native mammal comprising a minimum of six confirmed species/species groups including:
 - Seven macropods (including Red-necked Wallaby {*Macropus rufogriseus*} and one unidentifiable macropod species)
 - Three Common Brushtail Possum (*Trichosurus vulpecula*)
 - One Northern Brown Bandicoot (*Isodon macrourus*)
 - One Echidna (*Tachyglossus aculeatus*).
- One (3.7 per cent) introduced mammal species; a European Fox (*Vulpes vulpes*).
- One (3.7 per cent) native reptile; a Blue or Pink Tongue Snake (*Tiliqua sp.*) that was too badly damaged to identify to species level.

No opportunistic road kill mortalities were recorded outside of the weekly monitoring events for Stage 2B and no frog road kill recordings were made.

Figures 3.1 and **3.2** show the number of fauna road kills recorded each monitoring event over the 12-week monitoring period. The number of fauna mortality records peaked during week 7 of Stage 2B being operational with five road kill fauna records observed. Results indicate a general trend with the number of fauna road kill records increasing slightly over time. Week 5 of the 12 weeks of monitoring was the only monitoring event where no fauna mortalities were recorded.

No road kill recordings of BC or EPBC Act listed threatened species occurred during the monitoring.



Plate 1.1 Barn Owl road kill recorded 16 August 2018

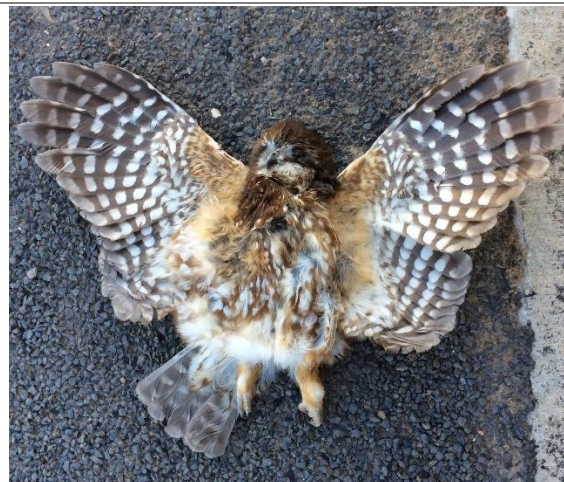


Plate 1.2 Southern Boobook road kill recorded 30 August 2018

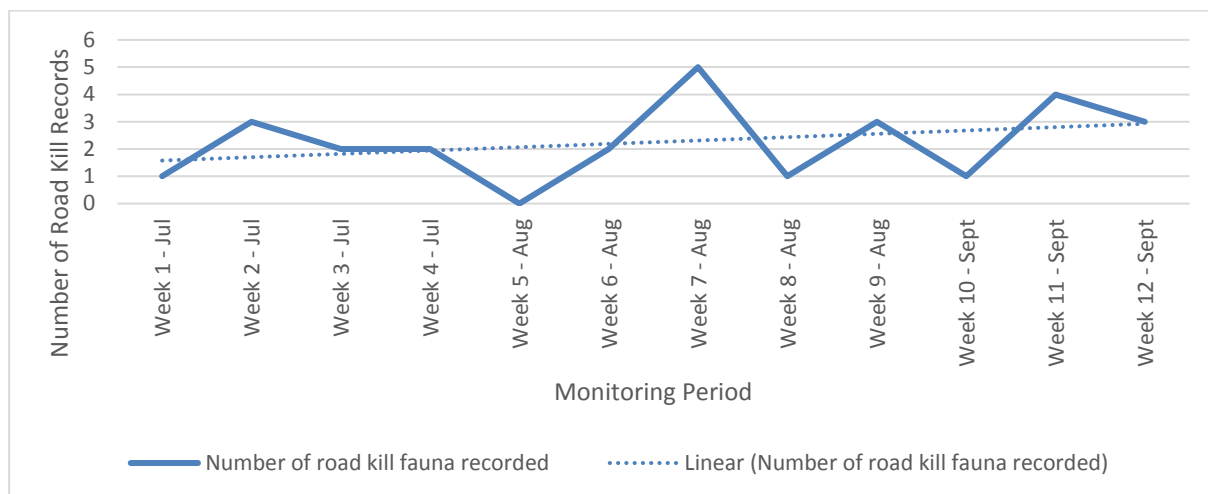


Figure 3-1 Number of fauna road kills recorded during each monitoring event and trend line

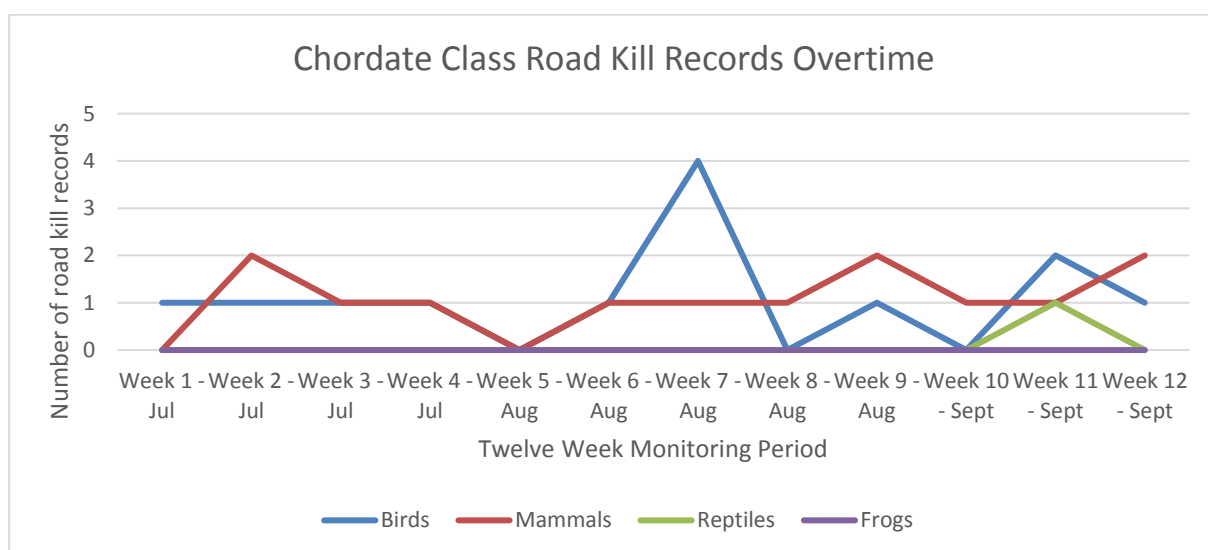


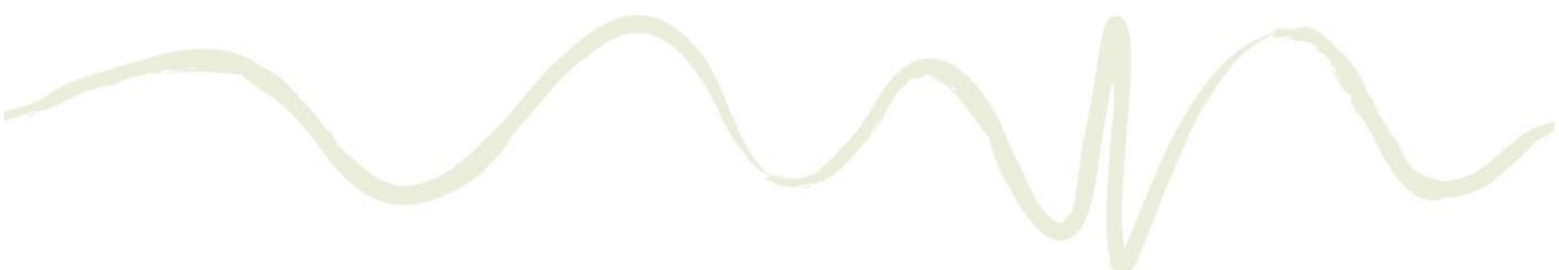
Figure 3-2 Number of road kill chordate class recorded over time

3.2 Distribution of Fauna Road Kill Records

Illustration 1-1 to Illustration 1-7 show the location of the road kill records. Two main concentrations of road kill records were observed:

- Chainages 44100 to 44860 from south of Rosewood Creek to just north of Rosewood Tributary (not fenced). The majority of records were mammal species both native and introduced. Two Barn Owl records were observed within this grouping.
- Chainages 45300 to 45500 north of Rosewood Road overpass (not fenced). The majority of records were bird species with one reptile record.

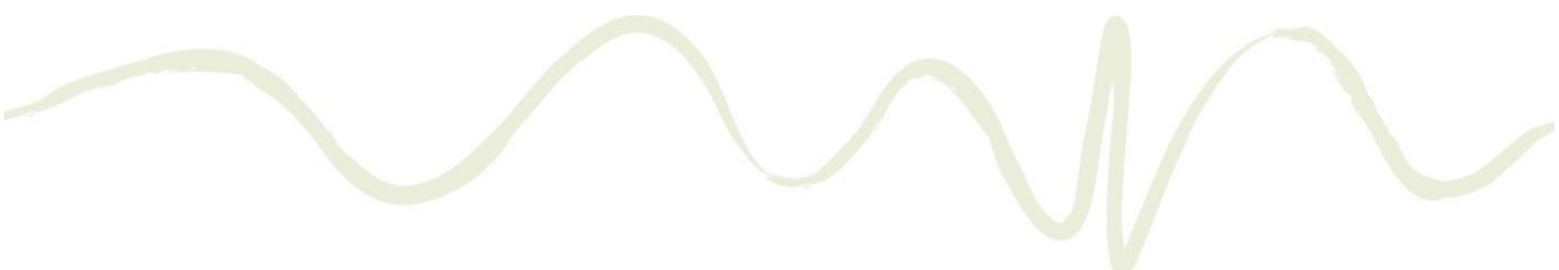
Two additional small concentrations (three records) were noted at chainages:

- 
- 43050 to 43100 north of Cockburns Lane overpass (fauna fence adjacent).
 - 46650 to 46700 approximately 300 m south of Williamson Creek (not fenced).

Of the 27 road kill fauna records, five records (18.5 per cent) were located along the highway carriageway where fauna exclusion fence is installed. Thirteen of the 27 records (50 per cent) were birds which are not prevented from entering the road corridor by fauna exclusion fencing due to their ability to fly. Twenty-two (81.5 per cent) of road kill records were located where no fauna exclusion fencing was installed, of which 11 records (41 per cent) were birds.

No Giant Barred frogs were observed within the vicinity of the Type 2 exclusion fencing between chainages 42550 and 43400.

A concentration of Red-necked Wallaby road kill records were observed within the Rosewood Creek and Tributary area where no fauna exclusion fencing was installed between chainages 44100 to 44860. With the exception of one Red-necked Wallaby record was observed with approximately 120 m from the beginning of the fauna exclusion fencing at Chainage 44120.



4. Discussion

4.1 Discussion

No BC or EPBC Act listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment, that the fencing aims to protect, were recorded. Such species include the Koala, Spotted-tailed Quoll or Giant Barred Frog.

Of the 27 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were moderate (12 of 27 records) over the reporting period.

The majority of animals impacted by traffic have been bird species (12 individuals or 45.5 per cent). Fauna exclusion fencing does not effectively mitigate against vehicle strike to birds due to their ability to fly over fauna fencing and into the road corridor. Although some areas of the newly finished batters received the recent application of hydroseed and hand seed, birds which are attracted to the grain and seeds within the mix have not been recorded in similar numbers to what was observed within the initial 12 monitoring of Stage 2A (GeoLINK, 2018) which recorded a substantial number of road kill Ducks and Galah.

Medium to large mammals were predominantly recorded within the Rosewood Creek and Rosewood Tributary areas. Of the 10 mammals recorded within this concentration five of the records were Red-necked Wallabies and one unidentified macropod. A local population of Red-necked Wallaby have been observed with this location and adjacent to the site while the highway upgrade was under construction.

A recommendation has been suggested (refer to **Section 4.4**) with the aim to further reduce fauna road kills associated with Stage 2B of the highway upgrade.

4.2 Comparison with Construction Road Kill Monitoring

The road kill monitoring during February 2015 and June 2018 (42 months) undertaken during construction between Chainages 41000 and 48100 (Stage 2B equivalent) by the WC2NH contractor recorded 40 road kill mortalities. One EPBC Act listed road kill was recorded. It is not possible to make a meaningful comparison between this construction monitoring data and the subject operational monitoring data due to:

- Differences in survey methodologies, data collected and personnel skill levels.
- Construction monitoring targeting different locations (i.e. subject sections of WC2NH follows a different alignment to the old Pacific Highway).

Notwithstanding, when pooling the 40 construction phase roadkill monitoring results where chainages were recorded into one kilometre segments, the data anecdotally shows roadkill 'hotspots' at:

- Chainage 41001-42000 (Upper Warrell Creek locality): six roadkill recordings
- Chainage 44001-45000 (Rosewood Creek locality): eight roadkill recordings
- Chainage 47001-48000 (south of Lower Warrell Creek locality): six roadkill recordings
- Chainage 48001-49000 (north of Lower Warrell Creek locality): eight roadkill recordings.

4.3 Analysis of Data

As limited data was available, native and non-native non-flying mammals were pooled to increase sample size. The data shown in **Table 4.1** was available for analysis.

Table 4.1 Summary of Road Kill Data Used in the Analyses

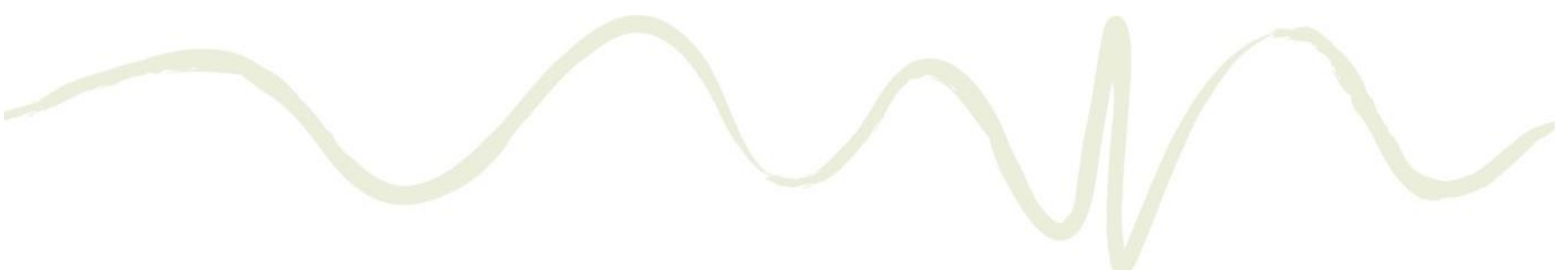
<i>Survey Date</i>	<i>No. Mammal Road Kill (Fauna Fence)</i>	<i>No. Mammal Road Kill (No Fauna Fence)</i>
5/07/2018	0	0
12/07/2018	0	2
19/07/2018	0	1
26/07/2018	0	1
2/08/2018	0	0
9/08/2018	0	1
16/08/2018	0	1
23/08/2018	0	1
30/08/2018	1	1
6/09/2018	0	1
13/09/2018	0	0
20/09/2018	2	0
Sum	3	9

The G-test comparing fenced versus unfenced road kill frequencies produced $\chi^2 = 1.573$, $p = 0.21$. There was no evidence that fencing affected the number of road kill along the highway alignment. However, this does not necessarily mean that there was no difference between fence and non-fenced areas. Limited road kill data was available for analysis and the test results could simply be an artefact of low statistical power. This could be remedied if more data was able to be collected, or to use additional data from other highway monitoring sites in a meta-analysis. To demonstrate that there is truly no difference in the data, the burden of proof is reversed and an equivalence test using the null hypothesis that there is a difference due to fencing would be required. Equivalence tests use two one-tailed tests to determine whether the data fall within specific bounds that are assumed to indicate that there is no true difference (Quertemont 2011).

4.4 Observations

The following observation is provided to further augment road kill mitigations along Stage 2B of WC2NH or to incorporate into future road kill mitigation strategies:

- Should the trend of mammal (particularly Macropod) road kill records continue from the Rosewood Creek to Rosewood Tributary area, a review of the fauna fence and fauna drop down structure configuration is suggested. The design could be improved by extending the Type 1 fauna fence on both the eastern and western sides of the alignment from chainages 44300 to 45100 and incorporating additional fauna drop down structures around culvert headwalls and within 100 m from the end of the fauna fence.



5. Summary and Conclusion

No BC or EPBC Act listed species were recorded during the monitoring period. No road kill recordings of target threatened species known to occur within habitat adjacent to the highway alignment that the fencing aims to protect were recorded. Such species include the Koala, Spotted-tailed Quoll or Giant Barred Frog.

Of the 27 road kill recordings, medium to large terrestrial native mammals comprise the main species group to which the fence design provides a barrier for. Recordings of these species were moderate (44.5 per cent of records) over the reporting period.

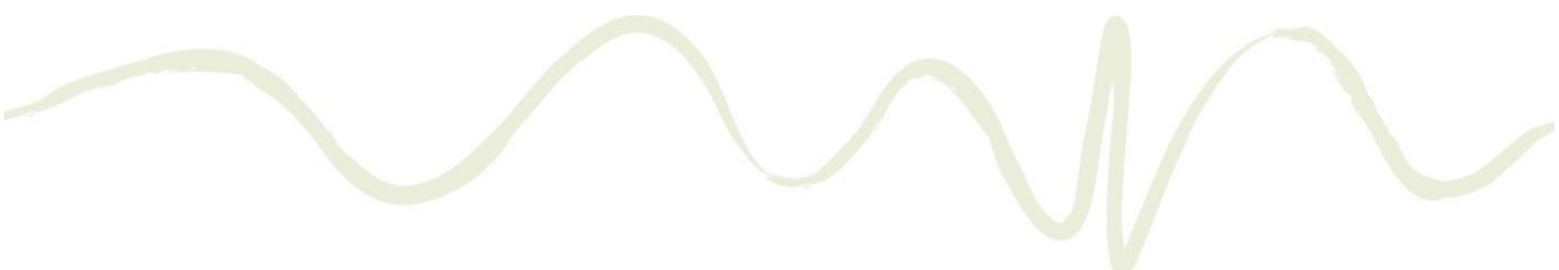
Two road kill hotspots were identified across Stage 2B including the Rosewood Creek to Rosewood Tributary and to a lesser degree to the north of Rosewood Road overpass.

No Giant Barred Frog road kill records were made in the vicinity of the Type 2 fauna fencing (Giant Barred Frog fencing) between chainage 42550 and 43400.

Results indicate a general trend with the number of fauna road kill records increasing slightly over time. Week 5 of the 12 weeks of monitoring was the only monitoring event where no fauna mortalities were recorded.

Statistical analysis to determine the effectiveness of the fauna fencing does not contain strong statistical power due to the small results data pool, particularly of relevant fauna groups (i.e. medium to large sized terrestrial mammals). The results of future monitoring should be consolidated to develop a larger data set to allow for future statistical analysis.

A recommendation to review the fauna fence and drop down structure configuration within the Rosewood Creek to Rosewood Tributary area has been suggested should the trend of mammal road kill records at this location continue.

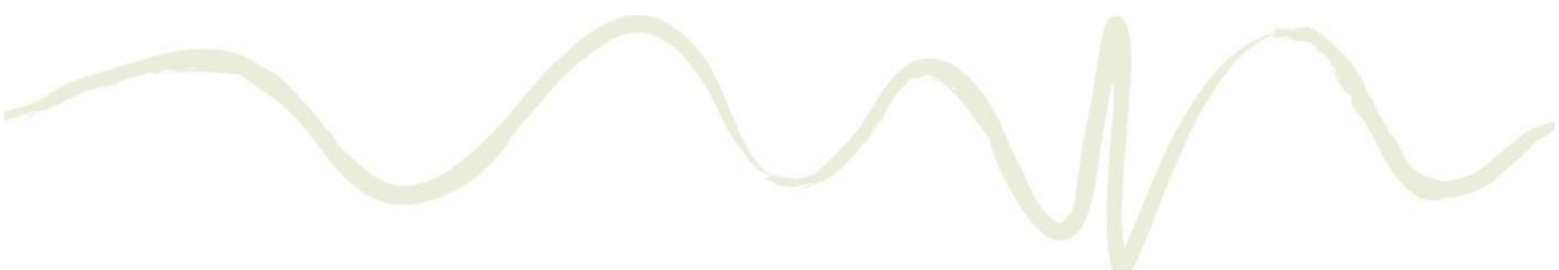


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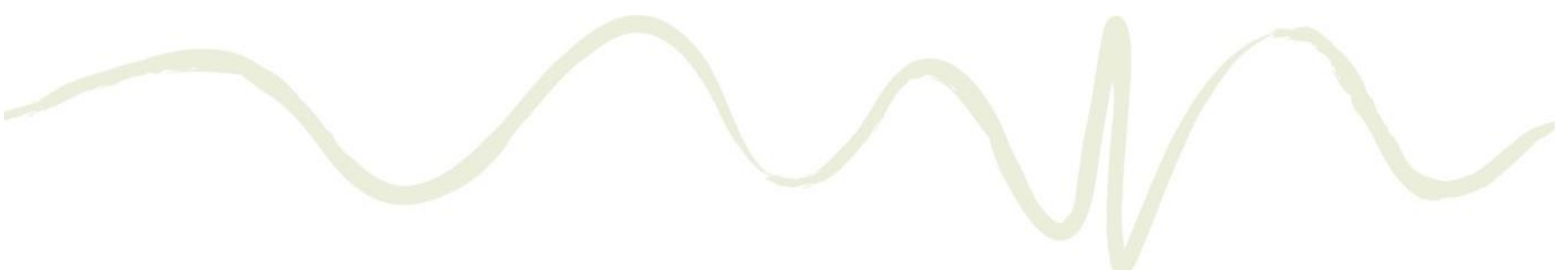


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Appendix A

Stage 2B Road Kill Monitoring Results

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	Carriageway (northbound or southbound)	Location Description	Fauna Fence Present (yes/no)	Distance to Nearest Fauna Fence	Comments	Image No.	Stage 2B
Week 1	1	Pacific Black Duck (<i>Anas superciliosa</i>)	Bird	5/07/2018	490859	6596643	Southbound	100 m north of Rosewood Road overpass	No	n/a for birds	Nil	7544	Stage 2B
Week 2	2	Magpie-lark (<i>Grallina cyanoleuca</i>)	Bird	12/07/2018	491394	6597726	Southbound	400 m south of Williamsons (Crouches) Creek Bridge	No	n/a for birds	Nil	n/a	Stage 2B
	3	Common Brushtail Possum (<i>Trichosurus vulpecula</i>)	Mammal	12/07/2018	489166	6594172	Southbound	On Upper Warrel Creek Bridge	No	~120 m to the north	Badly damaged Brushtail Possum.	7703	Stage 2B
	4	Red-necked Wallaby (<i>Macropus rufogriseus</i>)	Mammal	12/07/2018	490701	6596134	Northbound	Rosewood Tributary Culvert	No	~ 500 m to the south	Nil	7686	Stage 2B
Week 3	5	Red-necked Wallaby (<i>Macropus rufogriseus</i>)	Mammal	19/07/2018	490703	6596092	Centre median	Rosewood Tributary Culvert	No	~ 500 m to the south	Nil	2052	Stage 2B
	6	Australian Wood Duck (<i>Chenonetta jubata</i>)	Bird	19/07/2018	490811	6596790	Northbound	200 m north of Rosewood Road	No	n/a for birds	Nil	2055	Stage 2B
Week 4	7	Red-necked Wallaby (<i>Macropus rufogriseus</i>)	Mammal	26/07/2018	491383	6597723	Centre median	400 m south of Williamsons (Crouches) Creek Bridge	No	>500 m to nearest fauna fence	Nil	999	Stage 2B
	8	Feral Pigeon (<i>Columba livia</i>)	Bird	26/07/2018	491919	6598424	Southbound	Beneath Boral Quarry access bridge (near Scotts Head Road turnoff)	No	n/a for birds	Nil	n/a	Stage 2B

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	Carriageway (northbound or southbound)	Location Description	Fauna Fence Present (yes/no)	Distance to Nearest Fauna Fence	Comments	Image No.	Stage 2B
Week 5	-	No road kill records detected during week 5 monitoring event		2/08/2018	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Week 6	9	Red-necked Wallaby (<i>Macropus rufogriseus</i>)	Mammal	9/08/2018	490611	6595955	Northbound	600 m south of Rosewood Road overpass	No	~350 m to the south	Nil	2060-2063	Stage 2B
	10	Barn Owl (<i>Tyto alba</i>)	Bird	9/08/2018	491346	6597734	Northbound	400 m south of Williamsons (Crouches) Creek Bridge	No	>500 m to nearest fauna fence	Nil	2064-2072	Stage 2B
Week 7	11	Australian White Ibis (<i>Threskiornis molucca</i>)	Bird	16/08/2018	489163	6594196	Northbound	On Upper Warrell Creek Bridge	No	~120 m to the north	Nil	2100	Stage 2B
	12	Barn Owl (<i>Tyto alba</i>)	Bird	16/08/2018	490718	6596110	Centre median	Rosewood Tributary Culvert	No	n/a for birds	Centre median access not possible.	2099	Stage 2B
	13	Unidentifiable Macropod	Mammal	16/08/2018	490665	6596070	Northbound	Rosewood Tributary Culvert	No	~ 500 m to the south	Very badly damaged Macropod record. Possible Red-necked Wallaby.	2096	Stage 2B
	14	Barn Owl (<i>Tyto alba</i>)	Bird	16/08/2018	489687	6594685	Southbound	100m north of Cockburns Lane overpass	Yes	n/a for birds	Nil	2094-2095	Stage 2B
	15	Barn Owl (<i>Tyto alba</i>)	Bird	16/08/2018	490538	6595828	Centre median	Rosewood Creek Culvert	No	n/a for birds	Nil	2088-2093	Stage 2B

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	Carriageway (northbound or southbound)	Location Description	Fauna Fence Present (yes/no)	Distance to Nearest Fauna Fence	Comments	Image No.	Stage 2B
Week 8	16	Northern Brown Bandicoot (<i>Isodon macrourus</i>)	Mammal	23/08/2018	490662	6596062	Northbound	Rosewood Tributary Culvert	No	~ 500 m to the south	Nil	001-002	Stage 2B
Week 9	17	Red-necked Wallaby (<i>Macropus rufogriseus</i>)	Mammal	30/08/2018	490294	6595537	Southbound	300 m south of Rosewood Creek Culvert	Yes	Fence adjacent	Very dry damaged record.	n/a	Stage 2B
	18	Red-necked Wallaby (<i>Macropus rufogriseus</i>)	Mammal	30/08/2018	490679	6596095	Northbound	Rosewood Tributary Culvert	No	~ 500 m to the south	Very damaged dry record.	2063-2064	Stage 2B
	19	Southern Boobook (<i>Ninox novaeseelandiae</i>)	Bird	30/08/2018	491873	6598425	Northbound	South side of Boral Quarry access overpass	No	n/a for birds	Clear Boobook record.	2065-2067	Stage 2B
Week 10	20	Common Brushtail Possum (<i>Trichosurus vulpecula</i>)	Mammal	6/09/2018	490486	6595769	Southbound	Rosewood Creek Culvert	No	~150m to the south	Fur and claw only very damaged size consistent with Brushtail Possum.	2104-2105	Stage 2B
Week 11	21	European Fox (<i>Vulpes vulpes</i>)	Introduced Mammal	13/09/2018	490432	6595713	Southbound	100 m south of Rosewood Creek Culvert	No	~80m to the south	Appears to be female fox with the tail missing from the body.	001	Stage 2B
	22	Purple Swamphen (<i>Porphyrio porphyrio</i>)	Bird	13/09/2018	490853	6596764	Southbound	200m north of Rosewood Road overpass	No	n/a for birds	Nil	003	Stage 2B
	23	Australian Magpie (<i>Cracticus tibicen</i>)	Bird	13/09/2018	488787	6593901	Southbound	50m south of Browns Crossing Road	No	n/a for birds	Nil	004	Stage 2B

Monitoring Week	No. of Records	Species	Class of Chordate	Date	Easting	Northing	Carriageway (northbound or southbound)	Location Description	Fauna Fence Present (yes/no)	Distance to Nearest Fauna Fence	Comments	Image No.	Stage 2B
	24	Blue or Pink Tongue Sink (<i>Tiliqua sp.</i>)	Reptile	13/09/2018	490808	6596606	Northbound	50m north of Rosebank Road overpass	No	>500 m to nearest fauna fence	Very damaged could not be identified to species level.	005	Stage 2B
Week 12	25	Common Brushtail Possum (<i>Trichosurus vulpecula</i>)	Mammal	20/09/2018	489677	6594708	Centre median	Butchers Creek Culvert	Yes	Fence adjacent	Damaged record, beak visible to distinguish species.	n/a	Stage 2B
	26	Short-beaked Echidna (<i>Tachyglossus aculeatus</i>)	Mammal	20/09/2018	489662	6594694	Northbound	100m north of Cockburns Lane overpass	Yes	Fence adjacent	Female Echidna	8405-8410	Stage 2B
	27	Tawny Frogmouth (<i>Podargus strigoides</i>)	Bird	20/09/2018	489835	6594894	Northbound	100 m north Cockburns Lane overpass	Yes	n/a for birds	Very damaged record, likely Brushtail Possum.	8403-8404	Stage 2B

Appendix 6 Annual report 2018 inc. Spring (October)
2018 Monitoring Report.

Pacific Highway Upgrade Warrell Creek to Nambucca Heads: operational phase roadkill monitoring - annual report 2018



Sandpiper Ecological

1/94 Main Street
Alstonville

Final Report

27 November 2018

Document Review

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Cover Photo: Roadkilled barn owl.

Disclaimer:

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1. Introduction

1.1 Background

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

The upgrade included a number of roadkill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate roadkill included:

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

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

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

Sandpiper Ecological Surveys (SES) has been contracted by RMS to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal roadkill surveys over the entire upgrade length.

Monitoring of roadkilled fauna is a requirement of the approved WC2NH koala, spotted-tailed quoll and grey-headed flying-fox management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for roadkill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog (*Mixophyes iteratus*). Monitoring is required for the first five years of operation, and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Seasonal surveys are scheduled for October, January, April, and July. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced monitoring in October 2018. Previous roadkill monitoring was conducted by Geolink (2018a, b, c, d).

The aim of monitoring is to:

- report on any vertebrate roadkill following opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

The following report details the methods used to monitor roadkilled fauna in spring (October) 2018 and compares roadkill data from fenced versus unfenced sections of the alignment. Monitoring in October 2018 covered the entire alignment.

1.2 Study area

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

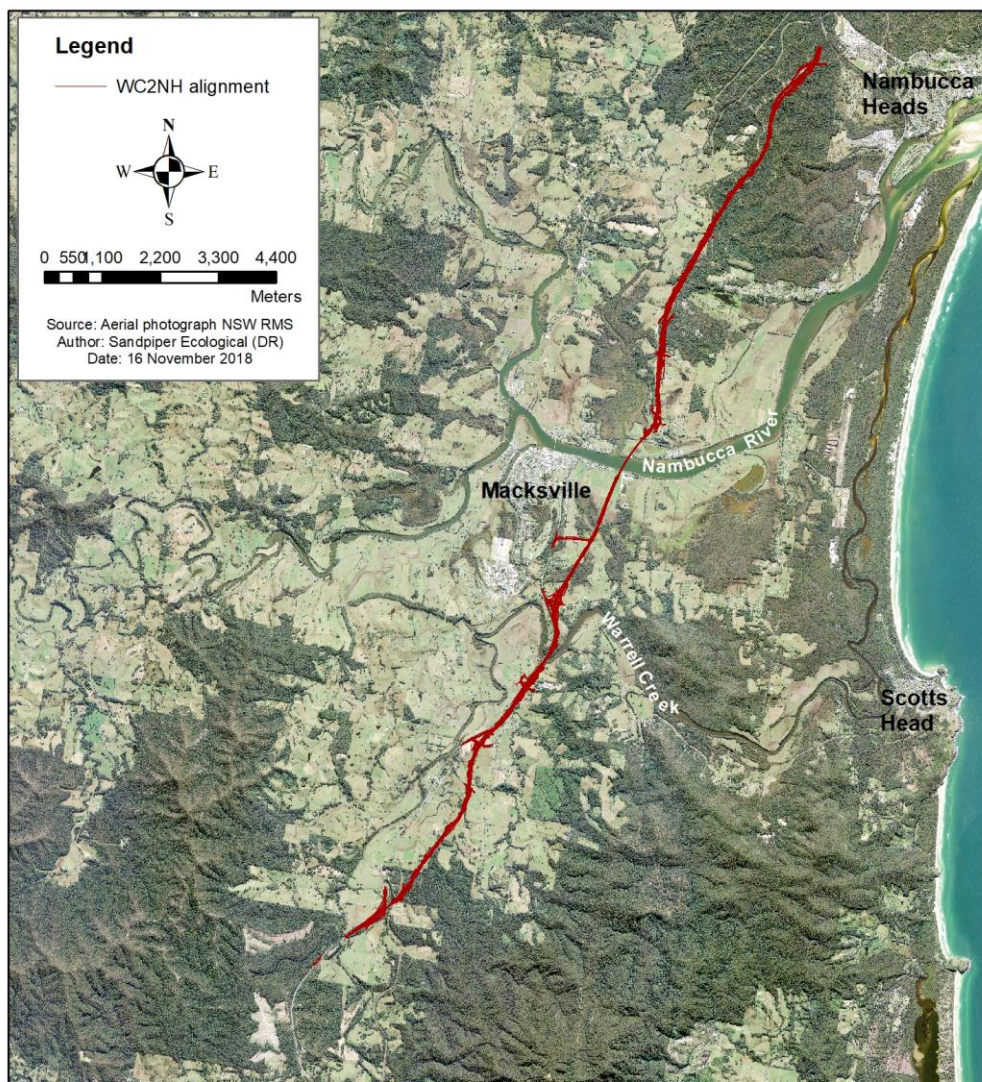


Figure 1: Location of the WC2NH alignment.

2. Methodology

2.1 Roadkill surveys

Roadkill surveys were conducted by a two-person team from a vehicle driven at 60-70km/hr in the left lane with amber (flashing) and hazard lights on. The team consisted of a driver and ecologist with experience identifying road-killed fauna. All surveys commenced within two hours of sunrise and where possible, were completed within three hours of sunrise, with an interval of 6-7 days between samples. During each survey both the driver and ecologist scanned the road surface and road shoulder for fauna. When roadkilled fauna were detected the vehicle was pulled onto the shoulder/parking bay and the subject animal was visually inspected by the ecologist. Fauna that could not be identified immediately were photographed and images sent to colleagues. Carcasses were removed from the road surface when safe to do so.

Data collected on each roadkill included:

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

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act* (1999) included, where possible: sex and age (juvenile/adult); presence of pouch young; presence of flightless young (flying-foxes); distance to a fauna connectivity structure (determined from GIS); distance to a drop-down structure (determined from GIS); damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

Distance to connectivity structure, and distance to drop-down was determined via GIS. All other data were uploaded to an Ipad onsite.

2.2 Data summary and analysis

Data from the October 2018 survey were uploaded to Microsoft excel. The October data were compared with results from the previous 12 week sample (see Geolink 2018d) to identify any duplicates. Using a combination of species and geographic location nine overlapping records were identified and removed from the October dataset. Graphs have been produced showing the total number of roadkills in October and the number of roadkills in different fauna groups each week of the survey. The location of roadkills has been overlaid on the WC2NH alignment to show their distribution. The number of roadkills for each species recorded during roadkill surveys over all monitoring periods was summarized by combining the October data with data from previous surveys (e.g. Geolink 2018a, b, c, d).

2.2.1 Statistical analysis

The primary aim of statistical analysis is to determine if there is a statistical difference in the frequency of roadkills between fenced and unfenced sections of the alignment. A secondary aim is to

determine if the frequency of roadkill varies through time in fenced and unfenced sections of the alignment.

Roadkill data were summarised by removing species/groups that would not (under normal circumstances) be stopped by exclusion fence from accessing the road alignment e.g. birds. Species/groups of fauna likely to be stopped by exclusion fence and therefore included in the analysis are listed in Table 1. Introduced species were included in the analysis to bolster sample size. Freshwater turtles were included as exclusion fence with a ground return should stop this group. Small lace monitors could move through exclusion fence, however, individuals of that size are rarely recorded in open habitats.

The location of each roadkill in relation to exclusion fence was determined from previous reports, and for October 2018, by overlaying roadkill records on a plan of exclusion fence extent using ArcGIS. If exclusion fence occurred on one side only the record was classified as “No fence”. Sections of the alignment with a single fence may be included as a separate category in future analysis as sample size increases.

Table 1: Fauna groups included in comparison of fenced and unfenced sections of alignment.

Group	Species included
Macropods	Red-necked wallaby, swamp wallaby & eastern grey kangaroo
Bandicoots	Long-nosed & northern brown bandicoots
Possum	Brush-tail & ringtail possums
Canid	Fox & dog
Feline	Cat
Leporidae	Hare & rabbits
Freshwater turtles	Long-necked, saw-shelled and Macleay river turtles
Goanna	Lace monitor

Data were pooled across all samples and divided into “fenced” and “unfenced”. Expected proportions were based on the proportion of highway with fence on both sides (“fenced”) and proportion with a single fence, or no fence (“no fence”). The proportion of fenced versus unfenced was 0.55 to 0.45. Data were analysed using a two-tailed G-test as per the equation of McDonald (2013), and a Kruskal-Wallis test in Systat 13.

3. Results

3.1 October 2018 sample

3.1.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses on the road surface (Table 1). Light showers occurred on two of the sample days but conditions were still suitable for roadkill surveys.

Table 2: Weather conditions in the 24hrs preceding each sample event. Data obtained from Envirodata weather station at the southern compound.

Date	Average Relative Humidity (%)	Total Rainfall (mm)	Maximum Temperature (°C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
4/10/18	81	0	25	5	Good	Nil
10/10/18	82	0	27	4	Good	Light
17/10/18	85	10	22	8	Good	Light
24/10/18	78	0	27	5	Good	Nil

3.1.2 Species richness and abundance

Forty-seven (47) roadkilled fauna were recorded during the October 2018 sample period. This included 19 native species, four introduced species, and seven fauna groups (Table A1, Appendix A). Birds were the most diverse group represented in roadkill with 12 species (including 2 introduced species) recorded. Six species of mammal (including 2 introduced species), five species of reptile, and possibly two species of frog were recorded (Table 3).

Eastern long-necked turtle (*Chelodina longicollis*) was the most frequently recorded species with six records, followed by barn owl (*Tyto javanica*) with three records (Appendix A). Unidentified mammals accounted for three records and frogs for three records. A possible eastern grass owl (*T. longimembris*), which is listed on the *Biodiversity Conservation Act 2017*, was recorded on the Gumma Floodplain between lower Warrell Creek and the Nambucca River. No target species were recorded during the October 2018 roadkill surveys.

Of the 47 roadkill records 18 (or 38%) were individuals expected to be blocked by exclusion fence. The remaining 29 records included birds, snakes, lizards, and frogs that readily move through or over exclusion fence.

Table 3: Species of vertebrate recorded during roadkill surveys during the operational phase of the WC2NH upgrade.

Species	Summer 17/18	Autumn 2018	Winter 2018	Spring 2018	Total
Australian magpie	6	1		1	8
Australian white ibis			1		1
Australian wood duck	20			2	22
Barn owl			11	3	14
Black flying-fox	2	1			3
Black rat	1				1
Blue tongue lizard	1			2	3
Cattle egret				1	1
Carpet python	1			2	3
Cat	1				1
Common-brushtail possum			1	2	3
Common tree snake	1	2			3

Species	Summer 17/18	Autumn 2018	Winter 2018	Spring 2018	Total
Crested pigeon	2				2
Domestic goose				1	1
Eastern grey kangaroo				3	3
Eastern long-neck turtle	1			6	7
Eastern water dragon	1			1	2
European fox	3	1	1	2	7
Forest kingfisher	1				1
Galah	7				7
Green tree frog	2				2
Grey butcherbird			1		1
Grass owl				1	1
Hare	2			1	3
Laughing kookaburra	3		2	1	6
Macleay river turtle	5	1			6
Magpie-lark	2		1		3
Masked owl	1				1
Northern brown bandicoot	1		1		2
Pacific black duck	2		1		3
Pied currawong				1	1
Purple swamphen	3		2	2	7
Rabbit	1				1
Red-necked wallaby	1		6		7
Red-bellied black snake	1				1
Rock pigeon			1	1	2
Short-beaked echidna				3	3
Southern boobook			1	1	2
Striped marsh frog	3				3
Swamp wallaby	2	1		1	4
Tawny frogmouth	1	3	1	2	7
Wattled bat				1	1
Whistling kite				1	1
Yellow-faced whipsnake				1	1
Macropod spp	3		2	1	6
Medium bird				1	1
Medium mammal				2	2
Large mammal				1	1
Medium frog				3	3
Large frog				1	1
Unidentifiable bird	5	4	1		10

Species	Summer 17/18	Autumn 2018	Winter 2018	Spring 2018	Total
Unidentified Chelidae (Turtle) species	6				6
Unidentified Mammal	1			3	4
Total	93	14	34	55	196

The number of roadkill recorded each week varied during the sample period. A trend of decreasing roadkill abundance was recorded over the first three sample weeks but roadkill abundance increased sharply in week four (Figure 2). Fifteen roadkilled fauna were recorded in week one, with 21 recorded in week four. Weeks one and four of the sample period coincided with the new and full moon respectively.

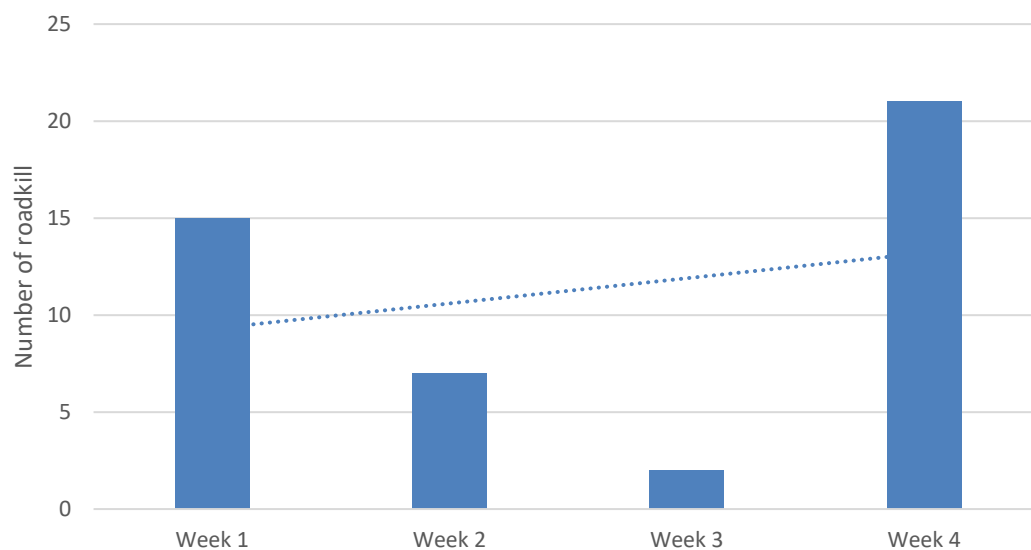


Figure 2: Number of roadkills recorded in each sample week during the October 2018 (Spring) sample period.

The abundance of roadkilled fauna in the four vertebrate groups varied during the sample period (Figure 3). The number of roadkilled mammals went from five in week one to none in week three and seven in week four. Likewise, the number of roadkilled birds decreased from four in week one to one in week three before rising to eight in week four. A similar trend was evident for reptiles, although the increase in week four was less distinct. Frogs were recorded in week four only (Figure 3).

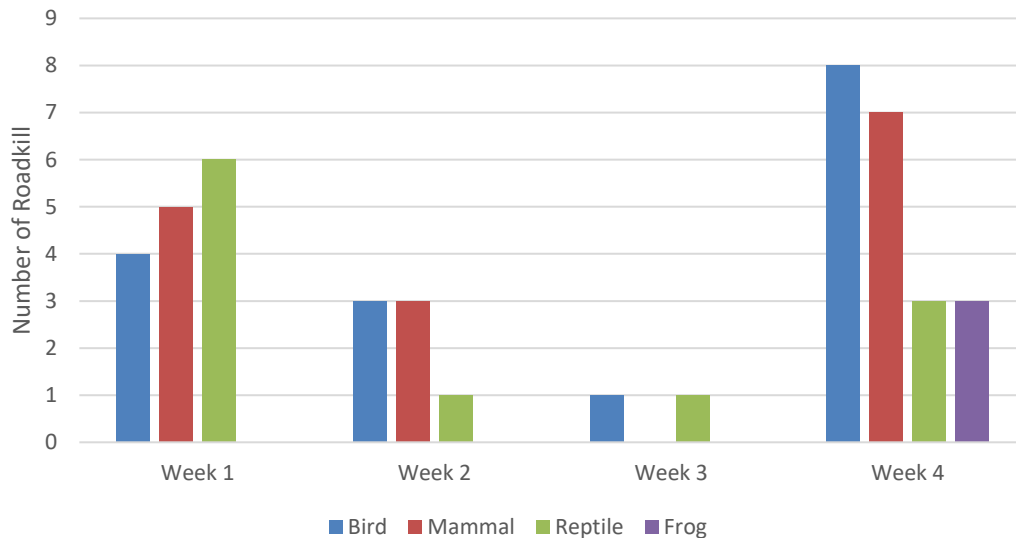


Figure 3: Number of roadkilled fauna from four vertebrate classes during each sample week in October 2018.

3.1.3 Opportunistic roadkill information

No opportunistic roadkill records were obtained during the reporting period.

3.1.4 Distribution of roadkill

In October 2018 roadkilled fauna was recorded over the entire WC2NH alignment (Figure 4-13), although the majority of records (62%) were recorded in stage 2B, between the southern end and lower Warrell Creek. Eighty-four percent (or 38 specimens) of roadkill was recorded between the Nambucca River and southern end of the project. Within that area, 53% of roadkill occurred between the southern end and Albert Drive (Figures 4 & 5). Seven roadkilled fauna were recorded in the 1.5km section of alignment south of Albert Drive (Figure 5). That section traverses predominantly cleared land with three drainage lines and does not contain fauna exclusion fence. The section of alignment north of Albert Drive traverses similar habitat and contained four roadkills (Figure 6). A cluster of long-necked turtle records occurred along the Gumma floodplain (Figure 7). That section contained Type 4 exclusion fence. The eastern grass owl was also recorded in that area.

Comparison with stage 2A monitoring indicates a substantial reduction in roadkill in October 2018 on the floodplain south of the Nambucca River and the 2.5km section north of the Nambucca River (Figures 8 & 9). Three records of frogs occurred immediately north of upper Warrell Creek where Type 2 (giant barred frog) fence occurs.

In October 2018, 25 roadkills were recorded in areas with exclusion fence, and 20 were recorded in areas without exclusion fence (Figures 4-13). Eleven records (or 44%) in sections with fence were species that should have been blocked by the fence (i.e. medium and large mammals & reptiles). In contrast, 30% of roadkills in sections without fence were of species that should have been blocked by the fence. Whilst these figures suggest that fauna are finding their way through or around exclusion fence they do not show how many individuals are being blocked by the fence.

