Transport for
New South Wales

Warrell Creek to Nambucca Heads

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

Transport for New South Wales | March 2024

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

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

SANDPIPER ECOLOGICAL SURVEYS

March 2024
Final Report

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1 Introduction

In 2015, Transport for New South Wales (formerly Roads and Maritime Services) NSW, in conjunction with Acciona Ferrovial Joint Venture (AFJV), commenced the Upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads (WC2NH). The WC2NH project was opened to traffic in two stages: stage 2a - 13.5km section from Lower Warrell Creek Bridge to Nambucca Heads opened on 18 December 2017; and stage 2b 6.25km section from the southern end of the project to the Lower Warrell Creek bridge opened in late June 2018. The Upgrade included several road-kill mitigation measures to minimise vehicle collisions with native wildlife. The types of structures constructed to mitigate road-kill included:

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

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

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

Sandpiper Ecological Surveys (SES) has been engaged by Transport for NSW (TfNSW) to deliver the WC2NH operational ecological and water quality monitoring program, which includes seasonal road-kill surveys over the entire upgrade length. Monitoring of road-kill is a requirement of the approved WC2NH koala, spotted-tailed quoll and grey-headed flying-fox management plans and the Ecological Monitoring Program (RMS 2018). Priority species for road-kill surveys are grey-headed flying-fox, koala, spotted-tailed quoll, and giant barred frog (*Mixophyes iteratus*). Monitoring is required for the first five years of operation and includes weekly surveys for the first 12 weeks of operation and four surveys (at weekly intervals) each season thereafter. Seasonal surveys are scheduled for January (summer), April (autumn), July (winter) and October (spring). Due to the staged opening of the project, monitoring of stage 2a commenced in December 2017 with monitoring of stage 2b commencing in July 2018. The 12-week monitoring period for stage 2b ended on 30 September 2018. Sandpiper Ecological commenced monitoring in October 2018, making the Winter 2023 survey the conclusion of the five-year operational monitoring.

The aim of road-kill monitoring is to:

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

The following report details the findings of the Winter 2023 sample, summarises findings from year five (2023) operational monitoring, and discusses the results in light of the monitoring aims and previous reports.

2 Methods

2.1 Study area

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

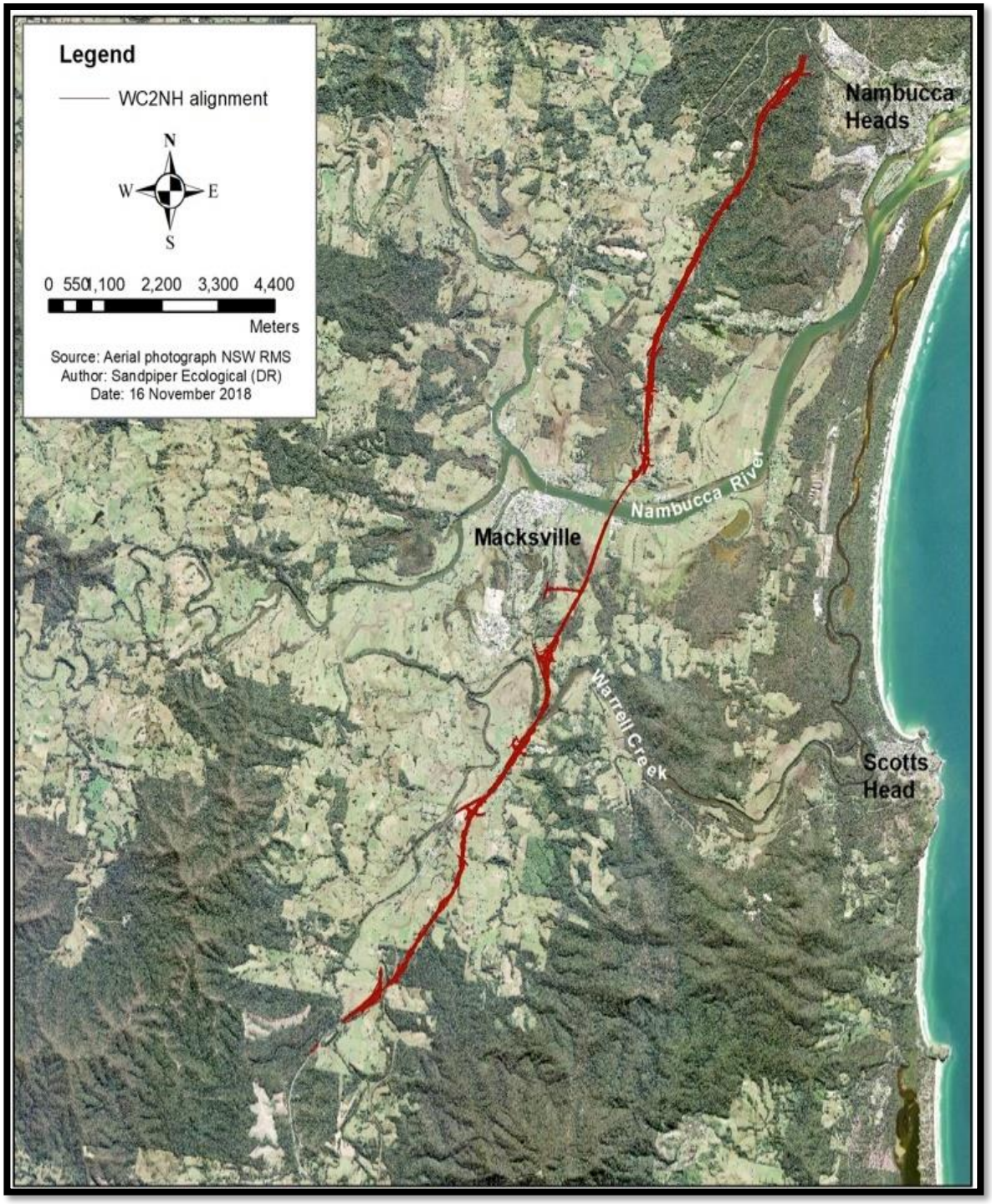

Figure 1: Location of the WC2NH alignment.

2.2 Road-kill surveys

Prior to the Autumn 2021 monitoring event the road mortality survey method was revised to ensure compliance with the updated TfNSW Traffic Control at Worksites Manual. The updated guidelines require vehicles to be parked 3 m from (& behind) a wire rope barrier, 11 m from the fog line if there is no wire rope barrier, and pedestrians to walk 3 m behind the wire rope. These distance restrictions could not be achieved using the former method which required a vehicle to pull off the highway each time a fauna mortality was observed.

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

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

Potential target species, that is spotted-tailed quoll, koala, grey-headed flying-fox, or giant barred frog, were inspected more closely from a safe location. At the end of each survey, the data were uploaded as a CSV file from Australia Topo maps application and recorded into Microsoft Excel on a desktop computer for further analysis.

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

Data collected on each road-kill included:

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

Data collected for threatened species listed on the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* and/or the *Biodiversity Conservation (BC) Act 2016*, included, where possible: sex and age (juvenile/adult); the presence of pouch young if applicable; the presence of flightless young (flying-foxes);

distance to a fauna connectivity structure; distance to a drop-down structure if applicable; damage to fauna fencing; weather conditions; if the animal was a flying-fox – distance to the nearest camp, distance to nearest canopy vegetation, and presence of flowering food trees in median or road-side vegetation.

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

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

2.3 Data summary and analysis

Mapping software QGIS was used to identify possible duplicates in the road-kill data. This was achieved by uploading all road-kill data to QGIS and cross-referencing it with the data from the previous week and/or season (i.e., autumn 2023). The consistent use of at least one team member, GPS coordinates, and carcass descriptions helped in identifying duplicates.

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

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

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

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

2.3.1 Statistical analysis

The primary aim of statistical analysis was to determine if there is a statistical difference in the frequency of road-kill between fenced and unfenced sections of the alignment. Road-kill data were summarised by removing species/groups that would not, under normal circumstances, be stopped by exclusion fence from

accessing the road alignment e.g. birds, small reptiles, frogs, small mammals and flying-foxes. Species/groups of fauna likely to be stopped by exclusion fence and therefore included in the analysis are listed in Table 1. Introduced species were included in the analysis. Freshwater turtles were included, as an exclusion fence with a ground return should stop this group. Juvenile lace monitors could move through exclusion fence; however, individuals of that size are rarely recorded in open habitats, and that species has been included.

The location of each road-kill in relation to the exclusion fence was determined by overlaying road-kill records on a plan of exclusion fence extent using QGIS. If exclusion fence occurred on one side only the record was classified as "No fence". Further, road-kill records on bridges were considered unfenced unless exclusion fence extended 100 m beyond both ends of the bridge. Data were summed across all samples and divided into "fenced" and "unfenced." Expected proportions were based on the proportion of the highway with fence on both sides ("fenced") and proportion with a single fence, or no fence ("no fence"). The proportion of fenced verses unfenced was 0.55 to 0.45. Data were analysed using a two-tailed G-test as per the equation of McDonald (2013).

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

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

2.4 Exclusion fence inspection

Four persons traversed the exclusion fence on foot on 20 and 21 August 2023. Sections of exclusion fence inspected included: type 1 chain mesh fence with floppy top feature (18.03km), Type 3 frog fence combined with floppy top (1.32 km) and Type 4 flying-fox fence (1km). The exclusion fence was assessed in relation to condition, structural integrity, overhanging vegetation and vine growth. Any issues were recorded on a datasheet, and the location logged using Australia topo maps with a written description of the issue and location.

3 Results

3.1 Winter 2023 sample

3.1.1 Weather condition

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

Table 2: Weather conditions were recorded at 9 am on each sample day in July 2023. Relative humidity and temperature data were obtained from the Bureau of Meteorology Coffs Harbour Airport (station 059151) with rainfall data from the Bellwood station (059150).

Date	Rain present	Rainfall to 9am (mm)	Relative humidity (%)	Temperature (^{0}C)	Cloud cover (Oktas)	Visibility
2/7/23	Nil	0	59	15.6	0	Good
9/7/23	Nil	0	57	15.8	0	Good
16/7/23	Nil	0	74	16.7	0	Good
23/7/23	Nil	0	57	15.9	0	Good

3.1.2 Winter 2023 road-kill survey

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

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

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

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

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

3.1.3 Distribution of road-kill

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

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

Table 4: The number of road-killed fauna recorded in fenced and unfenced sections of the WC2NH alignment during the July (winter) 2023 sample period. Includes sub-totals for fauna that the fauna fence should block under normal circumstances (excluded) and fauna that would not be stopped by the fauna fence (not excluded).

Species and fauna groups	Excluded vs not excluded	Fenced	Unfenced
Bandicoot spp.	Excluded	4	2
Eastern grey kangaroo	Excluded		1
Koala	Excluded	1	
Long-nosed bandicoot	Excluded	1	
Medium mammal	Excluded	1	
Possum spp.	Excluded		1
Red fox	Excluded		1
Red necked wallaby	Excluded		2
Sub-total (excluded)		**7**	**7**
Barn owl	Not excluded	1	
Bird spp.	Not excluded	2	2
Cattle egret	Not excluded	1	
Cormorant spp.	Not excluded	1	
Laughing kookaburra	Not excluded	1	
Magpie lark	Not excluded		3
Pheasant coucal	Not excluded		1
Reptile spp.	Not excluded		2
Rodent spp.	Not excluded	1	1
Small bird spp.	Not excluded		1
Tyto spp.	Not excluded		1
Sub-total (not excluded)		**7**	**11**
Grand total		**14**	**18**