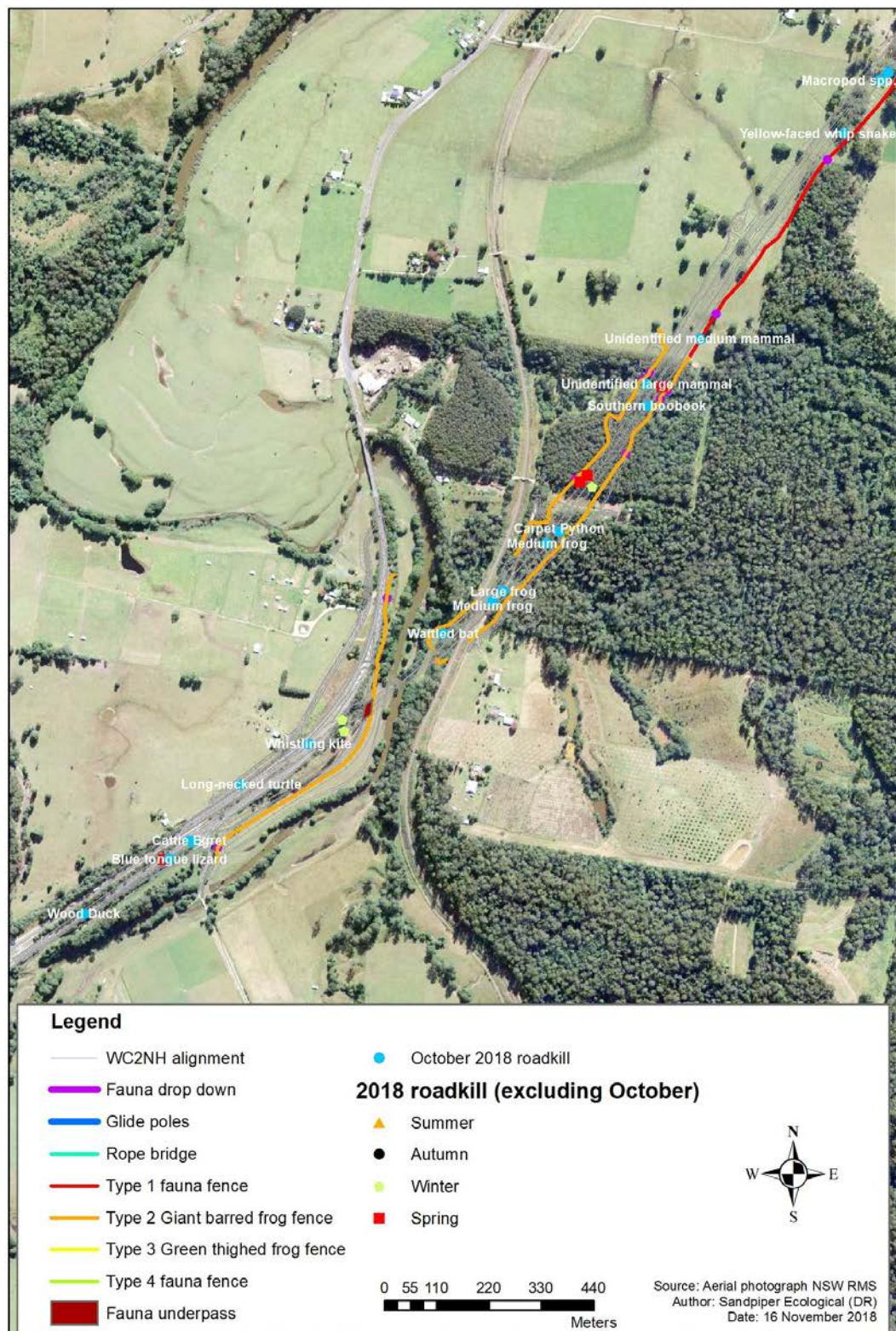


Figure 4: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

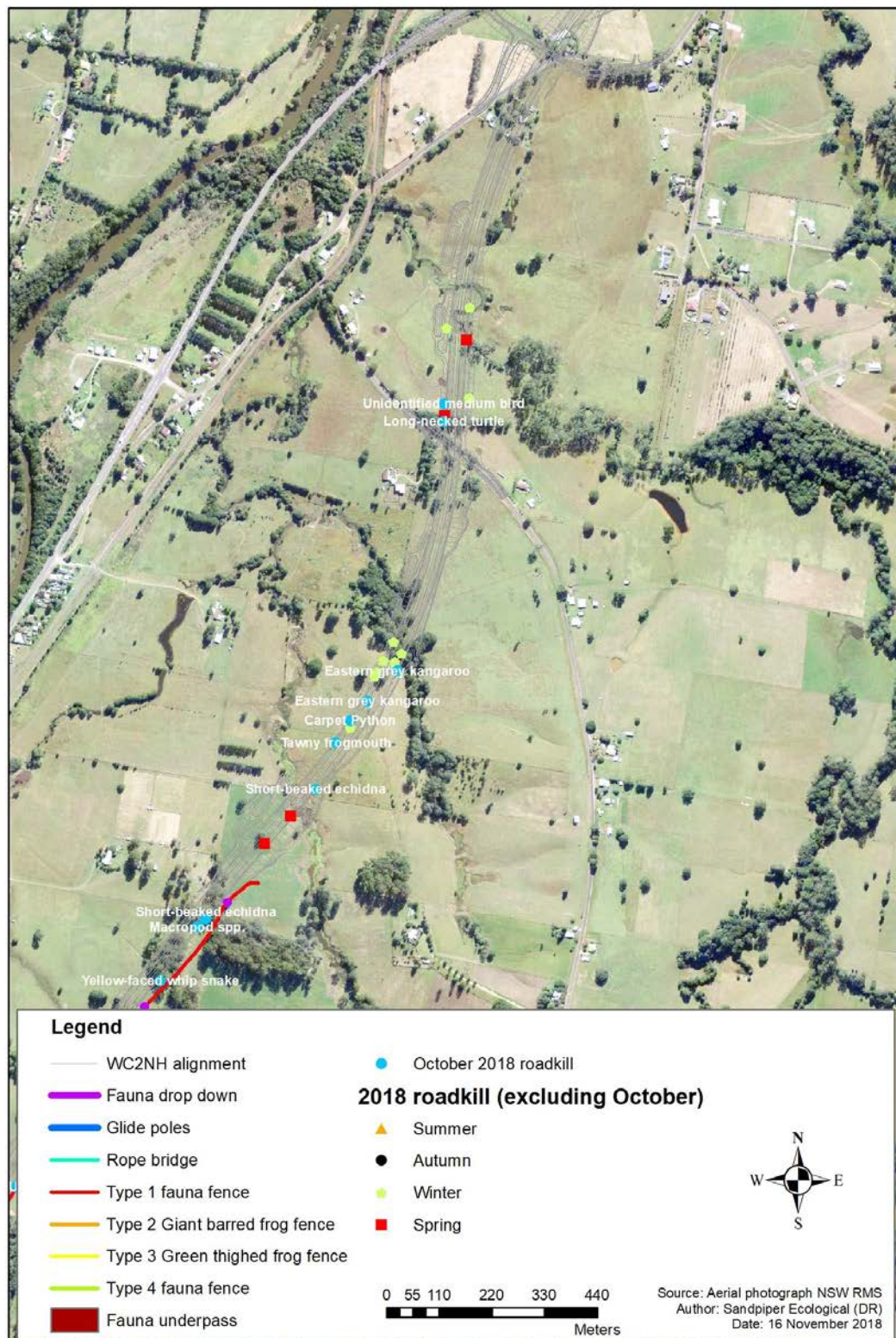


Figure 5: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

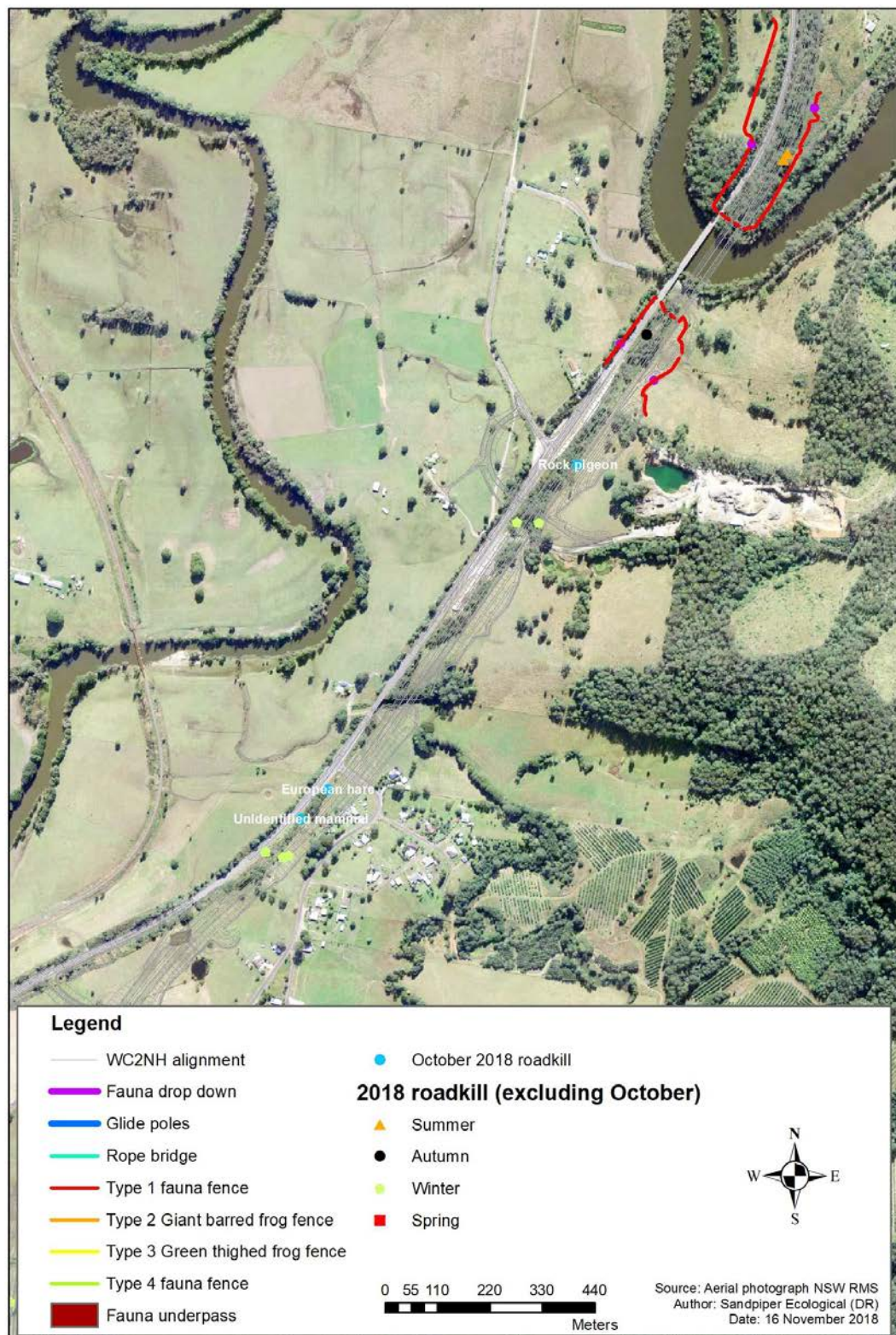


Figure 6: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

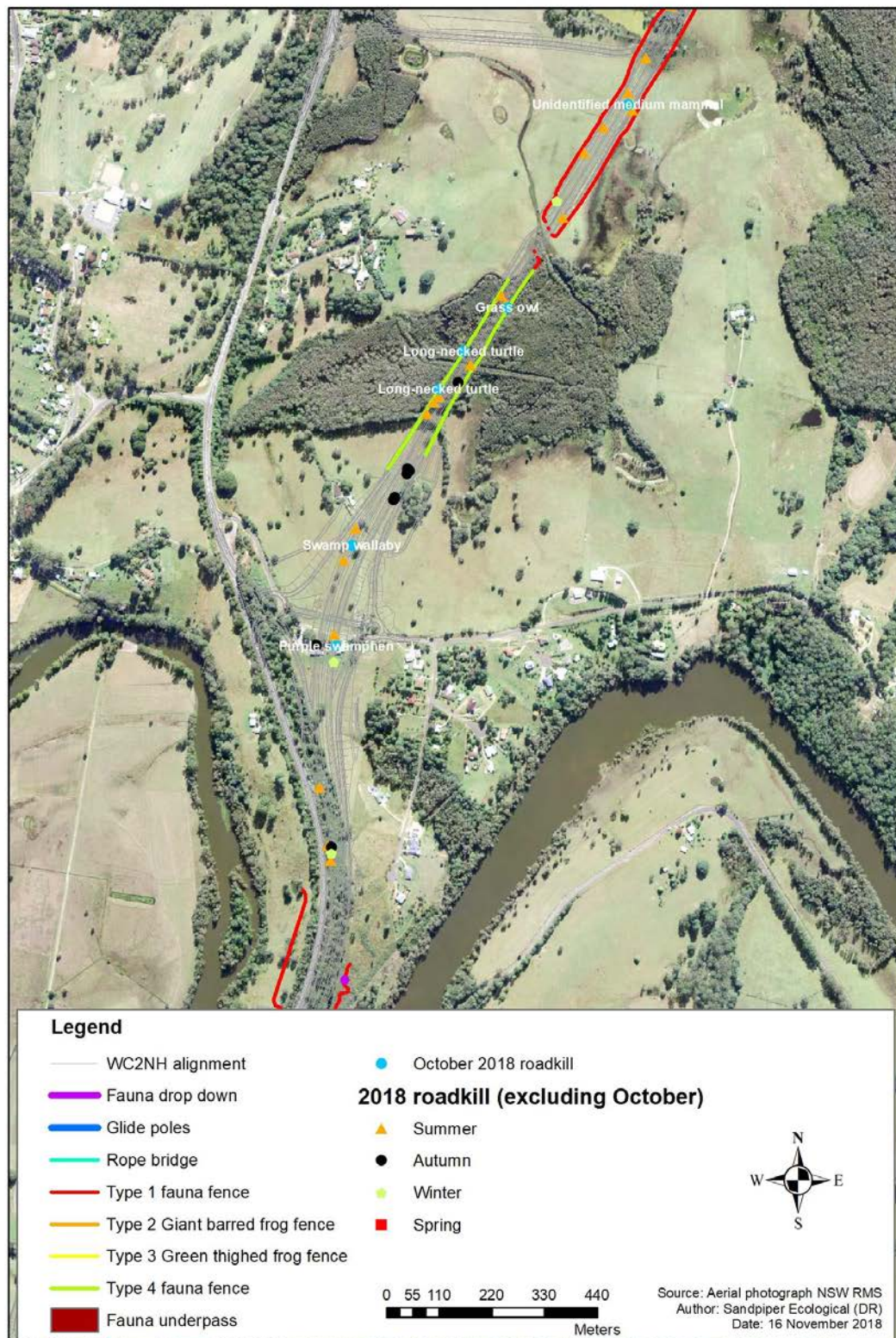


Figure 7: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

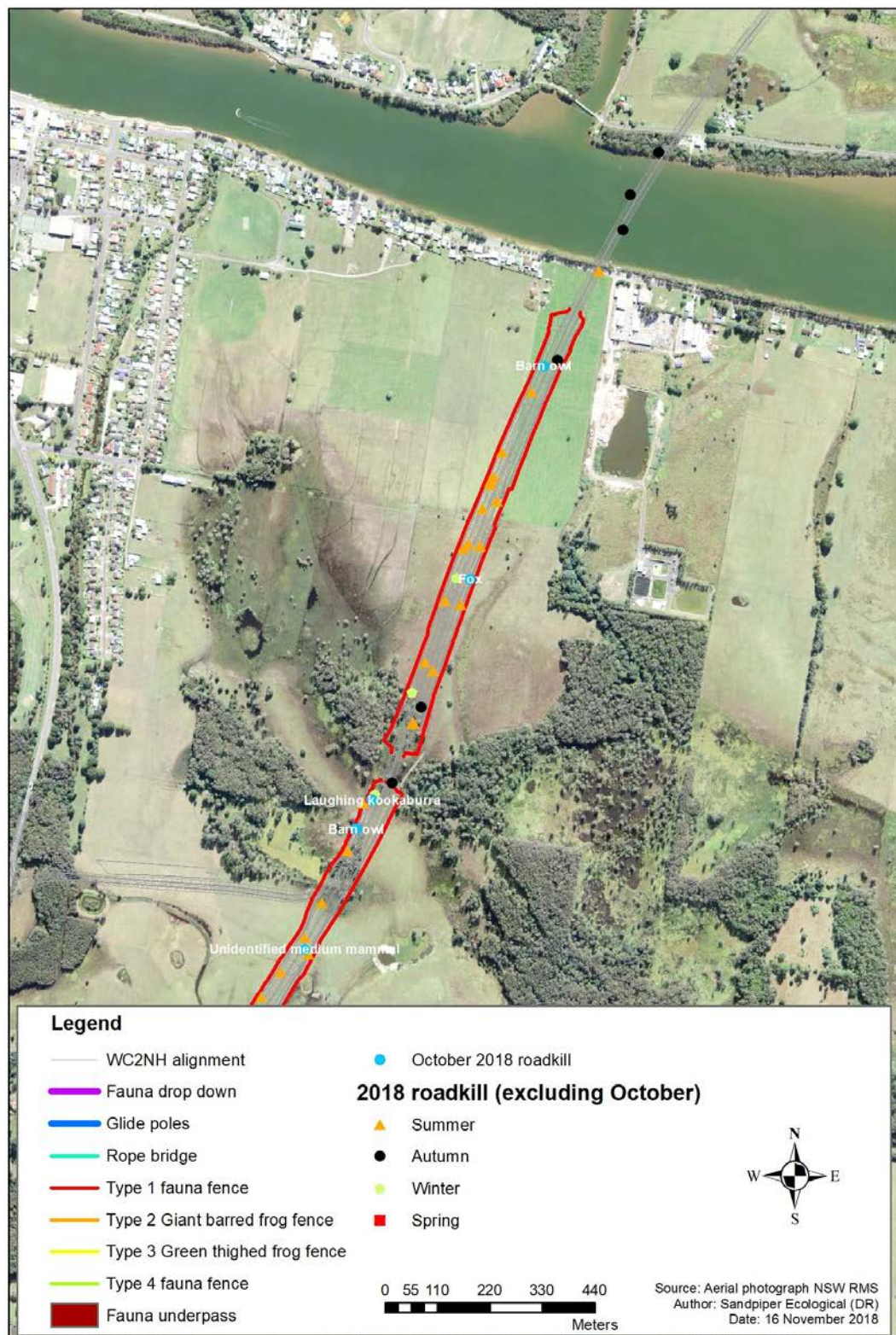


Figure 8: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

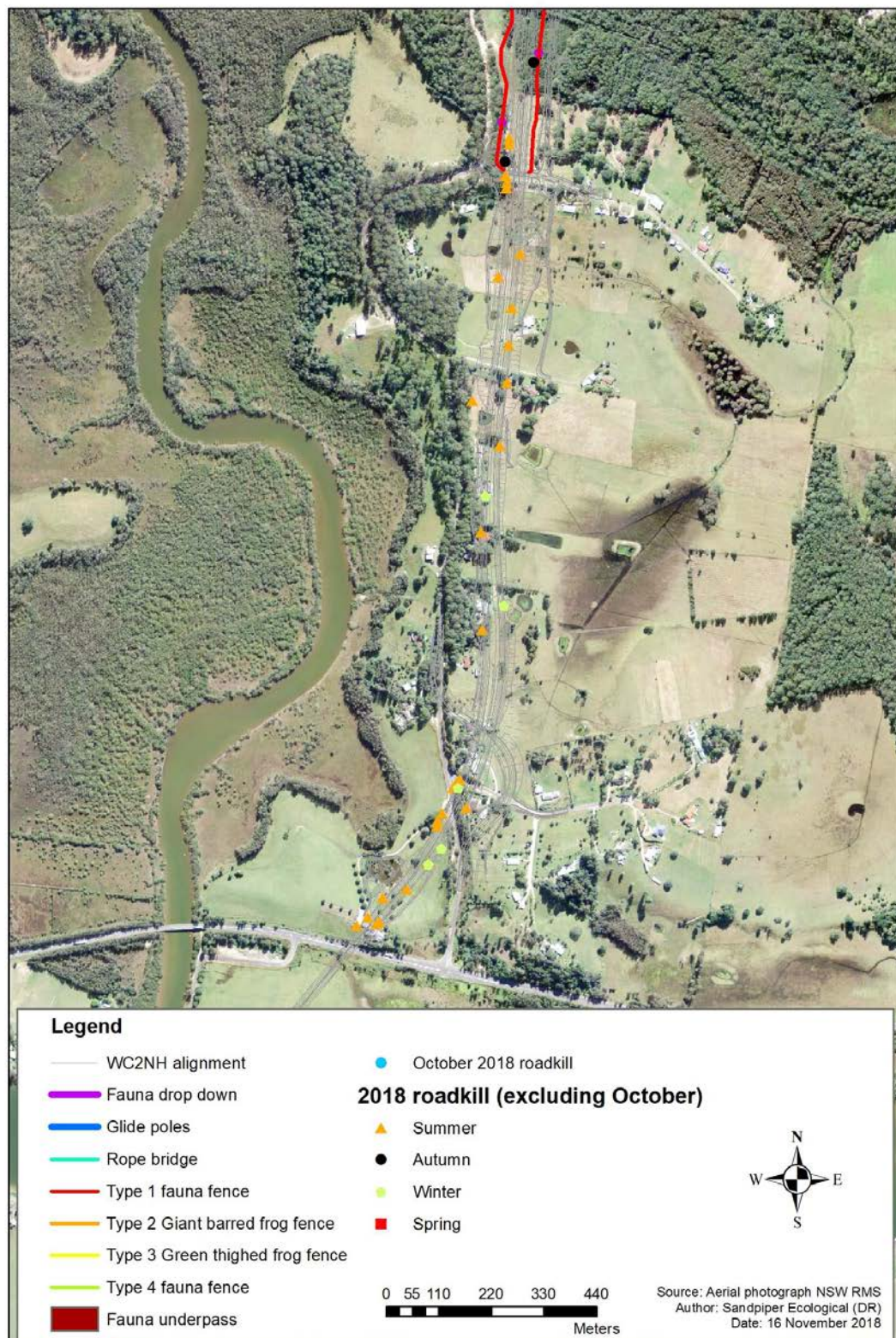


Figure 9: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

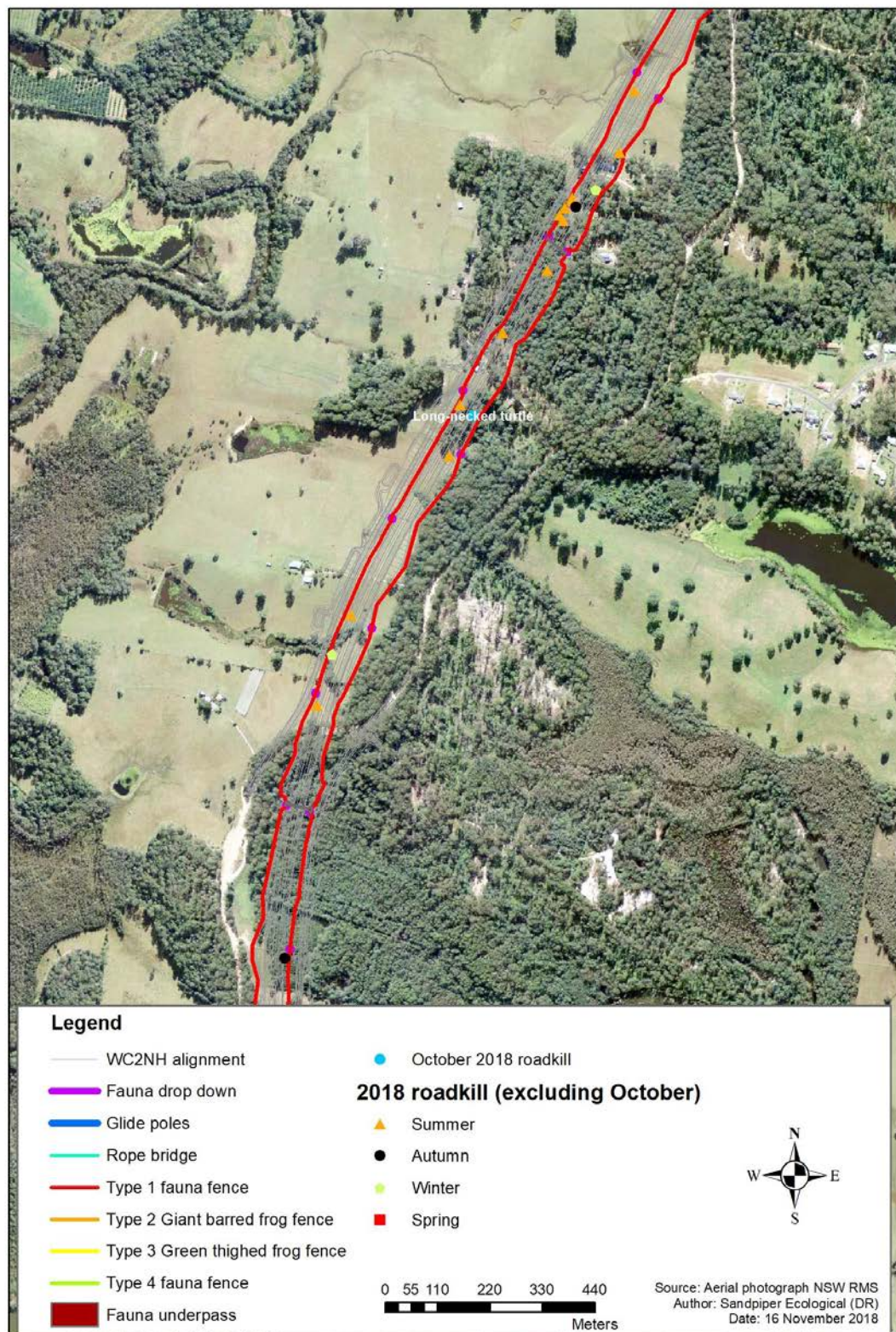


Figure 10: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

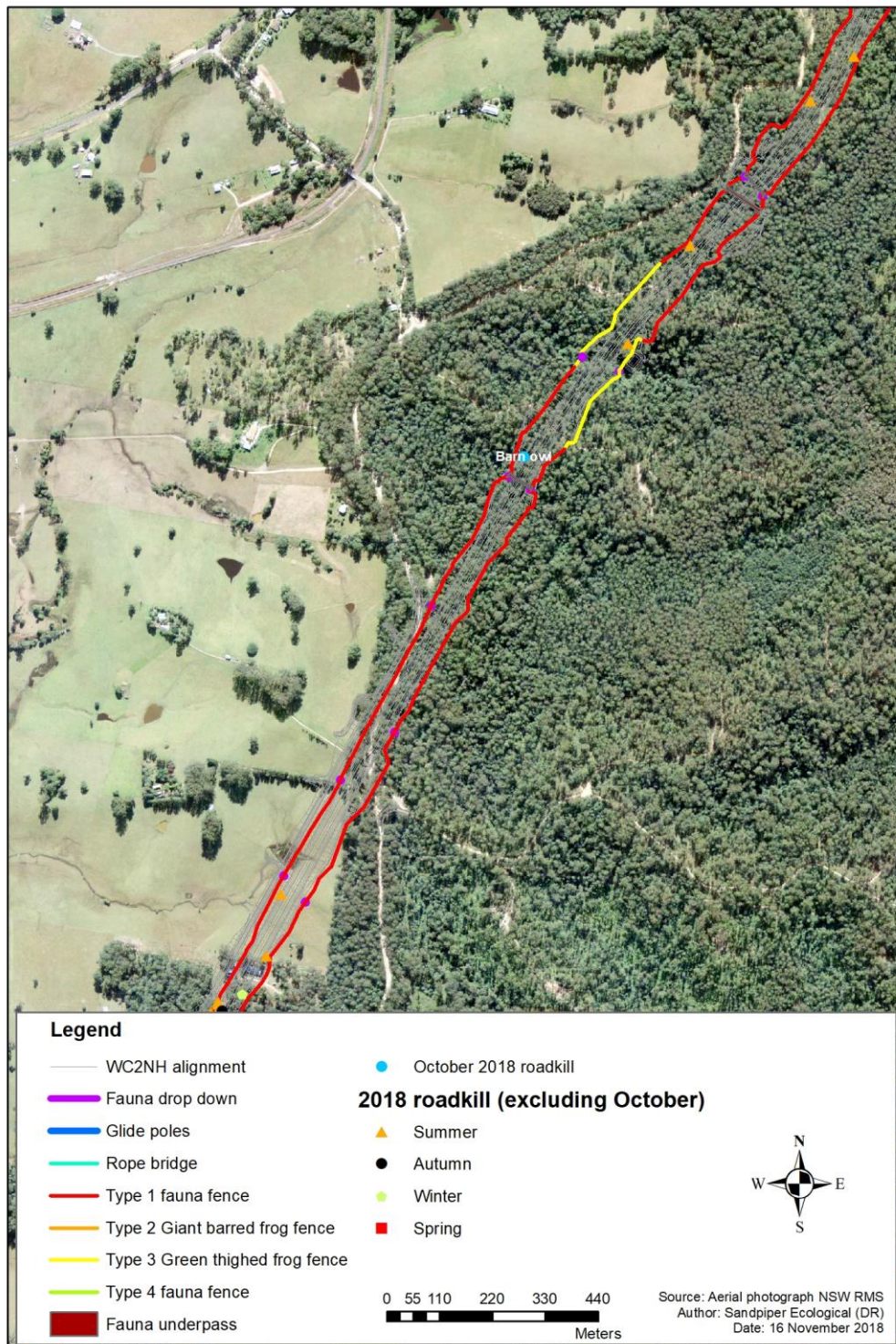


Figure 11: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

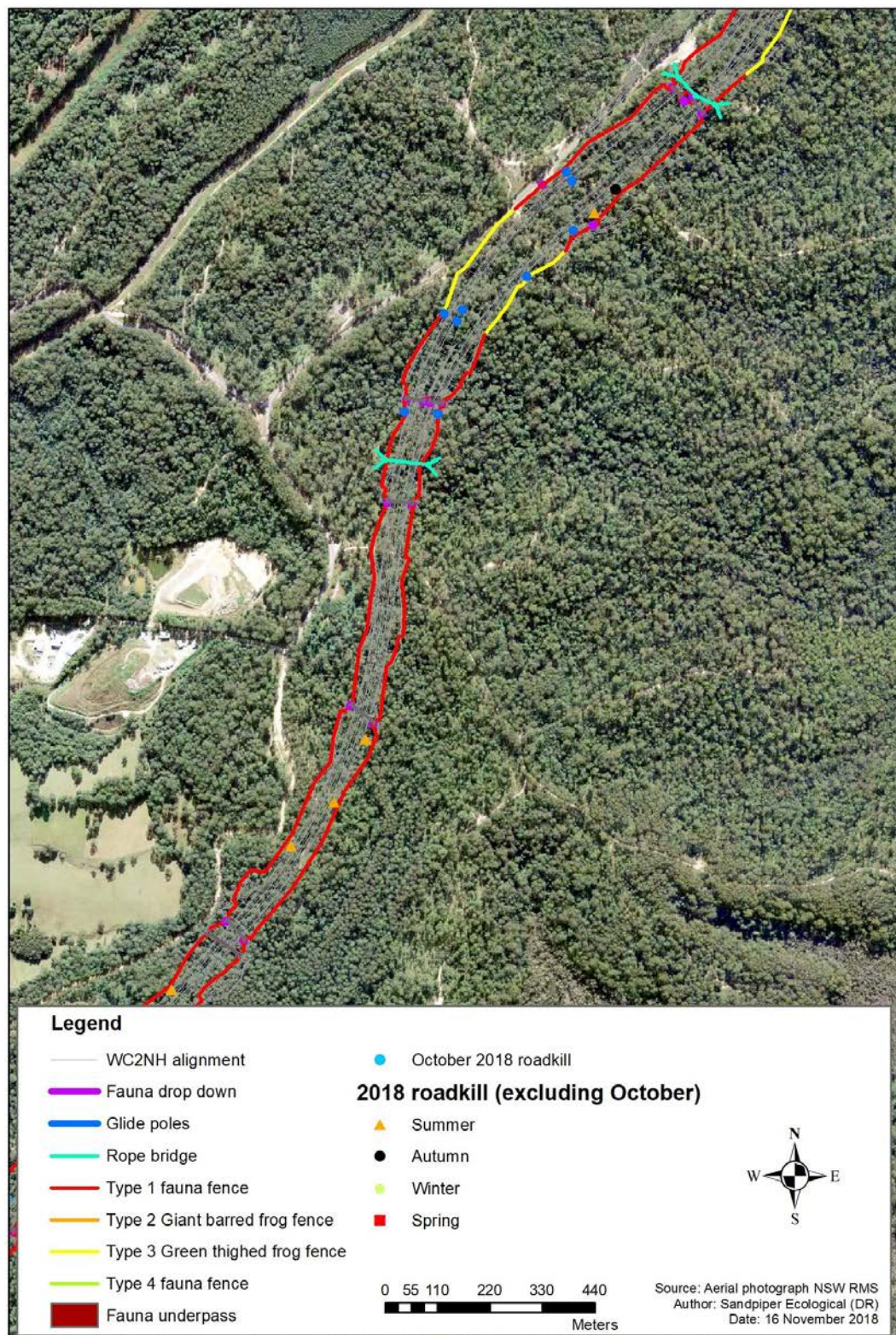


Figure 12: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

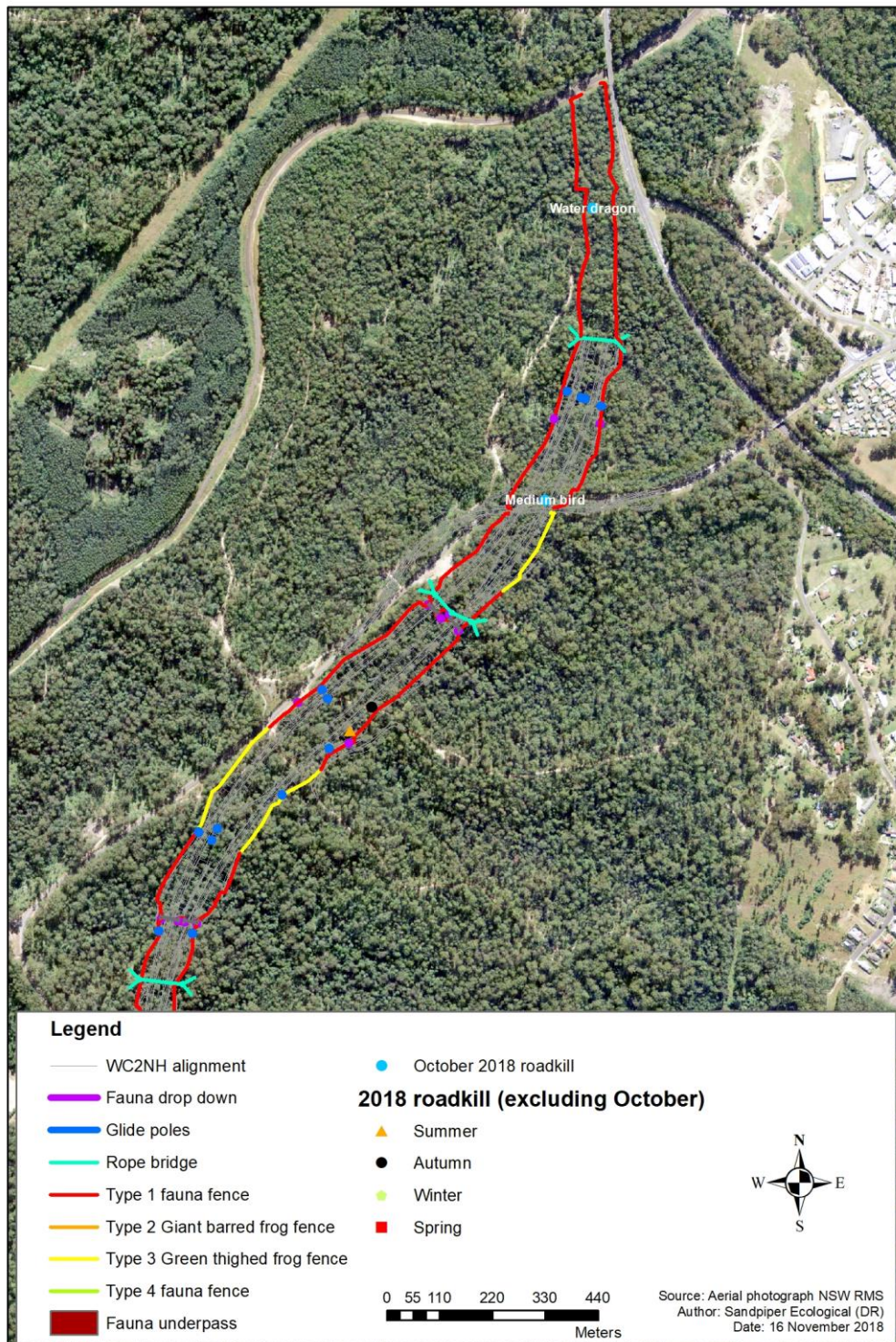


Figure 13: Location of roadkilled fauna recorded in October 2018 and stage 2A monitoring.

3.2 Annual results 2018

3.2.1 Statistical analysis

The G-test was run on three sets of data, all species (from Table 1), no reptiles, and no introduced species (Table 4). No statistically significant difference in number of roadkill was recorded for all species or no introduced species. A statistically significant difference in number of roadkill between fenced and unfenced sections of the alignment was recorded if reptiles were removed from the analysis ($P=0.042$), with a higher proportion of roadkill in unfenced sections of the alignment. The Kruskal-Wallis test did not record a statistically significant difference between fenced and unfenced sections of the alignment ($n=34$, $df=1$, $P=0.334$).

Table 4: Results of G-test on roadkills in fenced and unfenced sections of the alignment.

Group	Category	No. roadkill	Expected proportion	Expected N°.	Df	G statistic	P (2 tail)
All species	Fence	32	0.55	34.1	1	0.29	0.593
	No fence	30	0.45	27.9			
No reptiles	Fence	17	0.55	23.65	1	4.14	0.042
	No fence	26	0.45	19.35			
No introduced	Fence	25	0.55	28.05	1	0.73	0.392
	No fence	26	0.45	22.95			

3.2.2 Species richness and abundance

A total of 42 species have been recorded during roadkill surveys in 2018 (Table 3). This is comprised of 36 native species and six introduced species. The highest diversity of roadkill was recorded in summer (30 species), followed by spring (23 species), winter (7 species) and autumn (6 species). Nine additional fauna groups were identified (Table 3). The most commonly recorded species were Australian wood duck (22 records), barn owl (14 records), freshwater turtles (19 records), Australian magpie (8 records), and galah, fox, purple swamphen, red-necked wallaby and tawny frogmouth with seven records each. Laughing kookaburra, and Macropod spp each had six records (Table 3).

A total of 196 individuals were recorded across the 36 roadkill samples (Table A2, Appendix A). Birds were the most commonly recorded group with 105 records, followed by mammals (52 records), reptiles (32 records) and frogs (7 records). Roadkill abundance has fluctuated between sample weeks (Figure 14). The number of roadkill/km sampled was strongly correlated with the total number of roadkill recorded (Pearson correlation co-efficient 0.89) but the relationship weakened during the spring survey (weeks 33-36) when the entire alignment was sampled. The trendline suggests a slight temporal decrease in number of roadkill over the sample period (Figure 14).

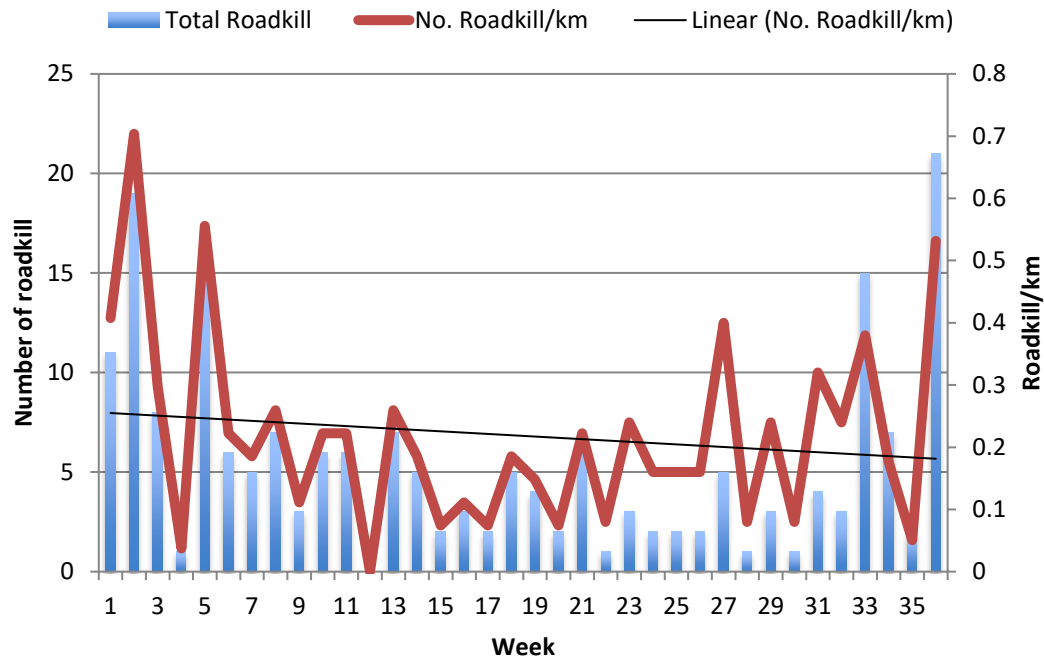


Figure 14: Number of roadkill recorded each week expressed as a total (Left axis) and number/km sampled (right axis).

Roadkill abundance has fluctuated substantially between seasons with notable peaks in summer and spring and decreases in autumn and winter (Figure 15).

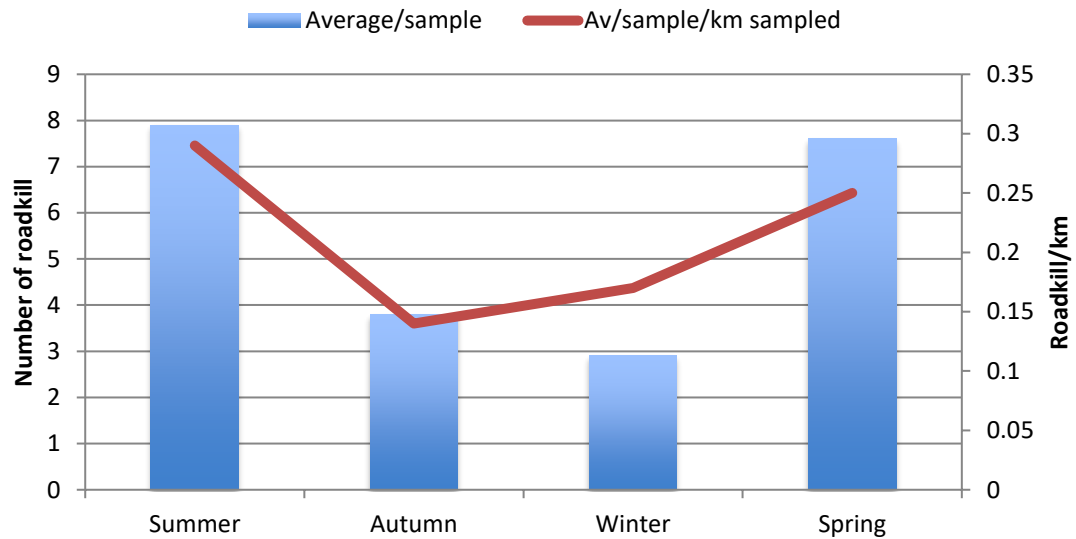


Figure 15: Average number of roadkills and number/sample/km for each season in 2018.

3.2.3 Distribution of roadkill

Roadkilled fauna have been recorded over the entire study area (Figures 4-13). Notable roadkill hotspots include:

- South end of project to Albert Drive (approx. 41 records – Figs 4&5)
- Gumma floodplain (approx. 62 records – Figs 7&8)
- Nambucca River to Mattick Road (31 records – Fig 9).

There are substantially fewer records through Nambucca State Forest where Type 1 exclusion fence occurs on both sides of the highway.

4. Discussion

4.1 October 2018

Monitoring of roadkill over the entire WC2NH alignment in October 2018 indicates that a substantial number of fauna continue to be killed by vehicles 12 weeks after the entire alignment was open to traffic. Monitoring identified a distinct clustering of roadkill in Stage 2B (i.e. between the southern end and lower Warrell Creek) with substantially fewer records in Stage 2A which was opened to traffic in December 2017 (Geolink 2018a). This difference may be indicative of fauna habituation to live traffic or the attrition of individuals that occupied habitat around the upgrade corridor during construction. A similar trend may become apparent in stage 2B over time. The absence of a notable temporal trend of decreasing roadkill, as recorded for stage 2A monitoring (see Geolink 2018a), may be due to the small sample size, or the influence of other variables such as lunar phase (Mizuta 2014; Grant *et al.* 2013). Indeed, the inclusion of lunar phase in future analysis may assist in identifying patterns in the frequency of roadkill.

A similar diversity and species composition of roadkill was recorded in October 2018 and Stage 2A monitoring, which occurred in summer/autumn 2017/18 (Geolink 2018a). The frequency of occurrence of different fauna groups (birds, mammals, reptiles & frogs) differed between the two samples, with a greater proportion of mammals recorded in October and fewer reptiles and birds. This difference could be due to season or the inclusion of different habitats in Stage 2B. Roadkill hotspots identified in October include the Gumma Floodplain, and from the southern end to Albert Drive. Geolink (2018a) also identified the Gumma Floodplain as a roadkill hotspot. Birds and reptiles comprised the majority of roadkills in both locations.

4.2 Seasonal variation and species composition

Monitoring identified a strong seasonal effect on roadkill frequency with peaks recorded in spring and summer. The observed pattern is not surprising as fauna tend to be more mobile during the spring / summer period when most species breed and disperse. Geolink (2018a) also highlighted the possible influence of grass seeding close to the highway at the time of opening to traffic on galah and wood duck roadkill.

Birds were more than twice as likely to be struck by vehicles as mammals, and the only threatened species recorded as roadkill were both birds (masked owl and grass owl), which highlights how susceptible that group is to vehicle strike. The occurrence of birds in roadkill is predicted to reduce overtime as individuals habituate to the highway. Nonetheless, the results provide further evidence of

the substantial impact that roads have on bird populations (Loss *et al.* 2014). The high occurrence of barn owls in winter and spring 2018 is consistent with opportunistic observations on the Pacific Highway throughout northern NSW over the same period (N. Priest pers obs). The result is attributed to drought conditions in western NSW forcing more owls into coastal areas.

4.3 Fenced vs unfenced

Analysis of roadkill data showed no statistically significant difference in the frequency of roadkill between fenced and unfenced sections of the alignment for target species (refer Table 1). This result suggests that fauna are being killed at the same frequency regardless of whether exclusion fence is present or not. The significantly higher frequency of roadkill in unfenced areas when reptiles were removed from the analysis indicates that reptiles, particularly freshwater turtles, contributed substantially to roadkill in fenced sections of the alignment. Turtle records were distributed across most of the alignment, with a noticeable cluster on the Gumma Floodplain, and north of the Nambucca River. Geolink (2018a) attributed the high incidence of roadkilled turtles during Stage 2A monitoring to individuals trapped on the roadside of the exclusion fence following fence construction. Whilst this suggestion is plausible further monitoring is required to determine if the frequency of turtle roadkill decreases with time. Roadkilled turtles were recorded in areas with both Type 1 and Type 4 exclusion fence and the frequency of roadkills was similar in Spring (1.5 individuals/week) and Summer/autumn (1.2 roadkills/week). Freshwater turtles, particularly eastern long-necked turtles, often move between wetlands in spring making them more susceptible to vehicle strike.

Freshwater turtles should be blocked by exclusion fence where there is a ground return. The incidence of turtle roadkill may be due to the absence of a ground return on the Type 4 fence across the flying-fox habitat section of the Gumma Floodplain, and/or use of open drains to get beneath the fence. Whilst efforts have been made to make open drains impenetrable to fauna, some gaps may exist.

Despite the equivalent incidence of target species roadkill in fenced and unfenced areas the results do not show how many individuals the exclusion fence stops from entering the alignment. Exclusion fence corresponds with vegetated areas that have a higher abundance of fauna. Without exclusion fence roadkill would be substantially higher in these areas (de Carvalho *et al.* 2014). In addition, general observation suggests that there is typically a spike in roadkill immediately after a highway is opened to traffic and a temporal decline in roadkill frequency is anticipated. The low incidence of fauna mortality in Stage 2A in October may be indicative of such a decrease. The low incidence of target species mortality through the Nambucca State Forest section shows that the exclusion fence is having a positive effect on roadkill frequency.

At this stage of monitoring no modifications to exclusion fence design or extent is recommended. Further monitoring is required to confirm the presence of roadkill hotspots and the overall frequency of roadkill within the WC2NH alignment.

Most of the species recorded near drop-down structures were non-target species (i.e. birds) and at this stage of monitoring there is no obvious correlation between drop-down structures and target species roadkill. As sample size increases correlations between drop-downs and target species should be explored.

5. Recommendations

1. Continue seasonal roadkill surveys during year two of the operational phase using the same methods applied in year one.
2. Continue to monitor the distribution of freshwater turtle roadkills in relation to habitat inside the exclusion fence.
3. Explore correlations between drop-downs and the distribution of target species in the year two annual report.

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Appendix A – Field Survey Data

Table A1: October 2018 roadkill results. NB = northbound; SB = southbound

Date	Observers	Start time	End time	Carriage way	Species	Species blocked by fauna fence	Sex & age class	Presence of pouch or back young	RK general location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition
5/10/2018	GM, OT	700	1000	SB	Fox	Yes	Adult	No	700m sth of bridge	493434	6601897	N	Floppy, 20m	Good
5/10/2018	GM, OT	700	1000	SB	Grass owl (probable)	No	Adult		700m nth bald hill rd	492836	6600697	N	3m cyclone fence	Good
5/10/2018	GM, OT	700	1000	SB	Purple swamp hen (possible)	No	Adult		50m sth bald hill rd	492479	6599990	N	Concrete barrier fence part of on ramp	Good
5/10/2018	GM, OT	700	1000	SB	Eastern grey kangaroo x 2	Yes	Adult	No	300m nth rosewood creek	490709	6596073	N	Absent	
5/10/2018	GM, OT	700	1000	SB	Short-beaked echidna	Yes	Adult			490310	6595555	N	Floppy top	Good
5/10/2018	GM, OT	700	1000	SB	Unidentified mammal	Yes				490294	6595539	N	Floppy top	Good
5/10/2018	GM, OT	700	1000	SB	Carpet Python	No	Adult		Under cockburn lane	489618	6594590	N	Floppy top	Good
5/10/2018	GM, OT	700	1000	SB	Tawny frogmouth	No	Adult		Near rosewood creek	490580	6595923	Y	Absent	
5/10/2018	GM, OT	700	1000	NB	Carpet Python	No	Adult		Near rosewood creek	490611	6595969	N	Absent	
5/10/2018	GM, OT	700	1000	NB	Long-necked turtle	Yes	Juv		550m nth bald hill rd	492745	6600606	Y	3m cyclone fence	Good
5/10/2018	GM, OT	700	1000	NB	Long-necked turtle	Yes	Adult		530m nth bald hill rd	492693	6600527	Y	3m cyclone fence	Good
5/10/2018	GM, OT	700	1000	NB	Long-necked turtle	Yes	Adult		520m nth bal hill rd	492745	6600606	Y	3m cyclone fence	Good
5/10/2018	GM, OT	700	1000	NB	Unidentified mammal	Yes			510 nth bald hill rd	492745	6600606	N	3m cyclone fence	Good
5/10/2018	GM, OT	700	1000	NB	Barn owl	No	Adult		100m sth Nambucca river flood plain bridge 2	493196	6601373	Y	Floppy top	Good
5/10/2018	GM, OT	700	1000	NB	Water dragon	No	Adult		250 sth of railway	497470	6610885	Y	Floppy top	Good
11/10/18	DR, OT	745	925	SB	Short-beaked echidna	Yes	Adult		480m Sth of rosewood rd (SB)	490539	6595826	Y	Absent	
11/10/18	DR, OT	745	925	SB	Macropod spp.	Yes	Adult			490292	6595538	Y	Absent	
11/10/18	DR, OT	745	925	SB	Southern boobook (possible)	No	Unknown			488903	6594854	N	Floppy top	Good
11/10/18	DR, OT	745	925	SB	Blue tongue lizard	No	Adult		Browns crossing	488799	6593902	NA	Absent	

Date	Observers	Start time	End time	Carriage way	Species	Species blocked by fauna fence	Sex & age class	Presence of pouch or back young	RK general location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition
11/10/18	DR, OT	745	925	SB	Goose /duck	No	Adult		Browns crossing	488850	6593939	N	Just south of floppy top	
11/10/18	DR, OT	745	925	NB	Whistling kite (possible)	No	Adult		Browns crossing	489092	6594144	N	Floppy top on east side	
11/10/18	DR, OT	745	925	NB	Unidentified mammal	Yes	Unknown		500m Sth macksville interchange	491421	6597802	Y	Absent	
18/10/18	GM/OT	710	900	NB	Long-necked turtle	No	Adult		50m north rosewood road	490807	6596594	Y	Absent	
18/10/18	GM/OT	710	900	NB	Laughing kookaburra	No	Adult		40m sth Nambuc river floodplain bridge 2	493229	6601434	Y	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Medium bird	No	Adult		Under Old Coast Rd Bridge	497371	6610277	N	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Medium mammal	Yes			700m north macksville interchanfe	493088	6601121	N	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Long-necked turtle	Yes			1km north of Mattick Rd	494890	6606136	Y	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Rock pigeon (possible)	No	Adult		200m north of overpass?	492000	6598545	Y	Absent	
25/10/18	NP/MJ	730	950	SB	Yellow-faced whip snake	No	Adult		1km north of Cockburns Lane	490215	6595426	Y	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Medium frog x 2	No			20m s Cockburns Lane	489592	6594565	Y	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Medium mammal	Yes			500m north Cockburns Lane	489913	6594995	N	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Large frog	No	Adult		40m north rail bridge	489501	6594465	N	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Medium frog	No	Adult		20m north Rail brudge	489478	6594444	N	Floppy top	Good
25/10/18	NP/MJ	730	950	SB	Cattle Egret (poss)	No	Adult		100m south of UWC	488841	6593941	N	Floppy top on east side	
25/10/18	NP/MJ	730	950	SB	Wood Duck x 2	No	Adult		500m south of UwC	488620	6593787	N	Absent	
25/10/18	NP/MJ	730	950	SB	Pied Currawong	No	Adult		700m south of UWC	488345	6593614	N	Absent	
25/10/18	NP/MJ	730	950	NB	Long-necked turtle	Yes	Adult		400m south of UWC	488950	6594059	N	Floppy top on east side	
25/10/18	NP/MJ	730	950	NB	Wattled bat (<i>Chalinolobus</i> spp.)	No	Adult		50m south of rail bridge	489374	6594376	N	Floppy top	Good
25/10/18	NP/MJ	730	950	NB	Large mammal	Yes			200m n off rail bridge	489801	6594900	N	Floppy top	Good
25/10/18	NP/MJ	730	950	NB	Eastern grey kangaroo	Yes	Adult		Rosewood Creek	490647	6596010	N	Absent	
25/10/18	NP/MJ	730	950	NB	Medium bird	No	Adult		50m north Rosewood Rd	490806	6596631	N	Absent	
25/10/18	NP/MJ	730	950	NB	European hare	Yes			500m south of Scott's	491478	6597864	N	Absent	

Date	Observers	Start time	End time	Carriage way	Species	Species blocked by fauna fence	Sex & age class	Presence of pouch or back young	RK general location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition
									Head turn off					
25/10/18	NP/MJ	730	950	NB	Swamp wallaby	Yes	Adult		100m north of Bald Hill Rd	492512	6600200	N	Absent	
25/10/18	NP/MJ	730	950	NB	Barn owl (prob)	No			100m s of Nambucca bridge	493588	6602344	N	Floppy top	Good
25/10/18	NP/MJ	730	950	NB	Barn owl	No				495733	6607729	N	Floppy top	Good

Appendix 7 Road Kill Monitoring Report – Summer
(January) 2019 monitoring.

Pacific Highway Upgrade
Warrell Creek to Nambucca Heads:
operational phase roadkill monitoring –
Summer (January) Report 2019.



Sandpiper Ecological

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Draft Report
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Cover Photo: Road-killed northern brown bandicoot detected during January 2019 surveys.

Disclaimer:

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1. Introduction

1.1 Background

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

The upgrade included a number of roadkill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate roadkill included:

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

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

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

Sandpiper Ecological Surveys (SES) has been engaged by Roads and Maritime to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal roadkill surveys over the entire upgrade length.

Monitoring of road-killed fauna is a requirement of the approved WC2NH koala (*Phascolarctos cinereus*), spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) management plans and the Ecological Monitoring Program (Roads and Maritime 2018a). Priority species for roadkill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog (*Mixophyes iteratus*). Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced seasonal monitoring in October 2018. The results of monitoring in 2018 were analysed and discussed by

Sandpiper Ecological (2018). The following report covers the January (summer) monitoring event and covered the entire WC2NH alignment. Remaining seasonal monitoring events in 2019 are scheduled for April (autumn), July (winter) and October (spring). Previous roadkill monitoring was conducted by Geolink (2018a, b, c, d).

The aim of monitoring is to:

- report on any vertebrate roadkill following opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

1.2 Study area

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

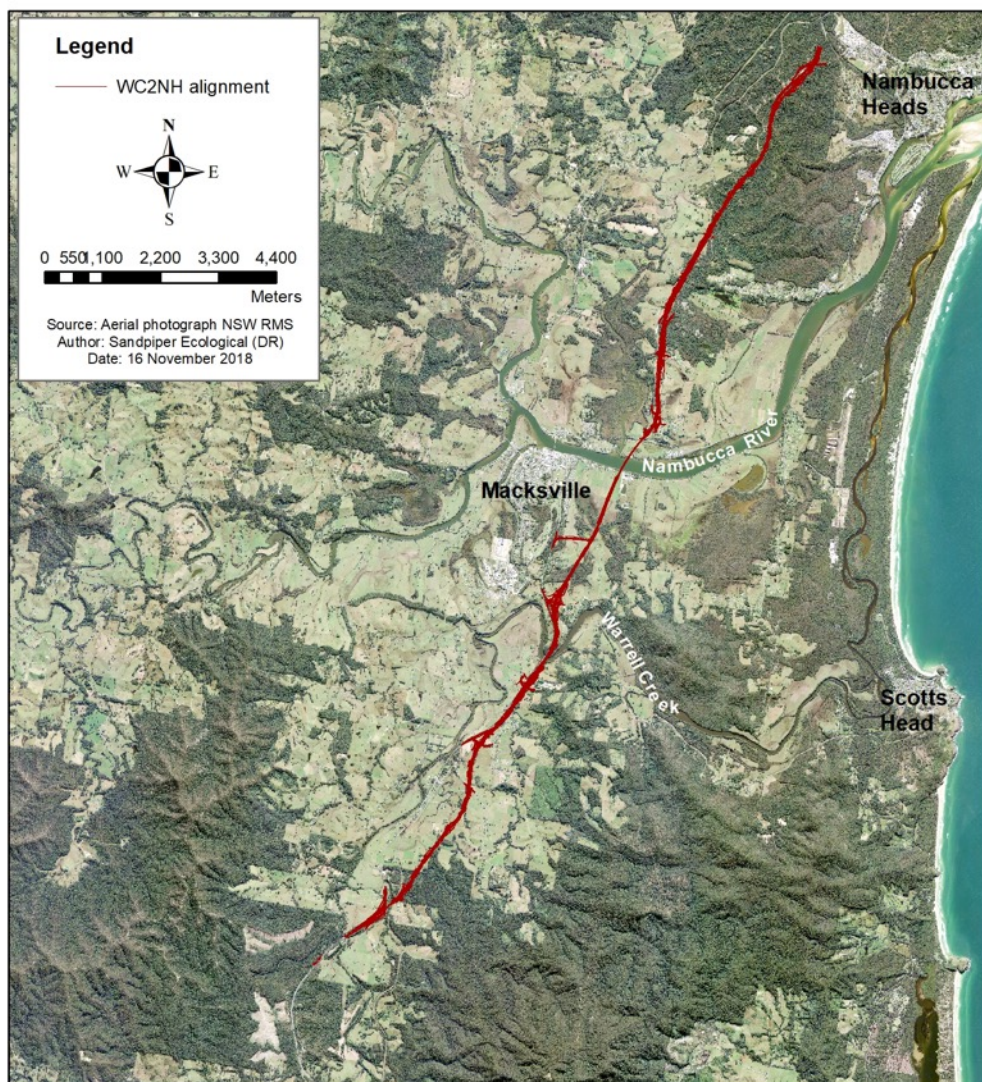


Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Roadkill surveys

Roadkill surveys were conducted by a two-person team from a vehicle driven at 70km/hr in the left lane with amber (flashing) and hazard lights on. The team consisted of a driver and ecologist with experience identifying road-killed fauna. All surveys commenced within two hours of sunrise, with an interval of seven days between samples. During each survey, both the driver and ecologist scanned the road surface and road shoulder for fauna. When road-killed fauna were detected the vehicle was pulled onto the shoulder/parking bay and the ecologist inspected the subject animal from the closest position behind wire rope and perpendicular to the specimen. Fauna that could not be identified immediately were photographed and images sent to colleagues. Carcasses were removed from the road surface when safe to do so.

Data collected on each roadkill included (Appendix A1):

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

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act (EPBC) 1999* and/or the *Biodiversity Conservation Act (BC) 2016*, included, where possible: sex and age (juvenile/adult); presence of pouch young; presence of flightless young (flying-foxes); distance to a fauna connectivity structure (determined from GIS); distance to a drop-down structure (determined from GIS); damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

All road-kills were cross referenced with the previous survey results to identify possible duplicates. Using the same team during the survey, GPS coordinates of each specimen, looking at carcass age and location on the carriageway, and detailed location description assisted with identification of duplicates.

Distance to connectivity structure, and distance to drop-down was determined via GIS. All other data were uploaded to an iPad in the field.

2.2 Data summary and analysis

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

3. Results

3.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses on the road surface (Table 1). No rain was recorded during survey days.

Table 1: Weather conditions in the 24hrs preceding each sample event. Data obtained from Envirodata weather station at the southern compound.

Date	Average Relative Humidity (%)	Total Rainfall (mm)	Maximum Temperature (°C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
10/1/19	73	0	31.8	3.7	Good	Nil
17/1/19	72.9	0	30.5	14	Good	Nil
24/1/19	71.2	0	36.2	4.2	Good	Nil
31/1/19	70.3	0	31	14.5	Good	Nil

3.2 Species richness and abundance

A total of 57 road-killed fauna were recorded during the January 2019 sample period. This included 19 native species, two introduced species, and seven fauna groups (Table A1, Appendix A). Birds were the most diverse group represented in roadkill with 11 species recorded. Seven species of mammal (including 2 introduced species), and two species of reptile were recorded.

Red-necked wallaby (*Macropus rufogriseus*) and grey-headed flying-fox (*Pteropus poliocephalus*) were the most frequently recorded species with eight records each, followed by black flying-fox (*Pteropus alecto*) with six records (Table 2). Grey-headed flying-fox is listed as vulnerable by the EPBC Act 1999 and the BC Act 2016. Unidentified mammals accounted for seven records and *Pteropus* spp. accounted for three records. A masked owl (*Tyto novaehollandiae*), which is listed as vulnerable by the BC Act 2016, was recorded on the Gumma Floodplain on 10 January 2019. A total of eight target species (all grey-headed flying-foxes) were confirmed during the January 2019 roadkill surveys. It is possible that some of the *Pteropus* spp. records were also grey-headed flying-fox. Of the 57 roadkill records, 17 (or 30%) were individuals expected to be blocked by exclusion fence. The remaining 40 records included birds, snakes, lizards, and small mammals that readily move through or over exclusion fence.