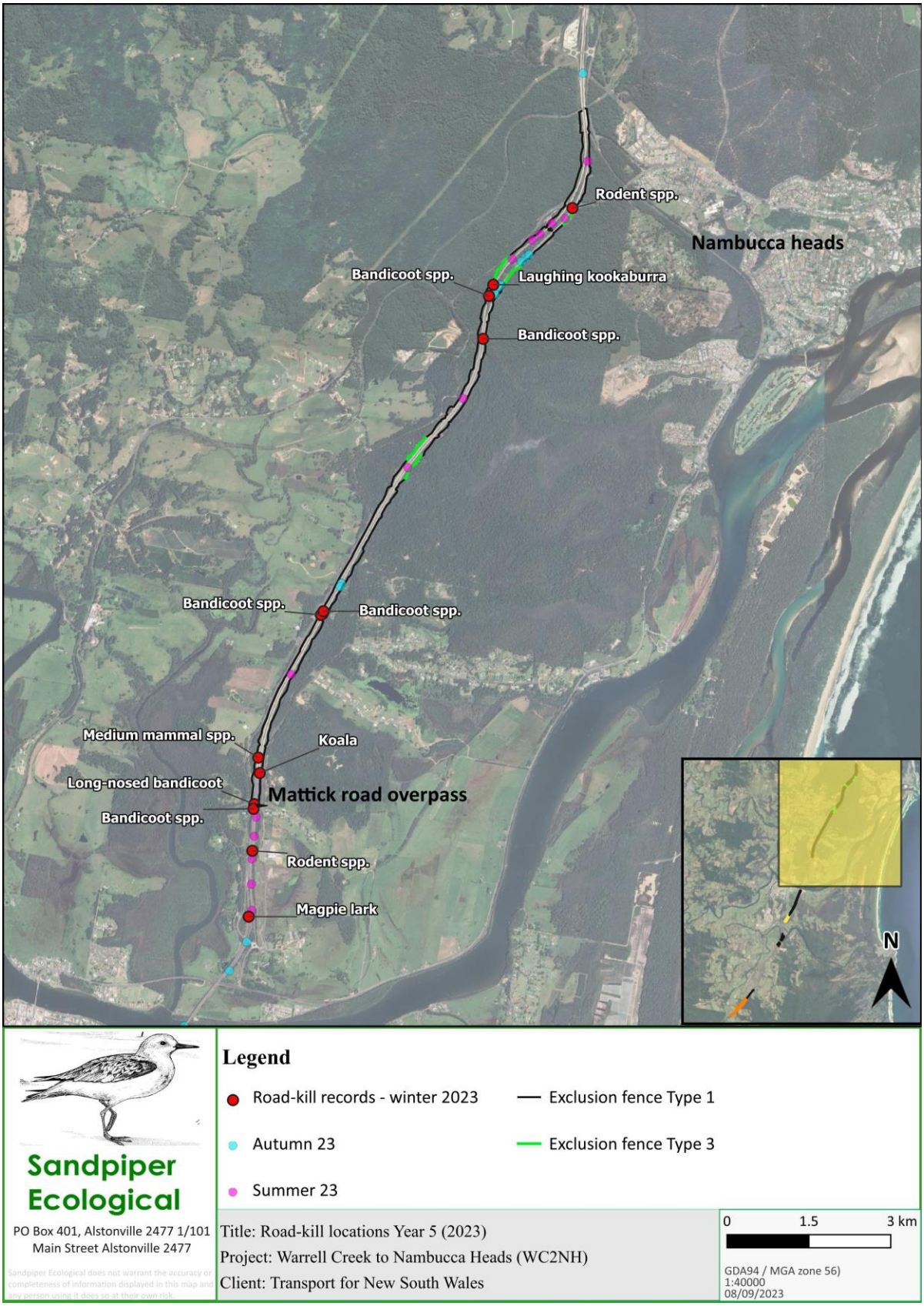

Figure 2: Location of road-killed fauna recorded in winter 2023 along the WC2NH alignment (northern extent).

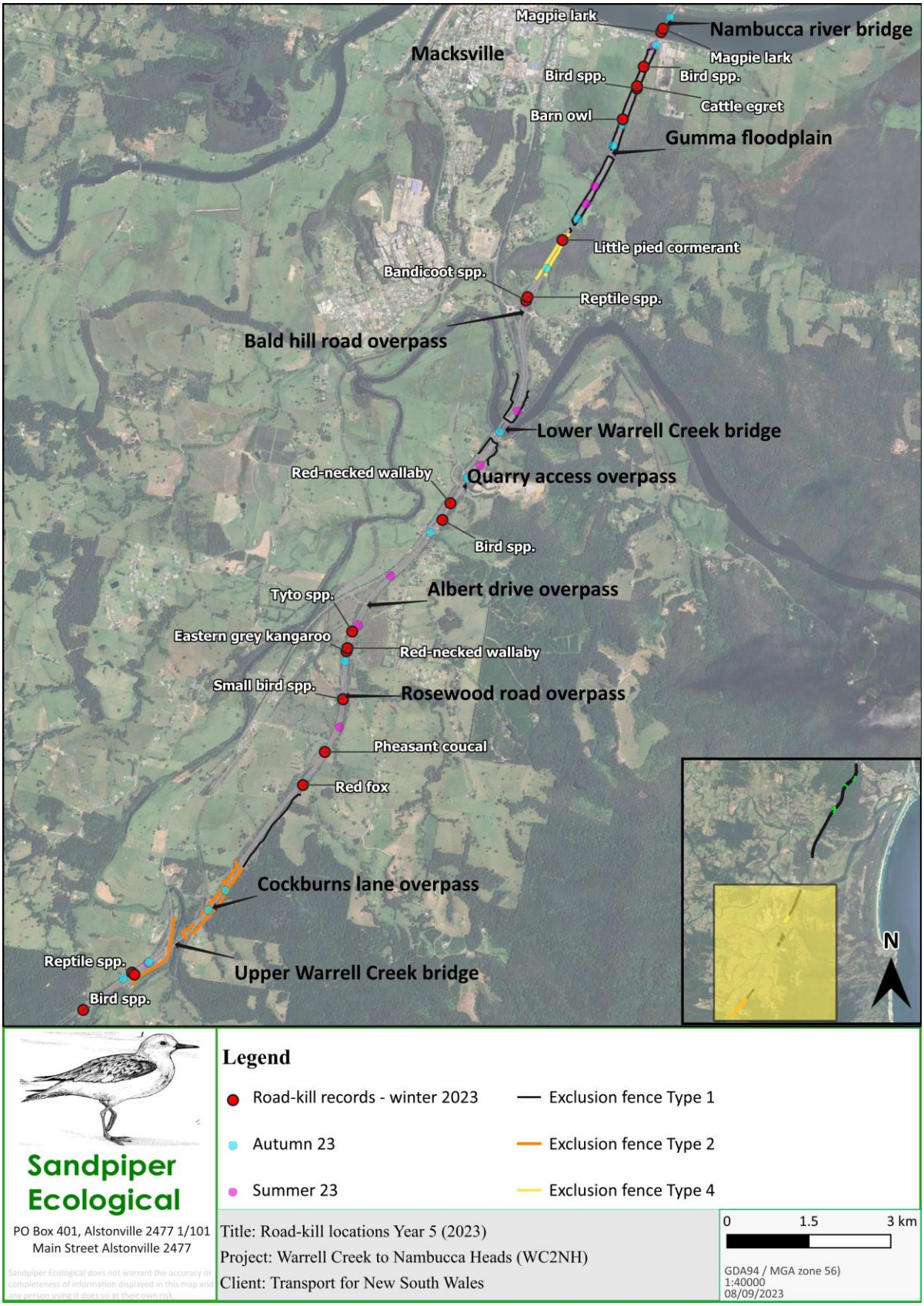

Figure 3: Location of road-killed fauna recorded in winter 2023 along the WC2NH alignment (southern extent).

3.2 Year 5 operational monitoring

3.2.1 Species richness and abundance

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

3.2.2 Koala road mortalities

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

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

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

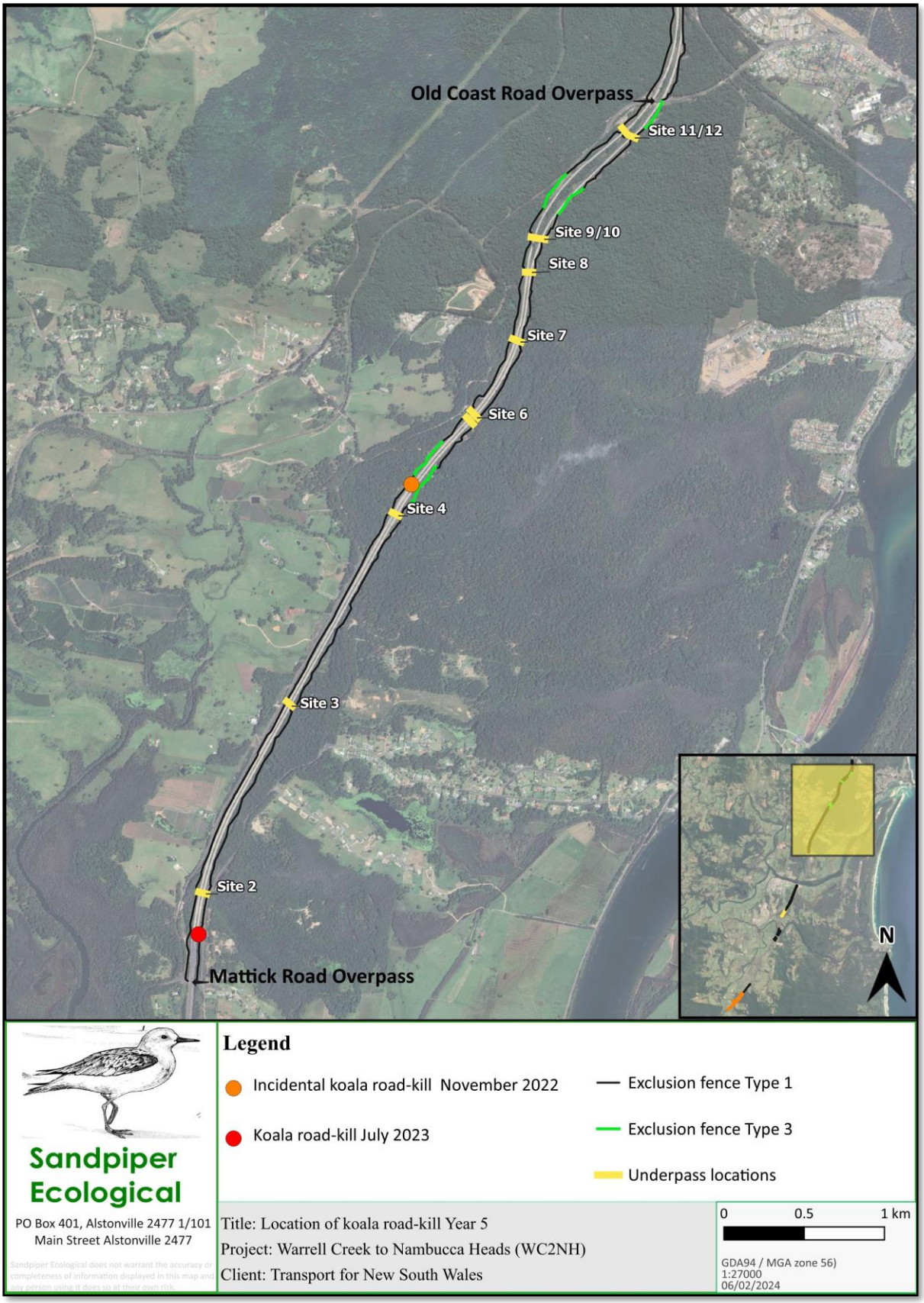

Figure 4: Koala road-kill records 2023 at WC2NH.