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

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Total
Birds						
Australian magpie	6	1		1		8
Grey butcherbird			1			1
Magpie-lark	2		1		1	4
Australian white ibis			1			1
Cattle egret				1		1
Little pied cormorant					1	1

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Total
Buff-banded rail					1	1
Purple swamphen	3		2	2		7
Crested pigeon	2					2
Galah	7				1	8
Eastern grass owl*				1		1
Southern boobook			1	1		2
Masked owl*	1				1	2
Barn owl			11	3		14
Tawny frogmouth	1	3	1	2		7
Owlet-nightjar					1	1
Laughing kookaburra	3		2	1		6
Forest kingfisher	1					1
Australian wood duck	20			2	2	24
Pacific black duck	2		1			3
Whistling kite				1		1
Black-shouldered kite					1	1
Toressian crow					1	1
Pied currawong				1		1
Dollarbird					1	1
Green catbird					1	1
Medium bird				1	2	3
Unidentifiable bird	5	4	1		3	13
Mammals						
Short-beaked echidna				3		3
Black flying-fox	2	1			6	9
Grey-headed flying-fox*					8	8
<i>Pteropus</i> spp.					3	3
Common brushtail possum			1	2		3
Common ringtail possum					1	1
Eastern grey kangaroo				3		3
Red-necked wallaby	1		6		8	15
Swamp wallaby	2	1		1		4
Macropod spp	3		2	1	1	7
Northern brown bandicoot	1		1		1	3
Wattled bat spp.				1		1
Microbat spp.					1	1
Small mammal					2	2
Medium mammal				2	4	6
Large mammal				1	1	2
Unidentified Mammal	1			3		4
Reptiles						
Common blue-tongue skink	1			2	1	4
Carpet python	1			2	1	4

Species	Summer 17/18**	Autumn 2018**	Winter 2018**	Spring 2018	Summer 2019	Total
Common tree snake	1	2				3
Eastern long-neck turtle	1			6		7
Macleay river turtle	5	1				6
Unidentified Chelidae (turtle) spp.	6					6
Red-bellied black snake	1					1
Eastern water dragon	1			1		2
Yellow-faced whipsnake				1		1
Frogs						
Green tree frog	2					2
Striped marsh frog	3					3
Medium frog				3		3
Large frog				1		1
Introduced species						
Cat	1					1
European fox	3	1	1	2	1	8
European hare	2			1		3
Rabbit	1					1
Black rat	1					1
House mouse					1	1
Rock pigeon			1	1		2
Domestic goose				1		1
Total	93	14	34	55	57	253

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

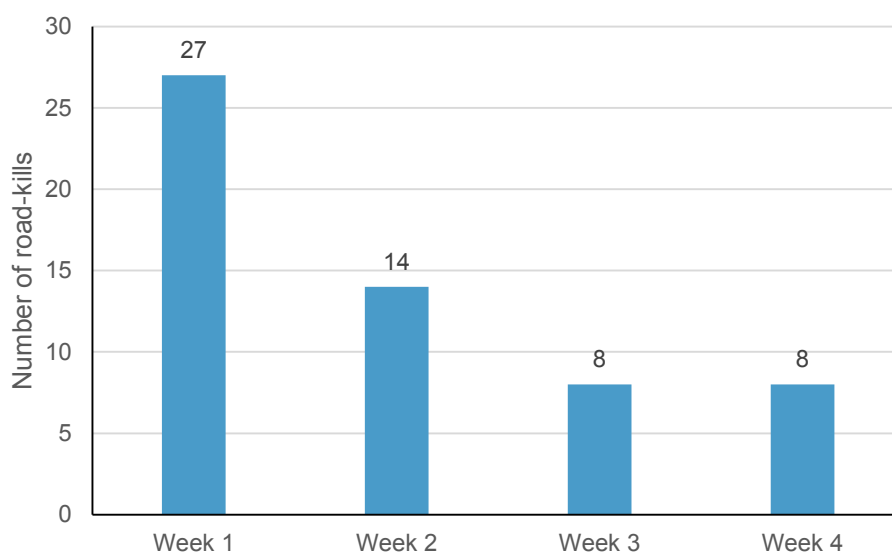


Figure 2: Number of road-kills recorded in each sample week during the January 2019 (summer) sample period.

The abundance of road-killed fauna in the four vertebrate groups varied during the sample period (Figure 3). The number of road-killed mammals went from 17 in week one to nine in week two, eight in week three and five in week four. Likewise, the number of road-killed birds decreased from eight in week one to four in week two and none in week three and back up to three in week four. Reptiles were only represented by one kill in week one and one in week two. No frogs were detected during January 2019 monitoring.

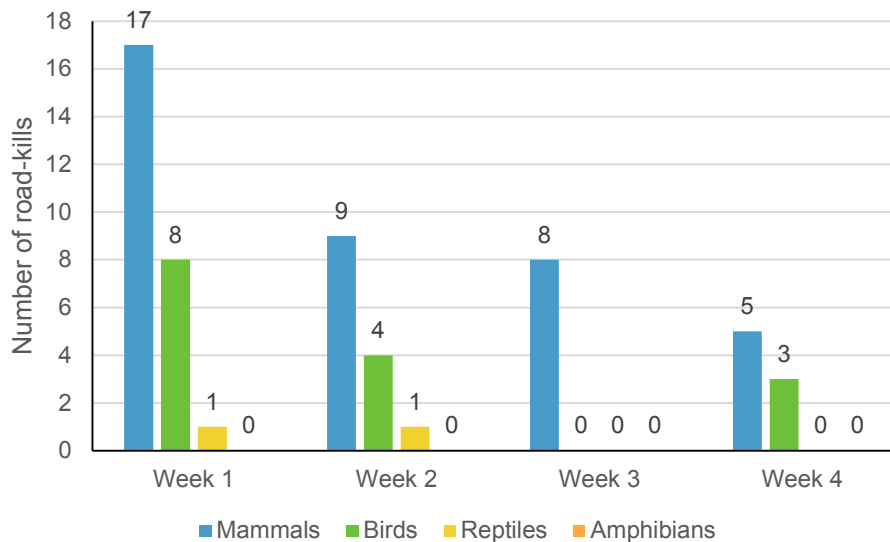


Figure 3: Number of road-killed fauna from four vertebrate classes during each sample week in January 2019.

3.1.3 Opportunistic roadkill information

A single Gould's wattled bat (*Chalinolobus gouldii*) was recorded road-killed as it flew into a company car window on the evening of 21 January 2019 (D. Rohweder pers obs). Driving southbound over the Nambucca River bridge the bat clipped the driver's side window sill and fell into the vehicle.

3.1.4 Distribution of roadkill

In January 2019, road-killed fauna was recorded over the entire WC2NH alignment (Figures 4-13), although the majority of records (93%) were situated between the Nambucca River and the southern end of the project. Within that area, 62% occurred between Albert Drive and the Nambucca River bridge (Figures 8-11) and the remaining 38% occurred between the southern end and Albert Drive (Figures 11-13). The section between the Nambucca River and the southern end of the project traverses predominantly cleared land with three drainage lines and minimal fauna exclusion fence. Four animals (7%) were recorded in the section north of the Nambucca River bridge. Notably, this northern section is entirely fenced with floppy top exclusion fence and in places, frog exclusion fence.

In January 2019, 17 road-kills were recorded in areas with exclusion fence, and 40 were recorded in areas without exclusion fence (Figures 4-13). Two records (or 11.7%) in sections with fence were species that should have been blocked by the fence (i.e. medium and large mammals & medium and large reptiles). In contrast, 35% of road-kills in sections without fence were of species that should have been blocked by an exclusion fence.

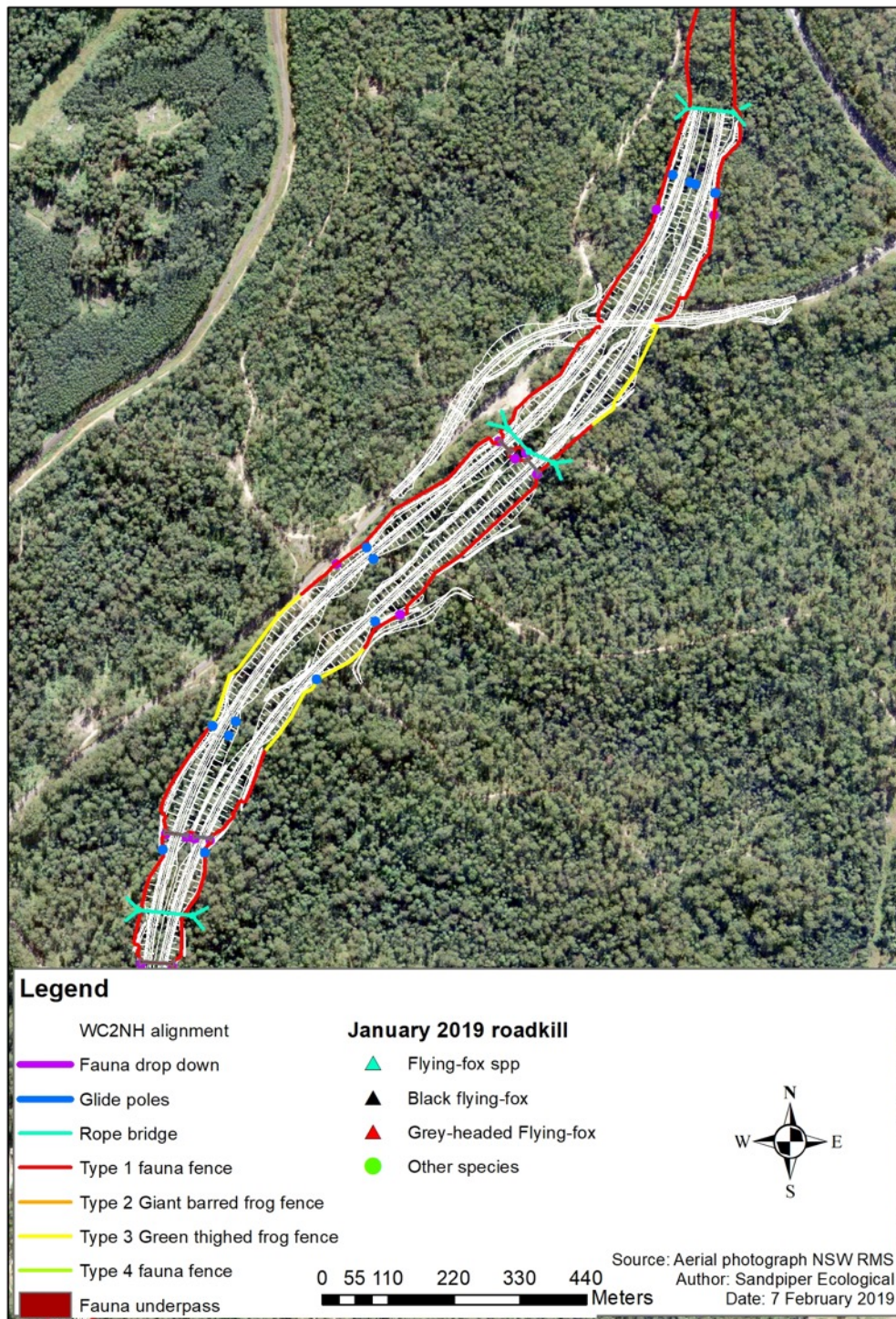


Figure 4: Location of road-killed fauna in January 2019.

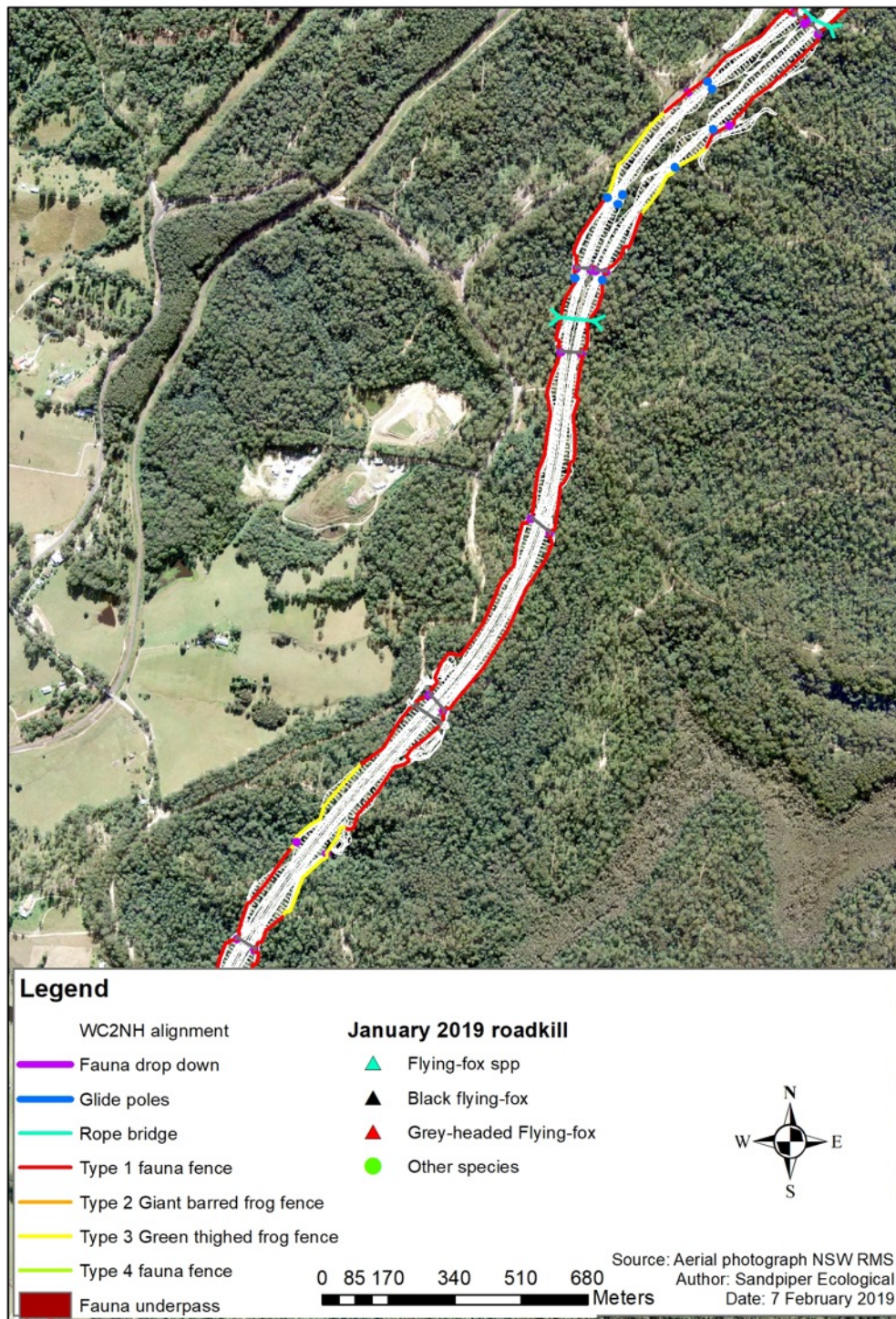


Figure 5: Location of road-killed fauna in January 2019.

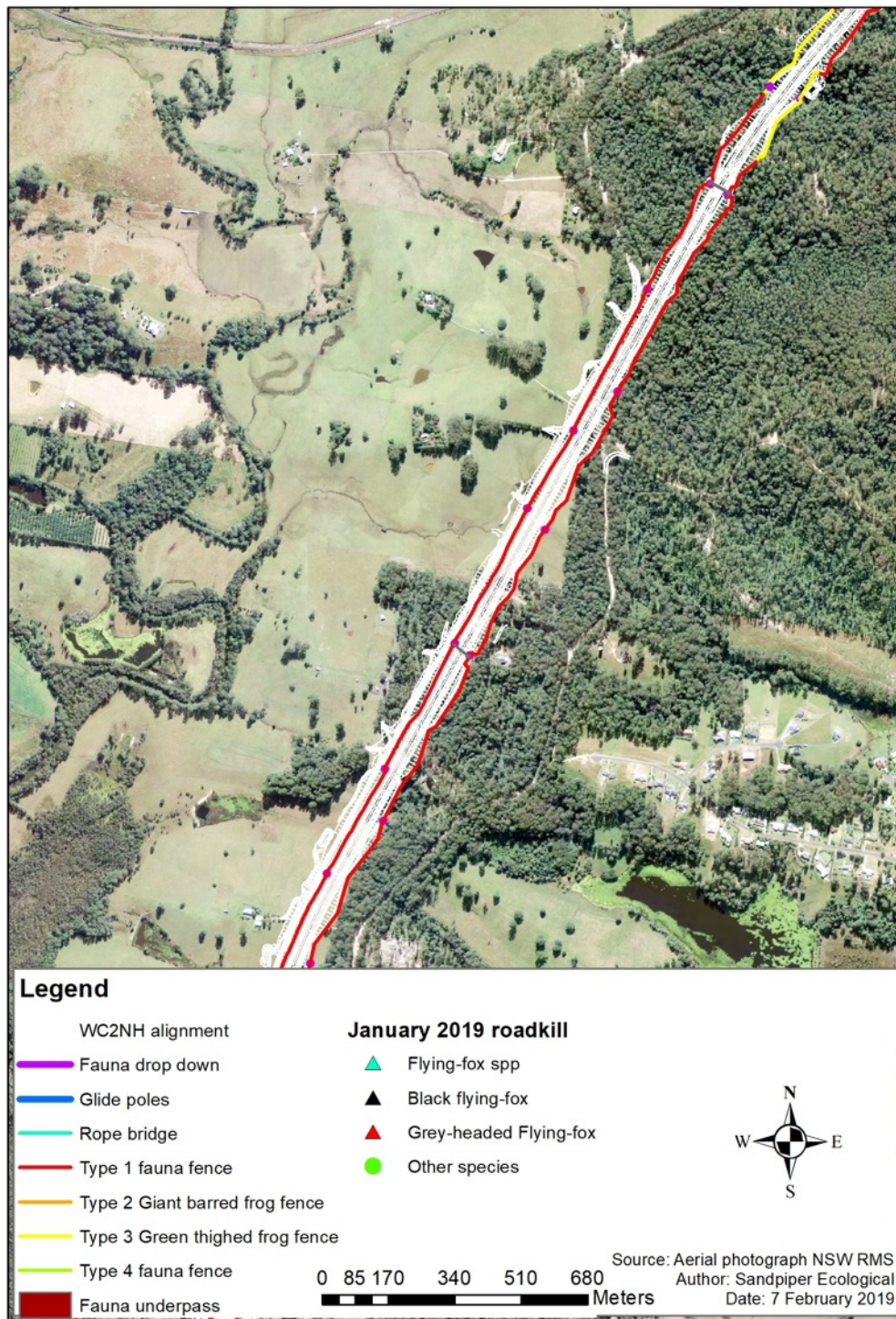


Figure 6: Location of road-killed fauna in January 2019.

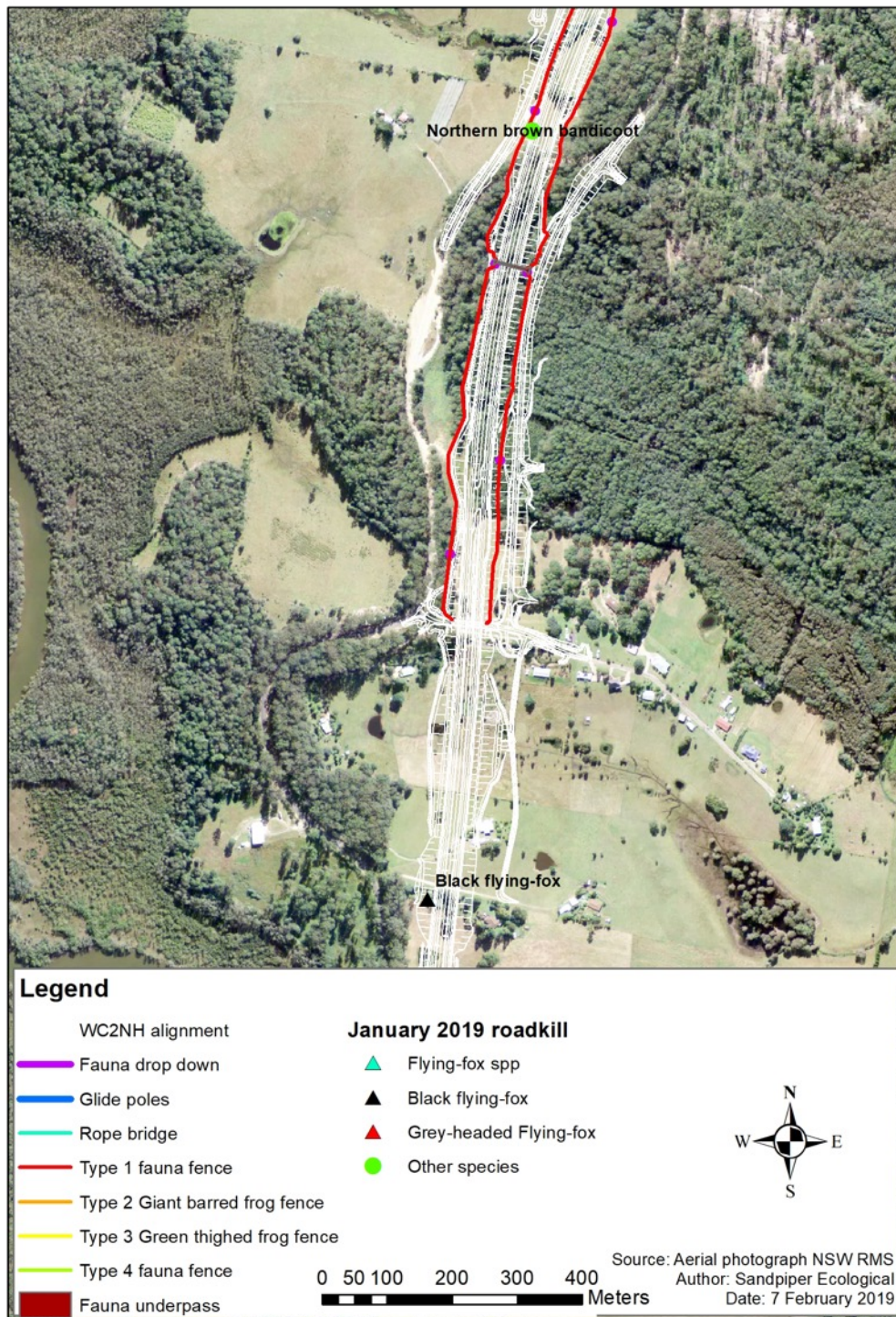


Figure 7: Location of road-killed fauna in January 2019.

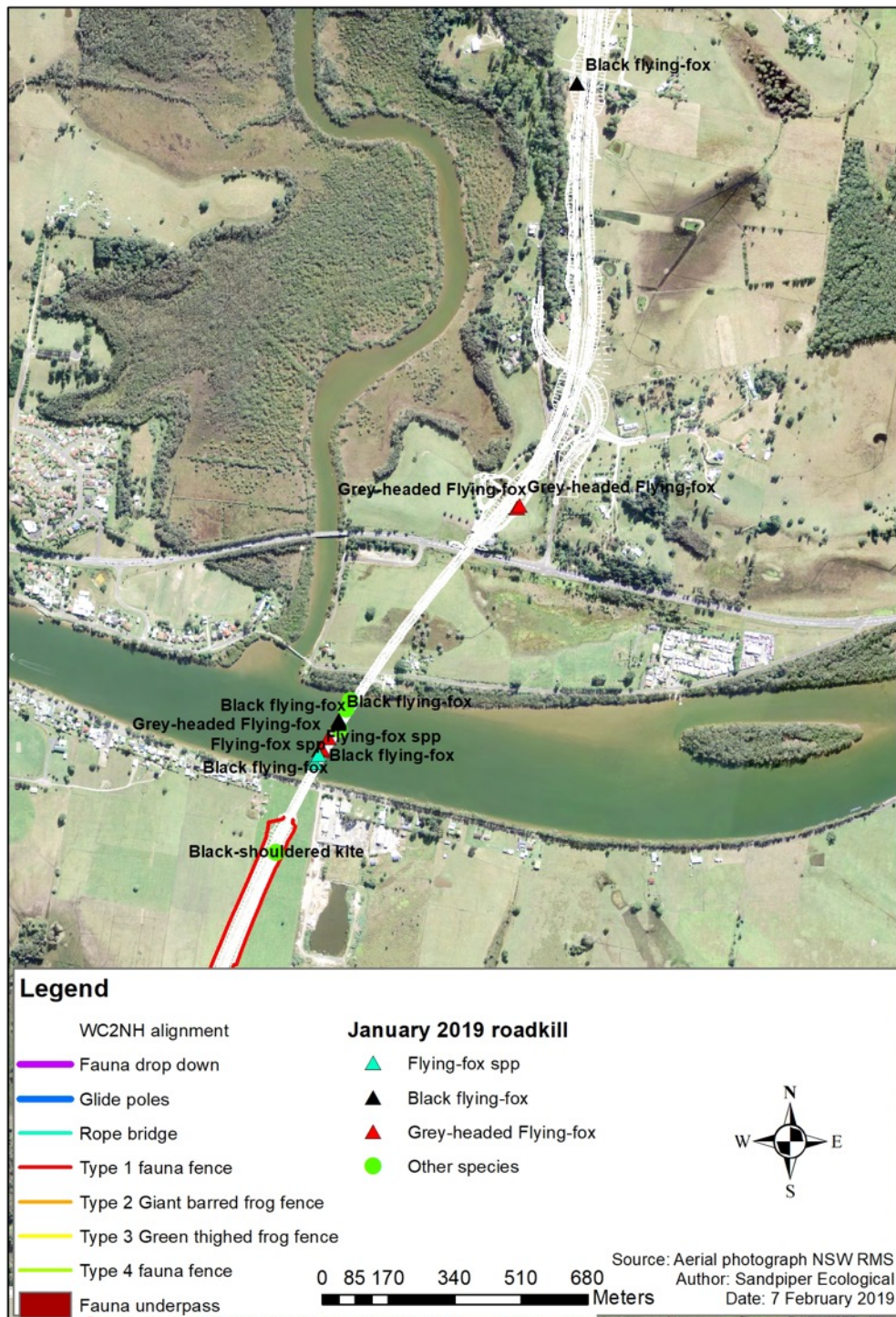


Figure 8: Location of road-killed fauna in January 2019.

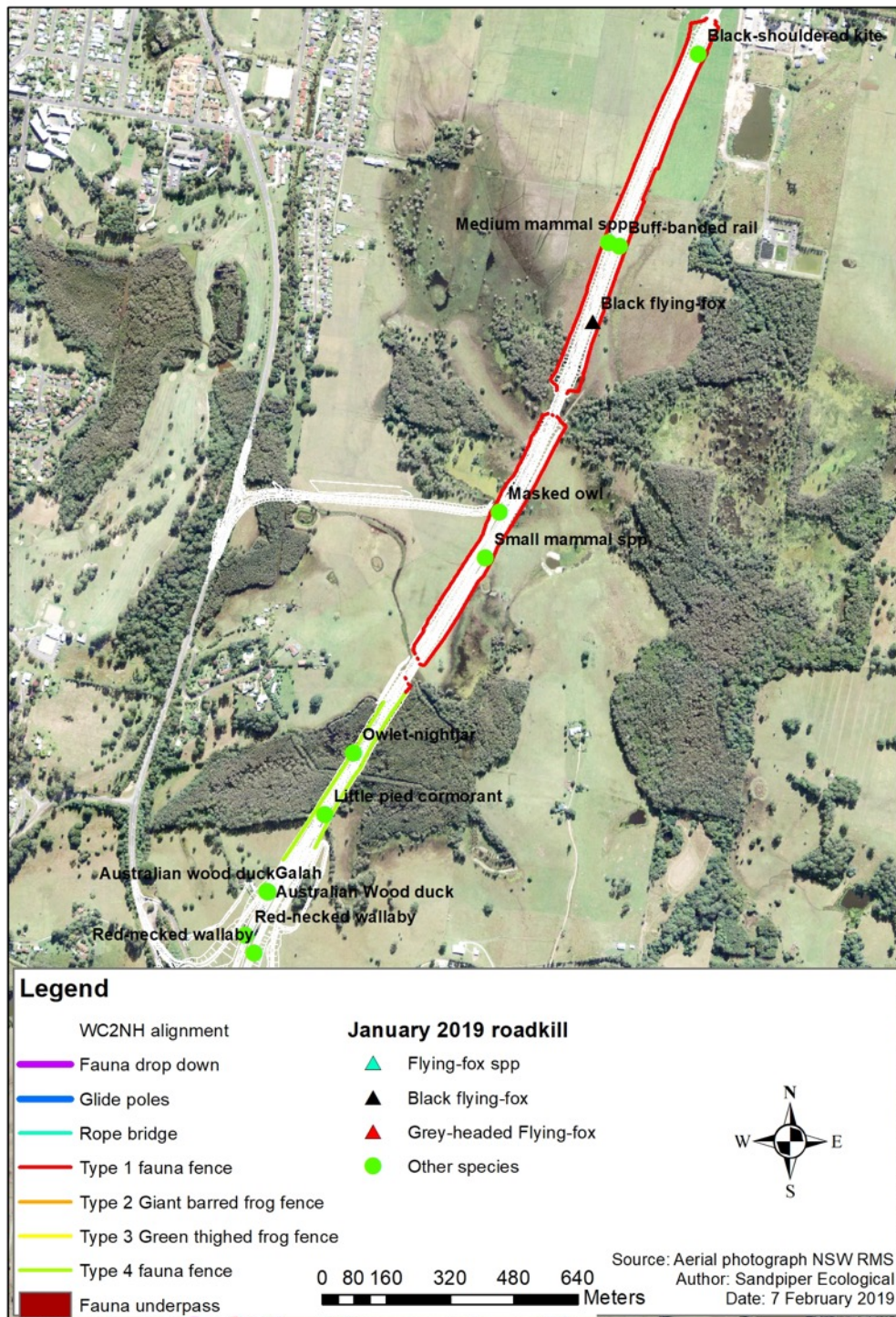


Figure 9: Location of road-killed fauna in January 2019.

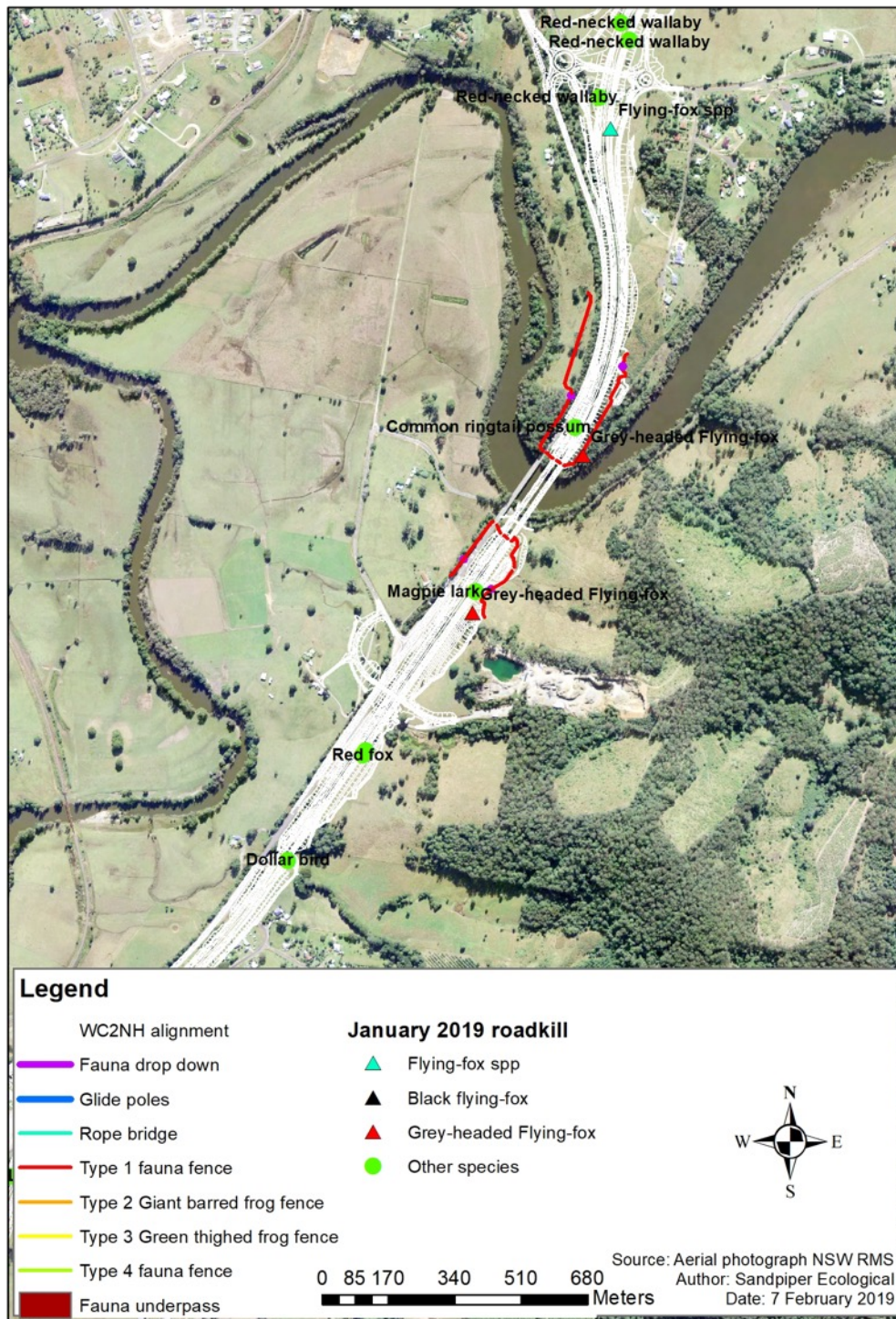


Figure 10: Location of road-killed fauna in January 2019.

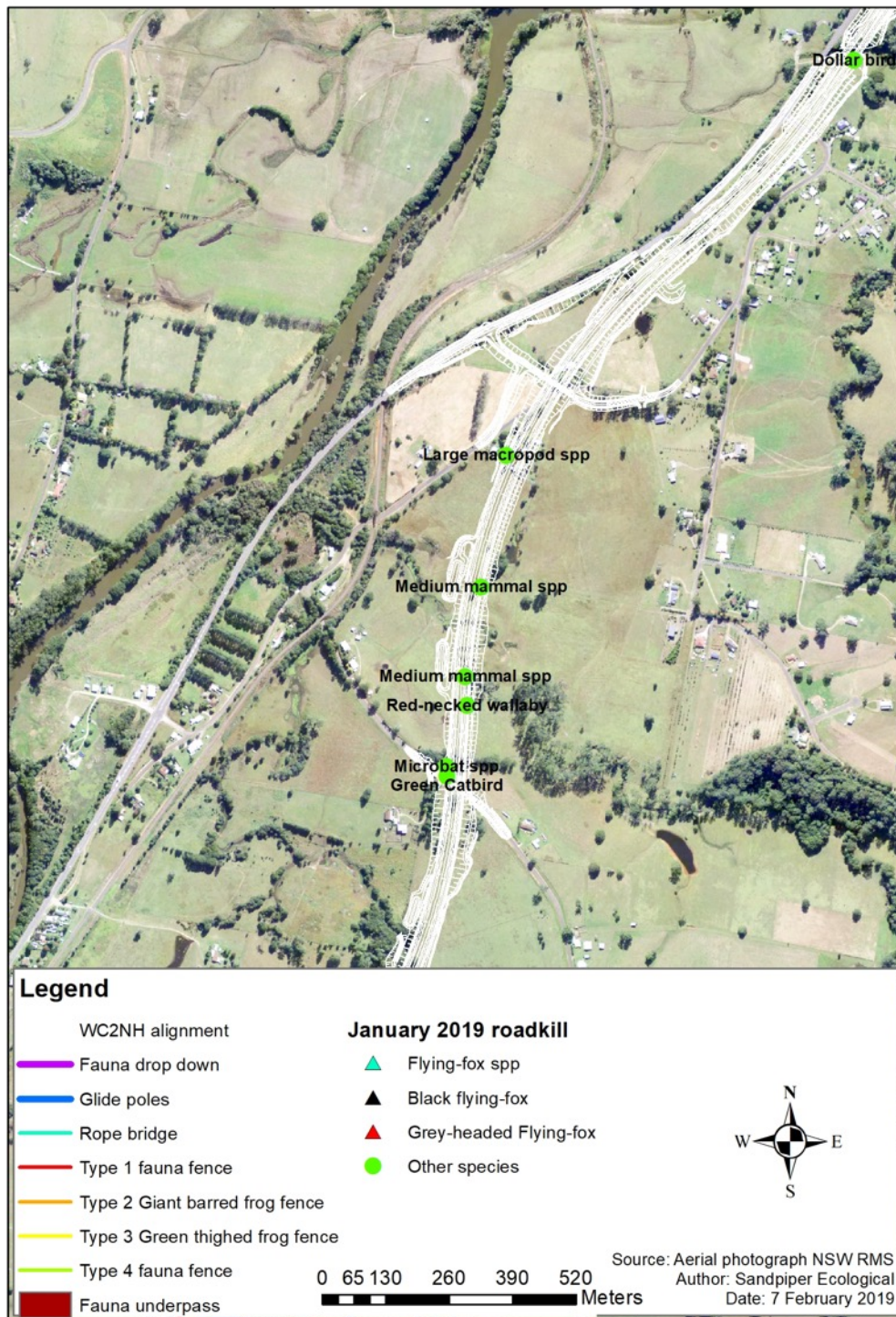


Figure 11: Location of road-killed fauna in January 2019.

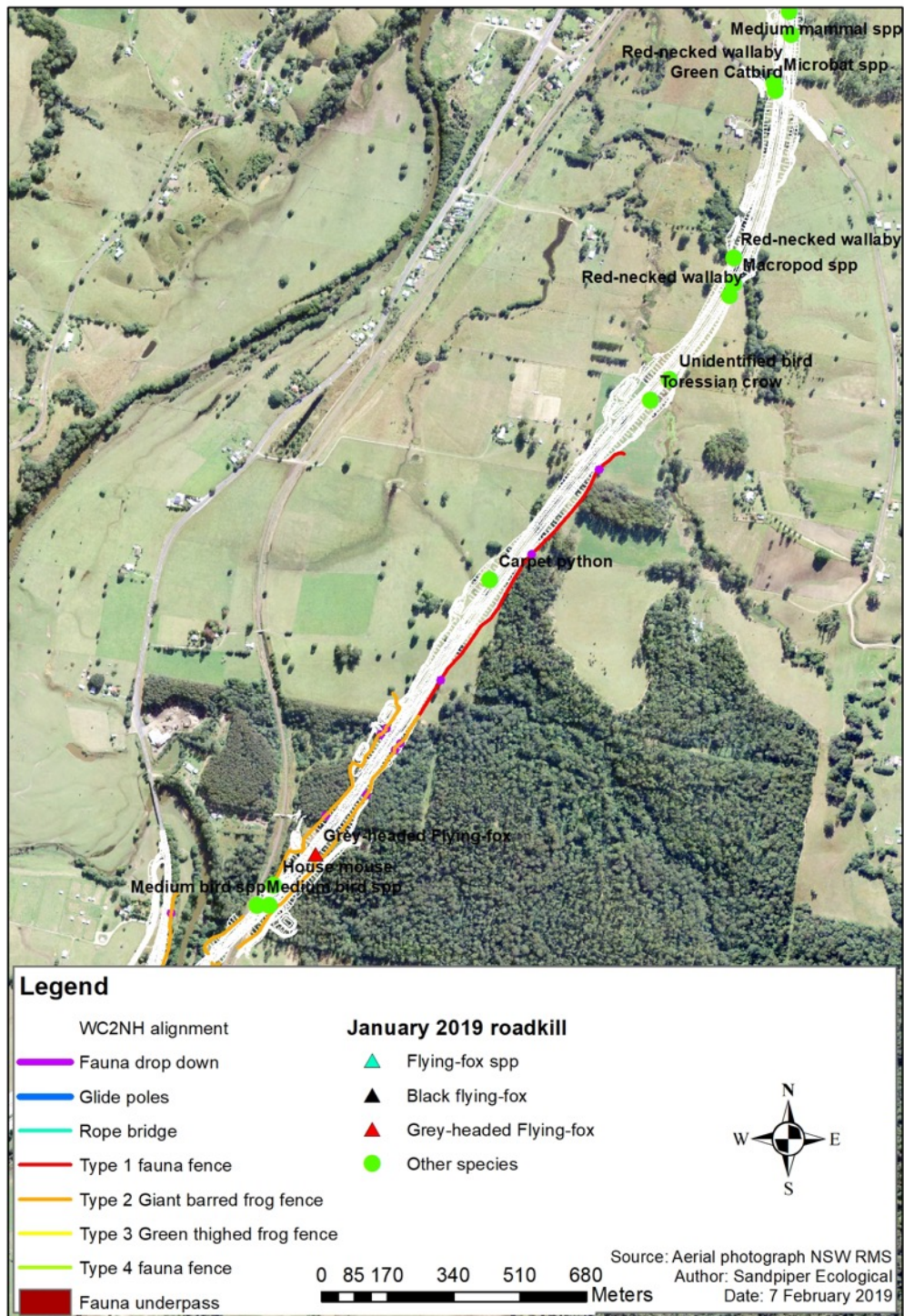


Figure 12: Location of road-killed fauna in January 2019.

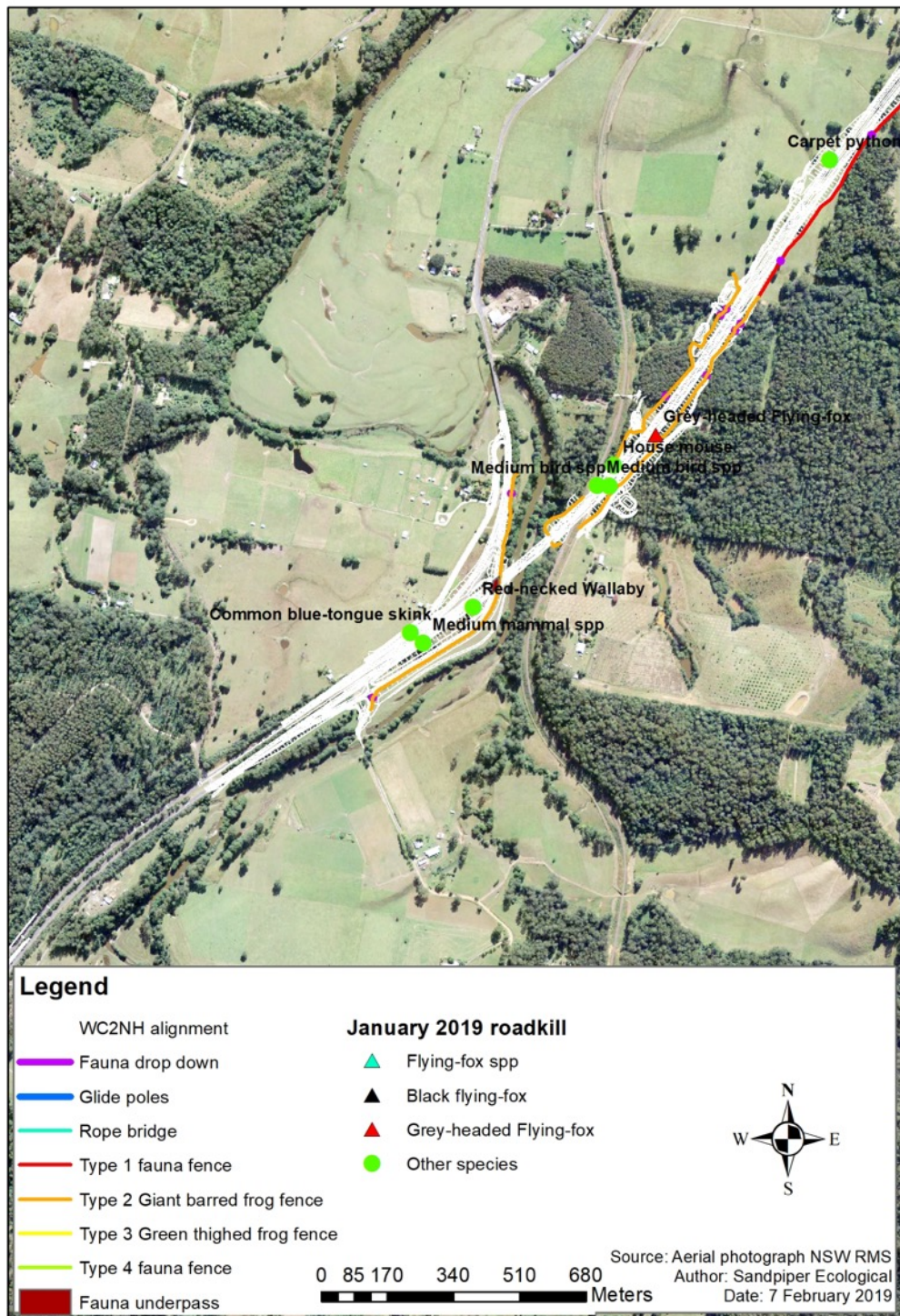


Figure 13: Location of road-killed fauna in January 2019.

4. Discussion

4.1 January 2019

Road-kill monitoring over the entire WC2NH alignment in January indicates that a substantial number of fauna continue to be killed by vehicles seven months after the entire alignment was open to traffic. With a total of 57 animals killed, January 2019 monitoring recorded an increase of 10 animals killed when compared to October 2018. An increase in road kills may be attributable to a number of factors including increased traffic over the summer holiday period and seasonal changes in animal behaviour (see section 4.2). A positive correlation has been recorded between traffic volume and the number of animals struck by vehicles (Jacobson *et al* 2016).

The increase in road-kills recorded in January may be bolstered by the time between samples. The October 2018 sample was conducted immediately after the conclusion of GeoLink monitoring in September. January 2019 monitoring was conducted after two months (November & December) of no monitoring. The higher number of road-kills recorded in the first January 2019 sample reflects the period over which samples could accumulate. This trend is likely to occur in all seasonal sample periods and it means that the number of road-kills recorded during a month overestimates the actual number of animals killed in that month.

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

4.2 Seasonal variation and species composition

The observed pattern of increased road-kill in spring and summer is not surprising as fauna tend to be more mobile during the spring/summer period when most species breed and disperse. Geolink (2018a) highlighted the possible influence of grass seeding close to the highway at the time of opening to traffic on galah and wood duck roadkill. Results in October and January have shown a decrease in galah, and wood duck roadkill, which supports the suggestion that grass seeding attracted these species to the road. The absence of freshwater turtles in the January 2019 sample corresponds with the drying of roadside waterbodies and lends support to the suggestion that turtles may have been residing within the road corridor rather than moving through the fence (Geolink 2018a). Nonetheless, this will not be confirmed until sampling occurs during the next turtle breeding season when the species become more mobile.

Red-necked wallabies may also be attracted to freshly sown grass on the highway verge, possibly explaining the high incidence of wallaby road-kill. Results of monitoring in October 2018 and January 2019 raise concerns about the effect of roadkill on the local red-necked wallaby population in the Albert Drive to upper Warrell Creek area. Continued roadkill at present rates is likely to reduce the abundance of wallabies in habitat adjoining the road (Huijser & Bergers 2000).

January monitoring detected no road-killed frogs. Along with the difficulty in detecting frogs via a vehicle this decrease may also be explained by climatic conditions which have not been conducive for

frog dispersal. The projects' southern compound weather station recorded only 6.4mm of rain over three rain days in January 2019.

Second to mammals, birds were the most impacted group of fauna. This highlights the susceptibility of the group to road-kill. The composition of birds in roadkill is predicted to change over time as larger species habituate to, and avoid, the highway and small birds take up residence on revegetated batters making some cover-dependant species more susceptible to road strike. Nonetheless, the results provide further evidence of the impact that roads have on bird populations (Husby 2016). Of particular concern is the impact on threatened species such as masked owl (Loss *et al.* 2014). The January 2019 record was the second masked owl road-kill since monitoring began.

4.3 Flying-fox impacts

A total of 18 flying-foxes were detected during January monitoring. Of these, eight were grey-headed flying-fox, seven were black flying-fox and three were unidentified *Pteropus* spp. Grey-headed flying-fox is listed as a vulnerable species by the *EPBC Act* and *BC Act*. Twelve of the 18 individuals were recorded on the Nambucca River bridge. As it is unsafe to stop or walk on the bridge none of these individuals could be examined for young, and no young were recorded with any of the adults that could be assessed. Five black flying-fox and one grey-headed flying-fox were deemed to be juveniles based on size. February corresponds with the approximate time when black and grey-headed flying-foxes become independent and begin to leave camps to forage (Australian Museum 2019; Department of the Environment 2019). It is possible that juveniles comprised a larger proportion of individuals than was recorded due to the inability to closely inspect several individuals. Juvenile bats are likely to be more susceptible to road strike as they tend to be less agile flyers and unfamiliar with their surroundings.

The direct distance to the nearest flying-fox camp, Gordon Park in Nambucca Heads, is approximately 9.8km from the Nambucca River bridge. Road-killed grey-headed flying foxes were also recorded north and south of Warrell Creek and south of upper Warrell Creek. During summer, flying-foxes often use waterways during their evening dispersal. As they fly along larger creeks and rivers individuals often drag their undersides in the water as a means of cooling themselves (Vardon *et al* 2001). The high incidence of flying-fox roadkill close to major river/creek crossings along the WC2NH upgrade is attributed to individuals flying low over the water and then trying to fly over the bridge but not gaining sufficient elevation. This is thought to be a seasonal impact and may reduce as the camp disperses and temperatures decline.

There was very little evidence of flowering or fruiting trees in proximity to roadkilled flying foxes. Whilst some blackbutt (*Eucalyptus pilularis*) trees were flowering in late January these were patchily distributed. The absence of food trees close to the highway further highlights the association between waterbodies and roadkill.

5. Recommendations

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

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Appendix A – Field Survey Data

Table A1: January (summer) 2019 roadkill results. DR = David Rohweder; LA = Luke Andrews; NP = Nick Priest; NB = northbound; SB = southbound, Y = yes, N = no, prox = proximity, xing = crossing, cond. = condition; * Gordon Park, Nambucca Heads

Date	Obs	Start time	End time	Carriage way	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence & prox.	Fence cond.	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp*; canopy vegt & food
10/1/2019	DR & LA	0650	1130	SB	Small mammal spp.	Adult	NA	Nambucca River bridge	493814	6602762	N	A	NA	2700m		
				SB	Black flying fox	Juvenile	Nil	Gumma floodplain	493359	6601705	Y	P	Good	110m	100m	11km; 130m; >1km
				SB	Small mammal spp.	Adult	NA	Gumma floodplain	493091	6601115	N	P	Good	200m	250m	
				SB	Little pied cormorant	Adult	NA	Gumma floodplain	492691	6600473	Y	P	Good		50m	
				SB	Red-necked wallaby	Adult	Nil	Bald Hill Road	492514	6600128	N	A	NA		NA	
				SB	Magpie-lark	Adult	NA	Sth Warrell Creek	492121	6598716	Y	P – east side	Good	100m		
				SB	Red-necked wallaby	Adult	Nil	100m nth Bald Hill Rd	491839	6598308	N	A	NA			
				SB	Red fox	Adult	NA	100m nth Bald Hill Rd	491831	6598297	N	A	NA			
				SB	Dollarbird	Adult	NA	Williamson's Ck bridge	491639	6598028	N	A	NA			
				SB	Mammal spp. (poss Bandicoot)	Adult	Nil	400m nth rosewood rd	490875	6596949	N	A	NA			
				SB	Macropod spp.	Adult	Nil	400m Sth Rosewood rd	490701	6596066	N	A	NA			
				SB	Red-necked	Adult	Nil	450m Sth	490689	6596035	N	A	NA			

Date	Obs	Start time	End time	Carriage way	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence & prox.	Fence cond.	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp*; canopy vegt & food
					wallaby			Rosewood Rd								
				SB	Unidentifiable bird	Unknown	NA	Rosewood Creek	490535	6595820	N	A	NA			
				SB	Toressian Crow (poss)	Adult	NA	Rosewood Creek	490486	6595766	N	A	NA			
				SB	Undertified bird (medium)	Unknown	NA	Railway overpass	489508	6594470	N	P	Good	50m		
				SB	Medium mammal (poss hare)	Adult	UK	Sth Upper Warrell Creek	489031	6594066	N	P	Good	100m		
				NB	House mouse	Adult	NA	Nth Upper Warrell Creek	489519	6594522	N	P	Good	150m		
				NB	Unid bird (medium)	Unknown	NA	Railway	489478	6594471	N	P	Good	100m		
				NB	Carpet python	Adult	NA	500m nth Butchers Creek	490074	6595306	Y	A	NA	500m		
				NB	Red-necked wallaby	Adult	Nil	Sth Rosewood Rd	490700	6596132	N	A	NA			
				NB	Large mammal (macropod)	Unknown	Nil	Albert Drive	490927	6597219	N	A	NA			
				NB	Common ringtail possum	Juvenile	Nil	Nth Albert Drive	492375	6599137	N	A	NA			
				NB	Red-necked wallaby	Adult	Nil	Bald Hill Rd	492438	6599982	N	A	NA			
				NB	Red-necked wallaby	Adult	Nil	Bald Hill Rd	492492	6600172	N	A	NA			
				NB	Masked owl	Adult	NA	Gumma floodplain	493127	6601230	N	P	Good	150m		

Date	Obs	Start time	End time	Carriage way	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence & prox.	Fence cond.	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp*; canopy vegt & food
17/1/2019	DR & LA	0745	1100	NB	Medium mammal spp.	Unknown	NA	Gumma floodplain	493399	6601903	N	P	Good			
				NB	Unidentifiable animal	Unknown	NA	Nambucca River bridge	493803	6602741	N	A	NA	2700m		
				SB	Black flying-fox x 3	Juveniles	NA	Nambucca River bridge	493784	6602708	N	P	Good	NA	NA	10km; 250m; >1km
				SB	Grey-headed flying-fox	Juvenile	UK	Nambucca River bridge	493758	6602667	N	P	Good	NA	NA	10km; 250m; >1km
				SB	Red-necked wallaby	Adult	Nil	100m nth Rosewood road	490847	6596706	N	A	NA		NA	
				SB	Red-necked Wallaby	Adult	Nil	50m nth Warrell Creek	489159	6594159	N	P	Good	100m		
				NB	Green catbird	Adult	NA	Rosewood Rd bridge	490806	6596561	Y	A	NA		NA	
				NB	Microbat spp.	Adult	Nil	Rosewood Rd bridge	490804	6596581	Y	A	NA		NA	
				NB	Aust wood duck	Adult	NA	Nth Bald Hill Road	492545	6600281	N	A	NA		NA	
				NB	Galah	Adult	NA	Nth Bald Hill Road	492545	6600281	N	A	NA		NA	
				NB	Owlet-nightjar	Adult	NA	300m nth Bald Hill Road/ Gumma flood plain	492762	6600628	Y	P	Good	250m	100m	
				NB	Black flying-fox x 2	Juvenile	NA	Nambucca River	493708	6602642	N	A	NA	NA	NA	10km; 250m; >1km
				NB	Common blue-tongue skink	Adult	NA	Nth end project	497469	6610816	Y	P	Good			

Date	Obs	Start time	End time	Carriage way	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence & prox.	Fence cond.	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp*; canopy vegt & food
				SB	Flying fox spp.	Unknown	UK	Nambucca River bridge	493722	6602603	N	P	Good	NA	NA	10km; 250m; >1km
24/1/2019	NP & LA	0750	0930	SB	Flying Fox spp.	Unknown	Nil	100 m s Bald hill road	492466	6599901	N	A		NA	NA	13km; 100m; none recorded
				SB	Medium mammal	Unknown	Nil	200 m N RoseWood Rd Bridge	490843	6596765	No	A				
				NB	Grey-headed flying fox	Adult	Nil	Cockburns Bridge	489627	6594601	No	A				18km; 50m; >1km
				NB	Grey-headed flying fox	Adult	Nil	150m sth Warrell Creek	492113	6598661	N	A	Good	No	Na	14km; 320m; >1km
				NB	Grey-headed flying fox	Adult	Nil	Lower Warrell Creek Bridge	492396	6599065	N	A				19km; 30m; none recorded
				NB	Grey-headed flying fox x 2	Adult	UK	Nambucca river bridge	494254	6603250	No	A				10km; 250m; >1km
				NB	Aus wood duck	Adult	Na	150m nth Bald Hill Rd	492549	6600280	No	A	Na	300m	150m	
				NB	Grey-headed flying fox x 2	Adult	UK	Nambucca River bridge	493741	6602634	No	A	Na	Na	Na	10km; 250m; >1km
31/1/2019	DR & SR	0715	1000	NB	Black flying-fox	Adult	Nil	420m Sth Mattick Rd	494394	6604343	No	A	Na	Na	Na	8.3km; 70m; none recorded
				NB	Northern brown bandicoot	Sub-adult	Nil	769m nth Mattick Rd	494555	6605523	No	P	Good	150m		
				SB	Flying-fox spp.	Adult	Nil	Nambucca river bridge	493732	6602624	No	A	Na	Na	Na	10km; 250m; >1km
				SB	Black-shouldered kite	Adult	NA	50m Sth Nambucca River bridge	493623	6602374	Yes	P	Good	100m	5m	

Date	Obs	Start time	End time	Carriage way	Species	Sex & age class	Presence of pouch or back young	RK general location	RK easting	RK northing	Cleared off Rd?	Fauna fence & prox.	Fence cond.	Prox. to crossing structure	Prox. to drop-down	If Fly-fox, prox. to camp*; canopy velt & food
				SB	Buff-banded rail	Adult	NA	720m Sth Nambucca river	493426	6601894	Yes	P	Good	300m		

Appendix 8 Road Kill Monitoring Report – Autumn (April) 2019 monitoring.