3.3 Operational monitoring – Years 1-5

3.3.1 Temporal comparisons

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

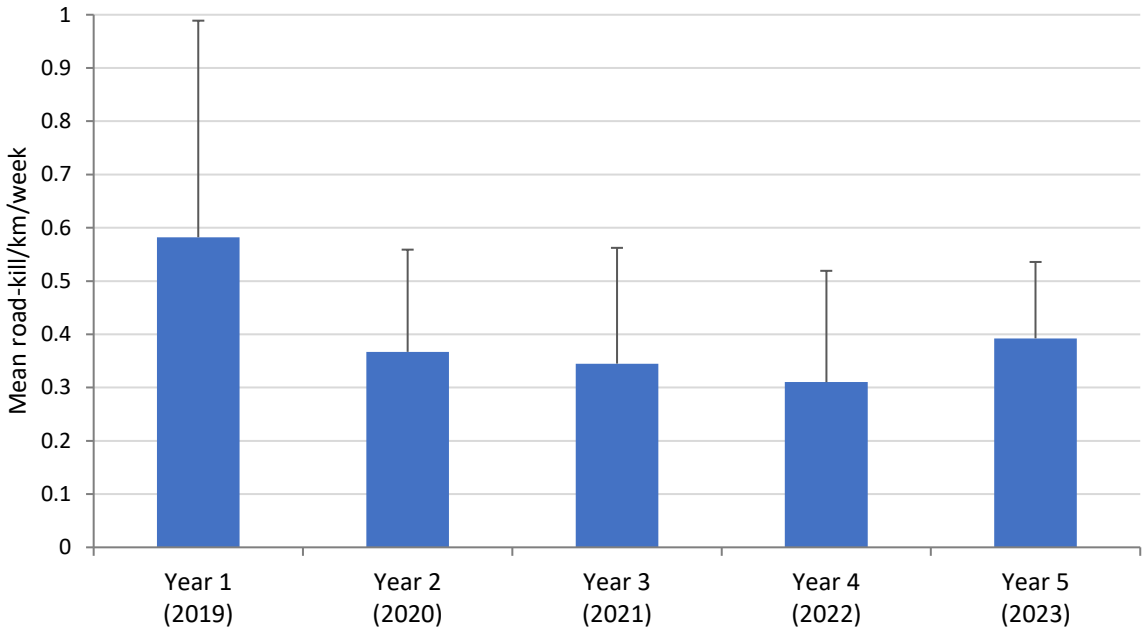

Figure 5: Mean (+SD) number of road-kill per kilometre per week. Years 1-4 (n=16), year 5 (n=12).

Road-kill rates have varied between and within fauna groups across operational monitoring (Figure 6). Since the commencement of operational monitoring and in order of detection, birds, macropods, bandicoots, medium mammals and flying foxes have recorded the highest road-kill rates (Figure 6). Road-kill rates for flying foxes and medium mammals have consistently declined since 2019 (Figure 6). A substantial decline (87%) in flying fox records was experienced between 2019 (0.09 ± 0.11 rk/km/week) and 2020 (0.013 ± 0.02 rk/km/week), with lower rates maintained in 2021 (0.013 ± 0.3 rk/km/week) and 2022 (0.006 ± 0.02 rk/km/week), and only one record in 2023 (0.004 ± 0.01 rk/km/week) (Figure 6). Macropod records peaked during 2020 (0.1 ± 0.09 rk/km/week) and have declined by 83% in 2023 (0.017 ± 0.03 rk/km/week) (Figure 6). In contrast, road-kill rates for bandicoots have consistently increased from 2019 monitoring, with the highest rate recorded in 2023 (0.09 ± 0.05 rk/km/week) (Figure 5). Consistently low mean annual road-kill rates less than 0.025 rk/km/week were recorded for feral predators, possums, echidnas and microbats (Figure 6). The mean annual road-kill rate for small mammals (i.e. rodents, antechinus etc) increased from <0.025 (in previous years) to 0.05 rk/km/week in 2023.

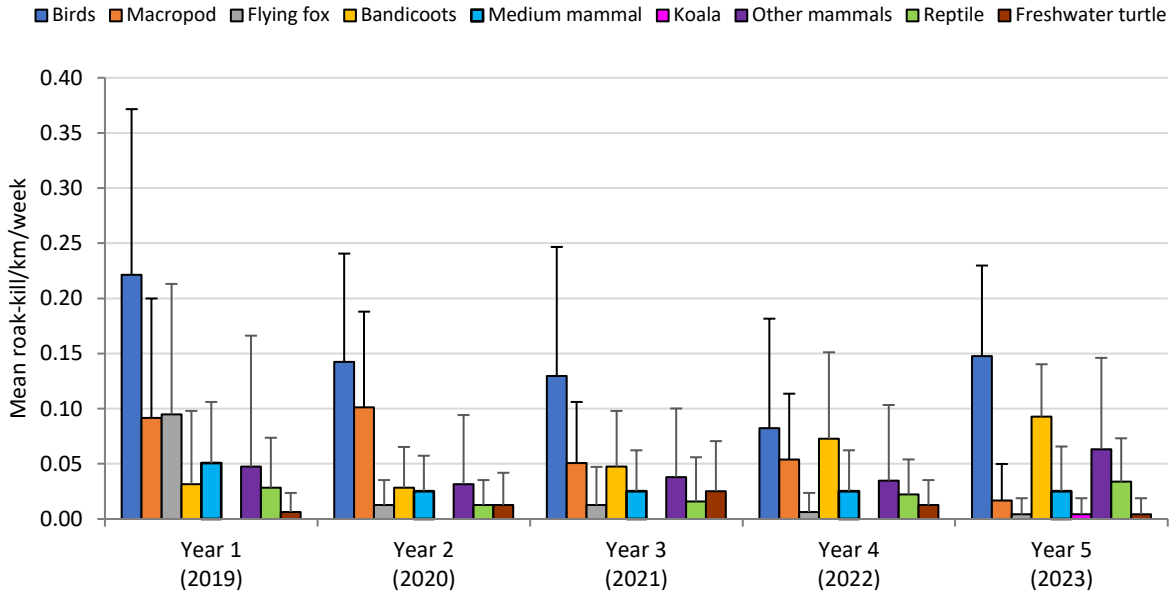

Figure 6: Mean (+SD) number of road-kill per kilometre per week. Year 1-4 (n=16), Year 5 (n=12). Other mammals = combined microbat spp., echidna, feral predators, and small mammal spp.

3.3.2 Spatial comparison – fenced vs unfenced

Road-kill rates have varied across the WC2NH alignment, with the primary determinant of variation being the presence or absence of fauna exclusion fence (Figure 7). During 2019 and 2020, fauna that should be blocked by fauna fence (see Table 1) recorded significantly higher road-kill rates in unfenced compared to fenced sections of the alignment (Figure 7, Table 5). During 2021 and 2022, fenced and unfenced sections of the alignment recorded no statistically significant difference. This result continued in 2023, with no statistically significant difference (P=0.656; DF=1; Table 5) between fenced and unfenced sections of the alignment (Figure 7). Road-kill rates in unfenced areas have decreased over time from 0.28 ± 0.37 rk/km/week in 2019 to 0.17 ± 0.12 rk/km/week in 2023 (Figure 7). In fenced areas, road-kill peaked in 2022 (0.17 ± 0.17 rk/km/week) with a slight decrease recorded in 2023 (0.15 ± 0.11 rk/km/week) (Figure 7).

Road-kill rates have differed between fauna groups in relation to the presence (fenced) and absence (unfenced) of fauna exclusion fencing, particularly for fauna groups that, under normal circumstances, would be blocked by fencing (Table 5, Figure 8). Throughout operational monitoring, macropods have consistently recorded higher road-kill rates in unfenced alignment sections (Figure 8). During 2023, there were no macropod road-kill in fenced sections, whereas, in unfenced sections the rate was 0.037 ± 0.07 rk/km/week (Figure 8).

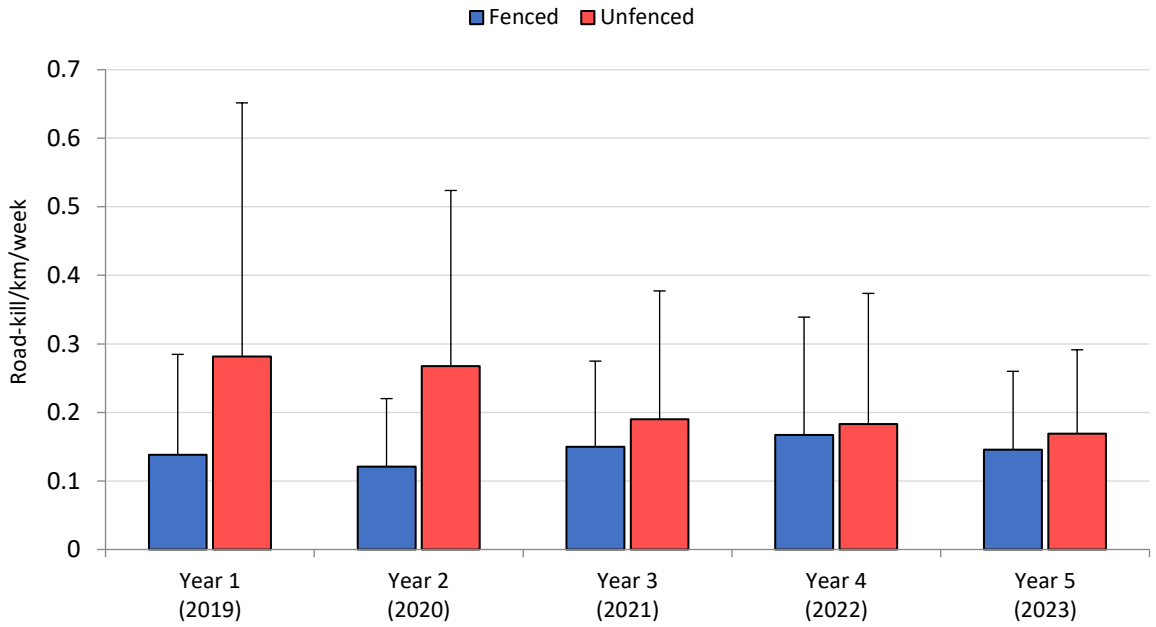

Figure 7: Annual comparison in the mean (+SD) number of road-kill per kilometre per week during 2019-2022 (n=16) and 2023 (n = 12) recorded in fenced (10.86km) versus unfenced (8.89km) sections of the WC2NH alignment. Only includes fauna that, under normal circumstances, would be blocked by the exclusion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

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

Group	Category	Nº. road-kill	Expected proportion	Expected Nº.	Df	G statistic	P (2-tail)
2019	Fence	24	0.55	35.2	1	7.897	**0.005**
	No fence	40	0.45	28.8			
2020	Fence	21	0.55	32.45	1	8.973	**0.003**
	No fence	38	0.45	26.55			
2021	Fence	26	0.55	29.15	1	0.752	0.386
	No fence	27	0.45	23.85			
2022	Fence	29	0.55	30.25	1	0.114	0.735
	No fence	26	0.45	24.75			
2023	Fence	19	0.55	20.35	1	0.198	0.656
	No fence	18	0.45	16.65			

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

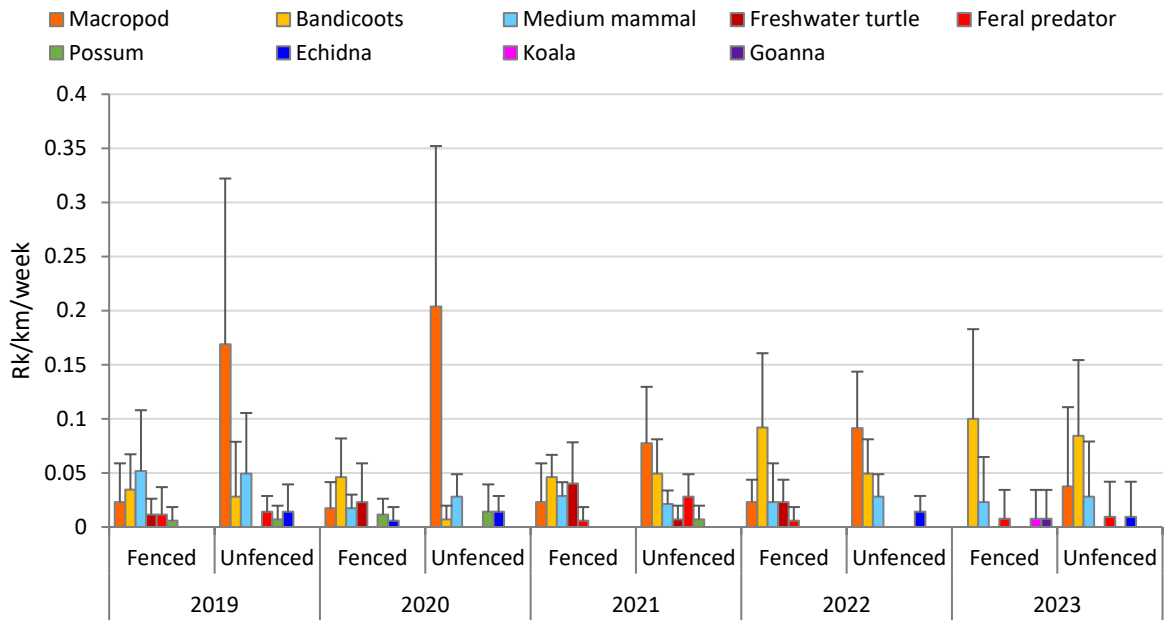

Figure 8: Annual comparison in the mean (+SD) number of road-kill per kilometre per week (2019-2022: n = 16; 2023: n = 12) along the WC2NH alignment in fenced (10.86km) and unfenced (8.89km) sections. Only includes fauna groups that, under normal circumstances, would be blocked by the exclusion fence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