Pacific Highway Upgrade Warrell Creek to Nambucca Heads

Operational phase roadkill monitoring –
Autumn 2019.



Sandpiper Ecological

1/94 Main Street
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Cover Photo: Road-killed black bittern (*Ixobrychus flavicollis*) detected during April 2019 surveys. Black bittern is listed as vulnerable by the New South Wales *Biodiversity Conservation Act 2016*.

Disclaimer:

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1. Introduction

1.1 Background

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

The upgrade included a number of roadkill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate roadkill included:

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna drop-down structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including underpasses, bridges, rope bridges and glide poles.

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

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

Sandpiper Ecological Surveys (SES) has been engaged by RMS to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal roadkill surveys over the entire upgrade length.

Monitoring of road-killed fauna is a requirement of the approved WC2NH koala (*Phascolarctus cinereus*), spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) management plans and the Ecological Monitoring Program (Roads and Maritime 2018a). Priority species for roadkill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog (*Mixophyes iteratus*). Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced seasonal

monitoring in October 2018. The results of monitoring in 2018 were analysed and discussed by Sandpiper Ecological (2018). The following report covers the April (autumn) monitoring event and includes the entire WC2NH alignment. Remaining seasonal monitoring events in 2019 are scheduled for July (winter) and October (spring). Previous roadkill monitoring was conducted by Geolink (2018a, b, c, d).

The aim of monitoring is to:

- report on any vertebrate roadkill following opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

1.2 Study area

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

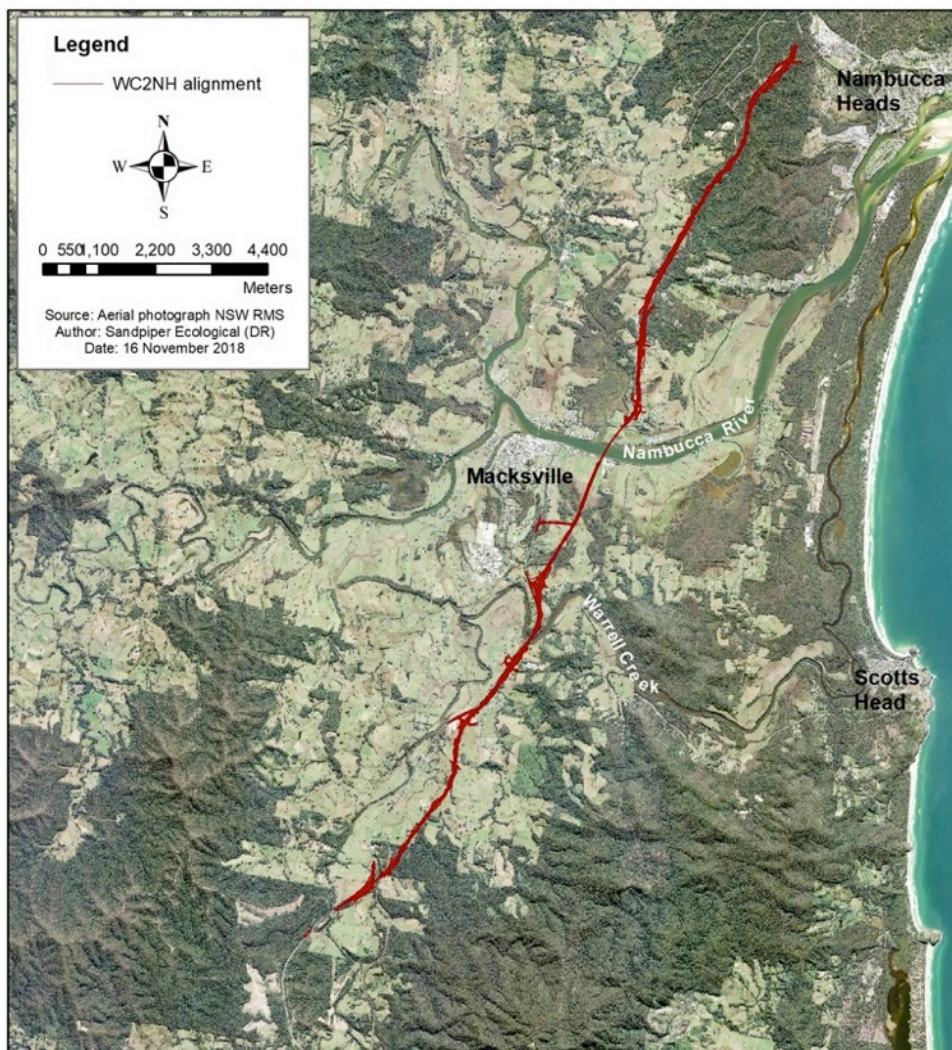


Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Roadkill surveys

Roadkill surveys were conducted by a two-person team from a vehicle driven at 70km/hr in the left lane. The vehicle was equipped with an amber (flashing) light and warning sign (Plate 1). The team consisted of a driver, and ecologist with experience identifying road-killed fauna. All surveys commenced within two hours of sunrise, with an interval of seven days between samples. During each survey, both the driver and ecologist scanned the road surface and road shoulder for fauna. When road-killed fauna were detected the vehicle was pulled onto the shoulder/parking bay and the ecologist inspected the subject animal from the closest position behind wire rope and perpendicular to the specimen. Fauna that could not be identified immediately were photographed and images sent to colleagues. Carcasses were removed from the road surface when safe to do so.



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

Data collected on each roadkill included (Appendix A1):

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

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act* (EPBC) 1999 and/or the *Biodiversity Conservation Act* (BC) 2016, included, where possible: sex and age (juvenile/adult); presence of pouch young if applicable; presence of flightless young (flying-foxes); distance to a fauna connectivity structure (determined from GIS); distance to a drop-down structure (determined from GIS); damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

All road-kills were cross referenced with the previous survey results to identify possible duplicates. Using the same team during the survey, GPS coordinates of each specimen, looking at carcass age and location on the carriageway, and detailed location description assisted with identification of duplicates.

Distance to connectivity structure, and distance to drop-down was determined via GIS. All other data were uploaded to an iPad in the field.

2.2 Data summary and analysis

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

3. Results

3.1 Weather conditions

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

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

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

3.2 Species richness and abundance

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

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

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



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



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

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

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

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

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

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

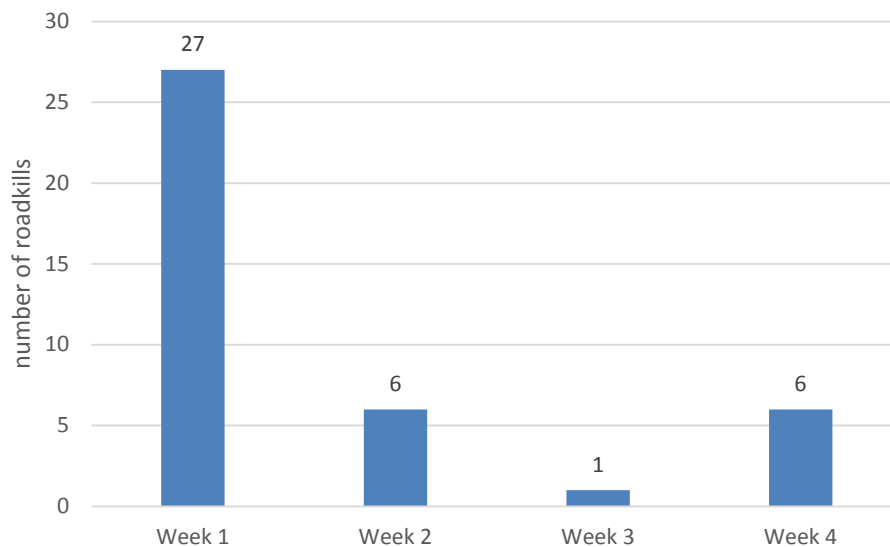


Figure 2: Number of road-kills recorded in each sample week during the April 2019 (autumn) sample period.

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

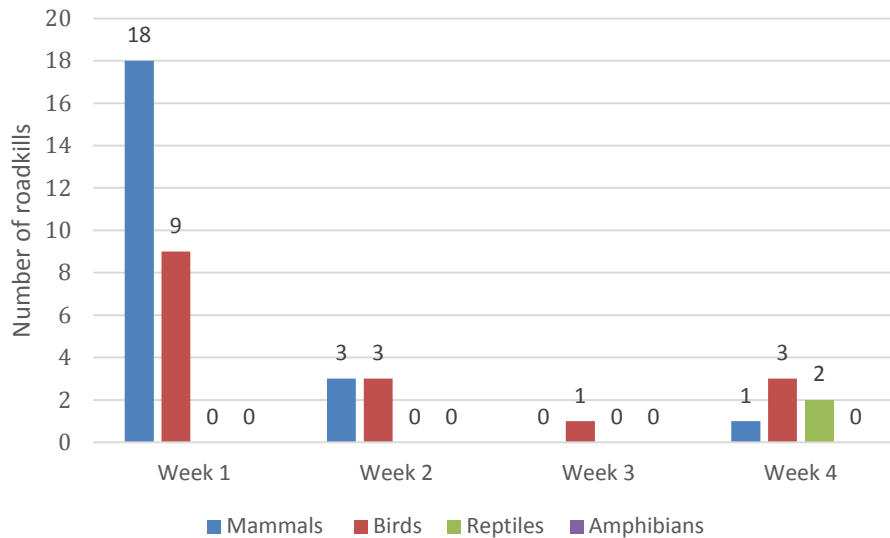


Figure 3: Number of road-killed fauna from four vertebrate classes during each sample week in April 2019.

3.1.3 Opportunistic roadkill information

No opportunistic roadkill records were detected during the period.

3.1.4 Distribution of roadkill

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

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

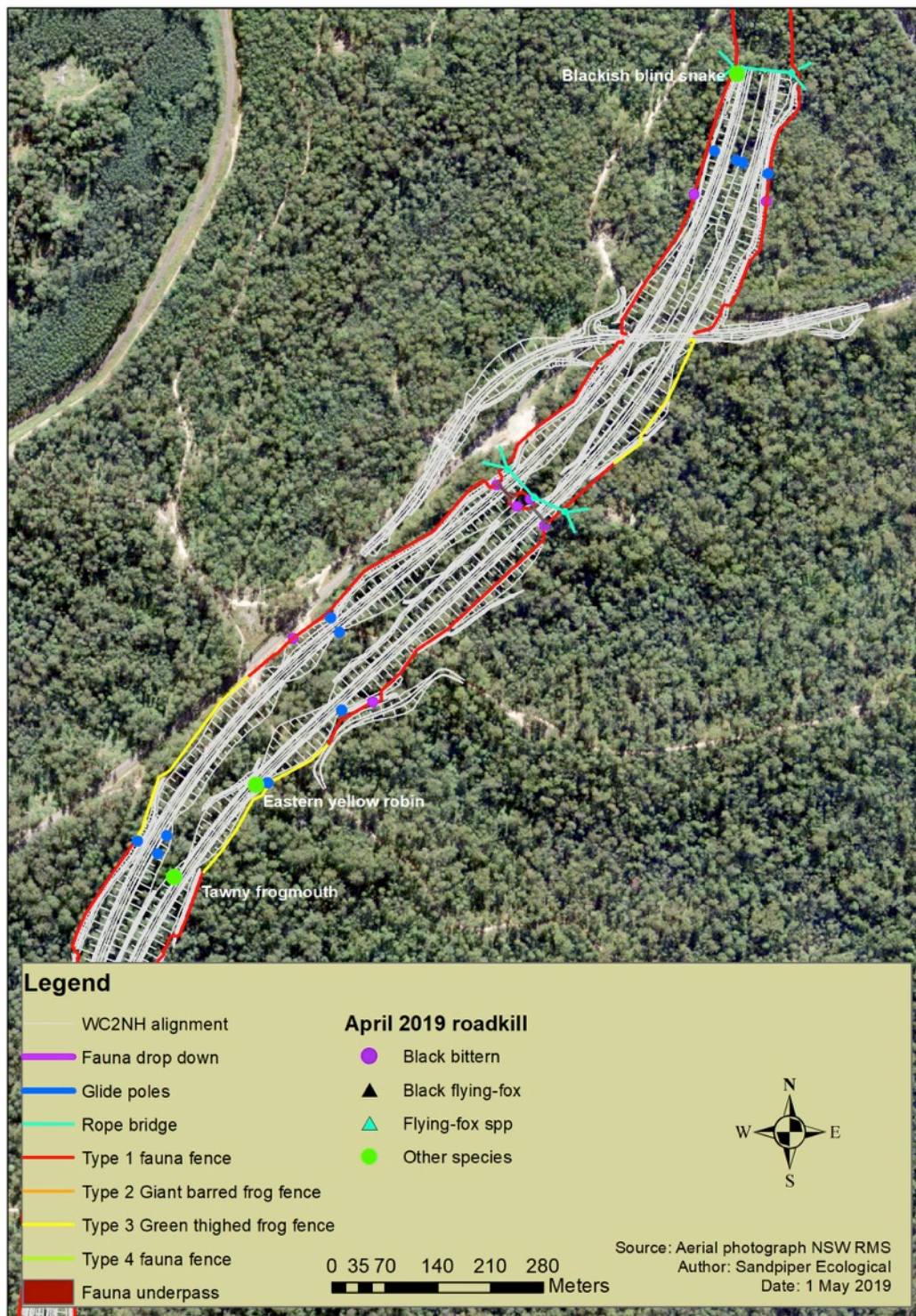


Figure 4: Location of road-killed fauna in April 2019.

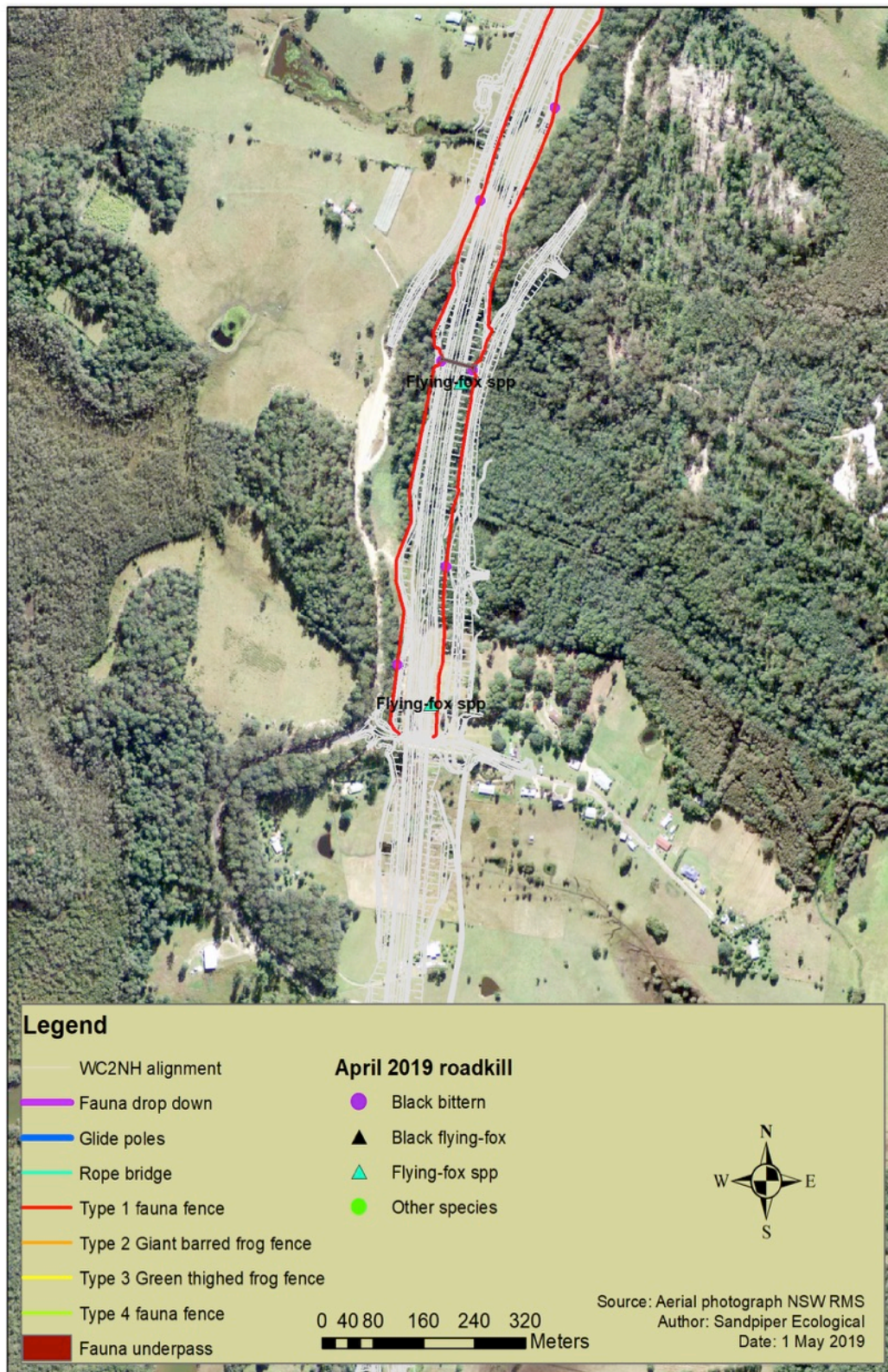


Figure 6: Location of road-killed fauna in April 2019.

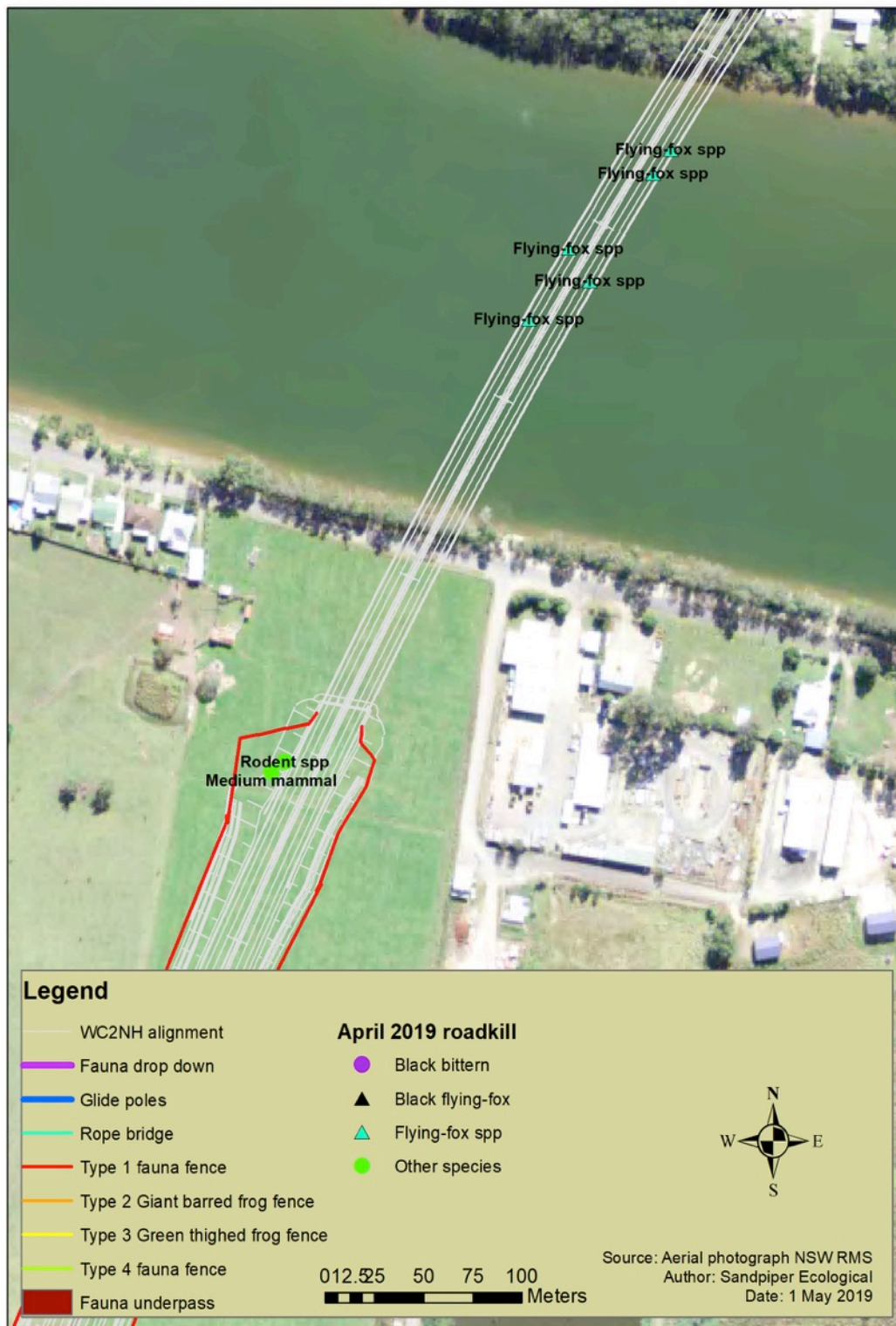


Figure 7: Location of road-killed fauna in April 2019. Flying-fox records overlap, refer to table A1.

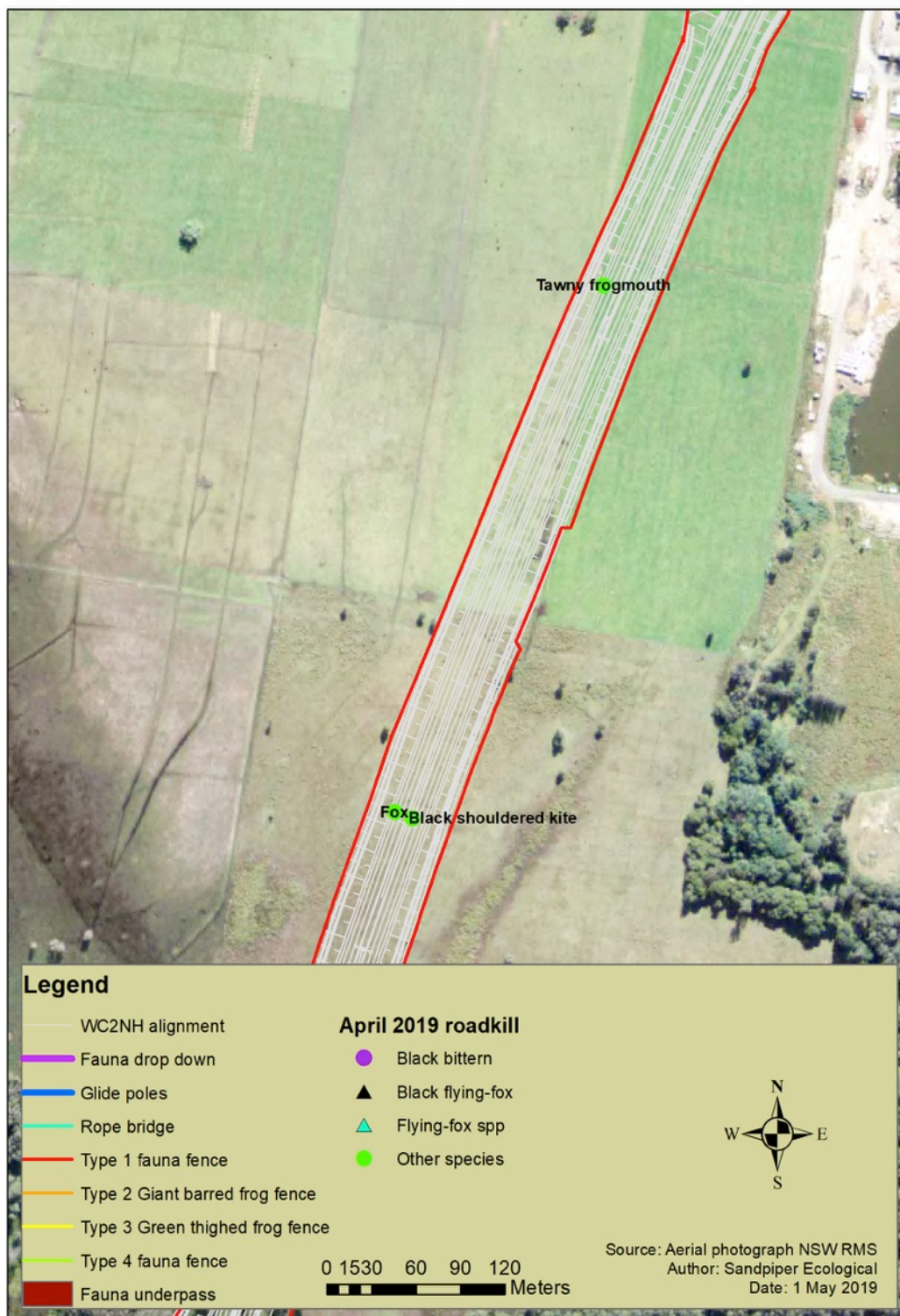


Figure 8: Location of road-killed fauna in April 2019.

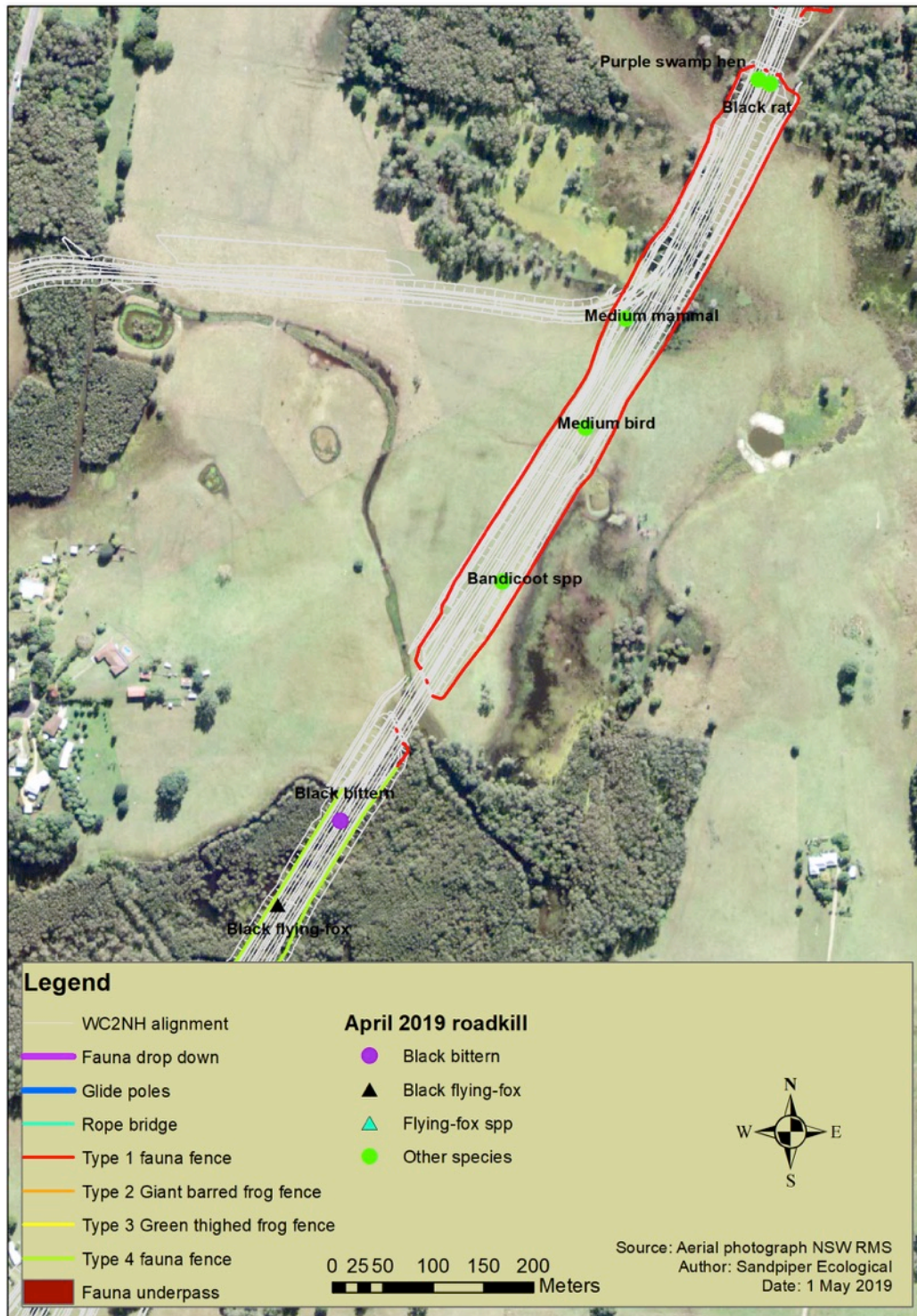


Figure 9: Location of road-killed fauna in April 2019.



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

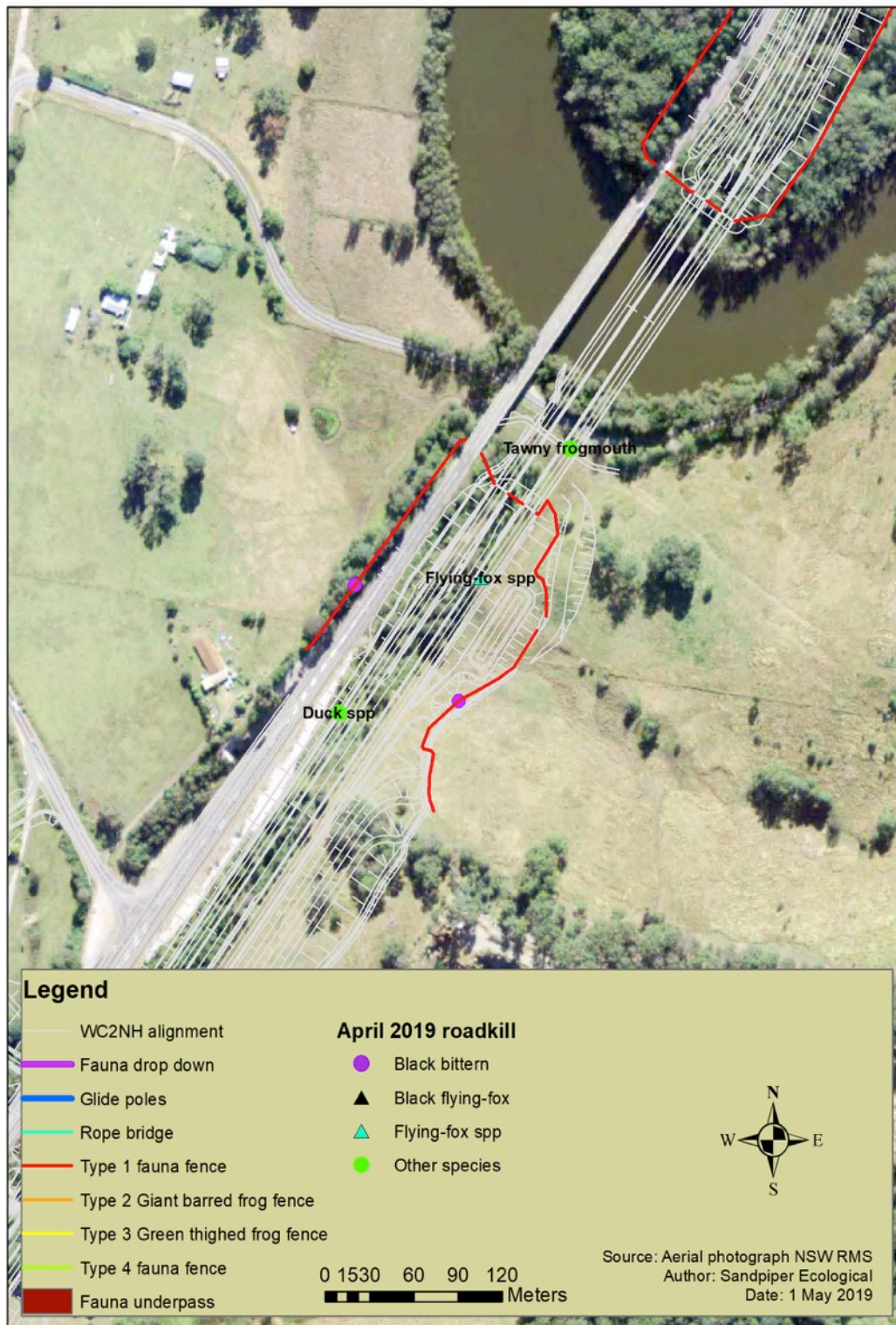


Figure 11: Location of road-killed fauna in April 2019.

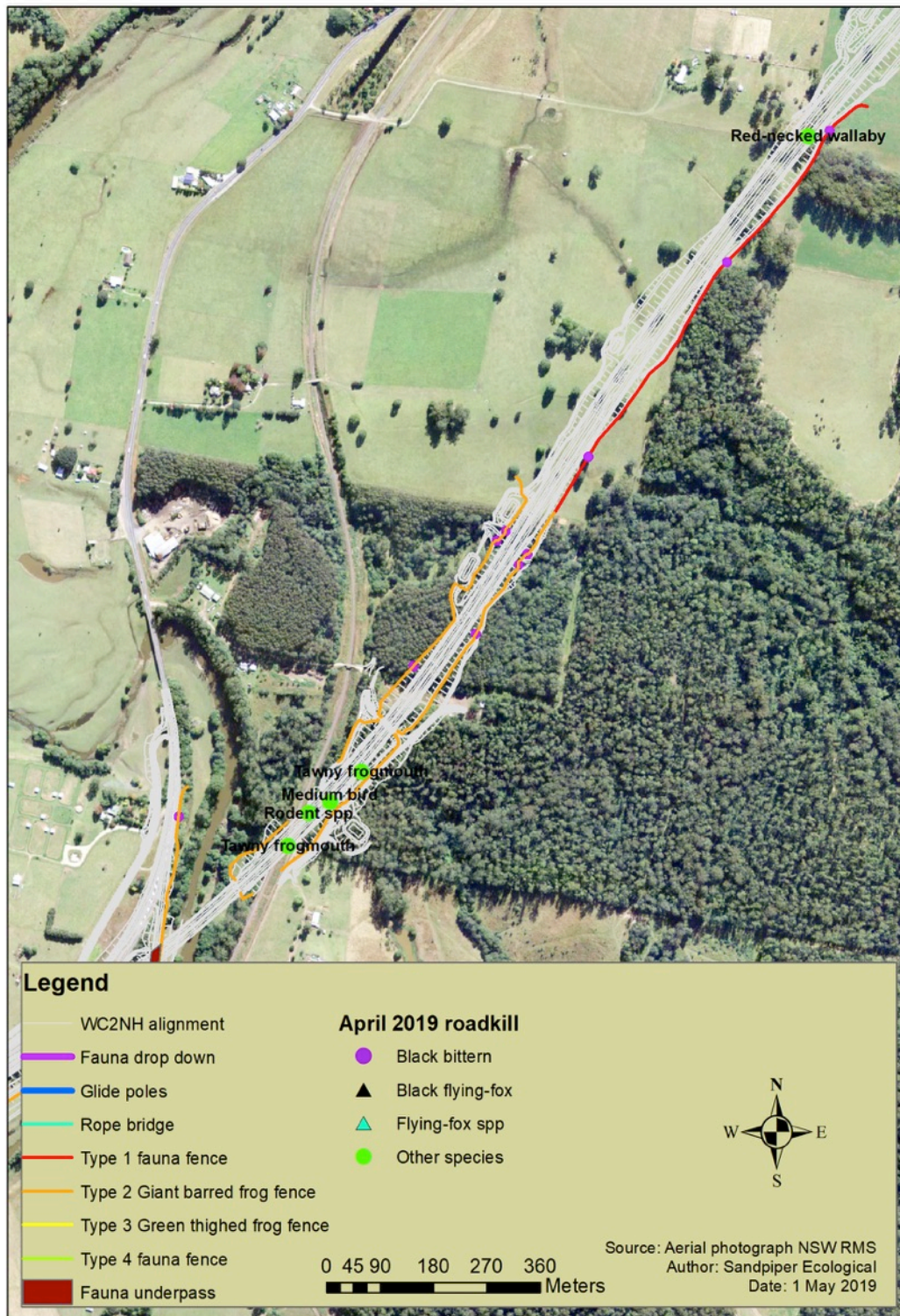


Figure 12: Location of road-killed fauna in April 2019.

4. Discussion

4.1 April 2019

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

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

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

4.2 Seasonal variation and species composition

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

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

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

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

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

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

4.3 Flying-fox impacts

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

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

5. Recommendations

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

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Appendix A – Field Survey Data

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

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

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

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

Appendix 9 Road Kill Monitoring Report – Winter (July) 2019 monitoring.

Pacific Highway Upgrade Warrell Creek to Nambucca Heads

Operational phase roadkill monitoring –
Winter 2019.



Sandpiper Ecological

1/94 Main Street
Alstonville

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Final Report
1 August 2019

Document Review

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Cover Photo: A red-necked wallaby (*Macropus rufogriseus*) road-killed on north-bound lane near Bald Hill Road overpass.

Disclaimer:

This report has been prepared in accordance with the scope of services described in the contract or agreement between Sandpiper Ecological Surveys (ABN 82 084 096 828) and NSW Roads and Maritime Services. The report relies upon data, surveys and measurement obtained at the times and locations specified herein. The report has been prepared solely for NSW Roads and Maritime Services. Sandpiper Ecological Surveys accepts no responsibility for its use by other parties. Sandpiper Ecological Surveys accepts no responsibility or liability for changes in context, meaning, conclusions or omissions caused by cutting, pasting or editing the report.

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1. Introduction

1.1 Background

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

The upgrade included a number of roadkill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate roadkill included:

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna drop-down structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including underpasses, bridges, rope bridges and glide poles.

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

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

Sandpiper Ecological Surveys (SES) has been engaged by Roads and Maritime to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal roadkill surveys over the entire upgrade length.

Monitoring of road-killed fauna is a requirement of the approved WC2NH koala (*Phascolarctos cinereus*), spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for roadkill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog. Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30

September 2018 and Sandpiper Ecological commenced seasonal monitoring in October 2018. The results of monitoring in 2018 were analysed and discussed by Sandpiper Ecological (2018). The following report covers the July (winter) 2019 monitoring event and includes the entire WC2NH alignment. Remaining seasonal monitoring events in 2019 are scheduled for October (spring).

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

The aim of monitoring is to:

- report on any vertebrate roadkill following opening to traffic; and
- assess the effectiveness of fauna fence in preventing fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

1.2 Study area

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

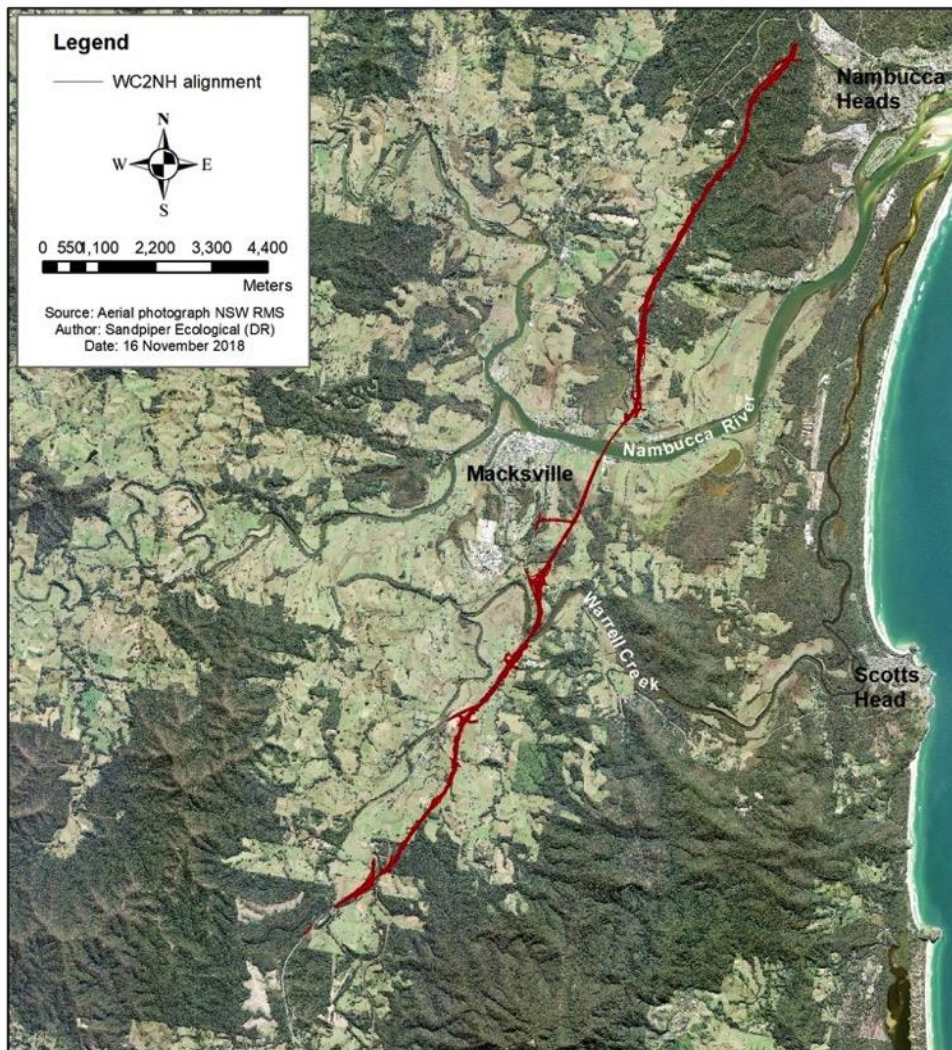


Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Roadkill surveys

Roadkill surveys were conducted by a two-person team from a vehicle driven at 80km/hr in the left lane. The vehicle was equipped with an amber (flashing) light and warning sign (Plate 1). The team consisted of a driver, and ecologist with experience identifying road-killed fauna. All surveys commenced within three hours of sunrise, with an interval of seven days between samples. During each survey, both the driver and ecologist scanned the road surface and road shoulder for fauna. When road-killed fauna were detected the vehicle was pulled onto the shoulder/parking bay and the ecologist inspected the subject animal from the closest position behind wire rope and perpendicular to the specimen. Fauna that could not be identified immediately were photographed and images sent to colleagues for assessment. Carcasses were removed from the road surface when safe to do so.



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

Data collected on each roadkill included (Appendix A1):

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

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act (EPBC) 1999* and/or the *Biodiversity Conservation Act (BC) 2016*, included, where possible: sex and age (juvenile/adult); presence of pouch young if applicable; presence of flightless young (flying-foxes); distance to a fauna connectivity structure (determined from GIS); distance to a drop-down structure if applicable (determined from GIS); damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

All road-kills were cross referenced with the previous survey results to identify possible duplicates. Using, at a minimum, one team member consistently across all surveys, GPS coordinates of each specimen, looking at carcass age and location on the carriageway, and detailed location description assisted with identification of duplicates.

Distance to connectivity structure, and distance to escape structure was determined via GIS. All other data were uploaded to an iPad in the field.

2.2 Data summary and analysis

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

3. Results

3.1 Weather conditions

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

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

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

3.2 Species richness and abundance

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

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



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



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

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

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

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

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

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

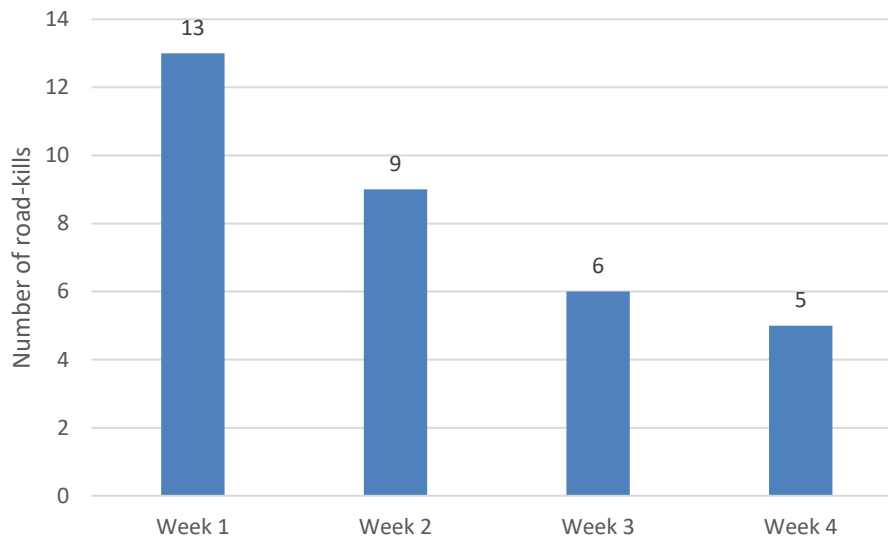


Figure 2: Number of road-kills recorded in each sample week during the July 2019 (winter) sample period.

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

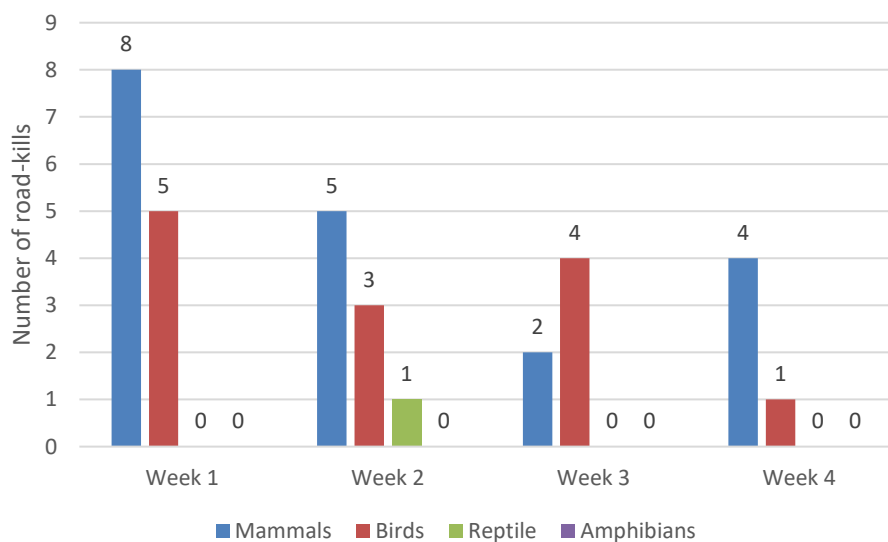


Figure 3: Number of road-killed fauna from four vertebrate classes during each sample week in July 2019.

3.1.3 Opportunistic roadkill information

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

3.1.4 Distribution of roadkill

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

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

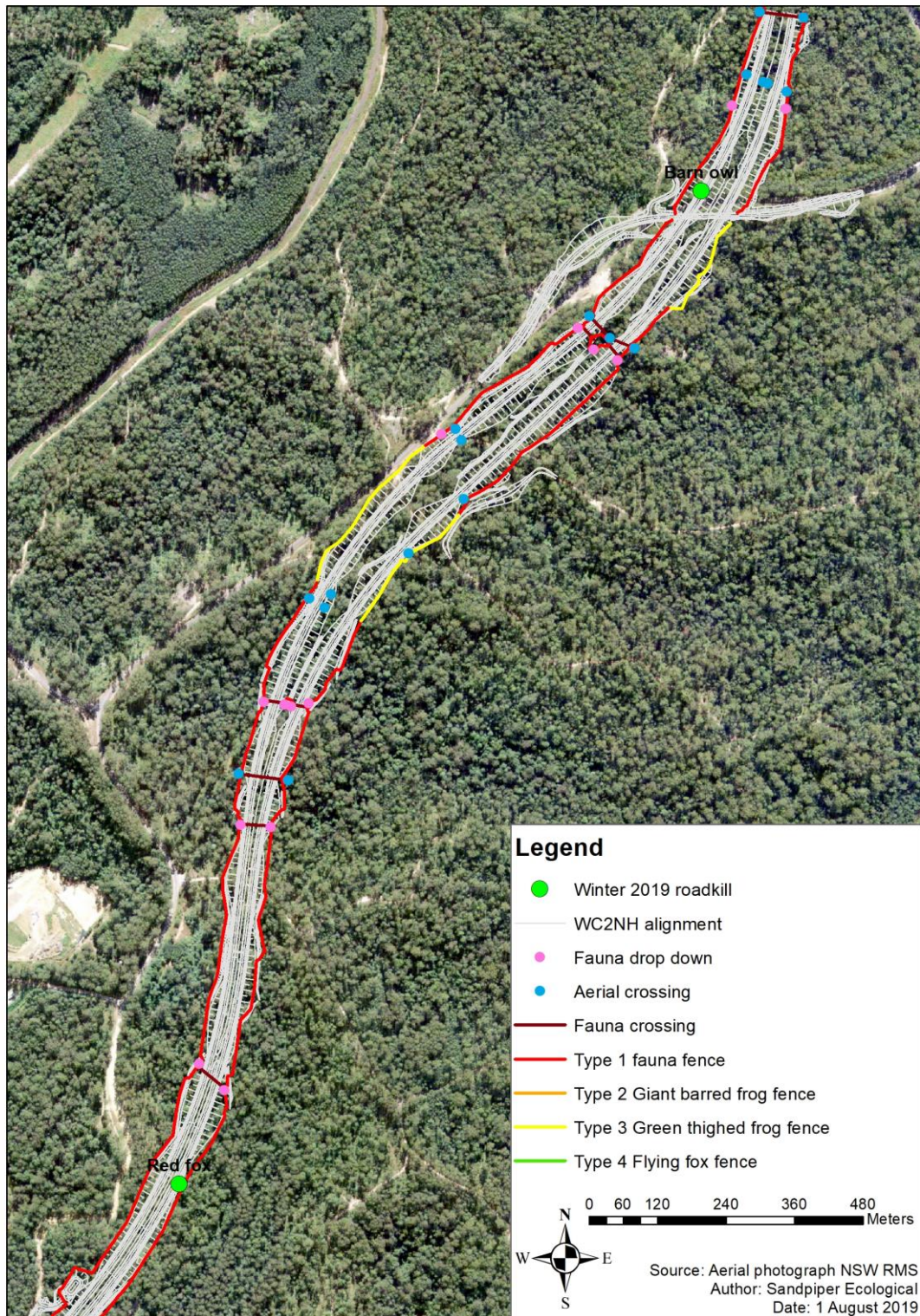


Figure 4: Location of road-killed fauna from July 2019 sample.

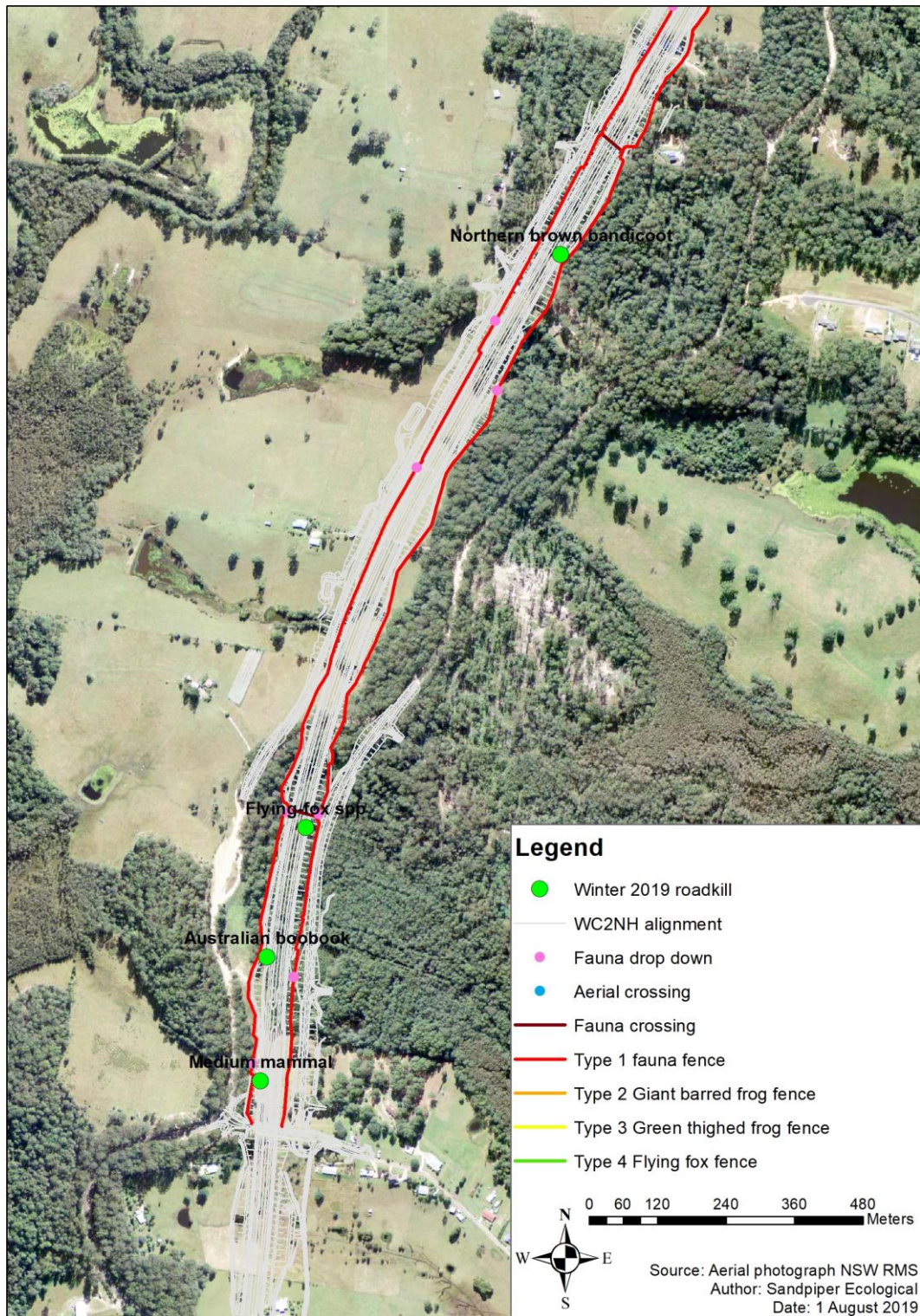


Figure 5: Location of road-killed fauna from July 2019 sample.