3.3.3 Distribution of road-kill

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

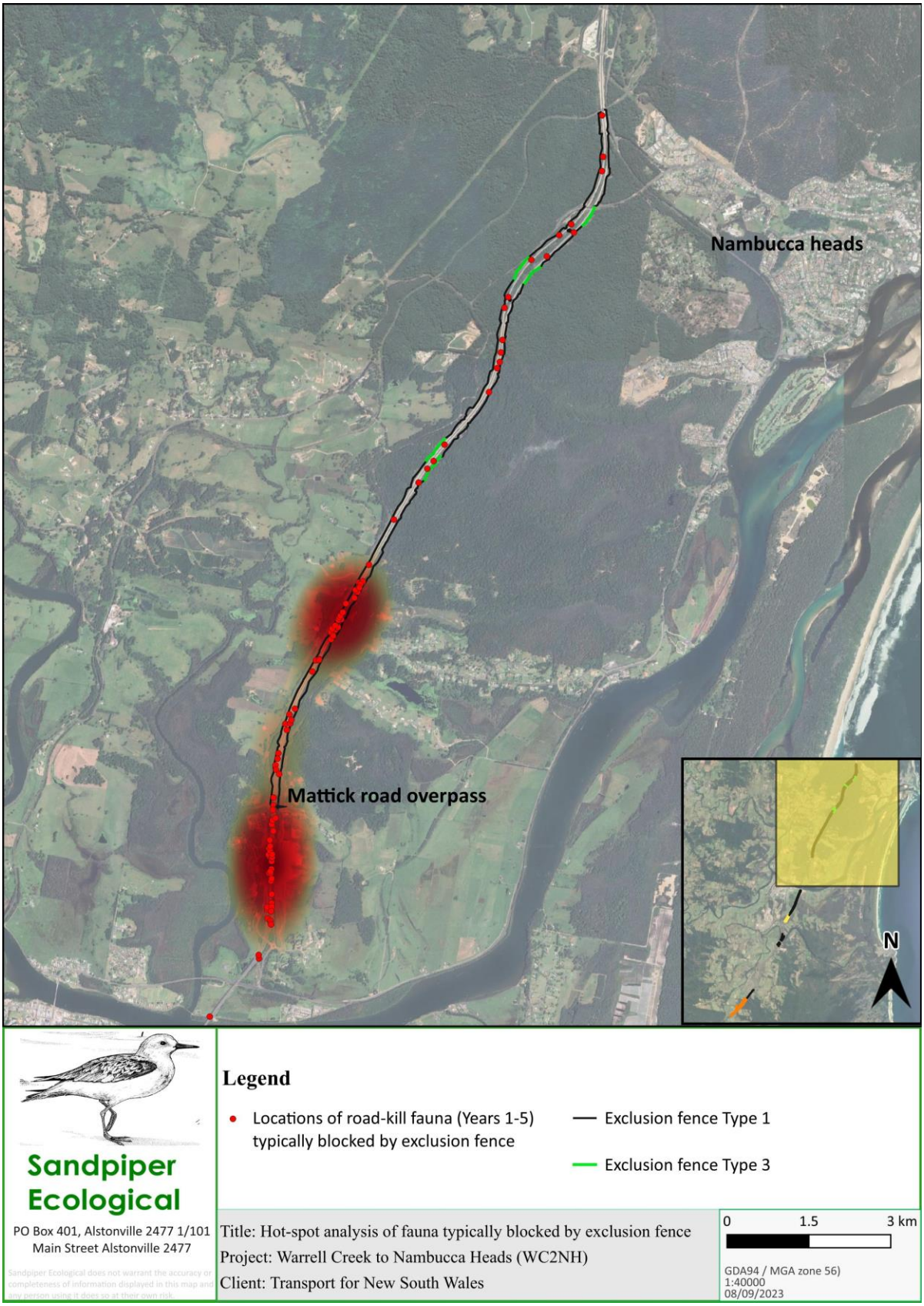

Figure 9: Heat map analysis of road-killed fauna that, under normal circumstances would be blocked by fauna fence (see Table 1) during operational monitoring surveys (2019-2023) at WC2NH. Overlaid red dots indicate the location of road-killed individuals recorded between 2019 and 2023.