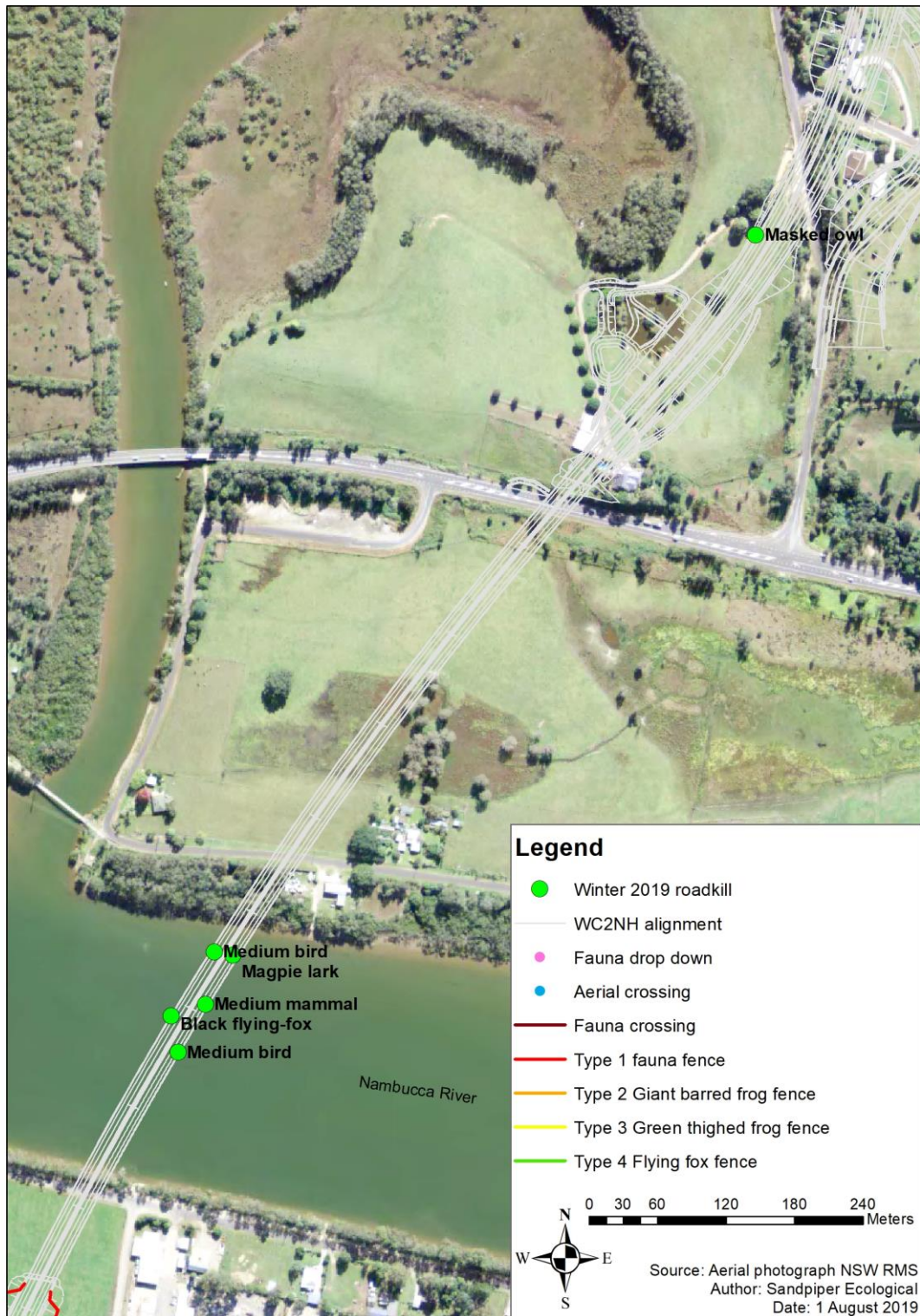


Figure 6: Location of road-killed fauna from July 2019 sample.

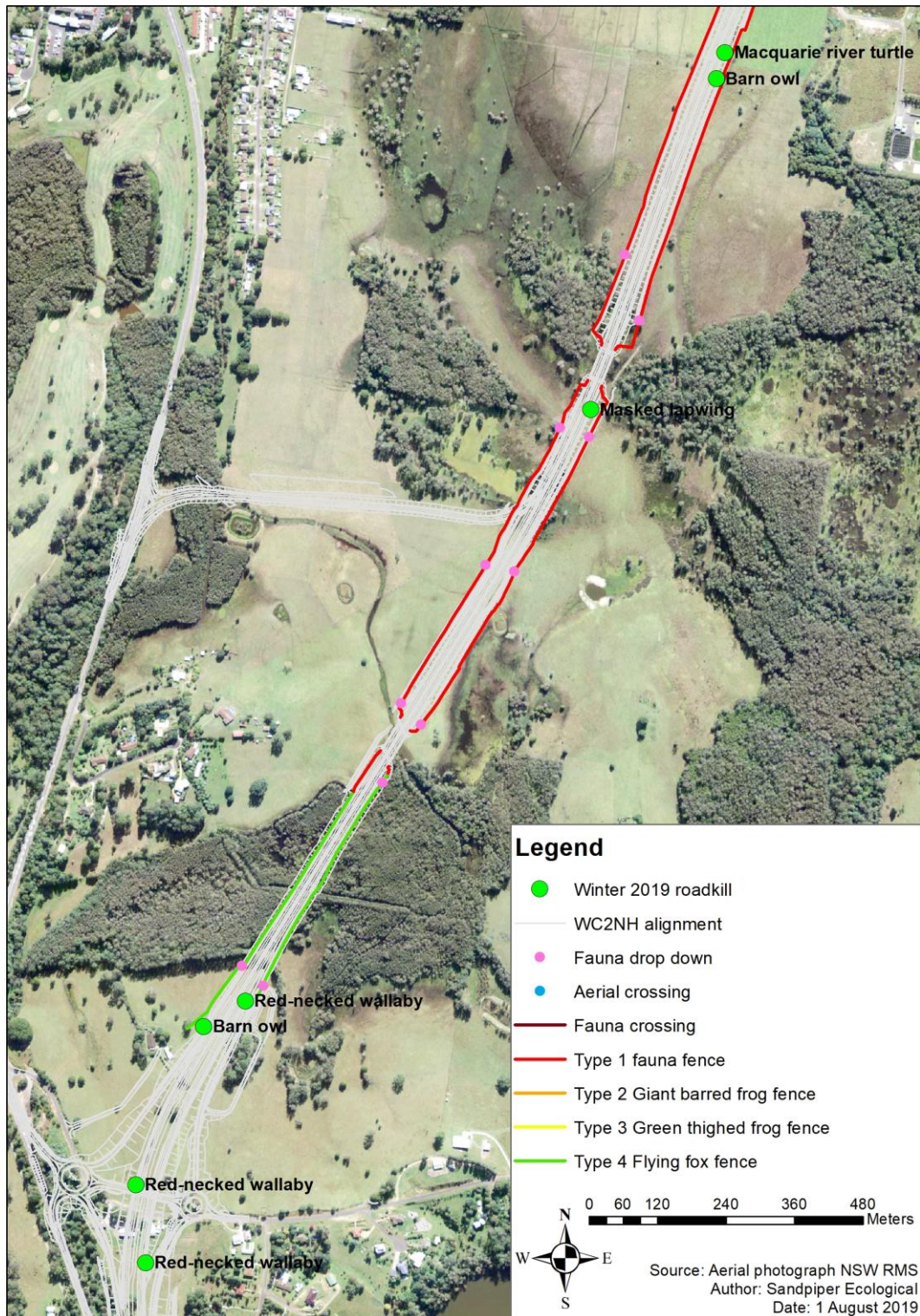


Figure 7: Location of road-killed fauna from July 2019.

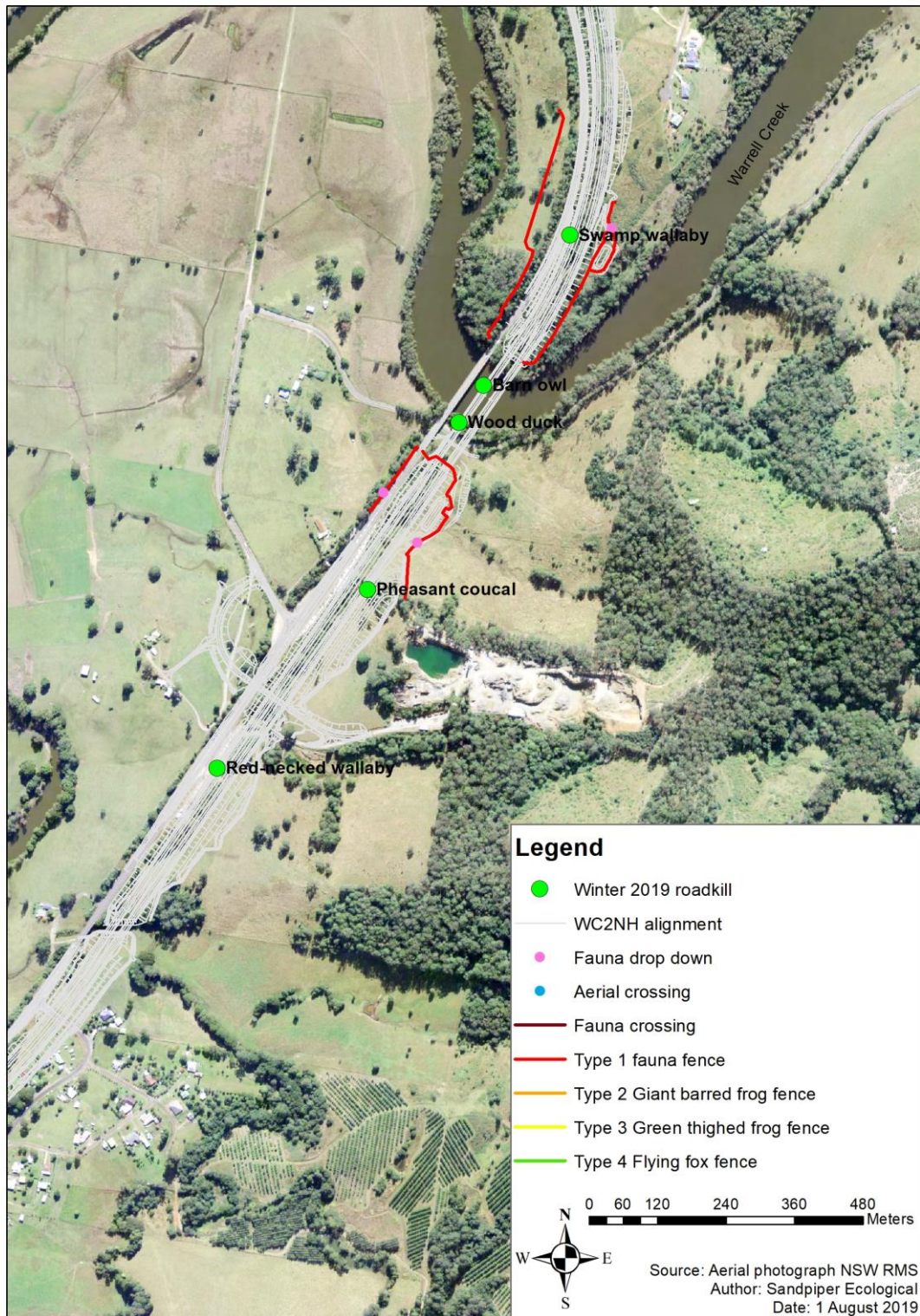


Figure 8: Location of road-killed fauna from July 2019.

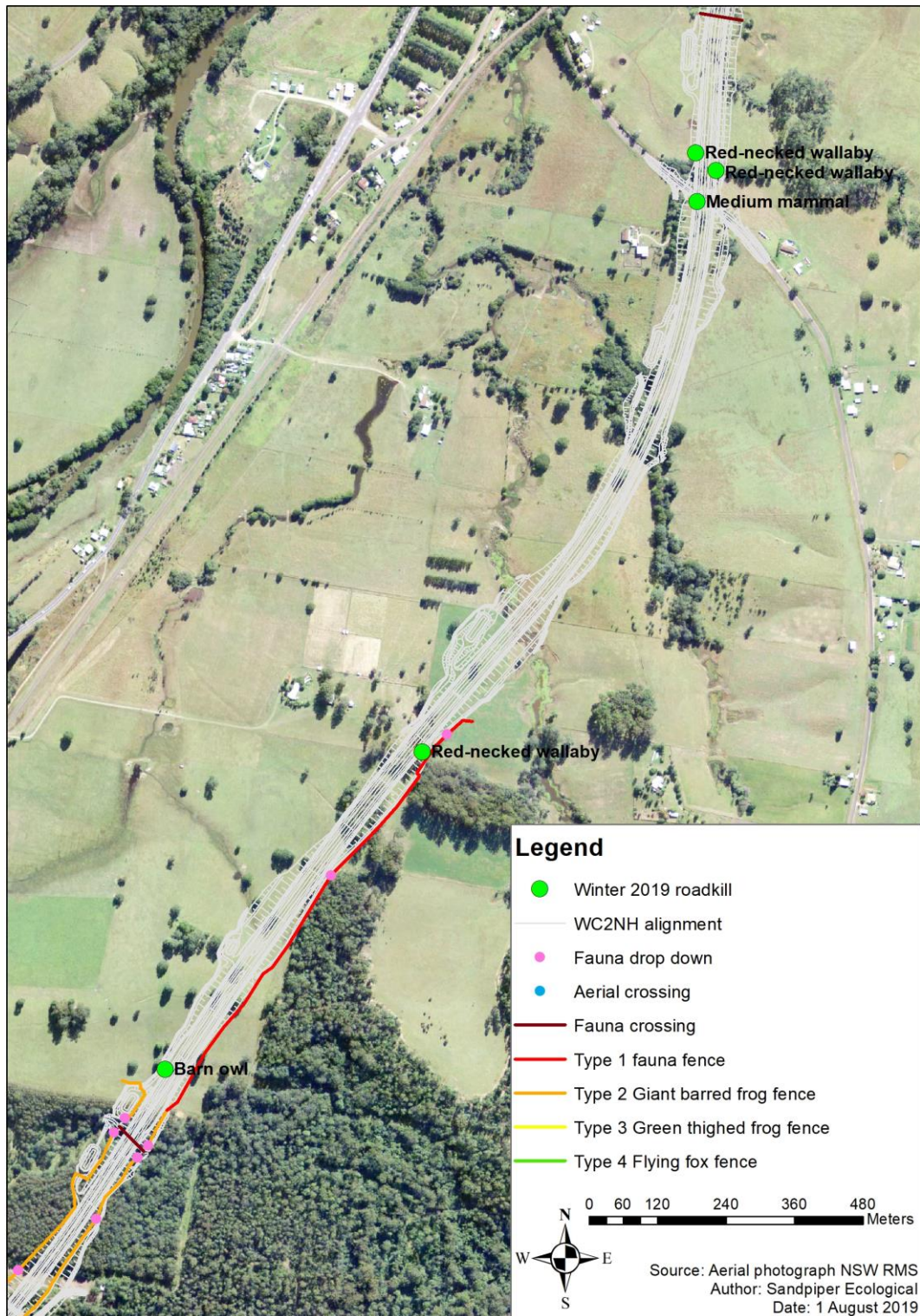


Figure 9: Location of road-killed fauna from July 2019 sample.

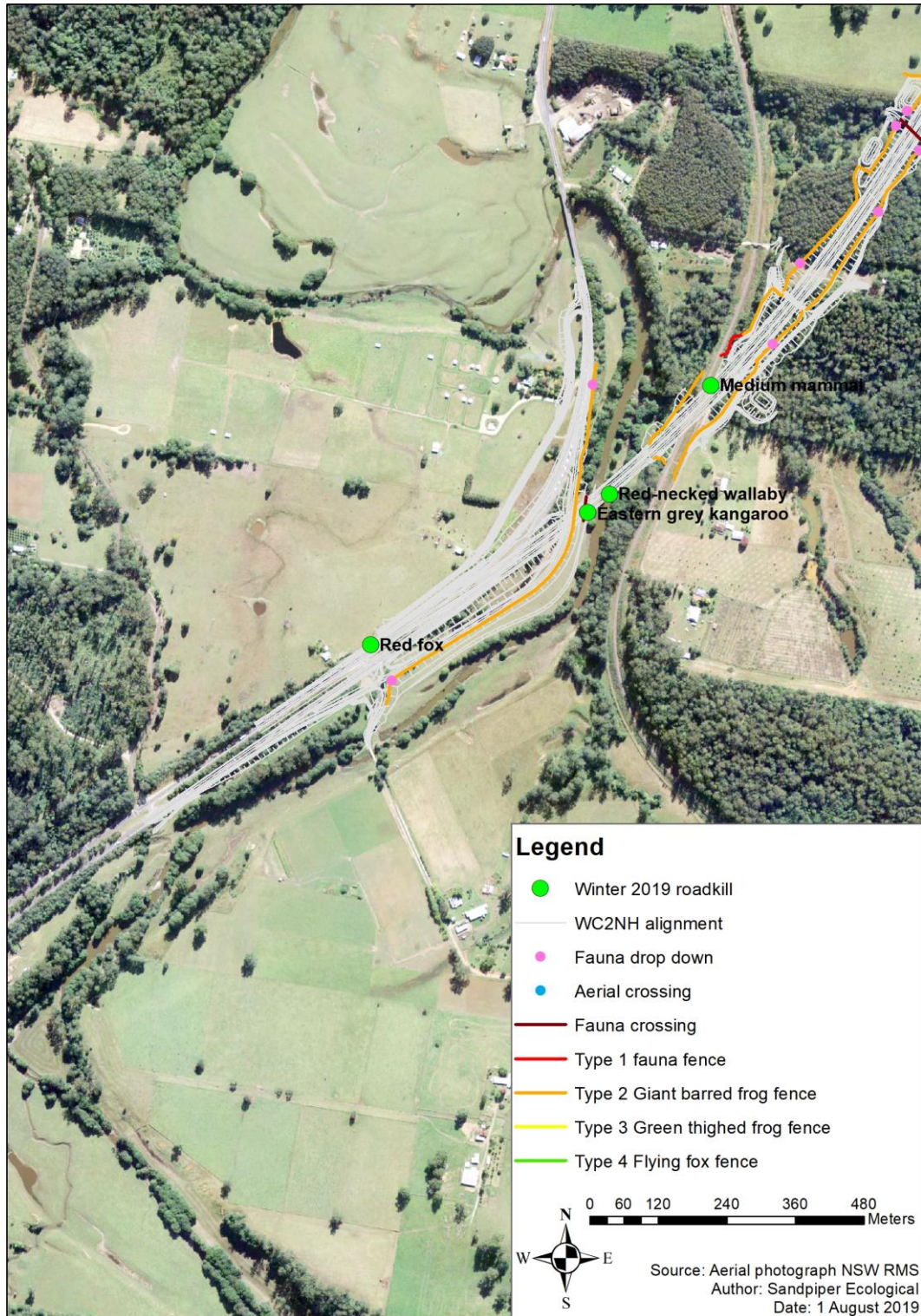


Figure 10: Location of road-killed fauna from July 2019 sample.

4. Discussion

4.1 July 2019

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

The higher number of road-kills recorded in the first week of all samples reflects the period over which kills could accumulate. This trend is likely to occur in all seasonal sample periods and it means that the number of road-kills recorded during a month overestimates the actual number of animals killed in that month.

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

4.2 Seasonal variation and species composition

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

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

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

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

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

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

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

4.3 Flying-fox impacts

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

5. Recommendations

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

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Appendix A – Field Survey Data

Table A1: July (Winter) 2019 roadkill results.

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

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

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

Appendix 10 Road Kill Monitoring Report – Spring (October) 2019 monitoring (Annual report 2019)

Appendix 10 2019 Annual Report inc. Spring (October)
2019 Monitoring Report.

Pacific Highway Upgrade: Warrell Creek to Nambucca Heads

Operational phase roadkill monitoring – annual report 2019



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Final Report
26 November 2019

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Cover Photo: Road-killed black bittern.

Disclaimer:

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1. Introduction

1.1 Background

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

The upgrade included a number of roadkill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate roadkill included:

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

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

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

Sandpiper Ecological Surveys (SES) has been contracted by RMS to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal roadkill surveys over the entire upgrade length.

Monitoring of road kill is a requirement of the approved WC2NH koala, spotted-tailed quoll and grey-headed flying-fox management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for roadkill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog (*Mixophyes iteratus*). Monitoring is required for the first five years of operation, and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Seasonal surveys are scheduled for October, January, April, and July. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced monitoring in October 2018. Previous roadkill monitoring was conducted by Geolink (2018a, b, c, d).

The aim of monitoring is to:

- report on any vertebrate roadkill following opening to traffic; and
- assess the effectiveness of the presence of fauna fencing to prevent fauna being killed by vehicles while attempting to cross the WC2NH Upgrade.

The following report details the methods used to monitor road kill in 2019 and compares roadkill data from fenced versus unfenced sections of the alignment.

1.2 Study area

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

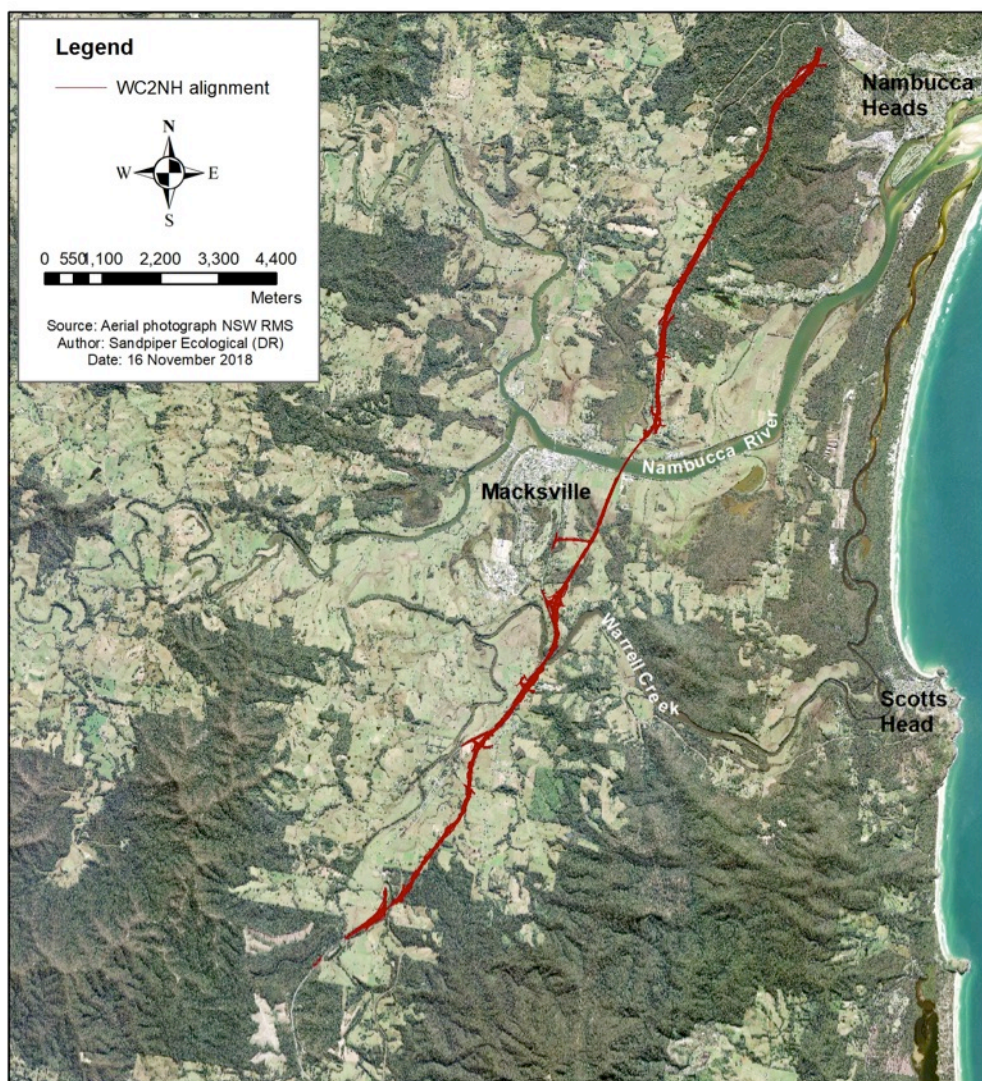


Figure 1: Location of the WC2NH alignment.

2. Methodology

2.1 Roadkill surveys

Road kill surveys were conducted over four, four-week sample periods in summer (January), autumn (April), winter (July) and spring (October). A two-person team consisting of an ecologist and driver conducted each survey from a vehicle driven at 80km/hr in the left lane. At least one team member was used consistently throughout each four-week sample period to minimise the likelihood of recording duplicate road kills. The vehicle was equipped with an amber (flashing) light and warning sign. All surveys commenced within three hours of sunrise, with an interval of 6-7 days between samples. During each survey, both the driver and ecologist scanned the road surface and road shoulder for fauna. When road-killed fauna were detected the vehicle was pulled onto the shoulder/parking bay and the ecologist inspected the subject animal from the closest position behind wire rope and perpendicular to the specimen. Fauna that could not be identified immediately were photographed and images sent to colleagues for assessment. Carcasses were removed from the road surface when safe to do so.

Data collected on each roadkill included (Appendix A1):

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

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act (EPBC) 1999* and/or the *Biodiversity Conservation Act (BC) 2016*, included, where possible: sex and age (juvenile/adult); presence of pouch young if applicable; presence of flightless young (flying-foxes); distance to a fauna connectivity structure (determined from GIS); distance to a drop-down structure if applicable (determined from GIS); damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

All road-kills were cross-referenced with the preceding weeks results to identify duplicate records. Distance to connectivity structure, and distance to escape structure was determined via GIS. All other data were uploaded to an iPad in the field.

2.2 Data summary and analysis

Data were uploaded to Microsoft excel and compared with results from the previous sample period to identify duplicate records. Three records obtained during the first October 2019 sample were deemed as duplicates and subsequently removed from the dataset. These included: a macropod spp., a red fox and a medium mammal. Graphs have been produced showing the total number of road kills in October 2019 and the number of road kills in different fauna groups each week of the October 2019 survey. The location of road kills has been overlaid on the WC2NH alignment to show their distribution. The October 2019 data are compared to the number of road-kills recorded in summer, autumn, winter and spring 2018, and summer, autumn, and winter 2019 (Sandpiper Ecological 2018; Sandpiper Ecological 2019).

2.2.1 Statistical analysis

The primary aim of statistical analysis is to determine if there is a statistical difference in the frequency of road kills between fenced and unfenced sections of the alignment. A secondary aim is to determine if the frequency of road kill varies through time in fenced and unfenced sections of the alignment.

Roadkill data were summarised by removing species/groups that would not (under normal circumstances) be stopped by exclusion fence from accessing the road alignment e.g. birds, small reptiles, frogs, small mammals. Species/groups of fauna likely to be stopped by exclusion fence and therefore included in the analysis are listed in Table 1. Introduced species were included in the analysis. Freshwater turtles were included as exclusion fence with a ground return should stop this group. Small lace monitors could move through exclusion fence, however, individuals of that size are rarely recorded in open habitats and that species has been included.

The location of each roadkill in relation to exclusion fence was determined by overlaying road kill records on a plan of exclusion fence extent using ArcGIS. If exclusion fence occurred on one side only the record was classified as “No fence”. Sections of the alignment with a single fence may be included as a separate category in future analysis as sample size increases.

Table 1: Fauna groups included in comparison of fenced and unfenced sections of alignment.

Group	Species included
Macropods	Red-necked wallaby, swamp wallaby & eastern grey kangaroo
Bandicoots	Long-nosed & northern brown bandicoots
Possum	Brushtail & ringtail possums
Canid	Fox & dog
Feline	Cat
Leporidae	Hare & rabbits
Freshwater turtles	Long-necked, saw-shelled and Macleay river turtles
Goanna	Lace monitor

Data were pooled across all samples and divided into “fenced” and “unfenced”. Expected proportions were based on the proportion of highway with fence on both sides (“fenced”) and proportion with a single fence, or no fence (“no fence”). The proportion of fenced verses unfenced was 0.55 to 0.45. Data were analysed using a two-tailed G-test as per the equation of McDonald (2013), and a Kruskal-Wallis test in Systat 13.

3. Results

3.1 October 2019 sample

3.1.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses on the road surface (Table 2). Light rain occurred on 1 October prior to the first sample.

Table 2: Weather conditions in the 24hrs preceding each sample event. Data obtained from BoM South West Rocks weather station.

Date	Average Relative Humidity (%)	Total Rainfall (mm)	Max Temperature (°C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
1/10/19	71	13	22.7	7	Good	Nil
8/10/19	99	0	24.3	2	Good	Nil
15/10/19	82	0	NR	15	Good	Nil
21/10/19	68	0	24.8	4	Good	Nil

3.1.2 Species richness and abundance

Fifty-three road killed fauna were recorded during the October 2019 sample period. This included 17 native species, and seven fauna groups (Table 3; Table A1, Appendix A). Birds were the most diverse group represented with 10 species and two groups recorded. Five species of mammal and two species of reptile were recorded (Table 3). No frogs or introduced species were recorded.

Grey-headed flying-fox (*Pteropus poliocephalus*) was the most frequently recorded species with five records, followed by tawny frogmouth (*Podargus strigoides*) with four records (Appendix A) and red-necked wallaby (*Macropus rufogriseus*), Laughing kookaburra (*Dacelo novaeguineae*), and galah (*Eolophus roseicapilla*) with three records each. Collectively, six road-killed bandicoots were recorded, two northern brown bandicoot (*Isodooon macrourus*) and four unidentified individuals. Medium and large mammals accounted for an additional six records (Table 3).

Grey-headed flying-fox was the only target species recorded in October 2019. That species is listed as vulnerable under the *Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and state *Biodiversity Conservation (BC) Act 2016*.

Of the 53 road-kill records 19 (or 36%) were individuals expected to be blocked by exclusion fence. The remaining 34 records included birds and snakes that readily move through or over exclusion fence.

Table 3: Species of vertebrate fauna recorded during seasonal road kill surveys throughout the operational phase of the WC2NH upgrade. * denotes threatened species; ** = stage 2a only.

Species	Sum 17/18**	Aut 2018**	Win 2018**	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Total
Birds									
Australian magpie	6	1		1				2	10
Grey butcherbird			1						1
Magpie-lark	2		1		1		1		5
Australian white ibis			1						1
Cattle egret				1					1
Little pied cormorant					1				1
Buff-banded rail					1				1
Purple swampphen	3		2	2		1		2	10
Crested pigeon	2								2

Species	Sum 17/18**	Aut 2018**	Win 2018**	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Total
Galah	7				1			3	11
Rainbow lorikeet								1	1
Eastern grass owl*				1					1
Australian boobook			1	1			1		3
Masked owl*	1				1		1		3
Eastern barn owl			11	3		1	5	2	22
Tawny frogmouth	1	3	1	2		6		4	17
Australian owl-nightjar					1				1
Laughing kookaburra	3		2	1		2		3	11
Forest kingfisher	1								1
Australian wood duck	20			2	2		1	2	27
Pacific black duck	2		1						3
Whistling kite				1					1
Black-shouldered kite					1	1			2
Torresian crow					1				1
Pied currawong				1					1
Black-faced cuckoo-shrike								1	1
Dollarbird					2				1
Green catbird					1				1
Black bittern*						1			1
Eastern yellow robin						1			1
Pheasant coucal							1		1
Masked lapwing							1		1
Welcome swallow								1	1
Duck spp.						1			1
Small bird								2	2
Medium bird				1	2	2	2	2	9
Unidentifiable bird	5	4	1		3				13
Mammals									
Short-beaked echidna				3				2	5
Black flying-fox	2	1			6	1	1		11
Grey-headed flying-fox*					8			5	13
<i>Pteropus</i> spp.					3	8	1		12
Common brushtail possum			1	2					3
Common ringtail possum					1			1	2
Eastern grey kangaroo				3			1		4
Red-necked wallaby	1		6		8	2	8	3	28
Swamp wallaby	2	1		1		1	1		6
Wallaby spp.						2			2
Macropod spp.	3		2	1	1				7

Species	Sum 17/18**	Aut 2018**	Win 2018**	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Total
Northern brown bandicoot	1		1		1	1	1	2	7
Bandicoot spp.						1		4	5
<i>Chalinolobus</i> spp. (microbat)				1					1
Microbat spp.					1				1
Rodent spp.						2			2
Small mammal					2				2
Medium mammal				2	4	2	4	5	17
Large mammal				1	1			1	3
Unidentified Mammal	1			3					4
Reptiles									
Common blue-tongued skink	1			2	1				4
Carpet python	1			2	1	1		1	6
Common tree snake	1	2						1	4
Eastern long-neck turtle	1			6					7
Macquarie river turtle	5	1					1		7
Unidentified <i>Chelidae</i> spp.	6							1	7
Red-bellied black snake	1								1
Eastern water dragon	1			1					2
Blackish blind snake						1			1
Yellow-faced whipsnake				1					1
Unidentified reptile								2	2
Frogs									
Green tree frog	2								2
Striped marsh frog	3								3
Medium frog				3					3
Large frog				1					1
Introduced species									
Cat	1								1
European fox	3	1	1	2	1	1	2		11
European hare	2			1					3
Rabbit	1								1
Black rat	1					1			2
House mouse					1				1
Rock pigeon			1	1					2
Domestic goose				1					1
Total	93	14	34	55	57	40	33	53	379

The number of road kill recorded each week varied during the sample period. A trend of decreasing roadkill abundance was recorded over the first three sample weeks but roadkill abundance increased sharply in week four (Figure 2). Twenty-five road killed fauna were recorded in week one and 12 were recorded in week four. Week one is not representative of the number of individuals killed in the preceding week as it includes the period between the July and October sample periods.

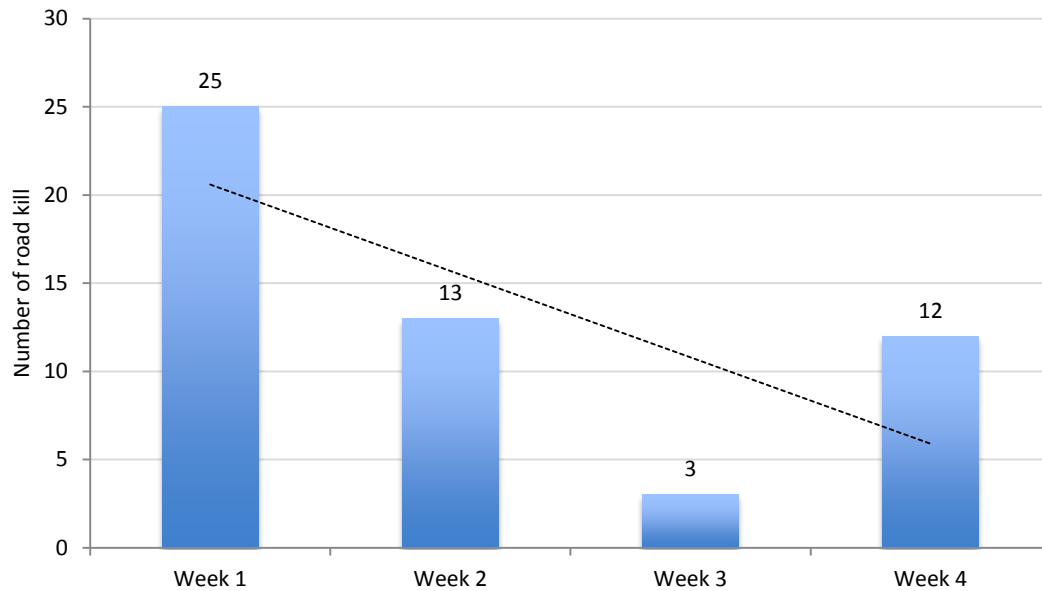


Figure 2: Number of road kills recorded in each sample week during the October 2019 (spring) sample period.

The abundance of road-killed fauna in the four vertebrate groups varied over the sample period (Figure 3). The number of road-killed mammals ranged from 15 in week one to none in week three and eight in week four. The number of road-killed birds was consistent in weeks one, two and four but decreased substantially in week three. Two reptiles were recorded in each of weeks one and two, with one recorded in week three and none in week four (Figure 3).

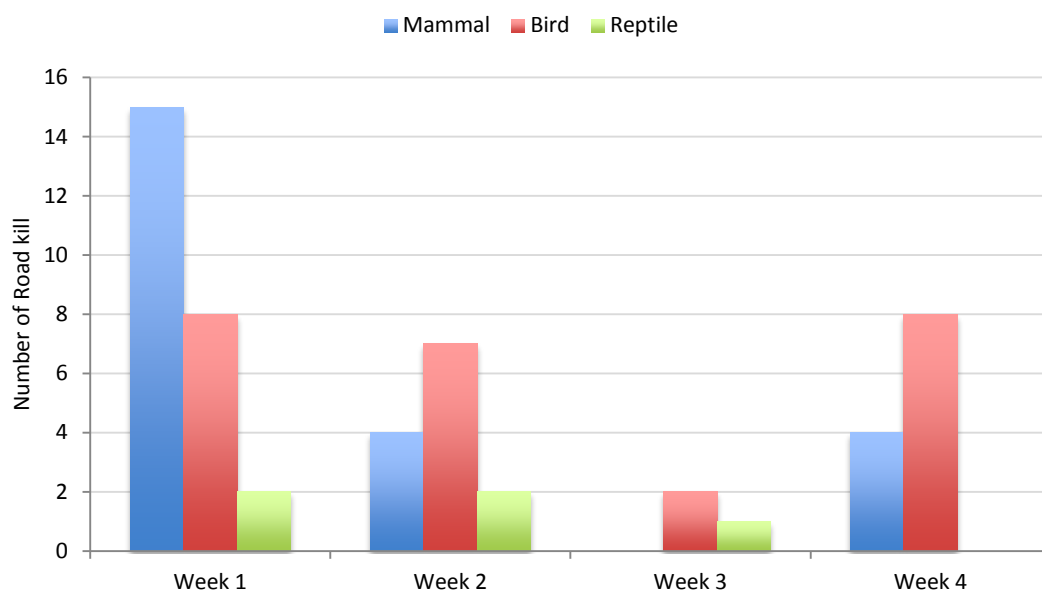


Figure 3: Number of road-killed fauna from four vertebrate classes during each sample week in October 2019.

3.1.3 Opportunistic road-kill information

No opportunistic roadkill records were obtained during the October 2019 sample period.

3.1.4 Distribution of road-kill

In October 2019 road-killed fauna was recorded over the entire WC2NH alignment (Figure 4-9), although the majority of records (83%) occurred south of Mattick Road. Of the nine road-kills recorded north of Mattick Road 66% were birds. Despite the broad distribution of road-kill a distinct cluster was evident between the Nambucca River and Mattick Road (13 individuals; 6.2 ind/km). Eight of the 13 individuals (or 62%) recorded in that area were birds. A comparable density of road-kill was recorded in vicinity of Rosewood Road.

In October 2019, 20 road-kills were recorded in areas with exclusion fence, and 33 were recorded in areas without exclusion fence (Figures 4-9). Road-kills in areas with exclusion fence on one side of the carriageway were classed as fence absent. Six records (or 30%) in sections with fence were species that should have been blocked by the fence (i.e. medium and large mammals & reptiles). In contrast, 39% of road-kills in sections without fence were of species that should be blocked by a fence.

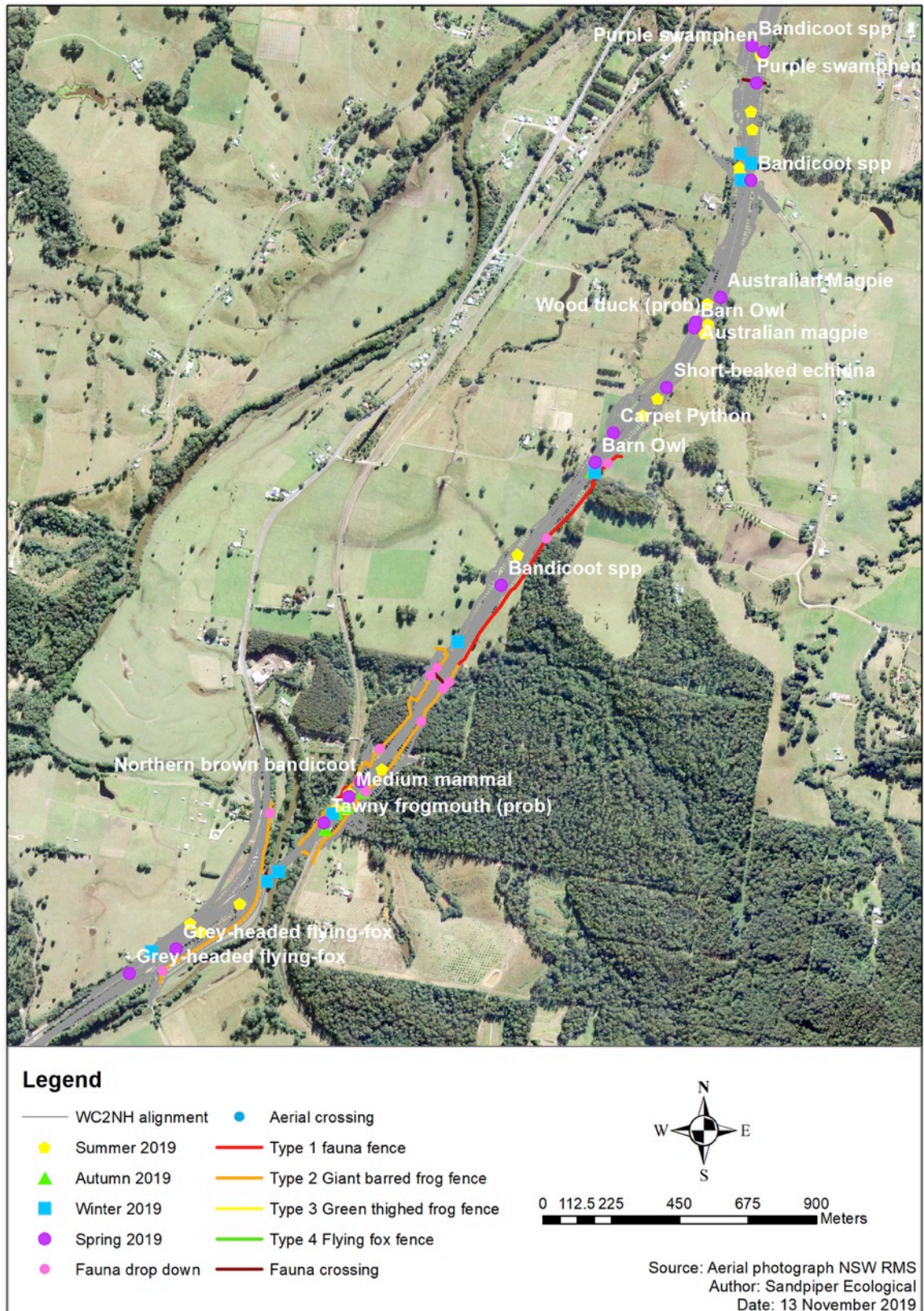


Figure 4: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

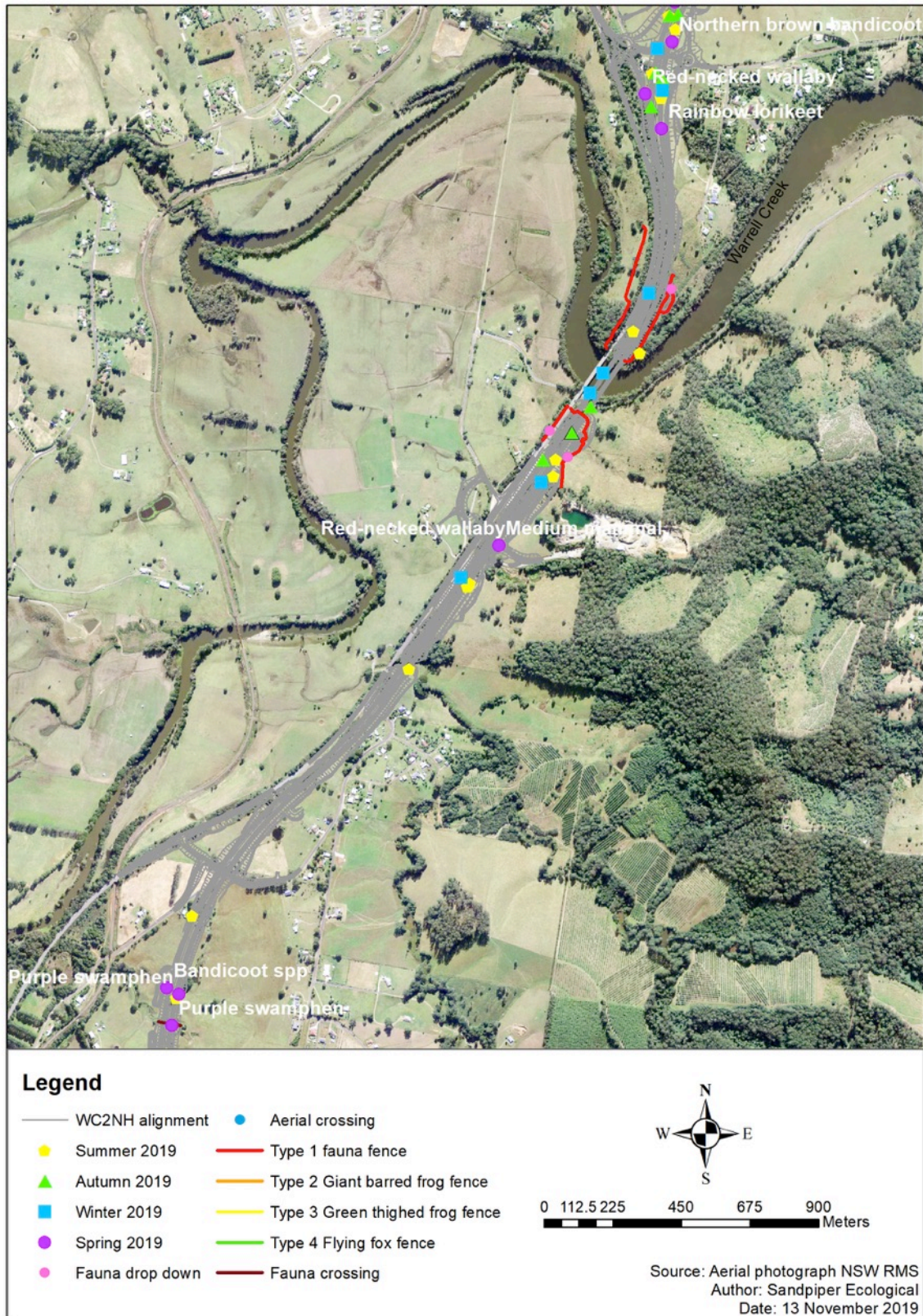


Figure 5: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

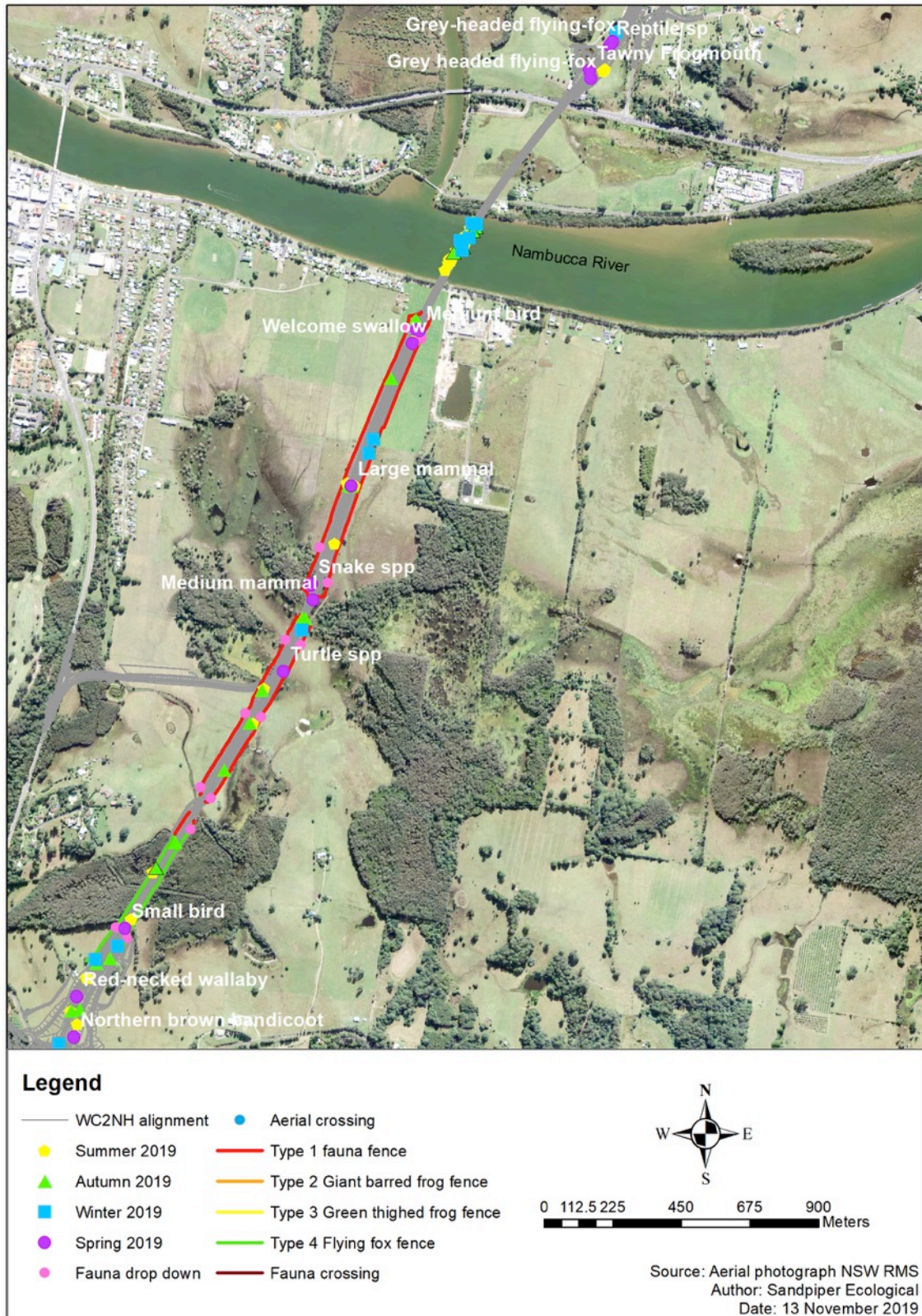


Figure 6: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

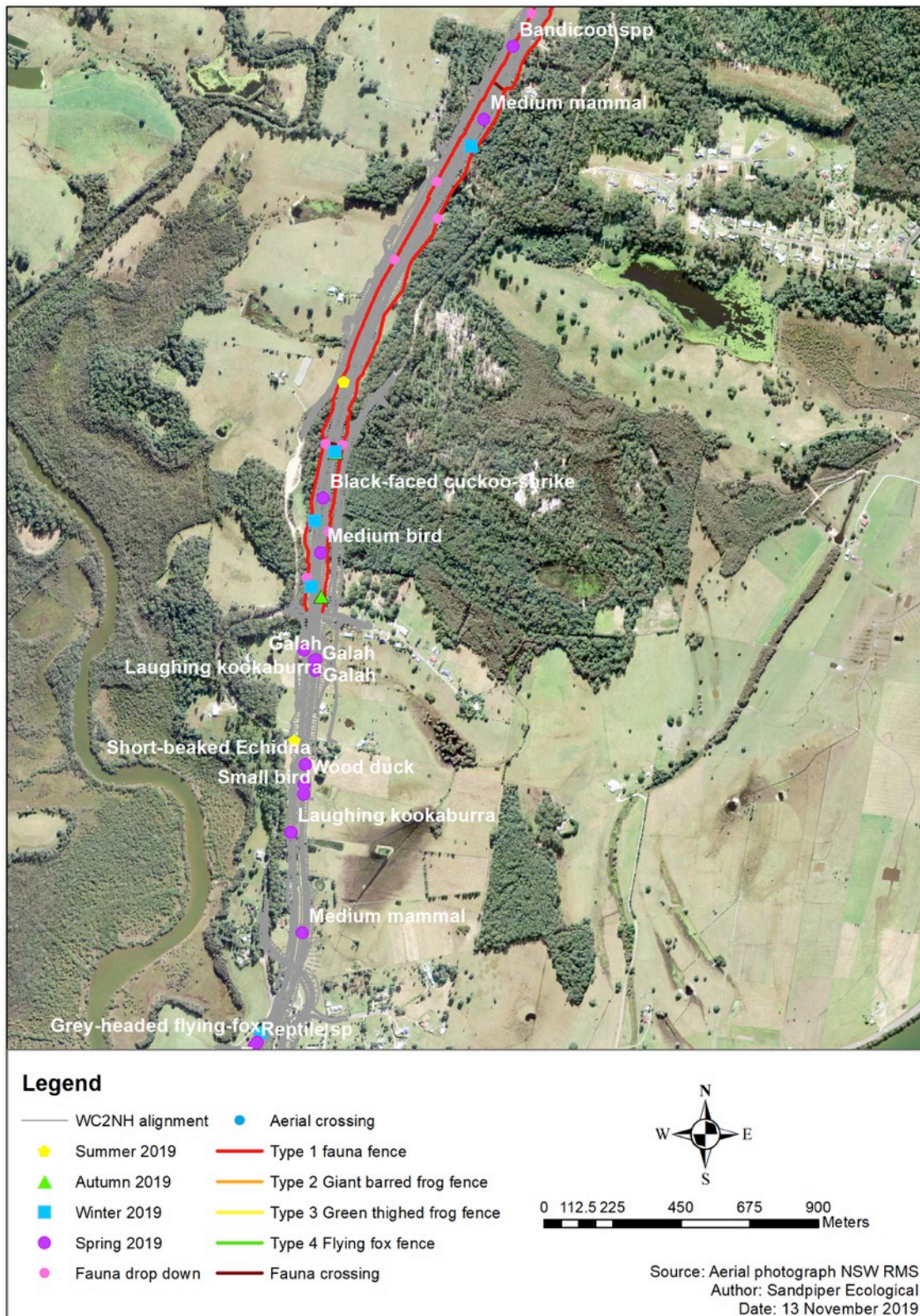


Figure 7: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

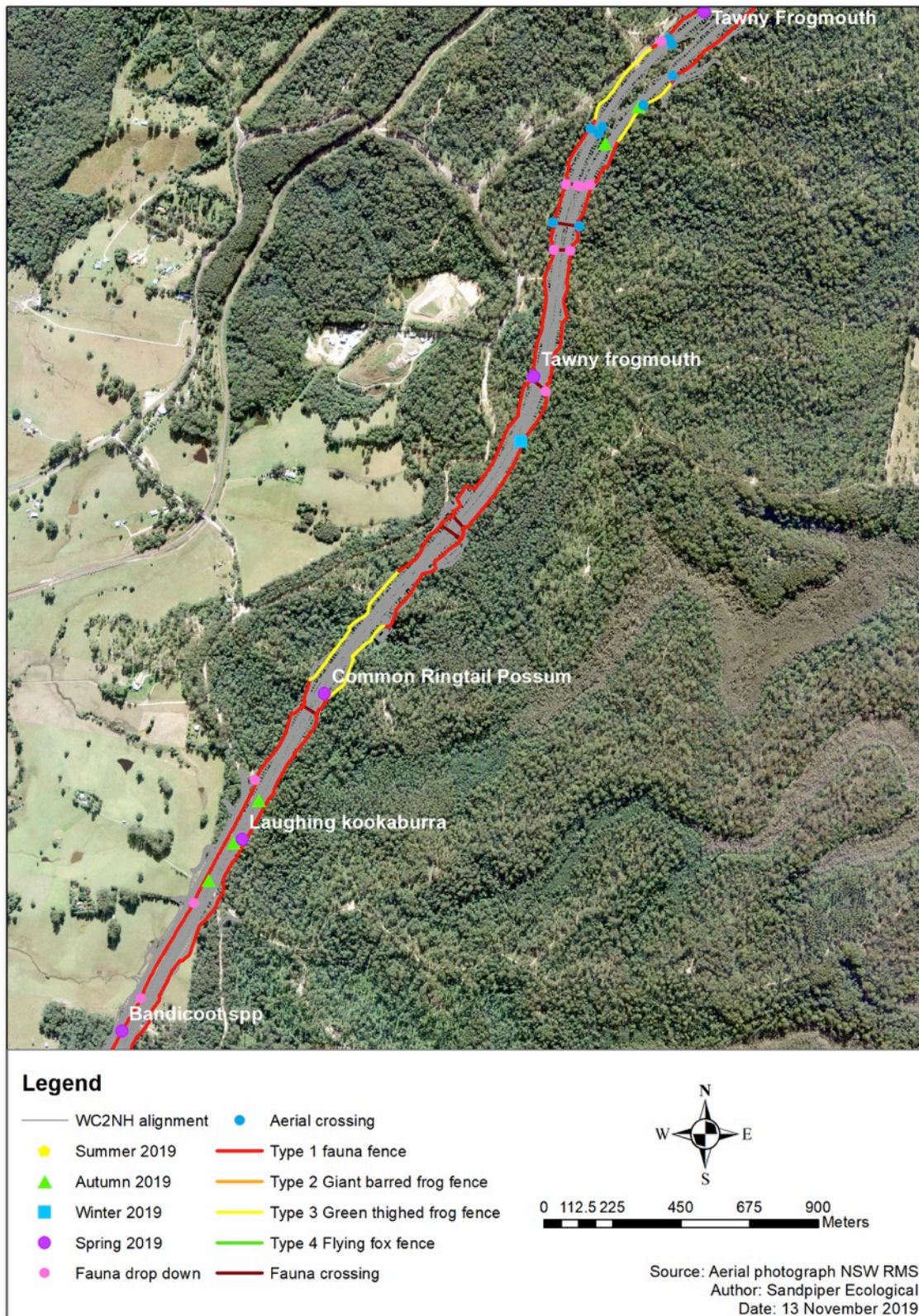


Figure 8: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

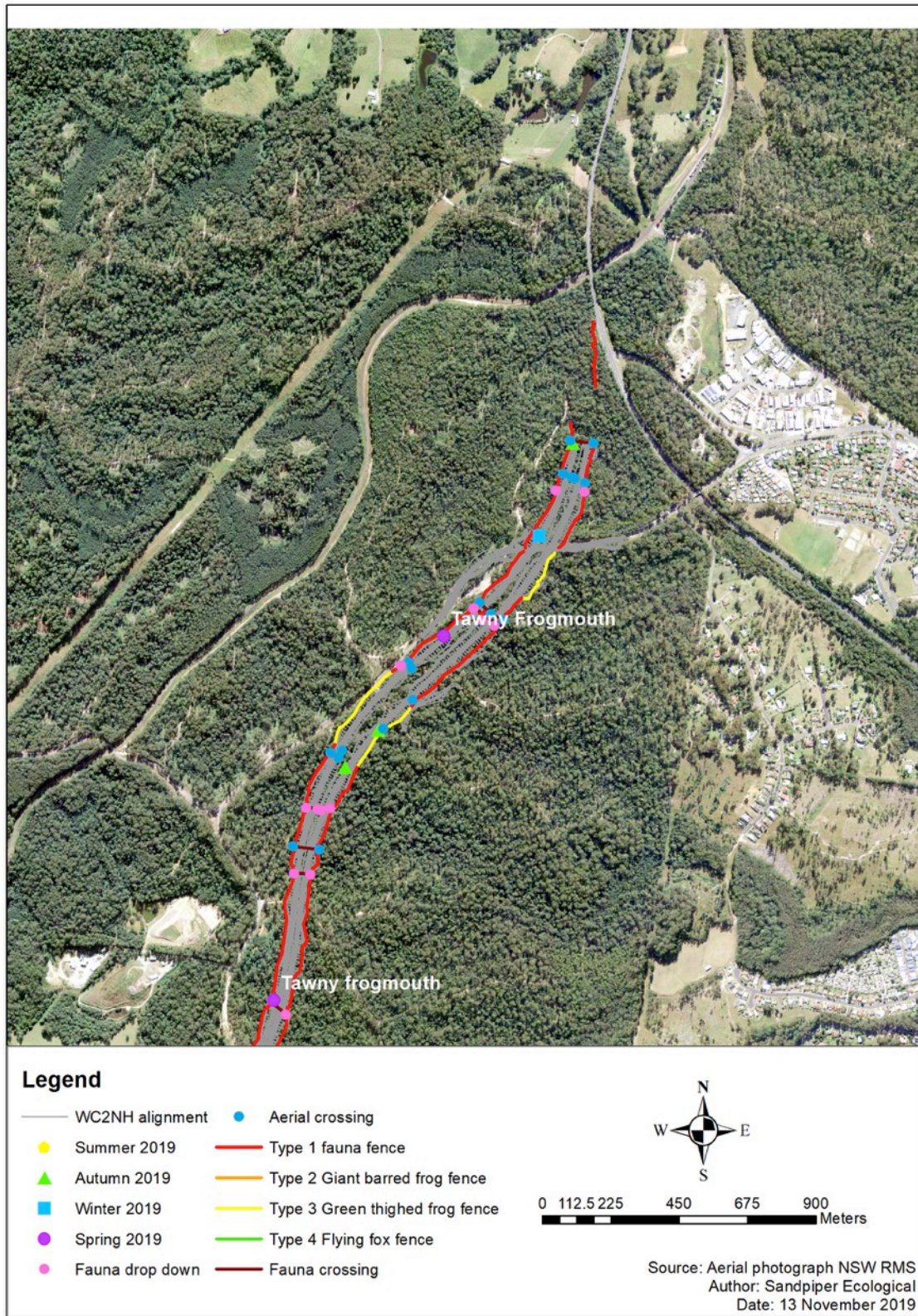


Figure 9: Location of road-killed fauna recorded in 2019. Note: only October 2019 records are labeled.

3.2 Annual results 2018

3.2.1 Statistical analysis

The G-test was run on two sets of data, all species (from Table 1), and all species excluding introduced species (Table 4). A statistically significant difference in the number of roadkill between fenced and unfenced areas was recorded for both data sets (Table 4). The number of road-kills was significantly higher in unfenced sections of the alignment. The Kruskal-Wallis test did not record a statistically significant difference between fenced and unfenced sections of the alignment ($n=16$, $df=1$, $P=0.132$).

Table 4: Results of G-test on road-kills in fenced and unfenced sections of the alignment.

Group	Category	No. road-kill	Expected proportion	Expected N°.	Df	G statistic	P (2-tail)
All species	Fence	21	0.55	35.2	1	12.77	0.0003
	No fence	43	0.45	28.8			
No introduced	Fence	19	0.55	33	1	13.28	0.0002
	No fence	41	0.45	27			

3.2.2 Species richness and abundance

A total of 40 species were recorded during road-kill surveys in 2019 (Table 3). This was comprised of 37 native species and three introduced species. Three threatened species were recorded in 2019, including two masked owl, one black bittern, and 13 grey-headed flying fox. The two former species are listed as vulnerable under the BC Act (2016). In addition to the 13 confirmed grey-headed flying-fox 12 individuals were identified to Genus only. Most of these occurred on the Nambucca River bridge where they could not be inspected.

The highest species richness of road-kill was recorded in summer (20 species; 8 groups), followed by spring (17 species; 7 groups), autumn (15 species; 7 groups) and winter (14 species; 3 groups). The most commonly recorded species were red-necked wallaby (21 records), grey-headed flying-fox (13 records), Pteropus spp. (12 records), tawny frogmouth (10 records), eastern barn owl (8 records), and black flying-fox (8 records) (Table 3). There were a further 15 records of medium mammal, which could have been bandicoots or wallaby remains.

A total of 183 individuals were recorded across the 16 road-kill samples (Table 3). Native mammals were the most commonly recorded group with 96 records, followed by birds (72 records), reptiles (10 records) and introduced mammals (6 records). Road-kill abundance has fluctuated between sample weeks (Figure 10). The number of road-kill typically peaks in the first sample week/season (i.e. weeks 1, 5, 9 and 13 in Figure 10) as that sample includes road-kills over a longer period than one week. A more accurate indication of road-kills/week is provided by weeks 2, 3 and 4 in each sample period. The number of road-kill/km sampled was strongly correlated with the total number of road-kill recorded (Pearson correlation co-efficient 0.99). The trendline suggests a slight temporal decrease in number of road-kill over the sample period (Figure 10).

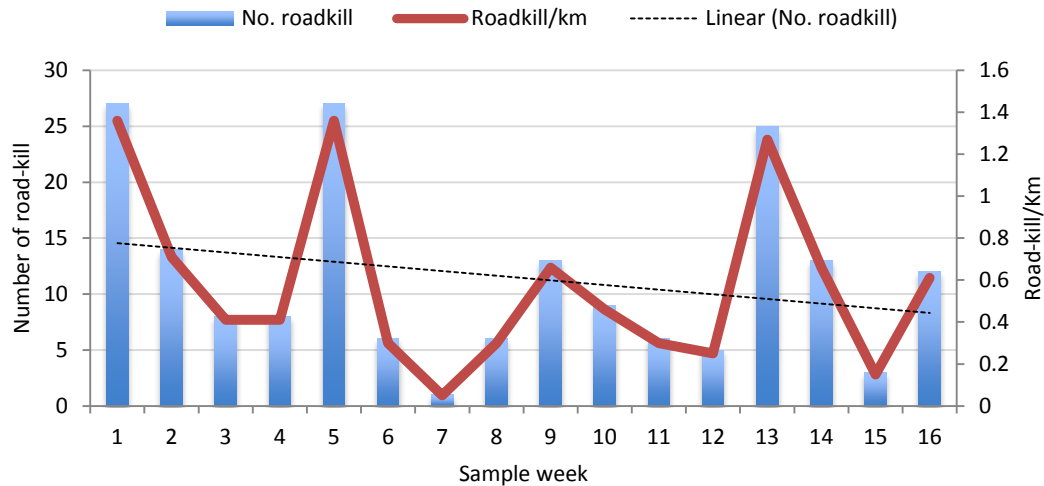


Figure 10: Number of road-kill recorded each week expressed as a total (Left axis) and number/km sampled (right axis).

The mean number of road-kills in each sample period shows a trend of decreasing numbers in autumn and winter and peaks in spring and summer (Figure 11). The large standard deviations reflect variations in road-kill number between weeks and the higher number recorded in the first week of each sample period.

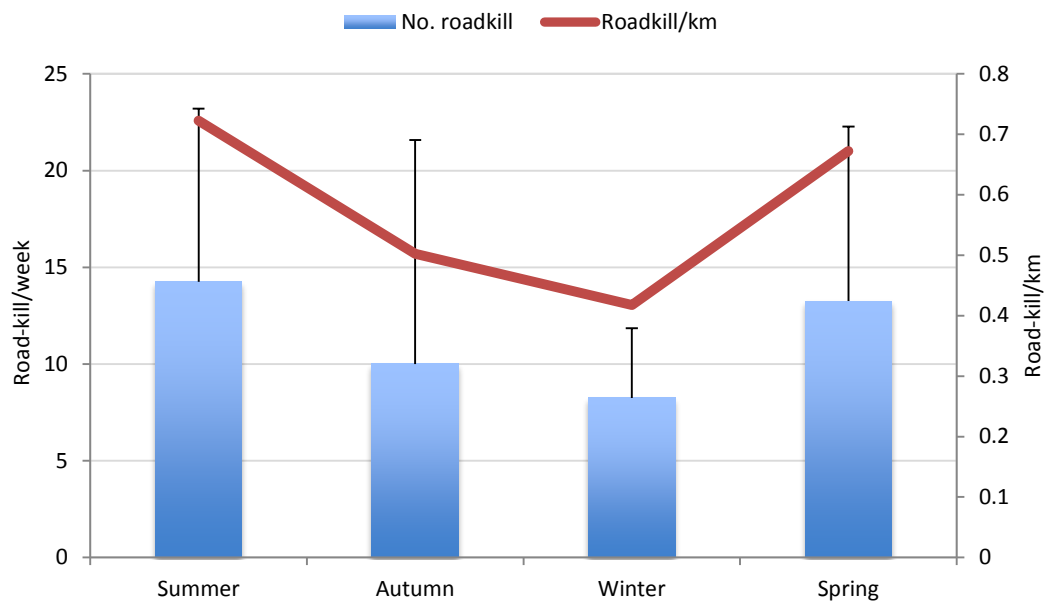


Figure 11: Mean number of road-kills/sample (+SD) and mean number/km/sample in 2019.

Comparison of road-kill numbers between 2018 and 2019 show that despite a similar overall total value the contribution of different fauna groups has varied substantially between years (Table 5). Substantially fewer birds, reptiles, amphibians and introduced species were recorded in 2019. In contrast, the number of mammals increased substantially from 39 in 2018 to 96 in 2019. This increase was due mainly to higher numbers of flying-foxes and macropods in 2019. Differences in survey method and site coverage, due to project staging, between 2018 and 2019 compromise direct comparisons, however, the scale of difference suggests that it is not due solely to survey effort. The

decrease in birds in 2019 is largely due to fewer Australian magpie, eastern barn owl, Australian wood duck, and galah, with numbers of these species decreasing from 51 in 2018 to 19 in 2019 (Table 3).

Table 5: Comparison of road-kill numbers between 2018 and 2019 sample periods.

Year	Total	Birds	Mammals	Reptiles	Amphibians	Introduced
2018	196	102	39	32	7	16
2019	183	72	96	10	0	6

3.2.3 Distribution of road-kill

Road-killed fauna have been recorded over the entire study area (Figures 4-9). There were substantially fewer road-kills in areas with continuous fauna fence north of Mattick Road. Road-kill density north of Mattick Road across all samples in 2019 was 3.73ind/km, which is substantially less than the 13.2ind/km recorded on the Gumma Floodplain, 11.2ind/km between the southern extent and just north of Rosewood Road, and 76.7ind/km on the Nambucca River Bridge. Notable road-kill hotspots include:

- South end of project to Albert Drive (46 records).
- Gumma floodplain (37 records).
- Nambucca River to Mattick Road (15 records).
- Nambucca River Bridge (23 records).

3.2.4 Flying-fox road-kill

Flying-fox road-kill data were interrogated further to gain a better understanding on the scale of impact. The distribution of flying-fox records was compared against the distribution of fauna exclusion fence types (Table 6). Results show one record of a black flying-fox within the Type 4 flying-fox exclusion fence area, six records with the type one fence and one within type 2 fence. A further two grey-headed flying-fox records were obtained in areas with Type 1 and 2 fence on one side of the carriageway only.

Table 6: Number of flying-fox road-kill records in sections of highway with different types of exclusion fence.

Species	Type 1 Fauna fence	Type 2 Giant barred frog	Type 3 Green-thighed frog	Type 4 Flying-fox
Grey-headed flying-fox	2	1		
Black flying-fox	1			1
<i>Pteropus</i> spp.	3			

The average number of flying-foxes killed per week was calculated by summing the number of individuals recorded in weeks 2, 3 and 4 of each sample period and dividing by three. Data from week one of each sample period were excluded as they are not representative of a week-long sample period. The total of 33 flying-fox records in 2019 was reduced to 22 records by excluding week one data. Weekly averages correspond to total counts and show a peak of 5.33 individuals in summer, low mortality in autumn and winter, and increasing mortality in spring. The "All flying-fox" value includes black flying-fox, grey-headed flying-fox and *Pteropus* spp. At least some of the *Pteropus* spp. could be grey-headed flying-fox.

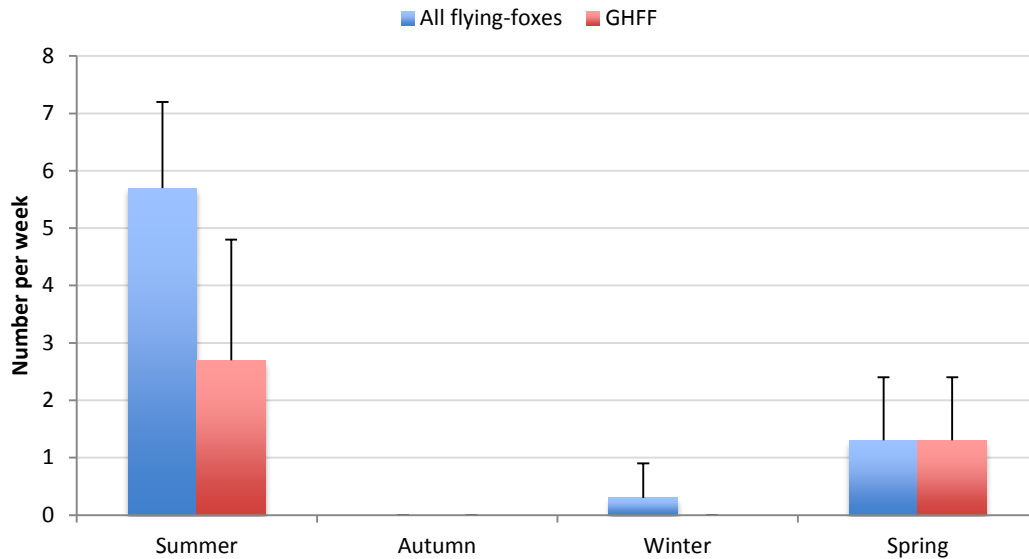


Figure 12: Average (+SD) weekly number of flying-foxes recorded during road-kill surveys on the Wc2NH upgrade in summer, autumn, winter and spring 2019. n = 3 for each season.

4. Discussion

4.1 October 2018

Road-kill monitoring over the entire WC2NH alignment in October 2019 indicates that a substantial number of fauna continue to be killed by vehicles 15 months after the entire alignment was opened to traffic. Road-kill abundance increased substantially from 33 individuals in winter to 53 individuals in spring (October). Species richness increased from 14 to 17 over the same period. As for previous samples the number of road-kill peaked in week one due to the accumulation of kills between samples. This trend is likely to occur in all seasonal sample periods and it means that the number of road-kills recorded during a month overestimates the actual number of animals killed in that month. Any calculation of road-kills/week should exclude week one of each sample period. Despite the peak in week one there was noticeable variation in abundance between weeks 2, 3 and 4. Similar variation was evident in autumn 2019 and spring 2018 (Sandpiper Ecological 2018; 2019b). Such variation may be due to subtle changes in environmental conditions that cause changes in animal behaviour and habitat use.

Monitoring identified a distinct clustering of road-kill consistent with previous samples (see Sandpiper Ecological 2019a, b, c). Areas around the Nambucca River, Gumma Floodplain, and southern extent to Rosewood Road had a high incidence of road-kill in spring 2019. Of particular note in spring 2019 was five grey-headed flying-fox, six bandicoots, five medium mammals and three red-necked wallabies. The absence of amphibians is attributed to dry conditions, which were unsuitable for dispersal.

4.2 Seasonal and temporal variation

Monitoring in 2019 confirmed the seasonal effect identified in 2018 (see Sandpiper Ecological 2018). Road-kill abundance peaked in spring and summer and decreased from autumn to winter. This trend

is likely due to seasonal changes in food availability and reproductive demands. There have been some notable increases and decreases in abundance of some species between 2018 and 2019. Notable decreases were recorded for:

- Eastern barn owl
- Australian magpie
- Australian wood duck
- Freshwater turtles
- Amphibians

These decreases are attributed to a combination of drought (eastern barn owl, amphibians, freshwater turtles), changes in habitat within the road corridor (Australian wood duck, freshwater turtles), and possibly reduced population size (Australian magpie). The substantial decrease in abundance of introduced species between 2018 and 2019 (see Table 5) is attributed to habituation to the highway, and reduced population size of some species. Introduced species are often the first group to regularly utilise underpasses (Sandpiper Ecological 2015).

Species/groups displaying notable increases in abundance in 2019 include:

- Flying-foxes
- Macropods
- Bandicoots

The abundance of road-killed flying-foxes increased from three in 2018 to 33 in 2019. Both black and grey-headed flying-foxes were identified, with 1/3rd of all individuals identified as *Pteropus* spp. Flying-fox road-kill is discussed further in Section 4.4.

Drought has likely contributed to the high incidence of macropod road-kill in 2019 when 27 individuals were recorded. At least some of the 17 medium and large mammals recorded in 2019 would also have been macropods. During droughts macropods are attracted to the road verge to forage and road-kill tends to increase (Klocker *et al.* 2006). Macropod road-kill may decrease once drought conditions ease. Continued road-kill at present rates is likely to reduce the abundance of wallabies in habitat adjoining the road (Huijser & Bergers 2000). Whilst bandicoots are not grazers they may be attracted to the highway to forage on mulch bunds and batters. Numerous bandicoot diggings have been observed on mulch bunds in some sections of the alignment. Bandicoots are capable of getting through small gaps in fauna fence and it is possible that some road-kill records are due to this.

Sites with notable decreases in the frequency of road-kill in 2019 were:

- Gumma Floodplain – total number decreased by 40% primarily due to lower number of turtles.
- Nambucca River to Mattick Road – total number decreased by 50% primarily due to lower numbers of wood duck and galah.

Sandpiper Ecological (2018) suggested that the occurrence of birds in road-kill might reduce overtime as individuals habituate to the highway. Whilst there was a 30% reduction in the number of road-killed birds in 2019 tawny frogmouth, eastern barn owl, Australian wood duck, and laughing kookaburra continue to be struck regularly. The highway is likely to represent a population sink for

resident territorial species such as frogmouths, owls, and kookaburras, and overtime may affect populations of some species (Loss *et al.* 2014).

4.3 Fenced vs unfenced

Analysis of roadkill data identified contradictory results. The G-test identified a statistically significant difference ($P < 0.05$) yet the Kruskal-Wallis test did not record a significant difference ($P = 0.132$). The data suggest an obvious difference with twice the number of road-kills recorded in unfenced or single fence sections, and the disparity may be due to the influence of zero values on the Kruskal-Wallis test. The G-test result suggests that fauna are being killed at a significantly higher frequency in unfenced sections. This result differs to 2018 when no significant difference between fenced and unfenced was recorded.

The difference is attributed to greater numbers of macropods and bandicoots killed in unfenced sections, and lower numbers of turtles killed in fenced sections in 2019. Sandpiper Ecological (2018b) found that a significantly higher frequency of road-kill occurred in unfenced areas when reptiles were removed from the analysis. Geolink (2018a) attributed the high incidence of road-killed turtles, during Stage 2A monitoring, to individuals trapped on the roadside of the exclusion fence following fence construction. The 2019 results support this observation, although it will not be confirmed until the condition of wetlands on the Gumma floodplain improves following rain.

Reasons for the high incidence of macropod and bandicoot road-kill were discussed in the previous section, and mortality of both groups is likely to decrease once the drought eases. Continuation of mortality at 2019 rates is likely to have a detrimental impact on the local populations of both groups.

Despite the higher incidence of road-kill in unfenced areas the results do not show how many individuals are blocked from entering the carriageway by exclusion fence. Exclusion fence corresponds with vegetated areas that have a higher abundance of fauna and without exclusion fence road-kill would be substantially higher in these areas (de Carvalho *et al.* 2014). The lower incidence of mortality through the Nambucca State Forest section shows that the exclusion fence is having a positive effect on road-kill frequency in that area.

At this stage of monitoring no modifications to exclusion fence design or extent is recommended. Due to the influence of drought on road-kill further monitoring is recommended to confirm the presence of hotspots and the overall frequency of road-kill within the WC2NH alignment.

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

4.4 Threatened fauna

Three threatened species were recorded during road-kill surveys in 2019, grey-headed flying fox (13 individuals), black bittern (1 individual) and masked owl (1 individual), which brings the total number of threatened species recorded to four. Masked owls are susceptible to vehicle strike due to their habitat of foraging along forest edges (see Higgins 1999) and they are likely to be regularly recorded in low numbers. Flying-foxes are also susceptible to vehicle strike when foraging close to traffic or traversing large bridges. Mortality of flying-foxes on the WC2NH upgrade in 2019 is attributed to both

situations. Numerous flying-foxes were struck at the Nambucca and Warrell Creek Bridges, with small numbers recorded elsewhere on the alignment.

There was a distinct seasonal pattern to flying-fox road-kill with numbers peaking in summer and decreasing substantially in winter, which is consistent with breeding and dispersal. A large number of dead flying-foxes, including grey-headed, were recorded along the Pacific Highway in late winter/spring 2019 (D. Rohweder pers obs). This was attributed to drought conditions forcing individuals to forage in medians and along roadsides. Low food abundance may have also affected the agility and strength of flying foxes making them more vulnerable to being struck by vehicles. The incidence of flying-fox road-kill in areas with low shrubs highlights an important issue regarding the type of plants used to landscape highway upgrades.

Vehicle strike is not identified as a major threat to grey-headed flying foxes (DotEE 2017). Scheelings and Frith (2015) found that 2.4% of individuals presented at clinics in Victoria were due to vehicle strike, and 84.6% of these were euthanised. As noted above vehicle strike may contribute to mortality during times of heat and food stress.

The number of grey-headed flying-foxes recorded during road-kill surveys in 2019 is concerning. Whilst the unseasonal dry weather has contributed to mortality across northern NSW the strikes at the Nambucca River Bridge could be related to barrier effect rather than food and is therefore unlikely to be ameliorated by a change in weather. It appears that flying-foxes moving along the river are not gaining sufficient elevation to pass safely over the bridge. It is uncertain if this is due to reduced flying ability associated with food stress or unfamiliarity with the bridge. It is possible that flying-foxes will fly higher over the bridge once they habituate to its presence. There is no easy solution to road strike at highway bridges and continued road-kill monitoring is required before actions are implemented.

5. Conclusion and recommendations

The 2019 road-kill monitoring program for the WC2NH upgrade has identified a distinct seasonal trend in road-kill frequency with numbers peaking in spring/summer and declining in autumn and winter. Drought conditions in NSW have undoubtedly affected road-kill rates with notable increases in the number of macropods and flying-foxes recorded. Whilst mortality rates for these groups are of concern further monitoring is required to confirm if rates will remain high. Whilst mortality rates for some species increased in 2019 there was notable declines in Australian wood duck and freshwater turtles, a result attributed to changing habitat inside the highway corridor. The high rate of mortality at the Nambucca River Bridge, including several flying-foxes, will require careful assessment in future monitoring. Importantly, no spotted-tailed quoll, koala, or giant barred frog was recorded as road-kill during the 2019 sample period. Whilst 13 grey-headed flying-foxes were confirmed no individuals were recorded near the former camp, or inside the flying-fox exclusion fence. The following recommendations are proposed:

1. Continue seasonal roadkill surveys during year three (2020) of the operational phase using the same methods applied in year one and two.
2. Maintain vegetation on road verges to reduce suitability for macropods.
3. Avoid planting fruit and blossom producing plants and dense vegetation around highways.
4. Examine flying-fox road-kill following the summer (January) 2020 sample.
5. Explore correlations between drop-downs and the distribution of target species in the year three annual report.

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Appendix A – Field Survey Data

Table A1: October 2019 road-kill results. NB = northbound; SB = southbound; C'way = carriageway.

Date	Observers	Start time	End time	C'way	Species	Sex & age class	Presence of pouch or back young	General location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to x-ing structure	Proximity to drop-down
2/10/19	NP & NM	920	1125	SB	Common Ringtail Possum	Unknown		Adjacent poplar trail	495776	6607732	No	Present	Good	50m	
2/10/19	NP & NM	920	1125	SB	Short-beaked Echidna	Adult		530m Sth Mattick Rd	494430	6604265	Yes	Absent	NA	2.30km	615m
2/10/19	NP & NM	920	1125	SB	Wood duck	Adult		570m Sth Mattick Rd	494426	6604201	Yes	Absent	NA	NA	NA
2/10/19	NP & NM	920	1125	SB	Small bird	Adult		580m Sth Mattick Rd	494424	6604167	No	Absent	NA	NA	NA
2/10/19	NP & NM	920	1125	SB	Grey headed flying-fox	Adult		10m Nth Nambucca Bridge	494200	6603232	No	Absent	NA	NA	NA
2/10/19	NP & NM	920	1125	SB	Large mammal	Unknown		750m Sth NB	493413	6601895	No	Present	Good	0.41km	340m
2/10/19	NP & NM	920	1125	SB	Medium mammal	Unknown		1m before floodplain Bridge 2	493288	6601521	No	Present	Good	0	70m
2/10/19	NP & NM	920	1125	SB	Northern brown bandicoot	Adult		25m Nth Bald Hill Rd	492503	6600086	No	Absent	NA	0.88km	365m
2/10/19	NP & NM	920	1125	SB	Rainbow lorikeet	Adult		240 Sth Bald Hill Rd	492468	6599801	Yes	Absent	NA	NA	NA
2/10/19	NP & NM	920	1125	SB	Medium mammal	Unknown		Scott's Head Rd overbridge	491934	6598434	Yes	Absent	NA	0.58km	370m
2/10/19	NP & NM	920	1125	SB	Purple swamphen	Adult		415 Nth Rosewood Rd	490884	6596960	Yes	Present	Good	NA	NA
2/10/19	NP & NM	920	1125	SB	Bandicoot spp	Unknown		Rosewood Rd	490843	6596539	No	Absent	NA	0.32km	1100m
2/10/19	NP & NM	920	1125	SB	Australian Magpie	Adult		490 Sth Rosewood Rd	490744	6596152	Yes	Absent	NA	NA	NA
2/10/19	NP & NM	920	1125	SB	Short-beaked echidna	Adult		700 Sth Rosewood Rd	490565	6595857	No	Absent	NA	1.07km	320m
2/10/19	NP & NM	920	1125	NB	Tawny frogmouth (prob)	Unknown		Railway bridge	489437	6594423	No	Present	Good	NA	NA
2/10/19	NP & NM	920	1125	NB	Medium mammal	Unknown		50 Sth Cockburns	489520	6594510	No	Present	Good	0.37km	59m
2/10/19	NP & NM	920	1125	NB	Bandicoot spp	Adult		900 Nth Cockburns Bridge	490021	6595206	No	Present	Good	1.25km	192m
2/10/19	NP & NM	920	1125	NB	Red-necked wallaby	Adult		720 Sth Rosewood Rd	491934	6598434	No	Absent	NA	0.55km	357m
2/10/19	NP & NM	920	1125	NB	Bandicoot spp	Adult		360 Sth Albert Dv	490845	6596982	Yes	Absent	NA	0.13km	1520m
2/10/19	NP & NM	920	1125	NB	Red-necked wallaby	Unknown		50 Sth Bald Hill Rd on offramp	492415	6599915	No	Absent	NA	0.91km	547m

Date	Observers	Start time	End time	C'way	Species	Sex & age class	Presence of pouch or back young	General location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to x-ing structure	Proximity to drop-down
2/10/19	NP & NM	920	1125	NB	Green tree snake	Adult		Floodplain Bridge 2	493281	6601568	Yes	Present	Good	0.05km	40m
2/10/19	NP & NM	920	1125	NB	Snake spp	Adult		Floodplain Bridge 2	493283	6601573	No	Present	Good	0.05km	40m
2/10/19	NP & NM	920	1125	NB	Laughing kookaburra	Adult		Mattick Rd	494426	6604641	No	Present	Good	NA	NA
2/10/19	NP & NM	920	1125	NB	Bandicoot spp	Unknown		2km n Mattick Rd	495111	6606623	No	Present	Good	0.13km	104m
2/10/19	NP & NM	920	1125	NB	Tawny frogmouth	Adult		Next to C7	496463	6608773	No	Adjacent	NA	NA	NA
9/10/19	NP & NM	900	1100	SB	Laughing kookaburra	Adult		600M s C5/6	495506	6607253	No	Present	Good	NA	NA
9/10/19	NP & NM	900	1100	SB	Medium bird	Adult		100M N Mattick Rd	494481	6604960	No	Present	Good	NA	NA
9/10/19	NP & NM	900	1100	Sb	Medium mammal	Adult		200 m N S old coast	494419	6603712	No	Present	Good	1.10km	1200m
9/10/19	NP & NM	900	1100	Sb	Small bird	Adult		N Bald Hill road 500	492671	6600443	No	Present	Good	NA	NA
9/10/19	NP & NM	900	1100	NB	Grey-headed flying-fox	Adult		On Warrell Creek Bridge	488950	6594009	No	Present	Good	NA	NA
9/10/19	NP & NM	900	1100	NB	Northern brown bandicoot	Adult		50 m s Cockburns Bridge	489557	6594560	No	Present	Good	0.40km	40m
9/10/19	NP & NM	900	1100	Nb	Carpet Python	Adult		770 South Rosewood	490390	6595707	No	Absent	NA	1.00km	98m
9/10/19	NP & NM	900	1100	NB	Australian magpie	Adult		600M S Rosewood Rd	490657	6596053	Yes	Absent	NA	1.43km	540m
9/10/19	NP & NM	900	1100	NB	Barn Owl	Adult		600M S Rosewood Rd	490655	6596053	Yes	Absent	NA	NA	NA
9/10/19	NP & NM	900	1100	NB	Grey-headed flying-fox	Adult		150 m S south old coast road	494272	6603352	No	Absent	NA	NA	NA
9/10/19	NP & NM	900	1100	NB	Reptile sp	Adult		150 m S south old coast road	494262	6603340	No	Absent	NA	0.72km	1540m
9/10/19	NP & NM	900	1100	NB	Laughing kookaburra	Adult		500 m north of south old coast road	494383	6604042	Yes	Present	Good	NA	NA
9/10/19	NP & NM	900	1100	NB	Tawny Frogmouth	Adult		700m south of north old coast road	497023	6609971	No	Present	Good	NA	NA
16/10/19	NP&NM	920	1010	SB	Turtle spp	Adult		200m S Nambucca flood plain bridge 2	493191	6601286	Yes	Present	Good	0.20km	106m
16/10/19	NP&NM	920	1010	SB	Purple swamphen	Adult		300m N Rosewood Rd	490861	6596858	No	Absent	NA	NA	NA
16/10/19	NP&NM	920	1010	NB	Tawny Frogmouth	Adult		235m S south old coast Rd	494196	6603258	Yes	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	SB	Medium mammal	Unknown		250M S culvert 3	495015	6606383	No	Present	Good	0.11km	260m
22/10/19	NP&NM	800	915	SB	Black-faced cuckoo-shrike	Adult		300M N Mattick Rd	494488	6605139	Yes	Present	Good	NA	NA
22/10/19	NP&NM	800	915	SB	Galah	Adult		140M s Mattick Rd	494466	6604609	Yes	Absent	NA	NA	NA

Date	Observers	Start time	End time	C'way	Species	Sex & age class	Presence of pouch or back young	General location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to x-ing structure	Proximity to drop-down
22/10/19	NP&NM	800	915	SB	Galah	Adult		140M s Mattick Rd	494461	6604607	Yes	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	SB	Galah	Adult		160m s Mattick Rd	494463	6604574	No	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	SB	Grey-headed flying-fox	Male Adult		South end Nambucca bridge	493628	6602406	No	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	SB	Welcome swallow	Juvenile		30M S Nambucca Bridge	493614	6602362	Yes	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	SB	Medium bird	Unknown		South end Nambucca bridge	493638	6602404	Yes	Absent	NA	NA	NA
22/10/19	NP&NM	800	915	NB	Grey-headed flying-fox	Adult		150M s upper Warrell Crk Bridge	488796	6593928	No	One side	Good	NA	NA
22/10/19	NP&NM	800	915	NB	Barn Owl	Adult		1050M s Rosewood Rd	490330	6595609	Yes	One side	Good	NA	NA
22/10/19	NP&NM	800	915	NB	Wood duck (prob)	Adult		480M s Rosewood Rd	490661	6596072	Yes	One side	Good	NA	NA
22/10/19	NP&NM	800	915	NB	Red-necked wallaby	Adult		190M N Bald Hill Rd	492512	6600218	No	Absent	Good	250m	100m

Table A2: Grey-headed flying-fox road-kill data collected in October 2019. Proximity to camp was measured from the Nambucca Heads camp to road-kill location.

Date	Observers	Carriageway	Sex & age class	General location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to crossing structure	Proximity to drop-down	If Flying Fox, proximity to camp; proximity to canopy veg, proximity to food
2/10/19	NP & NM	SB	Adult	10m Nth Nambucca Bridge	494200	6603232	No	Absent	NA	NA	NA	9.1km; 170m
9/10/19	NP & NM	NB	Adult	On Warrell Creek Bridge	488950	6594009	No	Present	Good	NA	NA	19.6km; 400m
9/10/19	NP & NM	NB	Adult	150 m S south old coast road	494272	6603352	No	Absent	NA	NA	NA	8.99km; 175m
22/10/19	NP&NM	SB	Male Adult	South end Nambucca bridge	493628	6602406	No	Absent	NA	NA	NA	10.13km; 490m
22/10/19	NP&NM	NB	Adult	150M s upper Warrell Ck Bridge	488796	6593928	No	One side	Good	NA	NA	19.79km; 105m

Appendix 11 Road Kill Monitoring Report – Summer (January) 2019 monitoring.

Pacific Highway Upgrade Warrell Creek to Nambucca Heads

**Operational phase road-kill monitoring –
Summer 2020.**



Sandpiper Ecological

**1/94 Main Street
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**Final Report
19 February 2020**

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Cover Photo: A northern brown bandicoot (*Isodon macrourus*) road-killed on 30 January 2020.

Disclaimer:

This report has been prepared in accordance with the scope of services described in the contract or agreement between Sandpiper Ecological Surveys (ABN 82 084 096 828) and Transport for NSW. The report relies upon data, surveys and measurement obtained at the times and locations specified herein. The report has been prepared solely for Transport for NSW. Sandpiper Ecological Surveys accepts no responsibility for its use by other parties. Sandpiper Ecological Surveys accepts no responsibility or liability for changes in context, meaning, conclusions or omissions caused by cutting, pasting or editing the report.

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1. Introduction

1.1 Background

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

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

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna drop-down structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including underpasses, bridges, rope bridges and glide poles.

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

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

Sandpiper Ecological Surveys (SES) has been engaged by Roads and Maritime to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal road-kill surveys over the entire upgrade length.

Monitoring of road-killed fauna is a requirement of the approved WC2NH koala (*Phascolarctos cinereus*), spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for road-kill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog. Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced seasonal monitoring in October 2018. The

results of monitoring in 2018 and 2019 were analysed and discussed by Sandpiper Ecological (2018, 2019). The following report covers the January (summer) 2020 monitoring event and includes the entire WC2NH alignment. Previous road-kill monitoring was conducted by GeoLink (2018a, b, c, d).

The aim of road-kill monitoring is to:

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

1.2 Study area

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

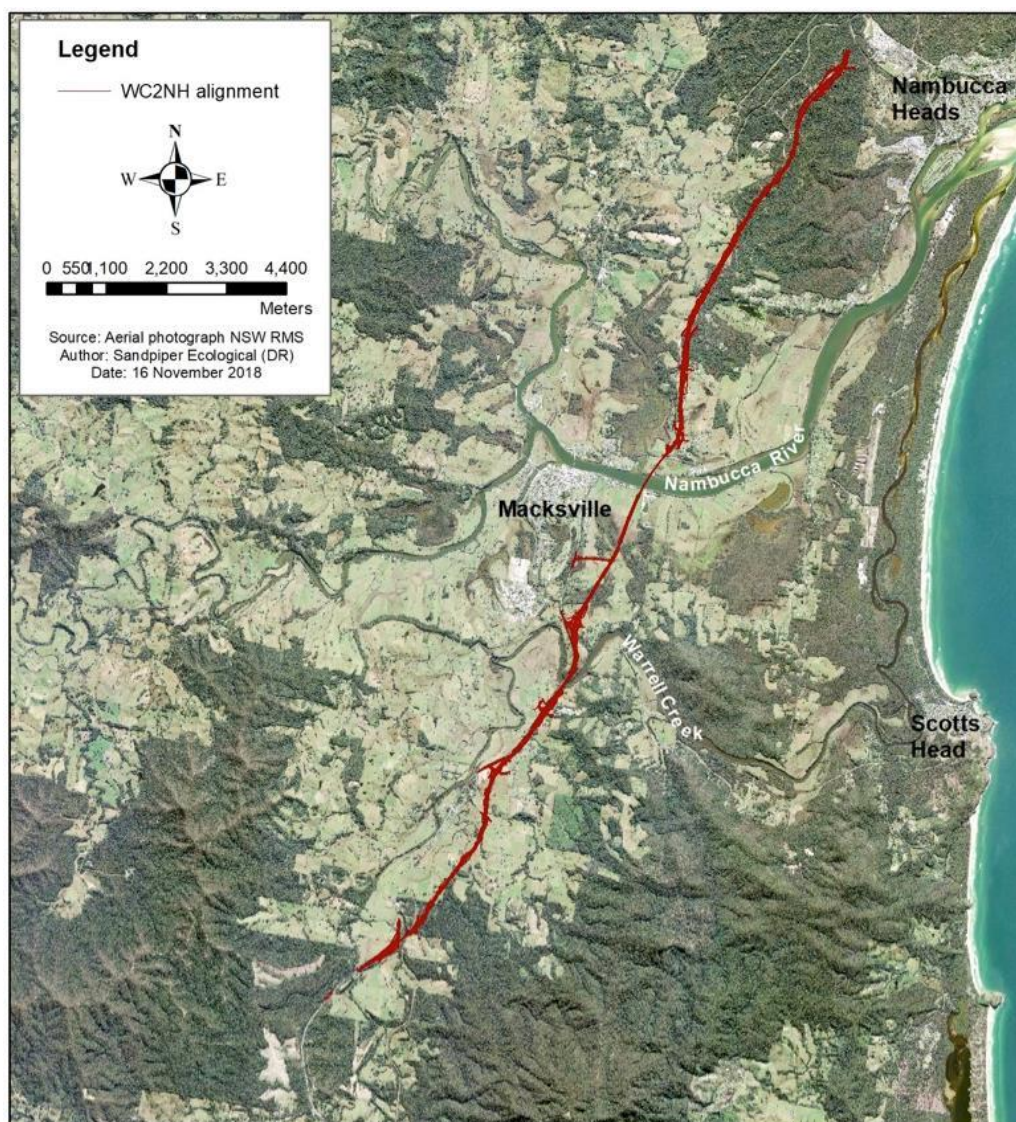


Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Road-kill surveys

Road-kill surveys were conducted by a two-person team from a vehicle driven at 80km/hr in the left lane. The vehicle was equipped with an amber (flashing) light and warning sign (Plate 1). The team consisted of a driver, and ecologist with experience identifying road-killed fauna. Surveys were undertaken weekly and commenced within three hours of sunrise. During each survey, both the driver and ecologist scanned the road surface and road shoulder for fauna. When road-killed fauna were detected the vehicle was pulled onto the shoulder/parking bay and the ecologist inspected the subject animal from the closest perpendicular position behind wire rope. Fauna that could not be identified immediately were photographed and images sent to colleagues for assessment. Carcasses were removed from the road surface when safe to do so.



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

Data collected on each road-kill included (Appendix A1):

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

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act (EPBC) 1999* and/or the *Biodiversity Conservation Act (BC) 2016*, included, where possible: sex and age (juvenile/adult); presence of pouch young if applicable; presence of flightless young (flying-foxes); distance to a fauna connectivity structure; distance to a drop-down structure if applicable; damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

All road-kills were cross referenced with the previous survey results to identify possible duplicates. Using, at a minimum, one team member consistently across all surveys, GPS coordinates of each specimen, looking at carcass age and location on the carriageway, and detailed location description assisted with identification of duplicates.

Distance to connectivity structure, and distance to escape structure was determined via GIS. All other data were uploaded to an iPad in the field.

2.2 Data summary and analysis

Data from the January 2020 survey were uploaded to Microsoft Excel. The January data were compared with results from October 2019 to identify duplicate records. Graphs have been produced showing the total number of road-kills in January and the number of road-kills in different fauna groups each week of the survey. The location of January road-kills has been overlaid on the WC2NH alignment to show their distribution. The January 2020 data are compared to the number of road-kills recorded in summer, autumn, winter and spring 2018 and 2019 (Sandpiper Ecological 2018 and 2019; Table 2).

3. Results

3.1 Weather conditions

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

Table 1: Weather conditions in the 24hrs preceding each sample event. Data obtained from Environdata weather station at the southern compound.

Date	Average Relative Humidity (%)	Total Rainfall (mm)	Average Temperature (°C)	Average Wind Speed (KPH)	Visibility during survey	Rain during survey
7/1/20	74.1	0	26	4.2	Good	Nil
13/1/20	75.2	0.2	20.2	6.1	Good	Nil
21/1/20	73.5	0	26.7	5.1	Good	Nil
29/1/20	NA	0	NA	NA	Good	Nil

3.2 Species richness and abundance

A total of 36 road-killed fauna were recorded during the January 2020 sample period. This included 11 native species and five fauna groups (Table A1, Appendix A). Birds were the most diverse group represented with six species and one group recorded. Three species of mammal and four groups, and one species of reptile were recorded.

Red-necked wallaby (*Macropus rufogriseus*) was the most frequently detected species with seven records, and medium bird was the most frequently detected group of fauna with six records (Table 2). Degradation of carcasses made identification to species level difficult in some cases. Grey-headed flying-fox was detected twice on the Nambucca River Bridge on 22 and 30 January 2020. The *Pteropus* spp. detected on the Nambucca Bridge on 14 January may have also been a grey-headed flying-fox. Of the 36 road-kill records, 15 (42%) were individuals expected to be blocked by exclusion fence. The remaining 21 records, including birds, flying-foxes and common blue-tongued skink, are species that readily move through or over exclusion fencing.



Plate 2: A road-killed pheasant coucal (*Centropus phasianinus*) (L) and a northern brown bandicoot (*Isoodon macrourus*) (R), both recorded on the 31 January 2020.

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

Species	Sum 17/18 **	Aut 2018 **	Win 2018 **	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Sum 2020	Total
Birds										
Australian magpie	6	1		1				2	2	12
Grey butcherbird			1							1
Magpie-lark	2		1		1		1		1	6
Australian white ibis			1						1	2
Cattle egret				1						1
Little pied cormorant					1					1
Buff-banded rail					1					1
Purple swamphen	3		2	2		1		2	3	13
Crested pigeon	2									2
Galah	7				1			3		11
Rainbow lorikeet								1		1
Eastern grass owl*				1						1
Australian boobook			1	1			1			3
Masked owl*	1				1		1			3
Eastern barn owl			11	3		1	5	2	1	23
Tawny frogmouth	1	3	1	2		6		4		17
Australian owl-nightjar					1					1
Laughing kookaburra	3		2	1		2		3	1	12
Forest kingfisher	1									1
Australian wood duck	20			2	2		1	2		27
Pacific black duck	2		1							3
Whistling kite				1						1
Black-shouldered kite					1	1				2
Torresian crow					1					1

Species	Sum 17/18 **	Aut 2018 **	Win 2018 **	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Sum 2020	Total
Pied currawong				1						1
Black-faced cuckoo-shrike								1		1
Dollarbird					2					1
Green catbird					1					1
Black bittern*						1				1
Eastern yellow robin						1				1
Pheasant coucal							1		1	2
Masked lapwing							1			1
Welcome swallow								1		1
Duck spp.						1				1
Small bird								2		2
Medium bird				1	2	2	2	2	6	15
Unidentifiable bird	5	4	1		3					13
Total birds	53	8	22	17	18	16	13	25	16	188
Mammals										
Short-beaked echidna				3				2		5
Black flying-fox	2	1			7	1	1			11
Grey-headed flying-fox*					8			5	2	15
<i>Pteropus</i> spp.					3	8	1		1	13
Common brushtail possum			1	2						3
<i>Trichosurus</i> spp.									1	1
Common ringtail possum					1			1		2
Eastern grey kangaroo				3			1			4
Red-necked wallaby			6		8	2	8	3	7	35
Swamp wallaby	2	1		1		1	1			6
Wallaby spp.						2			3	5
Macropod spp.	3		2	1	1					7
Northern brown bandicoot	1		1		1	1	1	2	2	9
Bandicoot spp.						1		4		5
<i>Chalinolobus</i> spp. (microbat)				1						1
Microbat spp.					1					1
Rodent spp.						2				2
Small mammal					2					2
Medium mammal				2	4	2	4	5	2	19
Large mammal				1	1			1		3
Unidentified Mammal	1			3						4
Total mammals	10	2	10	17	36	20	17	23	18	153
Reptiles										
Common blue-tongued	1			2	1				2	6

Species	Sum 17/18 **	Aut 2018 **	Win 2018 **	Spr 2018	Sum 2019	Aut 2019	Win 2019	Spr 2019	Sum 2020	Total
skink										
Carpet python	1			2	1	1		1		6
Common tree snake	1	2						1		4
Eastern long-neck turtle	1			6						7
Macquarie river turtle	5	1					1			7
Unidentified <i>Chelidae</i> spp.	6							1		7
Red-bellied black snake	1									1
Eastern water dragon	1			1						2
Blackish blind snake						1				1
Yellow-faced whipsnake				1						1
Unidentified reptile								2		2
Total reptiles	17	3	0	12	2	2	1	5	2	44
Frogs										
Green tree frog	2									2
Striped marsh frog	3									3
Medium frog				3						3
Large frog				1						1
Total frogs	5	0	0	4	0	0	0	0	0	9
Introduced species										
Cat	1									1
European fox	3	1	1	2	1	1	2			11
European hare	2			1						3
Rabbit	1									1
Black rat	1					1				2
House mouse					1					1
Rock pigeon			1	1						2
Domestic goose				1						1
Total introduced species	8	1	2	5	2	2	2	0	0	22
Total	93	14	34	55	57	40	33	53	36	415

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

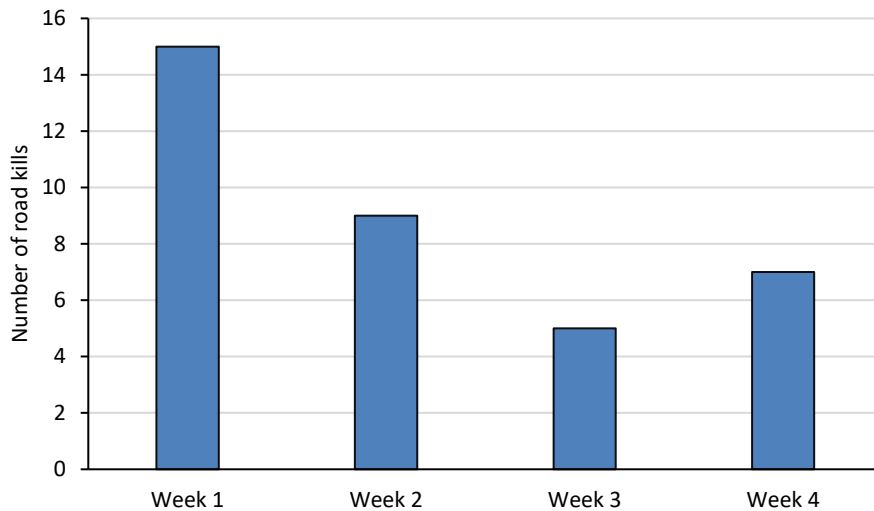


Figure 2: Number of road-kills recorded in each sample week during the January 2020 (summer) sample period.

The abundance of road-killed fauna in the four vertebrate groups also varied during the sample period (Figure 3). The number of road-killed mammals went from nine in week one to six in week two, and three in week three and four. The number of road-killed birds decreased from five in week one to three in week two and one in week three, and then increased to four in week four. Reptiles were represented by single specimens in weeks one and three. No amphibians were detected during January 2020 monitoring.

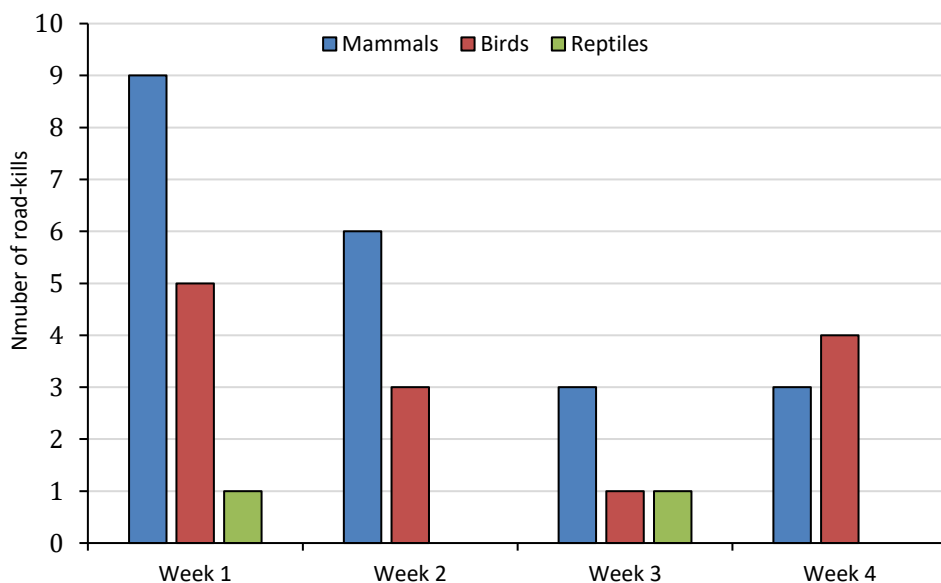


Figure 3: Number of road-killed fauna from three vertebrate classes during each sample week in January 2020.

The number of road-kill flying-foxes have varied over the monitoring period (Figure 4). Black flying-fox, grey-headed flying-fox and total number of flying-foxes peaked during summer 2019 with seven, eight and 18 road-kills respectively. Total number of flying-fox road-kill then decreased to nine in autumn 2019 and two in winter 2019, increasing to five in spring 2019 and decreasing to three in summer 2020.

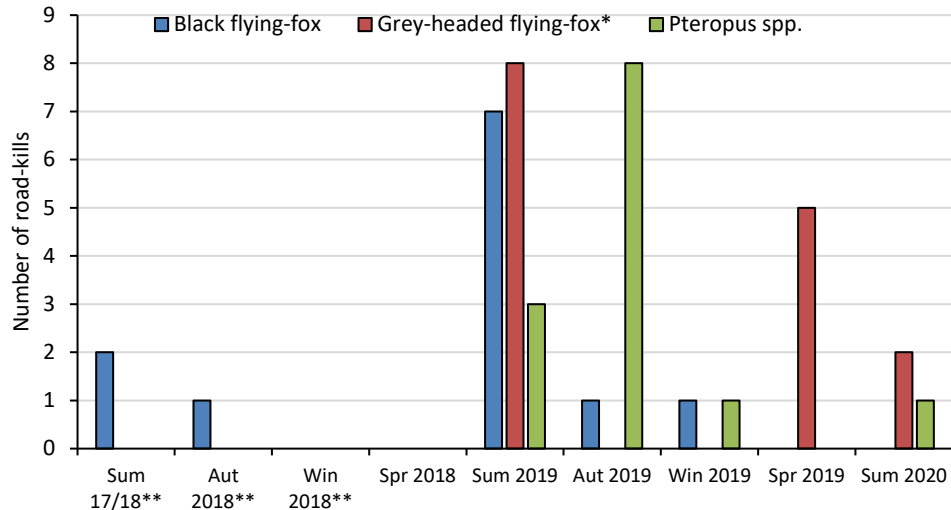


Figure 4: Number of road-killed flying-foxes from all sample periods. * denotes threatened species. **Stage 2a only.

3.1.3 Opportunistic road-kill information

No opportunistic road-kill was recorded within the sample month (January).

3.1.4 Distribution of road-kill

In January 2020, road-killed fauna was recorded over the entire WC2NH alignment (Figures 5-7), although the majority of records (94%) were situated between Mattick Road and the southern end of the project. Within that area, 85% occurred between Mattick Road and Albert Drive (Figures 6-7), and the remaining 15% between the southern end and Albert Drive. The section between the Nambucca River and the southern end of the project traverses predominantly cleared land with three drainage lines and minimal fauna exclusion fence. Two animals (6%) were recorded in the section north of Mattick Road. This section is entirely fenced with floppy top exclusion fence and in places, frog exclusion fence.

In January 2020, 12 road-kills were recorded in areas with exclusion fence, and 24 were recorded in areas without exclusion fence (Figures 5-7). Records were classified as occurring within a fenced area if fence occurred adjacent to the record regardless of whether the record was near the start/end of a fenced section. Two records (17%) (one northern brown bandicoot and one wallaby spp.) in sections with fence were species that would be expected to be blocked by the fence (i.e. medium and large mammals). In contrast, 13 (54%) records in sections without fence were of species that would be expected to be blocked by an exclusion fence.

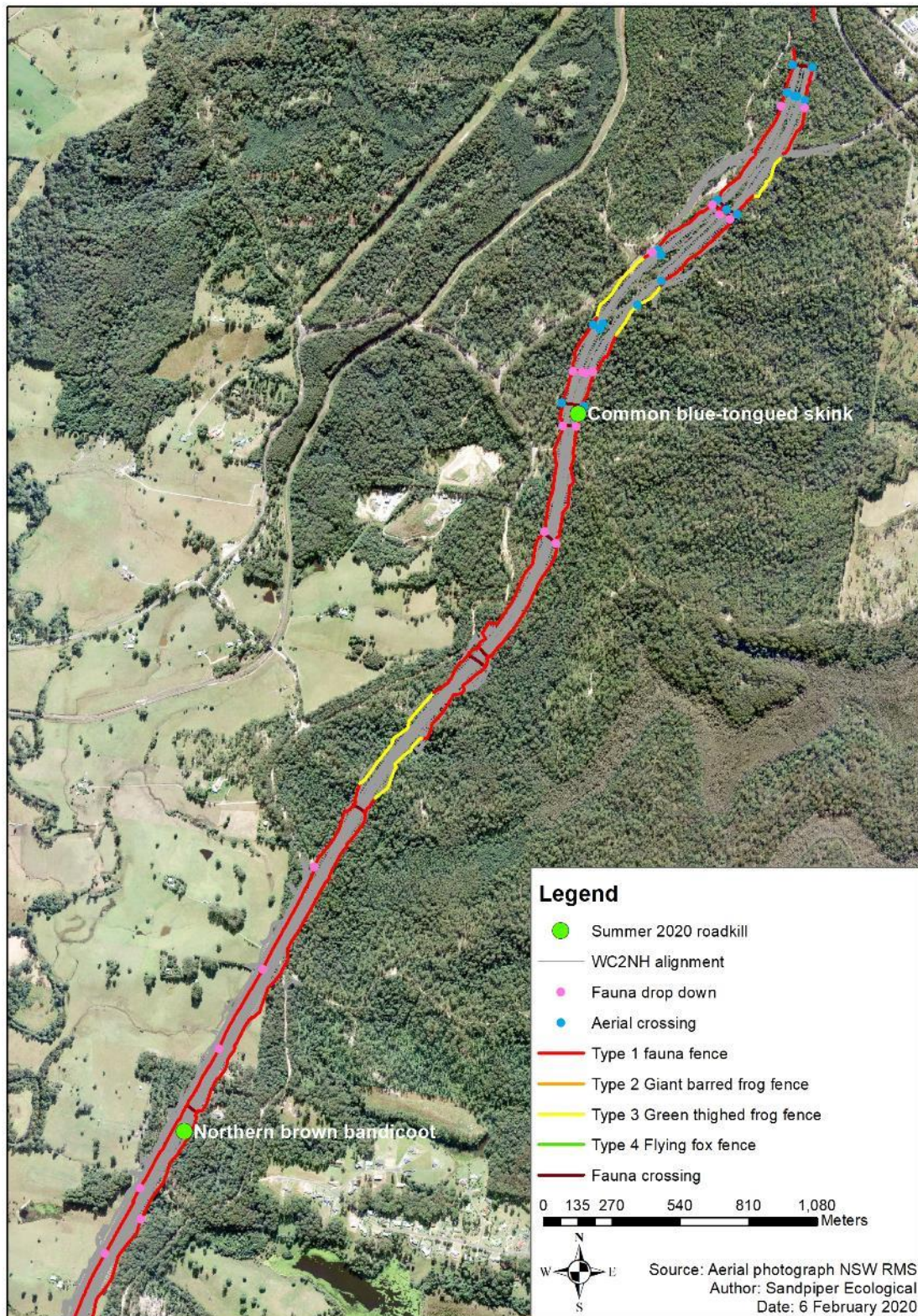


Figure 5: Location of road-killed fauna from January 2020 sample.

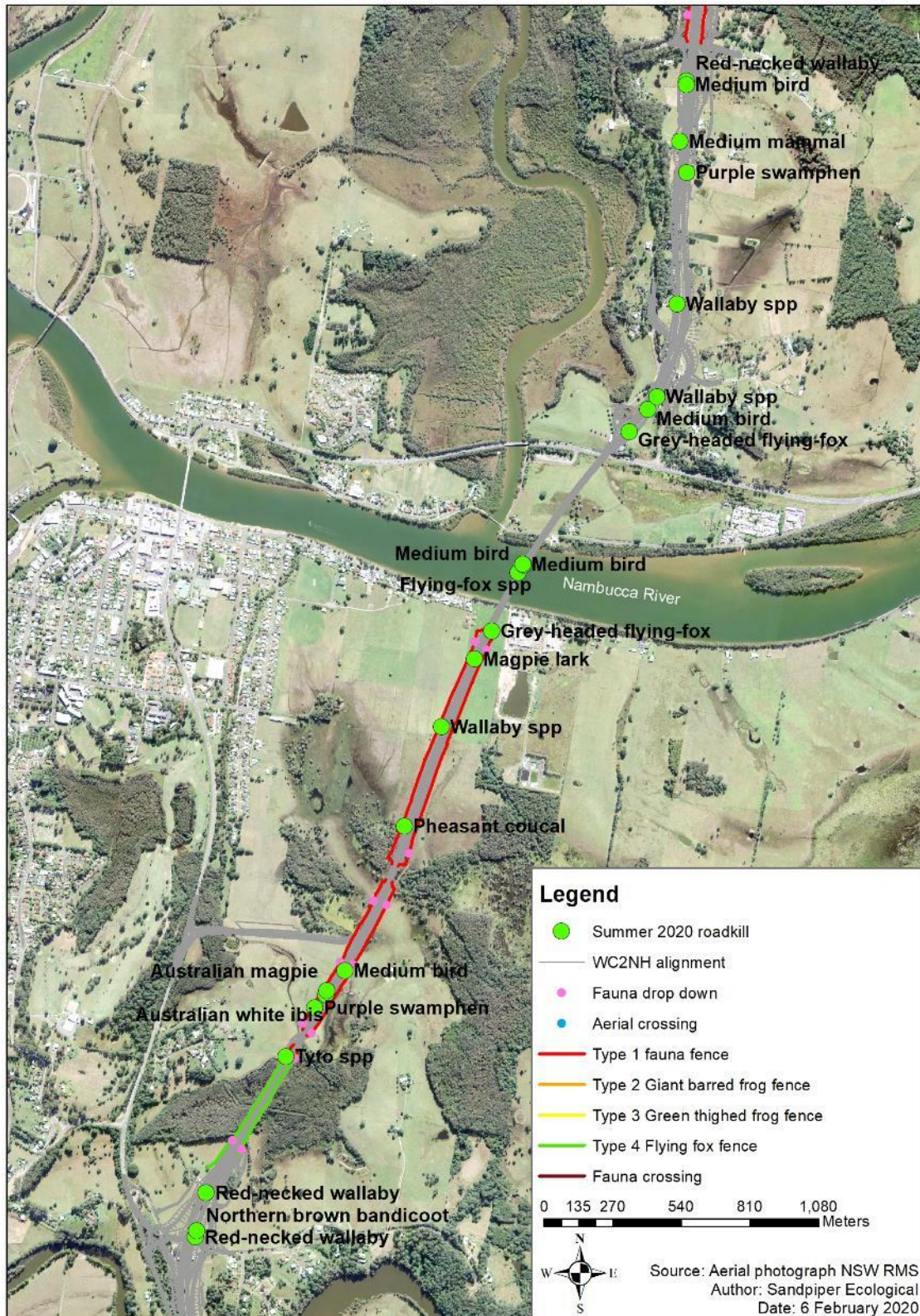


Figure 6: Location of road-killed fauna from January 2020 sample.

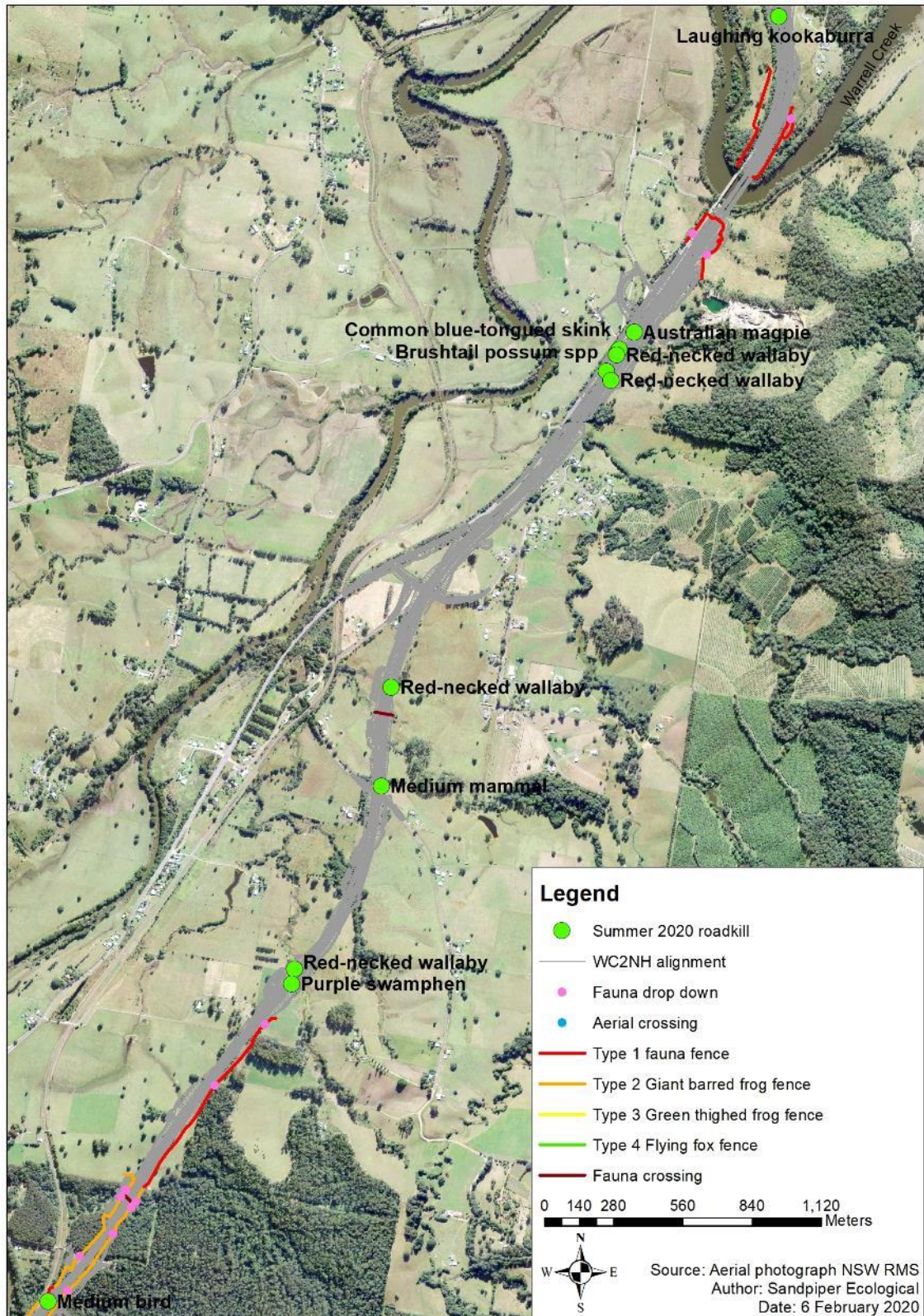


Figure 7: Location of road-killed fauna from January 2020 sample.

4. Discussion

4.1 Summer 2020

Road-kill monitoring over the entire WC2NH alignment in summer 2020 indicates that fauna continue to be killed by vehicles 18 months after the entire alignment was open to traffic. However, with a total of 36 animals killed, summer 2020 monitoring recorded a decrease of 18 individuals when compared to spring 2019, and a decrease of 21 when compared to summer 2019. These results are interesting given that monitoring in 2018 and 2019 identified a seasonal effect where road-kill peaked in spring and summer and decreased in autumn and winter (Sandpiper Ecological 2018, 2019). This seasonal effect was attributed to an increase in traffic volumes during the summer holidays, and an increase in animal movement due to juvenile dispersal and breeding. The lower number of road-kills in summer 2020 is encouraging but may be due to drought conditions, which persisted for most of the January 2020 sample period.

Although total road-kill numbers were lower in summer 2020, the abundance of road-killed wallabies was equivalent to summer and winter 2019. The drought has likely contributed to this by attracting macropods to the road verge to forage. Wallaby road-kill hotspots occur within the vicinity of Bald Hill Road and Albert Drive. Sandpiper Ecological (2018; 2019) raised concerns about the effect of road-kill on the local red-necked wallaby population in the Albert Drive to upper Warrell Creek area, and continued road-kill may have a negative impact on the local red-necked wallaby population. Indeed, road-strike has resulted in population level impacts on several species, including medium sized mammals (see Fahrig & Rytwinski 2009; Huijser & Bergers 2000).

The higher number of road-kills recorded in the first week of all samples reflects the period over which kills could accumulate. This trend is likely to occur in all seasonal sample periods and it means that the number of road-kills recorded during a month overestimates the actual number of animals killed in that month.

Road-kill hotspots identified in summer 2020 include Mattick Road to the Nambucca Bridge, the Gumma Floodplain (Albert Drive to Nambucca River bridge), and from the southern end to Albert Drive. The Gumma Floodplain and the southern end to Albert Drive have been identified as road-kill hotspots in previous years (Sandpiper Ecological 2018, 2019) and previous seasonal samples. Birds and mammals comprised the majority of road-kills in all surveys to date.

4.2 Flying-fox impacts

In summer 2020 all road-killed flying-foxes (i.e. two grey-headed flying-foxes and one *Pteropus* spp.) were recorded on or near the Nambucca River Bridge. Whilst the number of road-killed flying-foxes recorded in summer 2020 was substantially less than that recorded in summer 2019 (18 individuals) continued vehicle strike at the Nambucca River Bridge is concerning. Sandpiper Ecological (2019b) attributed the high incidence of flying-fox mortality at the Nambucca River Bridge to individuals moving along the river and not gaining sufficient elevation to pass safely over the bridge. It is uncertain if this is due to reduced flying ability associated with food stress or unfamiliarity with the bridge. The reduced incidence of road strike in summer 2020 may, in part, be due to lower breeding success of grey-headed flying-fox due to drought conditions. There is no easy solution to road strike at highway bridges and continued road-kill monitoring is required to fully understand the scale of impact.

4.2 Effectiveness of fauna fencing

Results obtained in summer 2020 are consistent with all previous seasonal samples, which show that road-kill rate of species expected to be blocked by the fence are lower in areas with exclusion fence than areas without exclusion fence. Importantly, no mortality of target threatened species (expected to be blocked by the fence) was recorded in summer 2020. Monitoring shows that where present exclusion fence is effective in mitigating road-strike for target species.

5. Recommendations

1. Continue seasonal road-kill surveys as per the project ecological monitoring brief.

6. References

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Appendix A – Field Survey Data

Table A1: January (Summer) 2020 roadkill results.

Date	Observers	Start time	End time	Carriageway	Species	Sex & age class	RK general location	Easting	Northing	Cleared off Rd	Fauna fence P/A & prox.	Prox. to xing structure	Prox. to drop-down	If FF: prox. to camp
8/01/2020	LA & SR	915	1115	SB	Red-necked wallaby	Adult	10 N Baldhill road	492496	6600065	N	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	Sb	Northern brown bandicoot	Adult	20M N bald hill road	492501	6600090	Partial	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	SB	Medium mammal	Unknown	50 m N rosewood road	490844	6596571	N	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Medium bird	Unknown	100M N lower Warrell crk bridge	489495	6594483	No	NA	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Red-necked wallaby	Adult	700m south of Rosewood R	490491	6595830	No	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Brushtail possum	Adult	250m sth of quarry access rd	491754	6598251	No	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Blue tongue	Adult	175 S f quarry access rd	491795	6598317	N	NA	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Red-necked wallaby	Adult	175 S f quarry access rd	491795	6598317	N	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Red-necked wallaby	Adult	200 m north of bald hill road	492539	6600239	Yes	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	White Ibis	Adult	500 m south Nambucca bridge	493011	6601018	Yes	NA	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Prob magpie	Adult	500M south Nambucca bridge	493014	6601036	No	NA	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Medium bird	Adult	On Nambucca bridge	493768	6602681	No	NA	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Wallaby spp	Adult	150 m Nth old coast	494393	6603740	No	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Red-necked wallaby	Adult	100m Nth Mattick Road	494430	6604603	No	Absent	NA	NA	NA
8/01/2020	LA & SR	915	1115	NB	Medium bird	Adult	100m Nth Mattick Road	494430	6604603	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	SB	Purple swamp hen	Adult	500m s mattick rd	494431	6604258	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	SB	Med bird	Unknown	10m north nam bridge	494278	6603325	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	SB	Med bird skeleton	Unknown	200m n flood bridge 1	493085	6601114	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	SB	Red-necked wallaby	Unknown	450m n rosewood rd	490883	6596972	Yes	Absent	NA	NA	NA
14/1/20	NM & LA	750	920	NB	Australian magpie	Adult	60m n quarry access rd	491866	6598409	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	NB	Masked owl	Adult	Flood plain bridge 1	492852	6600776	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	NB	Purple swamp hen	Adult	50m north flood plain bridge 1	492966	6600968	No	NA	NA	NA	NA
14/1/20	NM & LA	750	920	NB	Flying fox spp	Adult	Nambucca bridge	493789	6602711	No	NA	NA	NA	9.7km to Gordons Park

Date	Observers	Start time	End time	Carriageway	Species	Sex & age class	RK general location	Easting	Northing	Cleared off Rd	Fauna fence P/A & prox.	Prox. to xing structure	Prox. to drop-down	If FF: prox. to camp
14/1/20	NM & LA	750	920	NB	Medium mammal	Unknown	400m s mattick rd	494405	6604379	No	Absent	NA	NA	NA
22/01/2020	SR LA	900	1030	SB	Blue tongue	Adult	500M sth Nambucca rail bridge	496591	6609236	No	NA	NA	NA	NA
22/01/2020	SR LA	900	1030	SB	GHFF	Adult	Start Nambucca bridge	494204	6603236	Yes	NA	NA	NA	NA
22/01/2020	SR LA	900	1030	SB	Wallaby spp	Unknown	Start Nambucca bridge	494314	6603374	No	Absent	NA	NA	NA
22/01/2020	SR LA	900	1030	NB	Wallaby spp	Unknown	150 Sth Nambucca bridge	493466	6602074	Yes	Present	430	356	NA
22/01/2020	SR LA	900	1030	NB	Medium bird	Unknown	Middle of Nambucca bridge	493785	6602714	Na	Na	NA	NA	NA
30/1/20	SR NM	905	1025	SB	Northern brown bandicoot	Adult	1050m north old coast rd overpass	495035	6606403	No	Present	87	280	NA
30/1/20	SR NM	905	1025	SB	GHFF	Adult	Nambucca bridge southern end	493663	6602452	No	NA	NA	NA	10km to Gordons park
30/1/20	SR NM	905	1025	SB	Red-necked wallaby	Adult	120m north williamson creek	491773	6598214	No	Absent	NA	NA	NA
30/1/20	SR NM	905	1025	SB	Purple swamp hen	Adult	840m south rosewood road	490481	6595770	No	NA	NA	NA	NA
30/1/20	SR NM	905	1025	NB	Laughing kookaburra	Adult	360south bald hill rd	492451	6599688	No	NA	NA	NA	NA
30/1/20	SR NM	905	1025	NB	Pheasant coucal	Adult	160north nambucca river flood plain bridge 2	493319	6601683	No	NA	NA	NA	NA
30/1/20	SR NM	905	1025	NB	Magpie lark	Adult	Nambucca bridge	493595	6602341	No	NA	NA	NA	NA

Appendix 12 Road Kill Monitoring Report – Autumn (April) 2020 monitoring.

Pacific Highway Upgrade Warrell Creek to Nambucca Heads

**Operational phase road-kill
monitoring – autumn 2020.**

Sandpiper Ecological

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**Final Report
13 May 2020**

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1. Introduction

1.1 Background

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

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

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna drop-down structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including underpasses, bridges, rope bridges and glide poles.

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

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

Sandpiper Ecological Surveys (SES) has been engaged by Transport for NSW (TfNSW) to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal road-kill surveys over the entire upgrade length.

Monitoring of road-killed fauna is a requirement of the approved WC2NH koala (*Phascolarctus cinereus*), spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for road-kill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog. Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced seasonal monitoring in October 2018. The

results of monitoring in 2018 and 2019 were analysed and discussed by Sandpiper Ecological (2018, 2019). The following report covers the April (autumn) 2020 monitoring event and includes the entire WC2NH alignment. Previous road-kill monitoring was conducted by GeoLink (2018a, b, c, d).

The aim of road-kill monitoring is to:

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

1.2 Study area

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

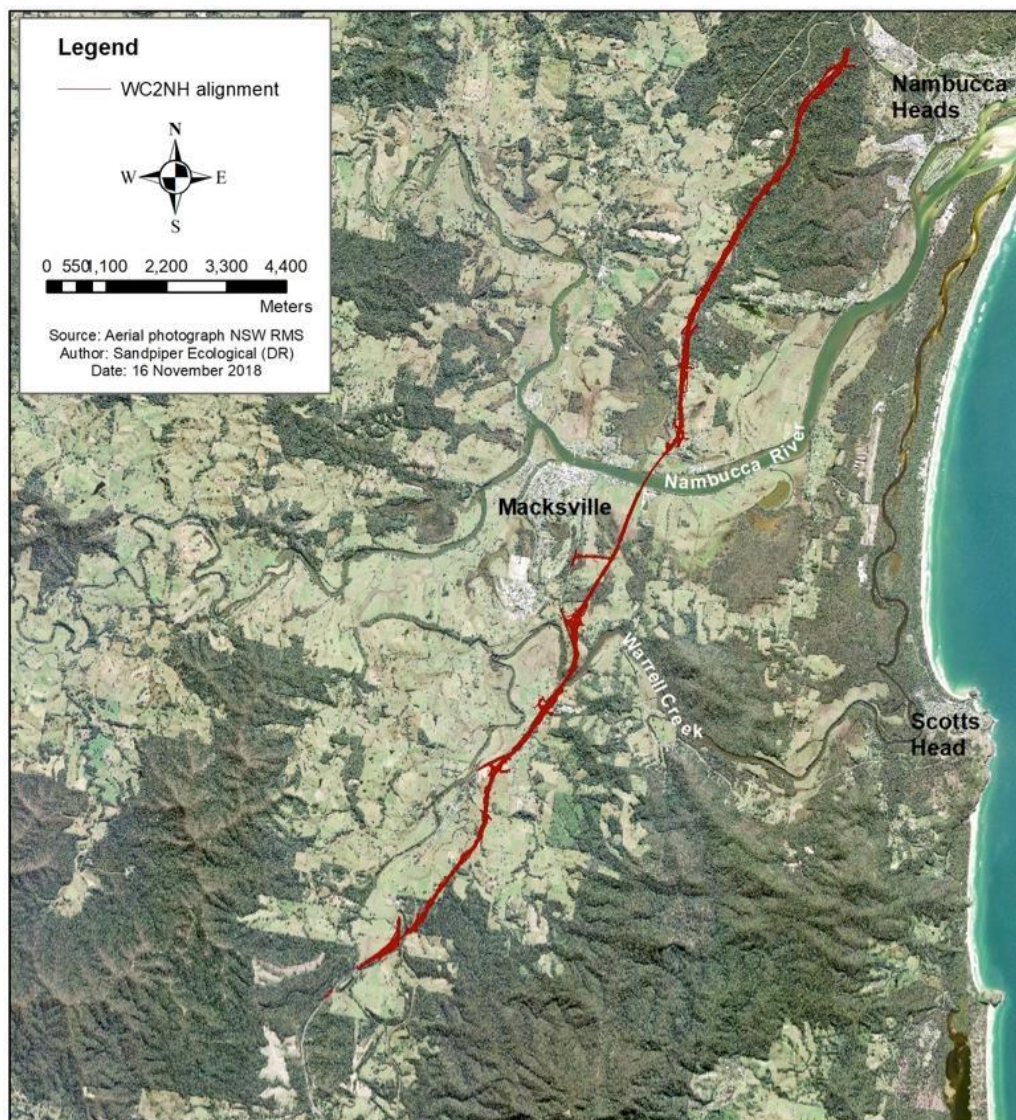


Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Logistical considerations

The April 2020 road-kill survey coincided with government imposed restrictions on social distancing to manage the spread of COVID-19. As part of these restrictions Sandpiper Ecological reviewed its fieldwork practices and initiated a one-person/vehicle restriction unless persons were from the same household. These restrictions meant that one person (an ecologist) conducted the first two road-kill surveys in April 2020, with the second two samples conducted by two operators (including one ecologist) from the same household. Limitations associated with a single operator were overcome by reducing vehicle speed (70-80km/hr) during surveys one and two, and conducting two surveys of the alignment, one immediately after the other, during survey two.

2.1 Road-kill surveys

Road-kill surveys were conducted by 1 or 2 person teams from a vehicle driven at 70-80km/hr in the left lane. The vehicle was equipped with an amber (flashing) light and warning sign (Plate 1). The team consisted of a driver, and ecologist, or single ecologist, with experience identifying road-killed fauna. Surveys were undertaken weekly and commenced within three hours of sunrise. During each survey, all personnel scanned the road surface and road shoulder for fauna. When road-killed fauna were detected the vehicle was pulled onto the shoulder/parking bay and the ecologist inspected the subject animal from the closest perpendicular position behind wire rope. Fauna that could not be identified immediately were photographed and images sent to colleagues for assessment. Carcasses were removed from the road surface when safe to do so.



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

Data collected on each road-kill included (Appendix A1):

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

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act* (EPBC) 1999 and/or the *Biodiversity Conservation Act* (BC) 2016, included, where

possible: sex and age (juvenile/adult); presence of pouch young if applicable; presence of flightless young (flying-foxes); distance to a fauna connectivity structure; distance to a drop-down structure if applicable; damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

All road-kills were cross referenced with the previous survey results to identify possible duplicates. Using, at a minimum, one team member consistently across all surveys, GPS coordinates of each specimen, looking at carcass age and location on the carriageway, and detailed location description assisted with identification of duplicates. Distance to connectivity structure, and distance to escape structure was determined via GIS. All other data were uploaded to an iPad in the field.

2.2 Data summary and analysis

Data from the April 2020 survey were uploaded to Microsoft Excel. The April data were compared with results from January 2020 to identify duplicate records. Graphs have been produced showing the total number of road-kills in April and the number of road-kills in different fauna groups each week of the survey. The location of April road-kills was overlaid on the WC2NH alignment to show distribution. The April 2020 data are compared to road-kills recorded in summer, autumn, winter and spring 2018 and 2019, and January 2020 (Sandpiper Ecological 2018, 2019, 2020; Table 2).

3. Results

3.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses (Table 1). Light rain occurred in the 24hr period prior to the first sample (Table 1).

Table 1: Weather conditions in the 24hrs preceding each sample event. *preceding 24hours. Data obtained from BoM Bellwood and Coffs Harbour weather stations.

Date	Average Relative Humidity (%)	Rainfall (mm)*	Max Temperature (°C)	Max Wind Speed (KPH)	Visibility during survey	Rain during survey
1/4/20	85	11	26.2	30	Good	Nil
8/4/20	70	0	23.8	28	Good	Nil
15/4/20	68	0	26.2	33	Good	Nil
22/4/20	50	0	26.7	35	Good	Nil

3.2 Species richness and abundance

A total of 27 road-killed fauna were recorded during the April 2020 sample period. This included 14 native species and five fauna groups (Table A1, Appendix A). Birds were the most diverse group represented with nine species and two groups recorded. Six species of mammal and three groups, and one species and group of reptile were also recorded.

Macropods were the most frequently detected group with four records, followed by bandicoot with three records (Table 2). Degradation, and location of carcasses on the carriageway (e.g. on bridges)

made identification to species level difficult in some cases. No grey-headed flying-foxes were confirmed, although one *Pteropus* spp. was observed on the Nambucca River Bridge on 8 April 2020. Three new species, white-headed pigeon, Australasian figbird and red-browed finch were recorded in April 2020. Of the 27 road-kill records, 14 (52%) were individuals expected to be blocked by exclusion fence. The remaining 13 records, mostly birds, are species that readily move through or over exclusion fencing.

Table 2: Species of vertebrate fauna recorded during seasonal road-kill surveys throughout the operational phase of the WC2NH upgrade. * denotes threatened species; ** = stage 2a only; Su = summer; A = autumn; W = winter; Sp = spring.

Species	Su 17/18 **	A 18 **	W 18 **	Sp 18	Su 19	A 19	W 19	Sp 19	Su 20	A 20	Total
Birds											
Australian magpie	6	1		1				2	2	1	13
Grey butcherbird			1								1
Magpie-lark	2		1		1		1		1		6
Australian white ibis			1						1		2
Cattle egret				1						1	2
Little pied cormorant					1						1
Buff-banded rail					1						1
Purple swamphen	3		2	2		1		2	3		13
White-headed pigeon										1	1
Crested pigeon	2										2
Galah	7				1			3			11
Rainbow lorikeet								1			1
Eastern grass owl*				1							1
Australian boobook			1	1			1				3
Masked owl*	1				1		1				3
Eastern barn owl			11	3		1	5	2	1		23
Tawny frogmouth	1	3	1	2		6		4		1	18
Australian owl-nightjar					1					1	2
Laughing kookaburra	3		2	1		2		3	1	1	13
Forest kingfisher	1										1
Australian wood duck	20			2	2		1	2			27
Pacific black duck	2		1								3
Whistling kite				1							1
Black-shouldered kite					1	1					2
Torresian crow					1						1
Pied currawong				1							1
Black-faced cuckoo-shrike								1			1
Dollarbird					2						1
Green catbird					1						1
Australasian figbird										1	1
Black bittern*						1					1

Species	Su 17/18 **	A 18 **	W 18 **	Sp 18	Su 19	A 19	W 19	Sp 19	Su 20	A 20	Total
Eastern yellow robin						1					1
Pheasant coucal							1		1		2
Masked lapwing							1				1
Welcome swallow								1			1
Red-browed finch										1	1
Duck spp.						1				1	2
<i>Tyto</i> spp.										1	1
Small bird								2			2
Medium bird				1	2	2	2	2	6	1	16
Unidentifiable bird	5	4	1		3						13
Total birds	53	8	22	17	18	16	13	25	16	11	199
Mammals											
Short-beaked echidna				3				2		1	6
Black flying-fox	2	1			7	1	1				11
Grey-headed flying-fox*					8			5	2		15
<i>Pteropus</i> spp.					3	8	1		1	1	14
Common brushtail possum			1	2						1	4
<i>Trichosurus</i> spp.									1	1	2
Common ringtail possum					1			1			2
Eastern grey kangaroo				3			1				4
Red-necked wallaby			6		8	2	8	3	7	1	36
Swamp wallaby	2	1		1		1	1			1	7
Wallaby spp.						2			3		5
Macropod spp.	3		2	1	1					2	9
Northern brown bandicoot	1		1		1	1	1	2	2	3	12
Bandicoot spp.						1		4			5
<i>Chalinolobus</i> spp. (microbat)				1							1
Microbat spp.					1						1
Rodent spp.						2					2
Small mammal					2						2
Medium mammal				2	4	2	4	5	2	2	24
Large mammal				1	1			1			3
Unidentified Mammal	1			3							4
Total mammals	10	2	10	17	36	20	17	23	18	13	166
Reptiles											
Common blue-tongued skink	1			2	1				2		6
Carpet python	1			2	1	1		1			6
Common tree snake	1	2						1			4

Species	Su 17/18 **	A 18 **	W 18 **	Sp 18	Su 19	A 19	W 19	Sp 19	Su 20	A 20	Total
Eastern long-neck turtle	1			6						1	8
Macquarie river turtle	5	1					1				7
Unidentified <i>Chelidae</i> spp.	6							1			7
Red-bellied black snake	1										1
Eastern water dragon	1			1							2
Blackish blind snake						1					1
Yellow-faced whipsnake				1							1
Unidentified reptile								2		1	3
Total reptiles	17	3	0	12	2	2	1	5	2	2	46
Frogs											
Green tree frog	2										2
Striped marsh frog	3										3
Medium frog				3							3
Large frog				1							1
Total frogs	5	0	0	4	0	0	0	0	0	0	9
Introduced species											
Cat	1										1
European fox	3	1	1	2	1	1	2				11
European hare	2			1						1	4
Rabbit	1										1
Black rat	1					1					2
House mouse					1						1
Rock pigeon			1	1							2
Domestic goose				1							1
Total introduced species	8	1	2	5	2	2	2	0	0	1	23
Total	93	14	34	55	57	40	33	53	36	27	442

The number of road-kill recorded each week declined over the April 2020 sample period (Figure 2). Road-kill peaked in week one with 12 individuals and declined to two in week four.

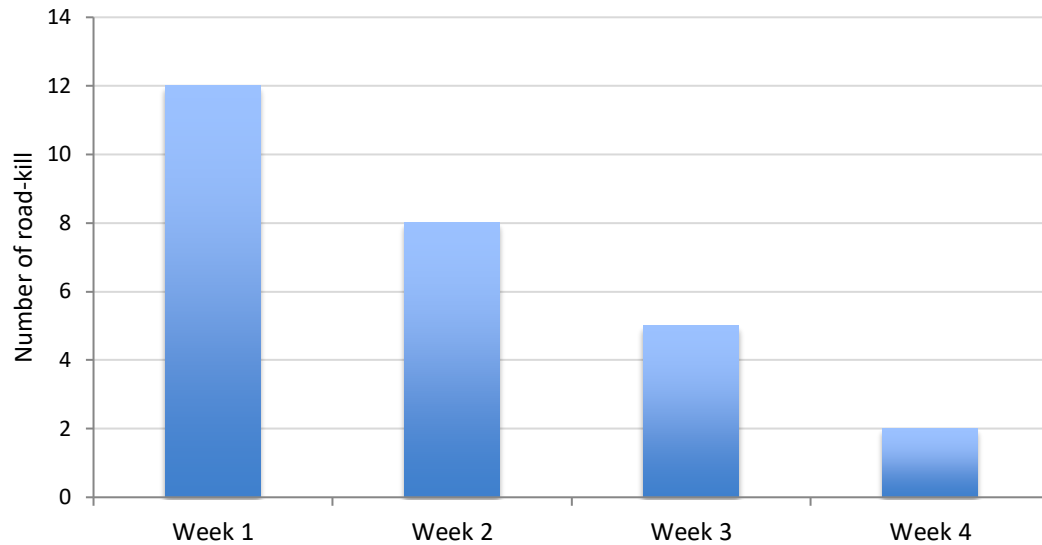


Figure 2: Number of road-kills recorded in each sample week during the April 2020 (autumn) sample period.

The abundance of road-killed fauna in the four vertebrate groups varied during the sample period (Figure 3). Reptiles were recorded in week one only and mammals were the only group recorded in all sample weeks. The number of road-killed mammals went from five in week one to four in week two, three in week three and two in week four. The number of road-killed birds decreased from five in week one to four in week two, two in week three, and none in week four. Reptiles were represented by two individuals in week one. No amphibians were detected in April 2020 monitoring.

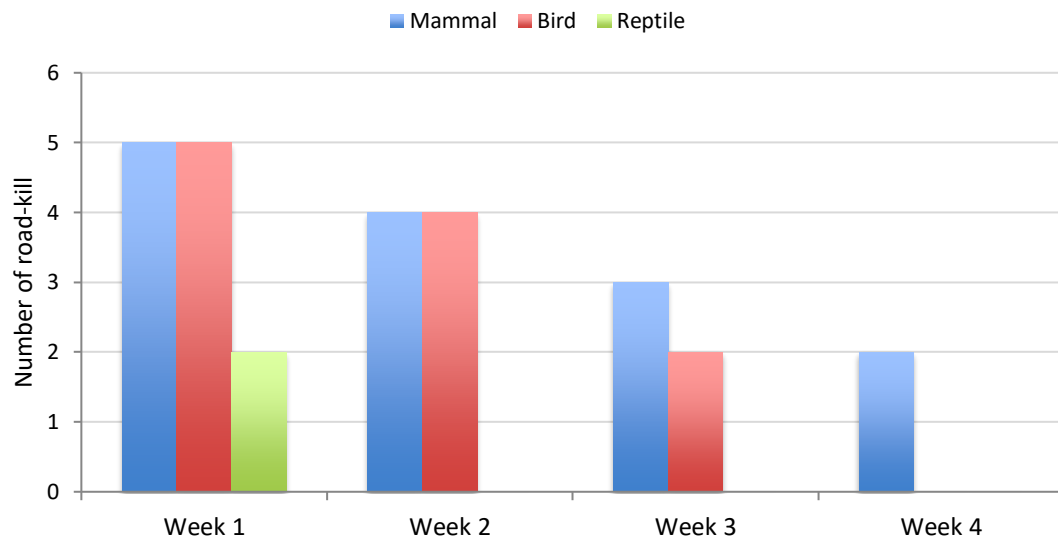


Figure 3: Number of road-killed fauna from three vertebrate classes during each sample week in April 2020.

The number of road-killed flying-foxes has varied over the monitoring period (Figure 4). Black flying-fox, grey-headed flying-fox and total number of flying-foxes peaked during summer 2019 with seven, eight and 18 road-kills respectively. Total number of flying-fox road-kill then decreased to nine in

autumn 2019 and two in winter 2019, increasing to five in spring 2019 and decreasing to three in summer 2020, and one in autumn 2020 (Figure 4).

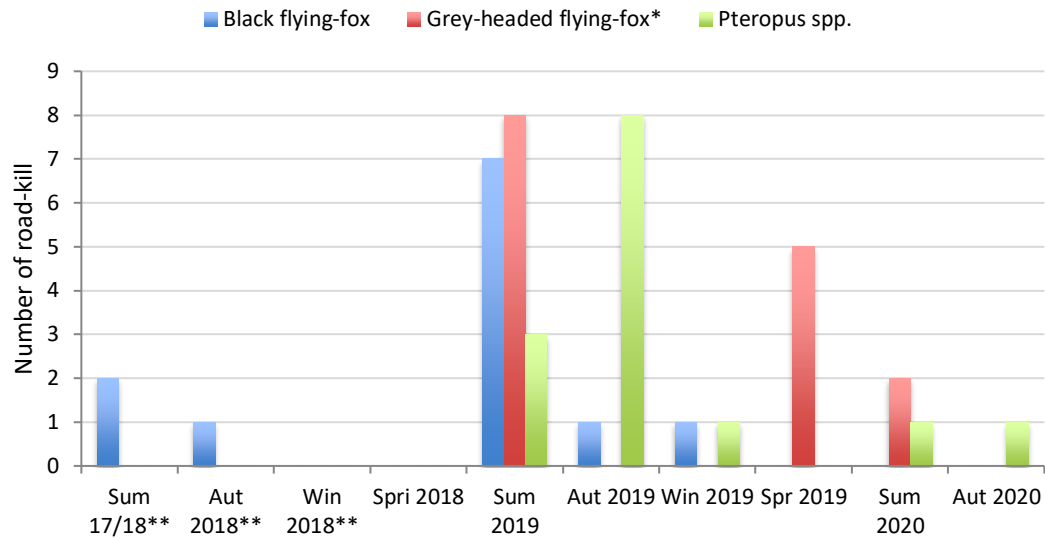


Figure 4: Number of road-killed flying-foxes from all sample periods. * denotes threatened species. **Stage 2a only.

3.1.3 Opportunistic road-kill information

No opportunistic road-kill was recorded within the sample month (January).

3.1.4 Distribution of road-kill

In April 2020, road-killed fauna was recorded over the entire WC2NH alignment (Figures 5-8). The majority of records (56%) were situated between Mattick Road and Bald Hill Road, with 30% of records occurring north of Mattick Road in the section entirely fenced with floppy top exclusion fence and in places, frog exclusion fence. There were few records (14%) south of Bald Hill Road. The section between Mattick Road and Bald Hill Road traverses predominantly cleared land and includes the Nambucca River and Gumma floodplain. Approximately 50% of that area is fenced with Type 1 and Type 4 exclusion fence.

In April 2020, 12 road-kills were recorded in areas with exclusion fence, and 15 in areas without exclusion fence (Figures 5-8). Records were classified as occurring within a fenced area if fence occurred adjacent to the record regardless of whether the record was near the start/end of a fenced section. Seven records (26%) in sections with fence were species that are expected to be blocked by the fence (i.e. medium and large mammals). This included a cluster of five records (3 x bandicoot, 1 x brushtail possum, and 1 red-necked wallaby) within 1.8km north of Mattick Road between underpass #2 and #3 (Figure 6). Seven (26% of all records) records in sections without fence were of species that would be expected to be have been blocked by an exclusion fence.

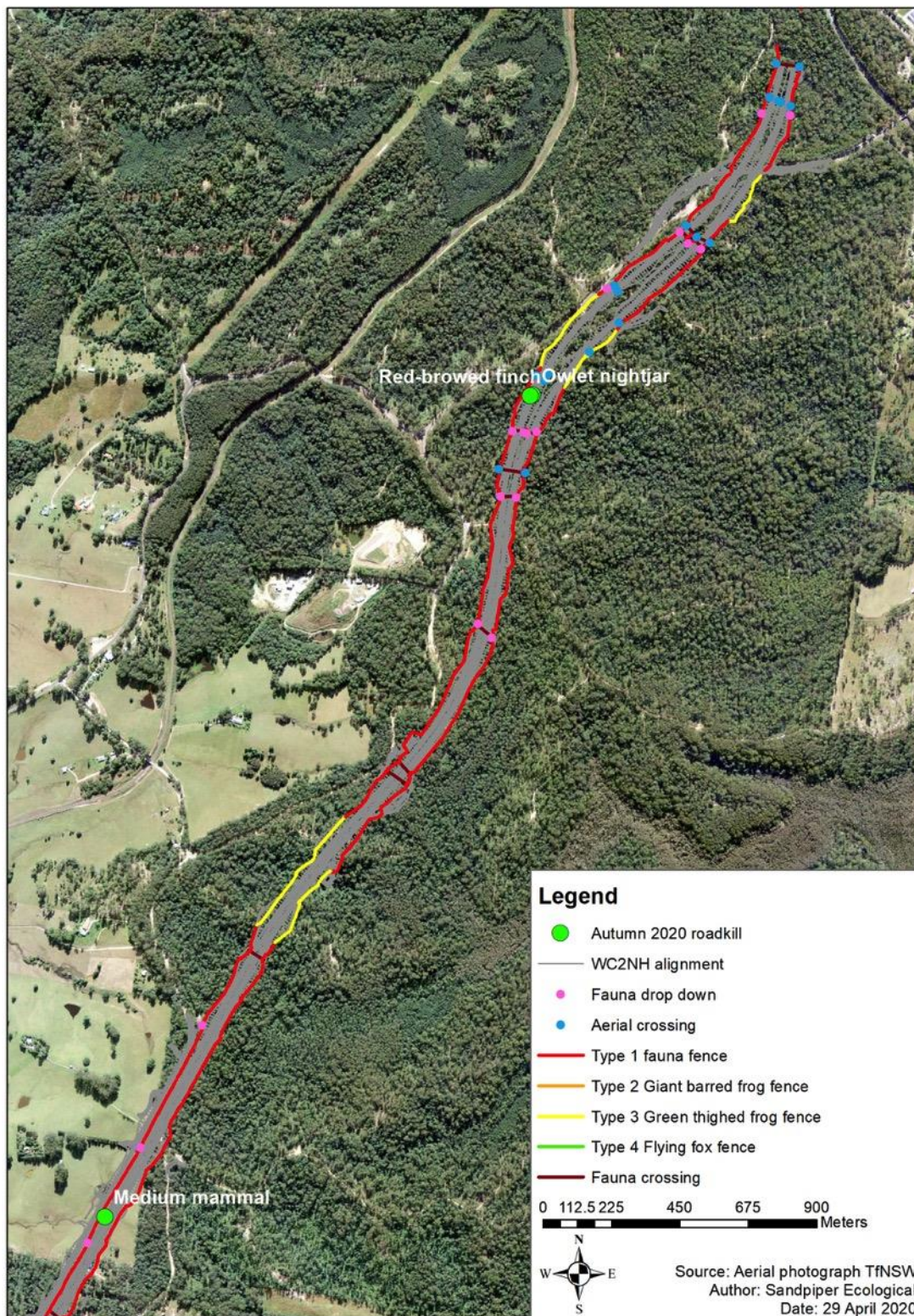


Figure 5: Location of road-killed fauna from April 2020 sample.

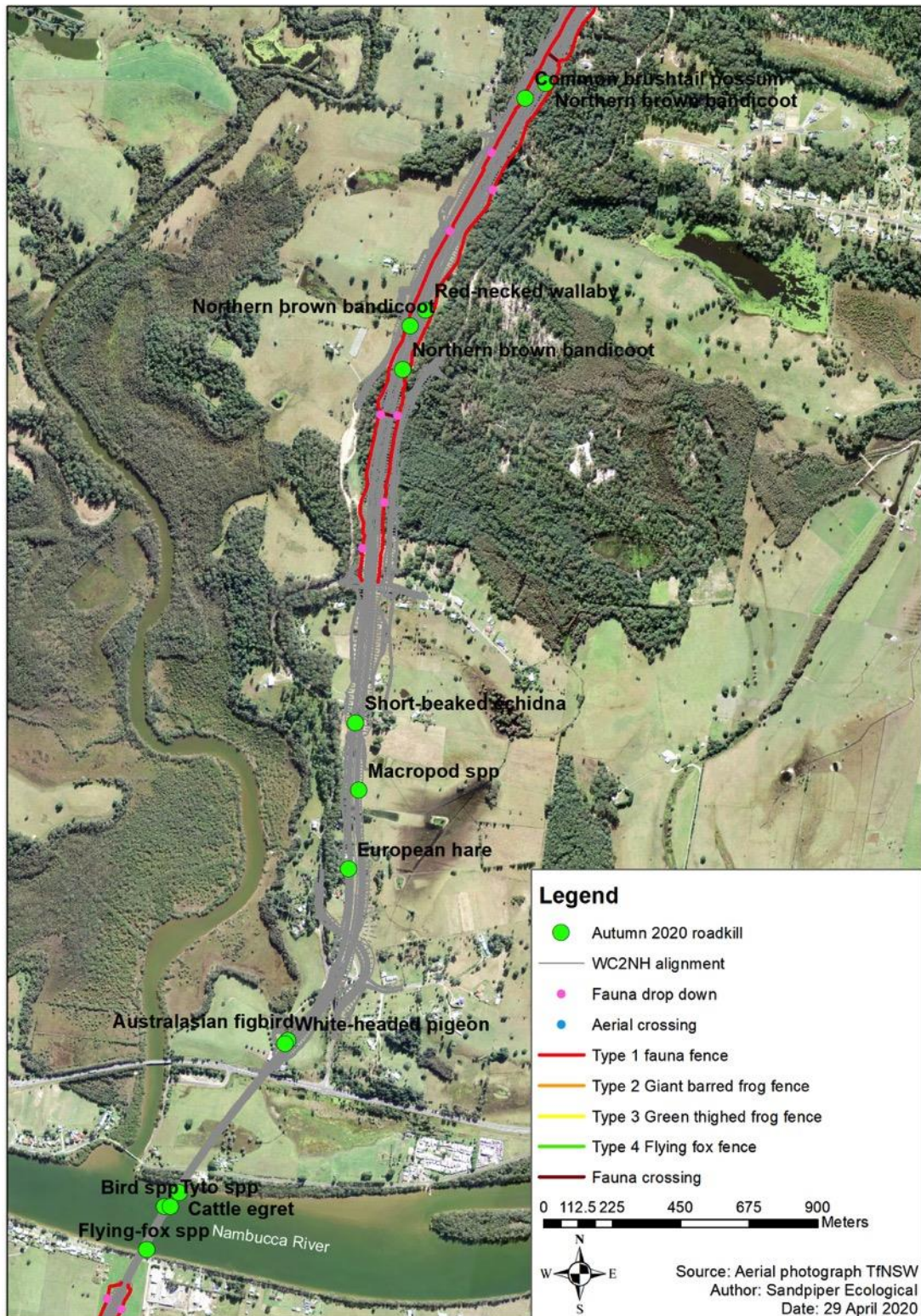


Figure 6: Location of road-killed fauna from April 2020 sample.

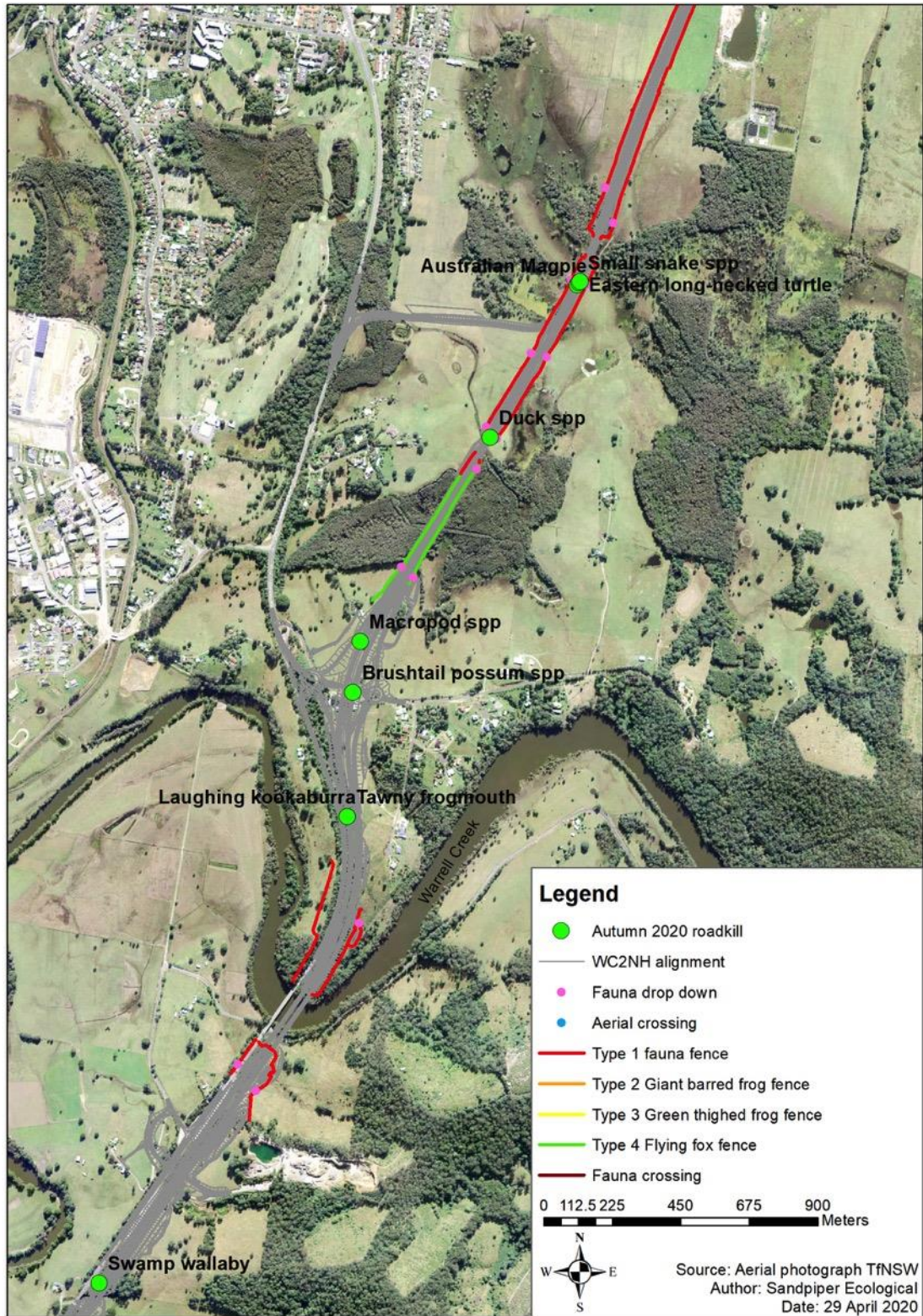


Figure 7: Location of road-killed fauna from April 2020 sample.

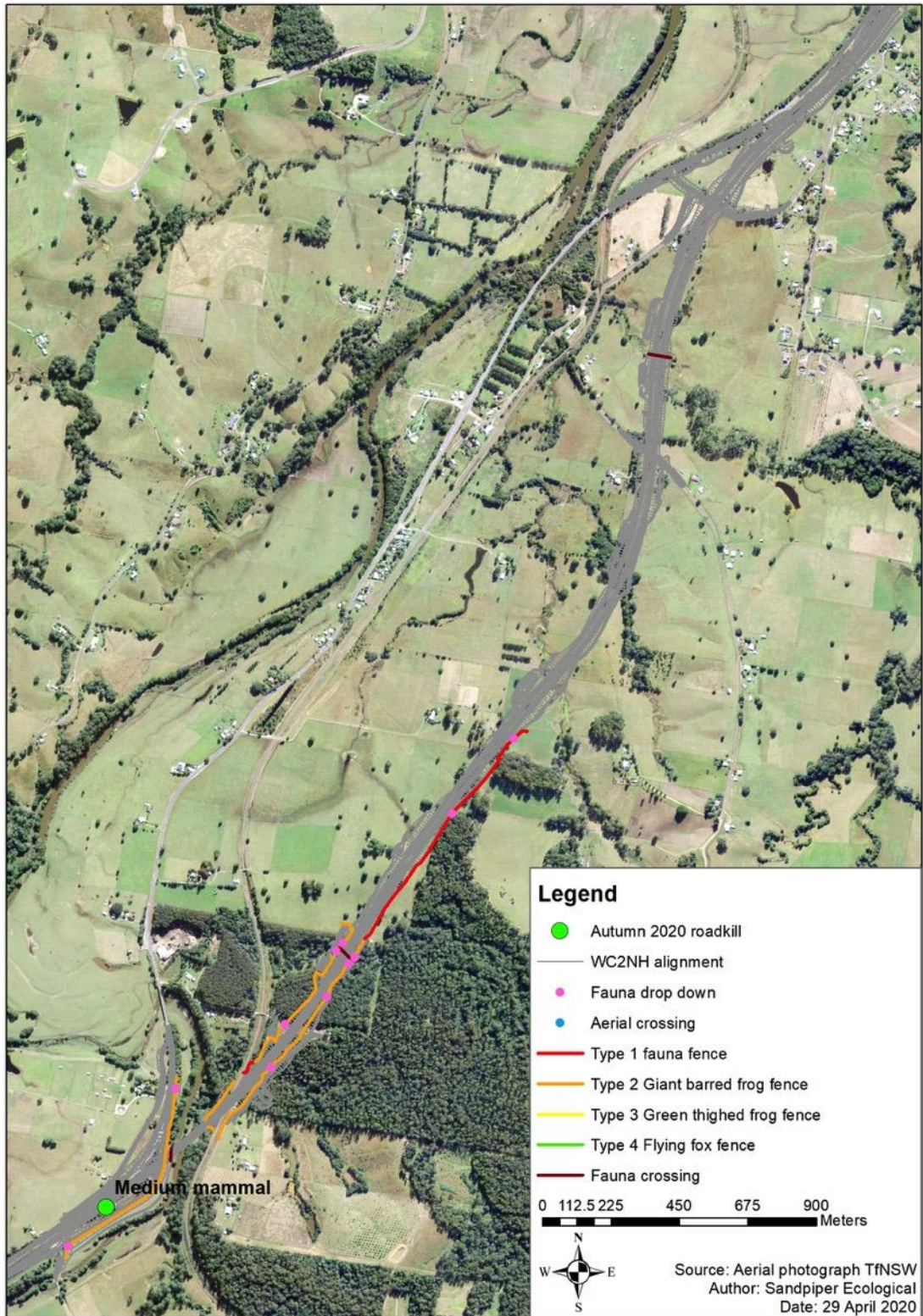


Figure 8: Location of road-killed fauna from April 2020 sample.

4. Discussion

4.1 Autumn 2020

Road-kill monitoring over the entire WC2NH alignment in autumn 2020 indicates that fauna continue to be killed by vehicles 18 months after the entire alignment was open to traffic. However, the number of road-kills recorded in autumn 2020 was the lowest since seasonal sampling commenced in spring 2018. The autumn 2020 total was 13 individuals less than the equivalent sample in 2019 and nine individuals less than the preceding summer 2020 sample. Whilst the result is consistent with lower seasonal road-kill in summer 2020 it may be due to reduced traffic volume associated with COVID-19 restrictions as opposed to an actual decrease in road-strike. Nonetheless, there is limited evidence of a relationship between traffic volume and road-kill abundance (Grilo *et al.* 2015; Clevenger *et al.* 2003).

Despite a reduced number of individuals, the autumn 2020 result is consistent with 2019 when road-kill abundance decreased from summer to autumn (Sandpiper Ecological 2018, 2019). The apparent seasonal effect has been previously attributed to an increase in traffic volume associated with holidays, however, key factors may be season (i.e. breeding and dispersal) and climatic conditions (Coulson 1989; D'Amico *et al.* 2015). If traffic volume is considered to not influence road-kill abundance then the lower number of road-kills in summer and autumn 2020 is encouraging.

Although total road-kill numbers were lower in autumn 2020, the abundance of road-killed wallabies was equivalent to autumn 2019. Drought in 2019 was considered to influence mortality of macropods, and whilst this remains likely, a seasonal pattern of road-kill peaks in winter and summer is emerging. Further sampling is required to confirm if such a trend occurs, and the reasons for such a trend given the noted flexibility in macropod breeding. Wallaby road-kill hotspots occur within the vicinity of Bald Hill Road and Albert Drive. Concern remains about the effect of road-kill on the local red-necked wallaby population in the Albert Drive to upper Warrell Creek area (Sandpiper Ecological 2018 & 2019). Indeed, road-strike has resulted in population level impacts on several species, including medium sized mammals (see Fahrig & Rytwinski 2009; Huijser & Bergers 2000).

Road-kill hotspots identified in autumn 2020 are broadly consistent with previous surveys. The area from Mattick Road to Bald Hill Road and including the Nambucca River and Gumma Floodplain has consistently recorded a high incidence of road-kill (Sandpiper Ecological 2018, 2019). The Gumma Floodplain and the southern end to Albert Drive have been identified as road-kill hotspots in previous years (Sandpiper Ecological 2018, 2019) and previous seasonal samples. Birds and mammals comprised the majority of road-kills in all surveys to date.

4.2 Flying-fox impacts

In autumn 2020 one road-killed flying-fox (*Pteropus* spp.) was recorded on the Nambucca River Bridge. The number of road-killed flying-foxes recorded in autumn 2020 is consistent with lower mortality in summer 2020. The declining incidence of road strike may, in part, be due to lower breeding success of flying-foxes due to drought conditions in 2019. There is no easy solution to road strike at highway bridges and continued road-kill monitoring is required to fully understand the scale of impact.

4.3 Effectiveness of fauna fencing

In contrast to previous samples, the road-kill rate of species expected to be blocked by exclusion fence was equal in areas with and without fence. A cluster of road-kill (5 records) was recorded in a fenced section of alignment north of Mattick Road, between underpasses #2 and #3. A gap in the exclusion fence may occur in that area and careful inspection of the fence will be warranted during the annual inspection, scheduled for June 2020. Importantly, no mortality of target threatened species (expected to be blocked by the fence) was recorded in autumn 2020. Monitoring shows that where present exclusion fence is effective in mitigating road-strike for target species.

4.4 Influence of single observer on results

The use of a single observer during the first two samples did not have an obvious effect on results. As most carcasses remain detectable for at least 2-3 weeks it is likely that individuals missed in weeks one and two would have been recorded in weeks three and four. The absence of an obvious spike in numbers in weeks three and four gives some confidence that the results are indicative of actual road-kill abundance in April 2020.

5. Recommendations

1. Continue seasonal road-kill surveys as per the project ecological monitoring brief.
2. Undertake a foot-based inspection of exclusion fence to search for potential gaps/holes in June 2020, with particular emphasis on the section of fence within 1.8km north of Mattick Road.

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Appendix A – Field Survey Data

Table A1: January (Summer) 2020 roadkill results. Obs = Observers; LA = Luke Andrews, DR = David Rohweder, TR = Trish Rohweder; C'way = Carriageway; P = present; A = absent; xing = crossing

Date	Obs	Start	End	C'way	Species	Sex & age class	Presence of pouch or back young	General location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to xing structure	Proximity to drop-down	If FlyFox, proximity to camp; prox to canopy veg, prox to food
1/4/20	LA	7.45	9:45	SB	Northern brown bandicoot	Adult	Unknown	1000m nth Mattick road	494569	6605467	Y	Present	Good	152	152	NA
				SB	Macropod spp	Unknown	Unknown	550m nth Old coast road	494424	6604083	Y	Absent	NA	NA	NA	NA
				SB	Medium bird	Unknown	NA	Middle Nambucca bridge	493785	6602714	No	Absent	NA	NA	NA	NA
				SB	Australian Magpie	Adult	NA	1200m S Nambucca bridge	493218	6601373	No	Present	Good	NA	NA	NA
				SB	Small snake spp	Unknown	NA	1200m S Nambucca bridge	493223	6601381	No	Present	Good	NA	NA	NA
				SB	Long necked turtle	Adult	NA	1200m S Nambucca bridge	493228	6601384	No	Present	Good	89m to end of fence	NA	NA
				SB	Brushtail possum	Unknown	Unknown	Bald Hill road	492480	6600033	No	Absent	NA	NA	NA	NA
				SB	Medium mammal	Unknown	Unknown	Sth Upper Warrell Creek	489031	6594066	No	Present on one side	Good	NA	NA	NA
				NB	Northern brown bandicoot	Sub adult	Unknown	1200m nth Mattick road	494593	6605610	No	Present	Good	297	297	NA
				NB	Owlet nightjar	Unknown	NA	700m S railway bridge	496637	6609523	No	Present	Good	NA	NA	NA
				NB	Australasian figbird	Unknown	NA	Nambucca River bridge	494191	6603260	No	Absent	NA	NA	NA	NA
				NB	Red-browed finch	Unknown	NA	Vegt median	496629	6609520	Yes	Present	Good	NA	NA	NA
8/4/20	DR	1000	1130	SB	Northern brown bandicoot	Unknown	Unknown		495038	6606407	No	Present	Good	82	288	NA
				SB	Tyto spp	Unknown	NA	Nambucca R bridge	493805	6602715	No	Absent	NA	NA	NA	NA
				SB	Pteropus spp	Unknown	Unknown	Nambucca R bridge	493727	6602572	No	Absent	NA	NA	NA	9.8km; 0.7km; 0.7km
				SB	Duck spp	Unknown	NA	Gumma floodplain bridge, 800m nth bald hill rd	492932	6600872	No	Absent	NA	NA	NA	NA
				NB	Swamp Wallaby	Unknown	Unknown	950m nth Albert drive	491646	6598091	No	Absent	NA	NA	NA	NA
				NB	Laughing	Unknown	NA	400m sth Bald Hill Road	492462	6599625	No	Absent	NA	NA	NA	NA

Date	Obs	Start	End	C' way	Species	Sex & age class	Presence of pouch or back young	General location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to xing structure	Proximity to drop-down	If FlyFox, proximity to camp; prox to canopy veg, prox to food
					kookaburra											
				NB	Tawny frogmouth	Unknown	NA	400m sth Bald Hill Road	492462	6599625	No	Absent	NA	NA	NA	NA
				NB	Macropod spp	Unknown	Unknown	100m nth Bald Hill Road	492505	6600201	No	Absent	NA	NA	NA	NA
15/4/20	DR&TR	946	1100	SB	Red-necked wallaby	Unknown	Unknown	870m nth Mattick rd	494643	6605661	No	Present	Good	357	273	NA
				SB	Cattle egret	Unknown	NA	Nambucca River bridge	493834	6602760	No	Absent	NA	NA	NA	NA
				NB	White-headed pigeon	Unknown	NA	Nambucca River bridge	494182	6603250	No	Absent	NA	NA	NA	NA
				NB	European Hare	Unknown	NA	300m nth Old Coast Road	494390	6603824	No	Absent	NA	NA	NA	NA
				NB	Short-beaked echidna	Unknown	Unknown	900m nth Old Coast Road	494413	6604305	No	Absent	NA	NA	NA	NA
22/4/20	DR&TR	1040	1130	NB	Common brushtail possum	Unknown	Unknown	2km nth Mattick rd	494971	6606359	No	Present	Good	166	210	NA
				NB	Medium mammal	Unknown	Unknown	2.2km nth Mattick rd	495229	6606817	No	Present	Good	359	103	NA

Appendix 13 Road Kill Monitoring Report – Winter (July) 2020 monitoring.

Pacific Highway Upgrade Warrell Creek to Nambucca Heads

Operational phase road-kill monitoring –
winter 2020.

Sandpiper Ecological

1/94 Main Street Alstonville

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Final Report
2 September 2020

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Report prepared for:

Transport for NSW

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Disclaimer:

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1. Introduction

1.1 Background

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

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

- Fauna fencing to exclude fauna from the road corridor and to guide fauna towards connectivity structures.
- Fauna drop-down structures (escape ramps) along the fauna fencing.
- Fauna connectivity structures, including underpasses, bridges, rope bridges and glide poles.

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

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

Sandpiper Ecological Surveys (SES) has been engaged by Transport for NSW (TfNSW) to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal road-kill surveys over the entire upgrade length.

Monitoring of road-killed fauna is a requirement of the approved WC2NH koala (*Phascolarctos cinereus*), spotted-tailed quoll (*Dasyurus maculatus*) and grey-headed flying-fox (*Pteropus poliocephalus*) management plans and the Ecological Monitoring Program (RMS 2018a). Priority species for road-kill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog. Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018 and Sandpiper Ecological commenced seasonal monitoring in October 2018. The

results of monitoring in 2018 and 2019 were analysed and discussed by Sandpiper Ecological (2018, 2019). The following report covers the July (winter) 2020 monitoring event and includes the entire WC2NH alignment. Previous road-kill monitoring was conducted by GeoLink (2018a, b, c, d).

The aim of road-kill monitoring is to:

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

1.2 Study area

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

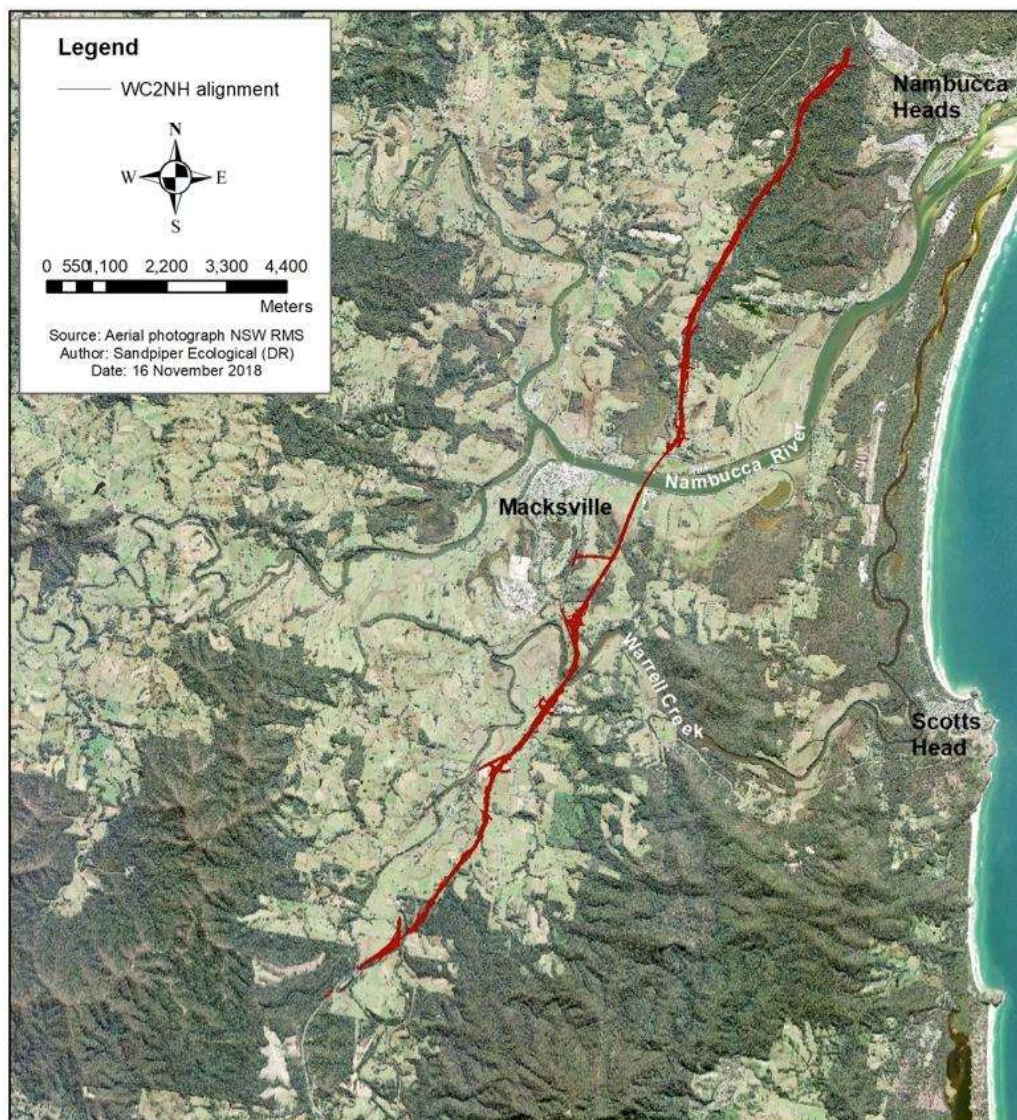


Figure 1: Location of the WC2NH alignment.

2. Methods

2.1 Road-kill surveys

Surveys were conducted by a two-person team from a vehicle driven at 80-90km/hr in the left lane. The vehicle was equipped with an amber (flashing) light and warning sign (Plate 1). The team consisted of a driver, and ecologist, with experience identifying road-killed fauna. Surveys were undertaken weekly and commenced within three hours of sunrise. During each survey, all personnel scanned the road surface and road shoulder for fauna. When road-killed fauna were detected the vehicle was pulled onto the shoulder/parking bay and the ecologist inspected the subject animal from the closest perpendicular position behind wire rope. Fauna that could not be identified immediately were photographed and images sent to colleagues for assessment. Carcasses were removed from the road surface when safe to do so.



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

Data collected on each road-kill included (Appendix A1):

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

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation Act (EPBC) 1999* and/or the *Biodiversity Conservation Act (BC) 2016*, included, where possible: sex and age (juvenile/adult); presence of pouch young if applicable; presence of flightless young (flying-foxes); distance to a fauna connectivity structure; distance to a drop-down structure if applicable; damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or roadside vegetation.

All road-kills were cross referenced with the previous survey results to identify possible duplicates. Using, at a minimum, one team member consistently across all surveys, GPS coordinates of each specimen, looking at carcass age and location on the carriageway, and detailed location description

assisted with identification of duplicates. Distance to connectivity structure, and distance to escape structure was determined via GIS. All other data were uploaded to an iPad in the field.

2.2 Data summary and analysis

Data from the July 2020 survey were uploaded to Microsoft Excel. The July data were compared with results from April 2020 to identify duplicate records. Graphs have been produced showing the total number of road-kills in July and the number of road-kills in different fauna groups each week of the survey. The location of July road-kills was overlaid on the WC2NH alignment to show distribution, and the data compared to road-kills recorded in summer, autumn, winter and spring 2018 and 2019, and January and April 2020 (Sandpiper Ecological 2018, 2019, 2020; Table 2).

3. Results

3.1 Weather conditions

Weather conditions in the 24hrs preceding each sample were conducive to fauna movement and retention of carcasses (Table 1). Rain occurred in the 24hr period prior to the second, third and fourth samples (Table 1).

Table 1: Weather conditions in the 24hrs preceding each sample event. *preceding 24hours. Data obtained from BoM Bellwood and Coffs Harbour weather stations.

Date	Average Relative Humidity (%)	Rainfall (mm)*	Max Temperature (°C)	Max Wind Speed (km/h)	Visibility during survey	Rain during survey
2/7/20	60	0	23.1	N/A	Good	Nil
9/7/20	95	1	19.0	19	Good	Nil
16/7/20	50	3	20.7	48	Good	Nil
28/7/20	57	28	20.3	31	Good	Nil

3.2 Species richness and abundance

A total of 28 road-killed fauna were recorded during the July 2020 sample period. This included eight native species and seven fauna groups (Table A1, Appendix A). Mammals were the most diverse group represented with four species and five groups recorded. Four species and two groups of birds were also recorded.

Macropods were the most frequently detected group with eight red-necked wallabies, one swamp wallaby and one medium macropod recorded. Bandicoot followed, with three records (Table 2). Degradation, and location of carcasses on the carriageway made identification to species level difficult in some cases. No grey-headed flying-foxes or any new species were recorded. Of the 28 road-kill records, 19 (68%) were individuals expected to be blocked by exclusion fence. The remaining nine records, predominantly birds, were species that readily move through or over exclusion fencing.



Plate 2: A road-killed northern brown bandicoot (*Isoodon macrourus*) (top) and a laughing kookaburra (*Dacelo novaeguineae*) (bottom), recorded during the July 2020 survey.

Table 2: Species of vertebrate fauna recorded during seasonal road-kill surveys throughout the operational phase of the WC2NH upgrade. * denotes threatened species; ** = stage 2a only; Sum = summer; Aut = autumn; Win = winter; Spr = spring.

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Total
Birds												
Australian magpie	6	1		1				2	2	1		13
Grey butcherbird			1									1
Magpie-lark	2		1		1		1		1		1	7
Australian white ibis			1						1			2
Cattle egret				1						1		2
Little pied cormorant					1							1
Buff-banded rail					1							1
Purple swamphen	3		2	2		1		2	3		1	14
White-headed pigeon										1		1
Crested pigeon	2											2
Galah	7				1			3				11
Rainbow lorikeet								1				1
Eastern grass owl*				1								1
Australian boobook			1	1			1				1	4
Masked owl*	1				1		1					3
Eastern barn owl			11	3		1	5	2	1			23
Tawny frogmouth	1	3	1	2		6		4		1		18
Australian owlet-nightjar					1					1		2
Laughing kookaburra	3		2	1		2		3	1	1	2	15
Forest kingfisher	1											1

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Total
Australian wood duck	20			2	2		1	2				27
Pacific black duck	2		1									3
Whistling kite				1								1
Black-shouldered kite					1	1						2
Torresian crow					1							1
Pied currawong				1								1
Black-faced cuckoo-shrike								1				1
Dollarbird					2							1
Green catbird					1							1
Australasian figbird										1		1
Black bittern*						1						1
Eastern yellow robin						1						1
Pheasant coucal							1		1			2
Masked lapwing							1					1
Welcome swallow								1				1
Red-browed finch										1		1
Duck spp.						1				1		2
Tyto spp.										1		1
Small bird								2				2
Medium bird				1	2	2	2	2	6	1	1	16
Unidentifiable bird	5	4	1		3						2	13
Total birds	53	8	22	17	18	16	13	25	16	11	8	199

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Total
Mammals												
Short-beaked echidna				3				2		1	2	8
Black flying-fox	2	1			7	1	1					11
Grey-headed flying-fox*					8			5	2			15
<i>Pteropus</i> spp.					3	8	1		1	1		14
Common brushtail possum			1	2						1		4
<i>Trichosurus</i> spp.									1	1	1	3
Common ringtail possum					1			1				2
Eastern grey kangaroo				3			1					4
Red-necked wallaby			6		8	2	8	3	7	1	8	44
Swamp wallaby	2	1		1		1	1			1	1	8
Wallaby spp.						2			3			5
Macropod spp.	3		2	1	1					2	1	10
Northern brown bandicoot	1		1		1	1	1	2	2	3	3	15
Bandicoot spp.						1		4				5
<i>Chalinolobus</i> spp. (microbat)				1								1
Microbat spp.					1							1
Rodent spp.						2						2
Small mammal					2						1	3
Medium mammal				2	4	2	4	5	2	2	2	26
Large mammal				1	1			1			1	4
Unidentified Mammal	1			3								4

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Total
Total mammals	10	2	10	17	36	20	17	23	18	13	20	166
Reptiles												
Common blue-tongued skink	1			2	1				2			6
Carpet python	1			2	1	1		1				6
Common tree snake	1	2						1				4
Eastern long-neck turtle	1			6						1		8
Macquarie river turtle	5	1					1					7
Unidentified <i>Chelidae</i> spp.	6							1				7
Red-bellied black snake	1											1
Eastern water dragon	1			1								2
Blackish blind snake						1						1
Yellow-faced whipsnake				1								1
Unidentified reptile								2		1		3
Total reptiles	17	3	0	12	2	2	1	5	2	2	0	46
Frogs												
Green tree frog	2											2
Striped marsh frog	3											3
Medium frog				3								3
Large frog				1								1
Total frogs	5	0	0	4	0	0	0	0	0	0	0	9
Introduced species												
Cat	1											1

Species	Sum 17/18 **	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Total
European fox	3	1	1	2	1	1	2					11
European hare	2			1						1		4
Rabbit	1											1
Black rat	1					1						2
House mouse					1							1
Rock pigeon			1	1								2
Domestic goose				1								1
Total introduced species	8	1	2	5	2	2	2	0	0	1	0	23
Total	93	14	34	55	57	40	33	53	36	27	28	470

Over the July 2020 sample period the number of road-kill recorded each week declined from 14 in week 1 to six in week 2, one in week 3, and then increased to seven in week 4 (Figure 2).

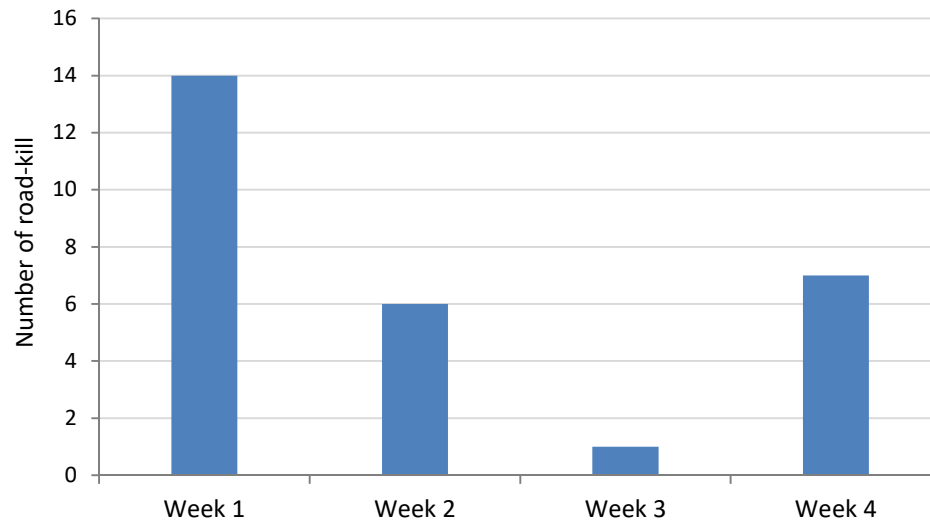


Figure 2: Number of road-kills recorded in each sample week during the July 2020 (winter) sample period.

The abundance of road-killed fauna in the two vertebrate groups varied during the sample period (Figure 3). Mammals were recorded in all weeks, and birds in three. The number of road-killed mammals went from nine in week one to five in week two, one in week three, and increased to five in week four. The number of road-killed birds decreased from five in week one to one in week two, none in week three, and increased to two in week four. No reptiles or amphibians were detected in July 2020 monitoring.

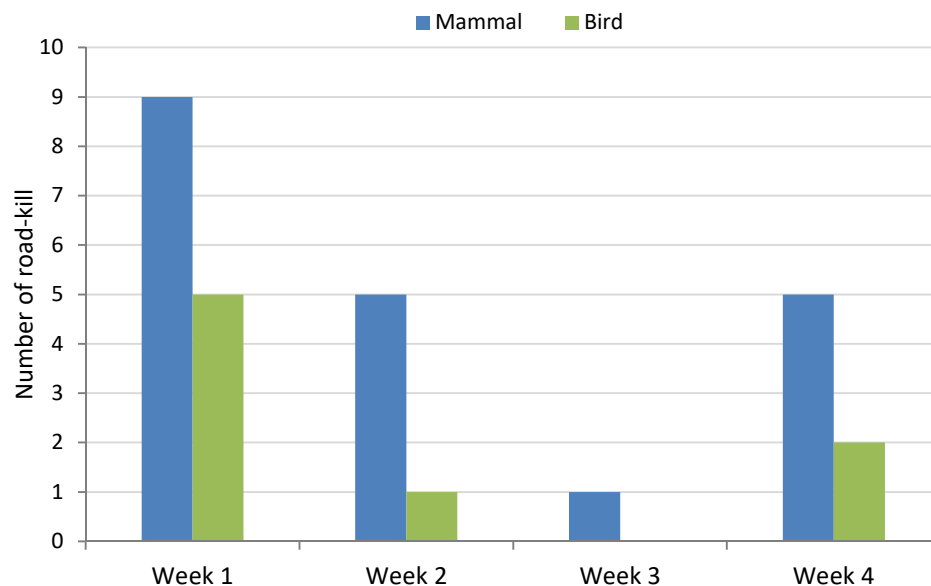


Figure 3: Number of road-killed fauna from three vertebrate classes during each sample week in July 2020.

The number of road-killed flying-foxes has varied over the monitoring period (Figure 4). Black flying-fox, grey-headed flying-fox and total number of flying-foxes peaked during summer 2019 with seven, eight and 18 road-kills respectively. Since then, numbers have fluctuated, with no flying-foxes recorded in winter 2020 (Figure 4).

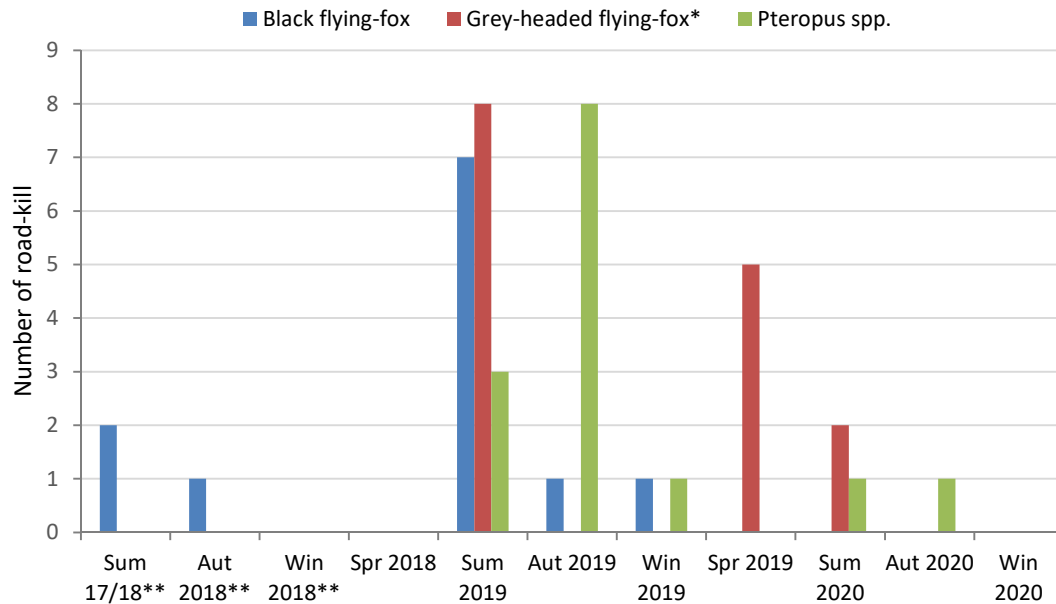


Figure 4: Number of road-killed flying-foxes from all sample periods. * denotes threatened species. **Stage 2a only.

3.1.3 Opportunistic road-kill information

No opportunistic road-kill was recorded within the sample month (July).

3.1.4 Distribution of road-kill

In July 2020, road-killed fauna was recorded over the entire WC2NH alignment (Figures 5-8). Almost half of the records (46%) were situated between Mattick Road and Bald Hill Road, with a further 32% occurring south of Bald Hill Road, and the remainder (i.e. 22%) north of Mattick Road in the section entirely fenced with type 1 and 3 exclusion fence. The section between Mattick Road and Bald Hill Road traverses predominantly cleared land and includes the Nambucca River and Gumma floodplain. Approximately 50% of that area is fenced with Type 1 and Type 4 exclusion fence.

In July 2020, 15 road-kills were recorded in areas without exclusion fence, 11 in areas with an exclusion fence and two in areas with an exclusion fence on only one side of the carriageway (Figures 5-8). Records were classified as occurring within a fenced area if fence occurred adjacent to the record regardless of whether the record was near the start/end of a fenced section. Five records (18% of all records) in sections with fence were species that are expected to be blocked by the fence (i.e. medium and large mammals). Twelve records (43% of all records) in sections without fence and two (7%) records in sections fenced on one side of the carriageway were of species expected to be blocked by exclusion fence if present on both sides of the carriageway.

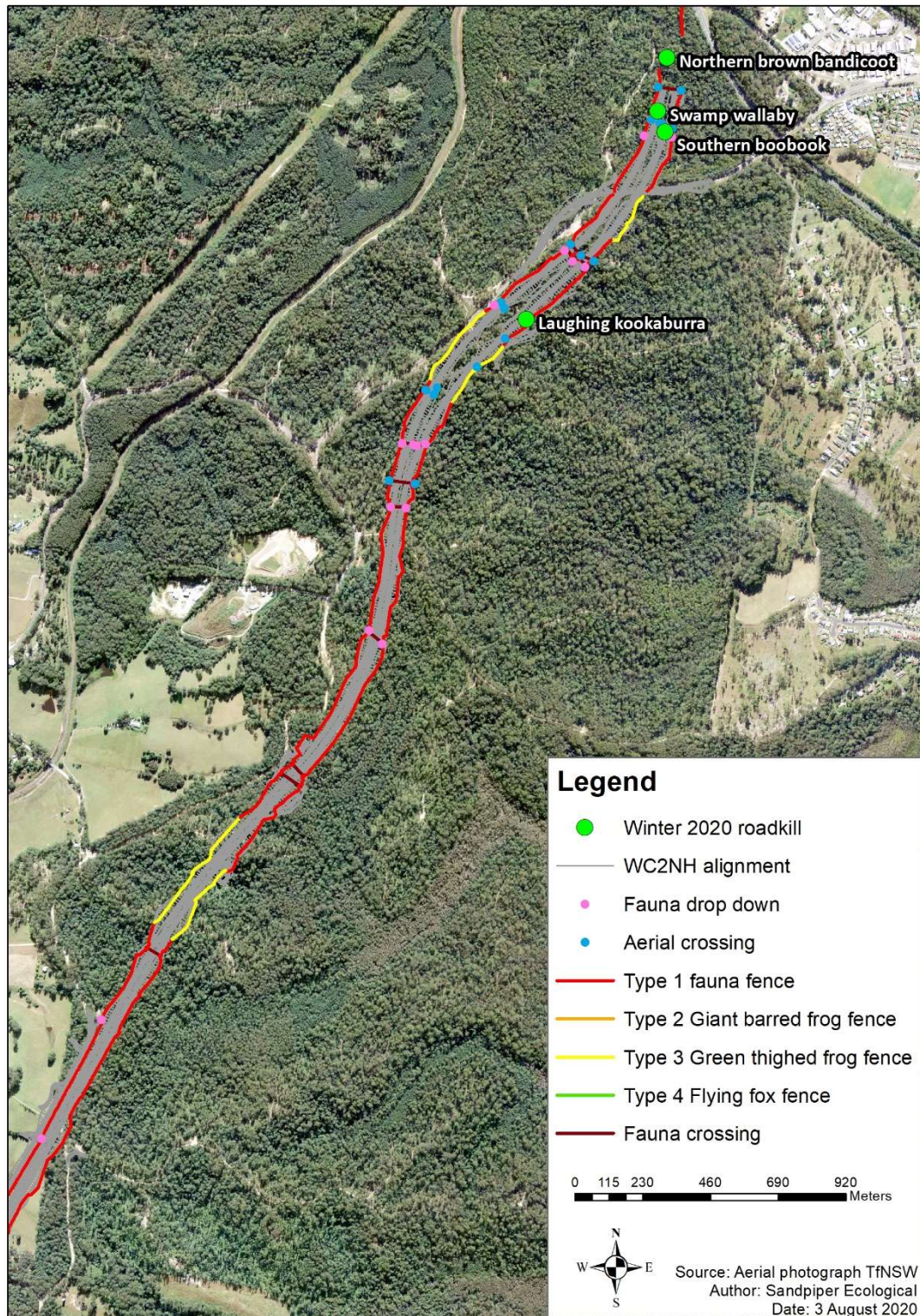


Figure 5: Location of road-killed fauna from July 2020 sample.

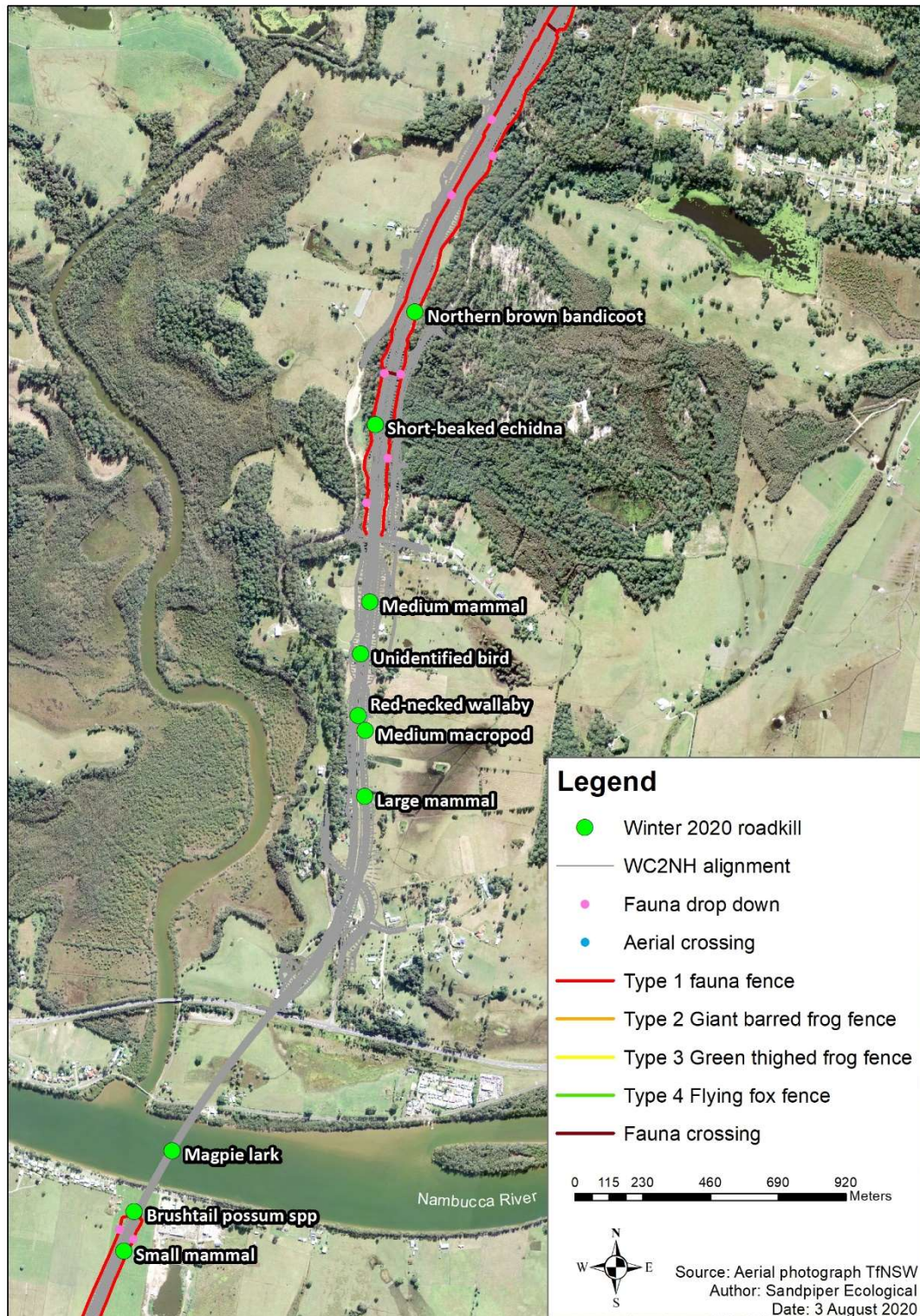


Figure 6: Location of road-killed fauna from July 2020 sample.

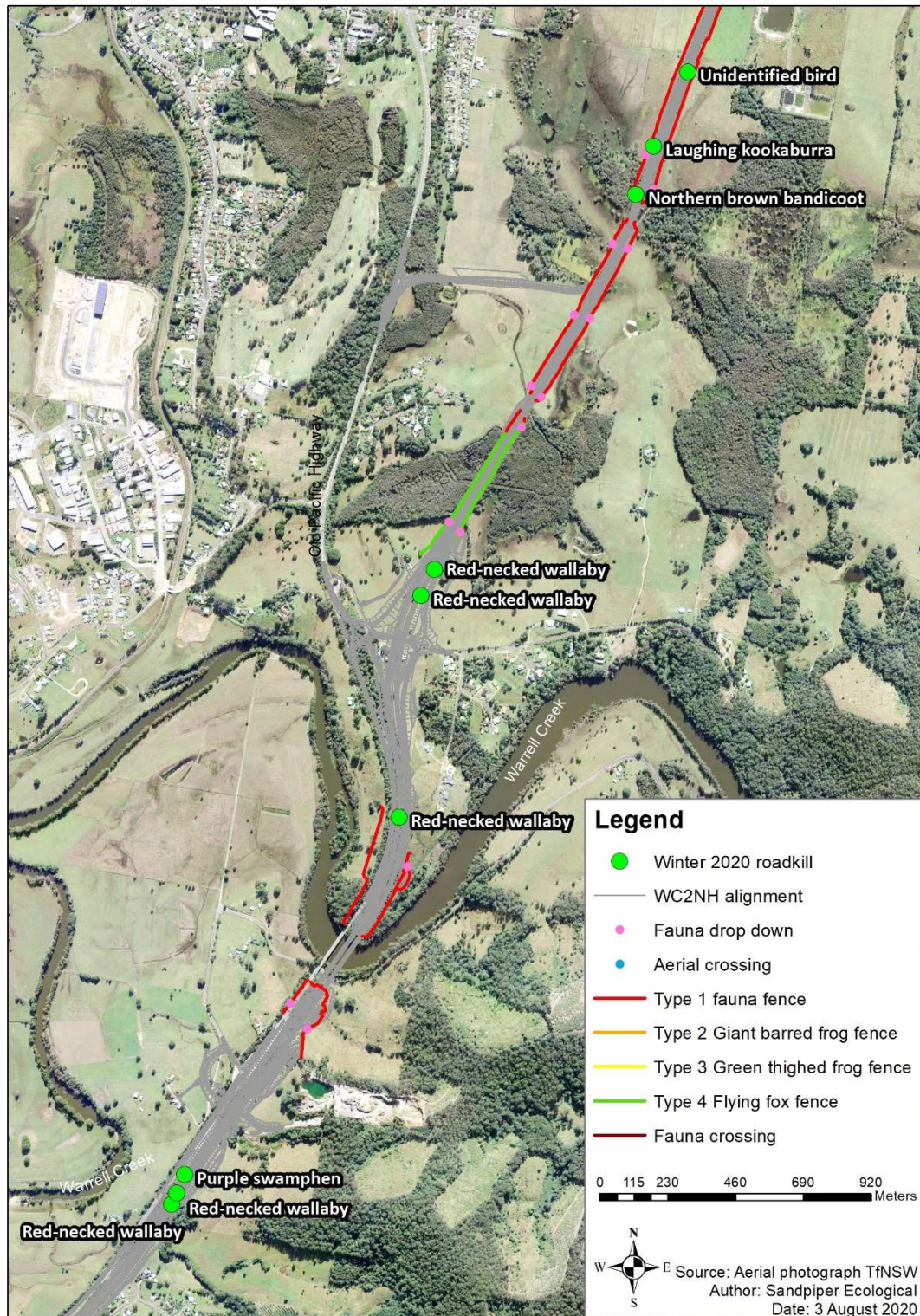


Figure 7: Location of road-killed fauna from July 2020 sample.

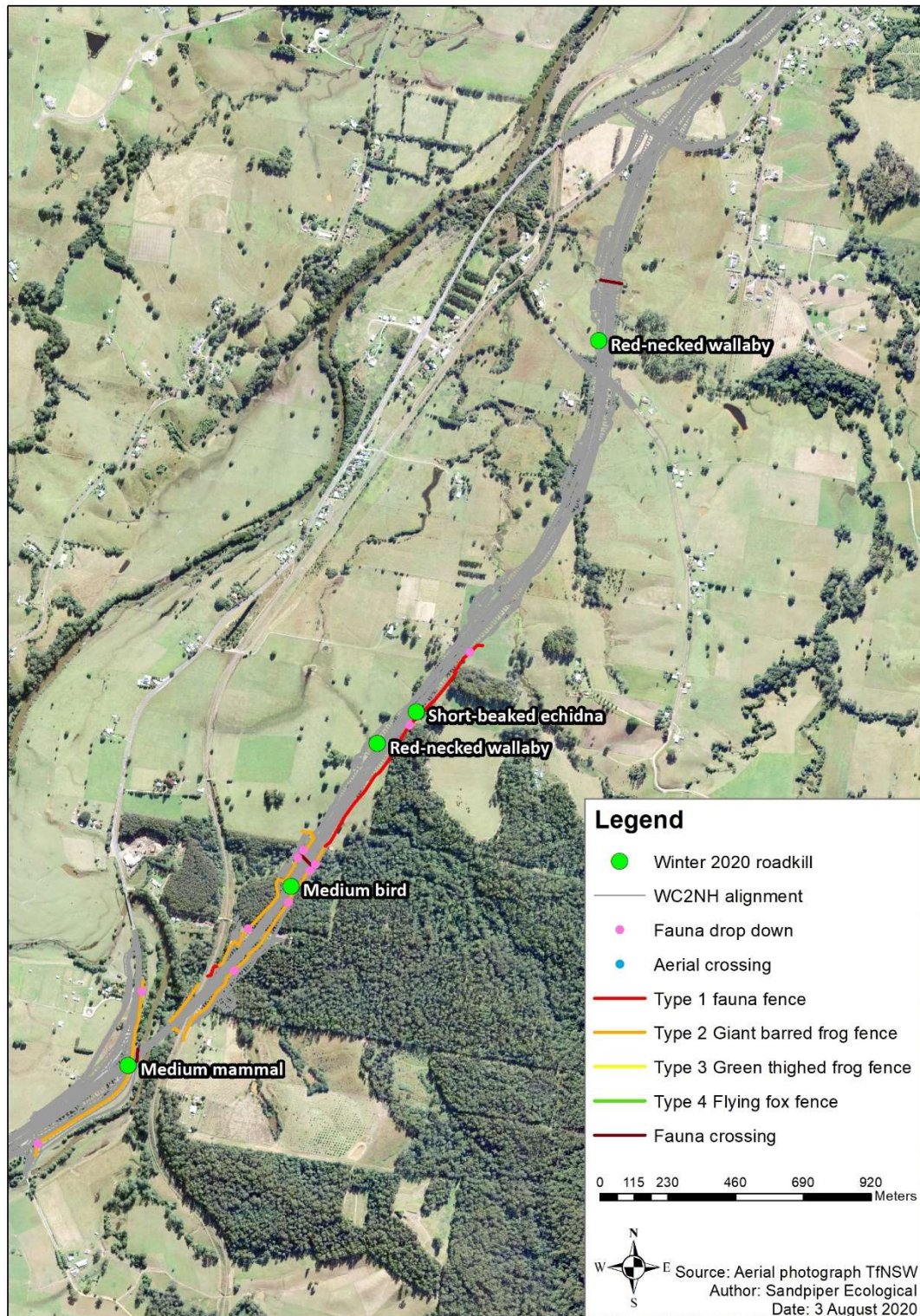


Figure 8: Location of road-killed fauna from July 2020 sample.

4. Discussion

4.1 Winter 2020

Road-kill monitoring over the entire WC2NH alignment in winter 2020 indicates that fauna continue to be killed by vehicles two years after the entire alignment was open to traffic. However, the number of road-kills recorded in winter 2020 was equivalent to Autumn 2020, which was the lowest road-kill sample period since seasonal sampling commenced in spring 2018. The winter 2020 total was also five individuals less than the equivalent sample in 2019. Importantly, no threatened species listed under the *Environment Protection and Biodiversity Conservation Act 1999*, or the *Biodiversity Conservation Act 2016* were recorded during the winter 2020 survey.

A decreasing trend in road-kill numbers from spring and summer to autumn and winter is apparent across all years (Sandpiper Ecological 2018, 2019). Alike previous surveys, the key factors contributing to this seasonal effect are season (i.e. in winter fauna tend to be less mobile compared to spring/summer when most species breed and disperse) and climatic conditions (Coulson 1989; D'Amico *et al.* 2015), as well as fluctuations in traffic volume. Mixed results associated with the relationship between traffic volume and road-kill abundance are evident (Grilo *et al.* 2015; Clevenger *et al.* 2003; Jacobson *et al.* 2016;). If traffic volume is considered to not influence road-kill abundance then the lower number of road-kills in summer, autumn and winter 2020 compared to equivalent surveys in 2019 is encouraging.

Although total road-kill numbers were lower in winter 2020, the abundance of road-killed macropods in winter 2020 (10 individuals) were similar or equivalent to high counts in summer 2019 (nine individuals), summer 2020 (10 individuals) and winter 2019 (nine individuals). Drought in 2019 was considered to influence mortality of macropods, and whilst this remains likely, a seasonal pattern of road-kill with peaks in winter and summer is emerging. Further sampling is required to confirm the trend and identify causal factors. The noted flexibility in macropod breeding season suggests that whilst breeding may be a contributing factor it is unlikely to be the sole factor. Macropod road-kill hotspots occur in vicinity of Bald Hill Road and Albert Drive. Concern remains about the effect of road-kill on the local red-necked wallaby population in the Albert Drive to upper Warrell Creek area (Sandpiper Ecological 2018 & 2019). Indeed, road-strike has resulted in population level impacts on several species, including medium sized mammals (see Fahrig & Rytwinski 2009; Huijser & Bergers 2000).

Road-kill hotspots identified in winter 2020 are broadly consistent with previous surveys. The area from Mattick Road to Bald Hill Road and including the Nambucca River and Gumma Floodplain has consistently recorded a high incidence of road-kill (Sandpiper Ecological 2018, 2019). The Gumma Floodplain and the southern end to Albert Drive have been identified as road-kill hotspots in previous years (Sandpiper Ecological 2018, 2019) and previous seasonal samples. Birds and mammals comprised the majority of road-kills in all surveys to date.

4.2 Flying-fox impacts

In winter 2020 there were no road-killed flying-foxes recorded, which is consistent with lower mortality in summer and autumn 2020. The declining incidence of road strike may, in part, be due to lower breeding success of flying-foxes due to drought conditions in 2019. The winter 2020 results may also be due to winter dispersal of camps (Churchill, 2008).

4.3 Effectiveness of fauna fencing

Results obtained in winter 2020 are consistent with previous seasonal samples (excluding autumn 2020). The road-kill rate of species expected to be blocked by the fence are lower in areas with exclusion fence than areas without exclusion fence. Importantly, no mortality of target threatened species (expected to be blocked by the fence) was recorded in winter 2020. Monitoring shows that where present, exclusion fencing is effective in mitigating road-strike for target species.

5. Recommendations

Recommendations relating to the winter 2020 operational phase road-kill monitoring are summarised in Table 3.

Table 3: Recommendations following the winter 2020 operational phase road-kill monitoring and Transport for NSW response.

Number	Recommendation	Transport for NSW Response
1.	Continue seasonal road-kill surveys as per the project ecological monitoring brief.	Agree and adopted.

6. References

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- Geolink (2018c). *Roadkill monitoring summary report: winter (July) 2018*. Letter report prepared for NSW Roads and Maritime Services.
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- Roads and Maritime (2018). *Warrell Creek to Nambucca Heads Stage 2 Ecological Monitoring Program*. Report prepared by NSW Roads and Maritime Services.
- Sandpiper Ecological (2018). *Pacific Highway Upgrade, Warrell Creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2018*. Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2019). Pacific Highway Upgrade, Warrell Creek to Nambucca Heads: operational phase road-kill monitoring- annual report 2019. Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2019b). Pacific Highway Upgrade, Warrell Creek to Nambucca Heads: operational phase road-kill monitoring- summer (January) 2019. Report prepared for NSW Roads and Maritime Services.

Appendix A – Field Survey Data

Table A1: July (winter) 2020 roadkill results. Obs = Observers; LA = Luke Andrews, DR = David Rohweder, NM = Nirvarna Makings, TR = Trish Rohweder; xing = crossing

Date	Observers	Start time	End time	Carriageway	Species	Sex & age class	Presence of pouch or back young	RK general location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to xing structure	Proximity to drop-down	If flying-fox, proximity to camp; prox. to canopy veg, prox. to food
2/07/2020	DR&TR	955	1200	SB	Sth boobook (prob)	Unknown	Nil	200m nth OCR	497462	6610462	No	Present	Good	NA	NA	NA
				SB	Laughing kookaburra	Unknown	Nil	560m nth OCR	496991	6609826	No	Present	Good	NA	NA	NA
				SB	Medium mammal	Unknown	Nil	200m Sth Mattick Rd	494446	6604541	No	Absent	NA	NA	NA	NA
				SB	Large mammal	Unknown	Nil	Macksville exit ramp	494429	6603881	No	Absent	NA	NA	NA	NA
				SB	Magpie lark	Unknown	Nil	NR bridge	493775	6602678	No	Absent	NA	NA	NA	NA
				SB	Small mammal	Unknown	Nil	Just Sth NR bridge	493612	6602338	No	Absent	NA	NA	NA	NA
				SB	Unid bird	Unknown	Nil	Sth NR bridge	493452	6601973	No	Absent	NA	NA	NA	NA
				SB	SB echidna	Unknown	Nil	600m nth Butchers Ck	490191	6595404	No	East side	Good	NA	NA	NA
				SB	Medium mammal	Unknown	Nil	Railway bridge	489213	6594204	No	Absent	NA	NA	NA	NA
				NB	Red-necked wallaby	Unknown	Nil	100m nth Rosewood Rd	490811	6596664	No	Absent	NA	NA	NA	NA
				NB	Red-necked wallaby	Unknown	Nil	600m Sth Bald Hill Rd	492472	6599442	No	Absent	NA	NA	NA	NA
				NB	Laughing kookaburra	Unknown	Nil	200m nth floodplain bridge	493335	6601721	No	Present	Good	NA	NA	NA
				NB	Possible Brushtail possum	Unknown	Nil	100m Sth NR bridge	493646	6602472	Yes	Present	Good	At end of fence	At end of fence	NA
				NB	Swamp wallaby	Unknown	Nil	300m nth OCR	494378	6693856	No	Present	Good	81m	95m	NA
9/7/20	LA & NM	1000	1200	SB	Medium macropod	Unknown	Nil	Macksville exit ramp	494430	6604105	No	Absent	NA	NA	NA	NA
				SB	Red-necked wallaby	Unknown	Nil	610M s Mattick road	494407	6604156	No	Absent	NA	NA	NA	NA
				SB	Medium bird	Unknown	Nil	200M n Cockburns lane	489766	6594812	No	Absent	NA	NA	NA	NA
				NB	Red-necked wallaby	Unknown	Nil	730N Cockburns lane	490060	6595296	No	East side	Good	NA	NA	NA
				NB	Echidna	Unknown	Nil	380M n Mattick road	494465	6605144	No	Present	Good	177m	121m	NA
				NB	NB Bandicoot	Adult	Nil	470M n old coast rd	497468	6610715	No	Absent	NA	NA	NA	NA
16/07/2020	LA & NM	800	930	SB	Red-necked wallaby	Adult	Nil	Just before Williamsons ck bridge	491699	6598128	No	Absent	NA	NA	NA	NA
28/7/20	DR & LA	930	1130	SB	NB bandicoot	Adult	Nil	700M N Mattick RD	494600	6605526	Yes	Present	Good	216	216	NA
				SB	Red-necked wallaby	Adult M	Nil	200M n bald hill road	494600	6605526	No	Absent	NA	NA	NA	NA
				SB	Red-necked wallaby	Adult M	Nil	100M n bald hill road	492546	6600195	No	Absent	NA	NA	NA	NA
				SB	Red-necked wallaby	Adult	Nil	100M N Williams creek	497515	6598167	No	Absent	NA	NA	NA	NA

Date	Observers	Start time	End time	Carriageway	Species	Sex & age class	Presence of pouch or back young	RK general location	Easting	Northing	Cleared off Rd (Y/N)	Fauna fence P/A & proximity	Fence condition	Proximity to xing structure	Proximity to drop-down	If flying-fox, proximity to camp; prox. to canopy veg, prox. to food
				NB	Purple swamp hem	Adult	Nil	200M S quarry access road	491743	6598229	No	Absent	NA	NA	NA	NA
				NB	NB bandicoot	Adult	Nil	Floodplain Bridge 2	493275	6601557	Yes	Present	Good	25m to bridge	63m	NA
				NB	Unid bird	Unknown	Nil	400M s Mattick road	494415	6604365	No	Present	Good	NA	NA	NA