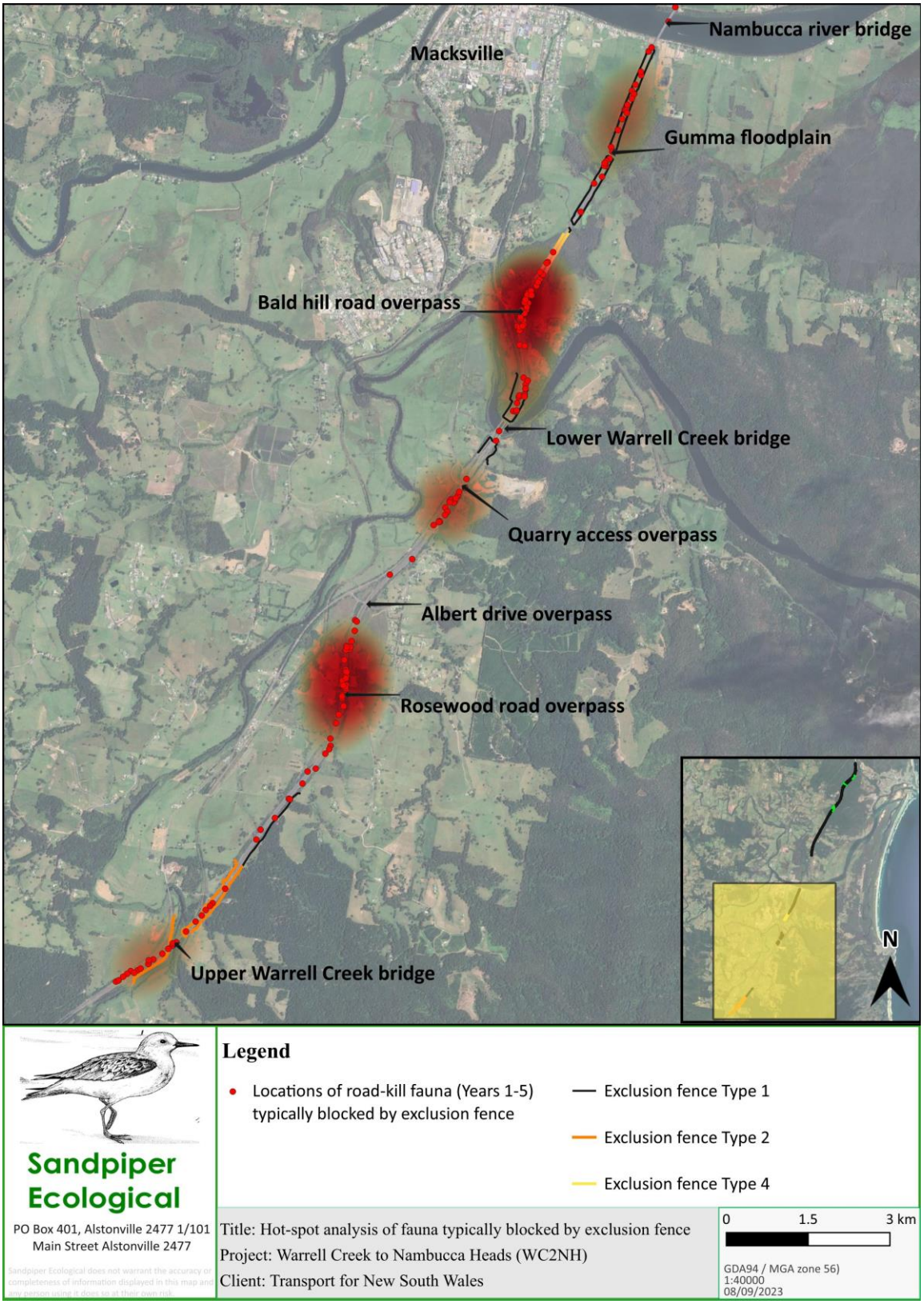

Figure 10: Heat map analysis of road-killed fauna that, under normal circumstances would be blocked by fauna fence (see Table 1) during operational monitoring surveys (2019-2023) at WC2NH. Overlaid red dots indicate the location of road-killed individuals recorded between 2019 and 2023.

3.3.4 Fence ends

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

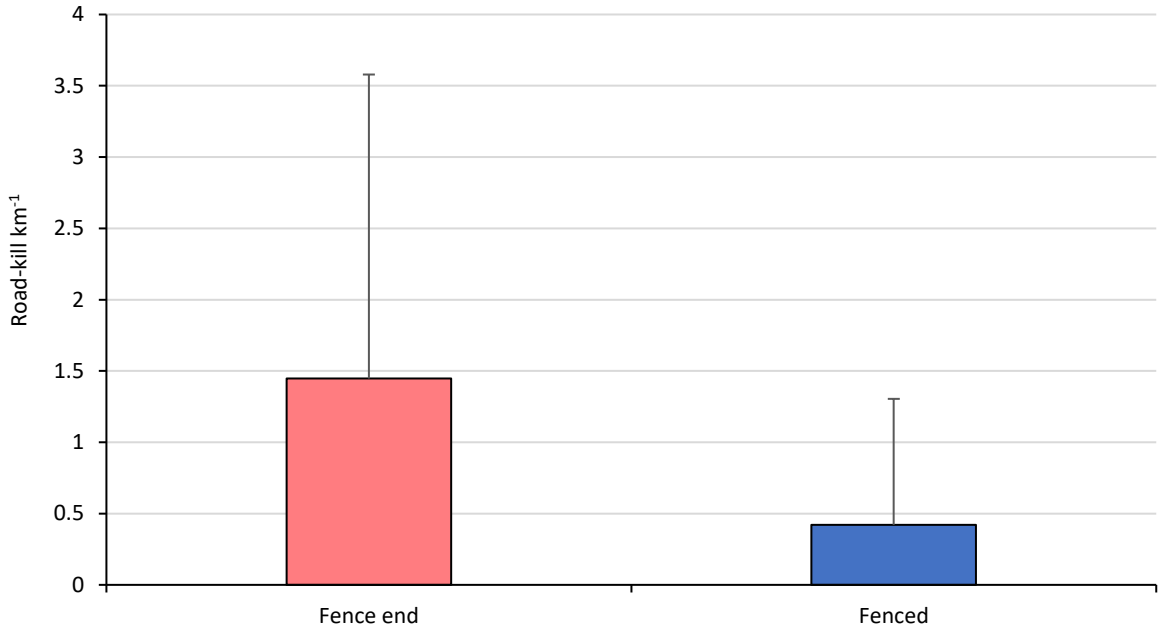

Figure 11: Mean (+SD) number of road-kill per kilometre per week during 2019-2022 (n=16) and 2023 (n=12) recorded in fence end and fenced sections of the WC2NH alignment. Only includes fauna groups that, under normal circumstances, would be blocked by the exclusion fence (see Table 1).

3.4 Exclusion fence inspection

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

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

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

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

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

4 Discussion

4.1 July 2023

Road-kill monitoring over the entire WC2NH alignment in July 2023 indicated that fauna continued to be killed by vehicles almost five years after the entire alignment was open to traffic. Road-kill was recorded at an overall rate of 0.41 individuals/km/week, which is the same as summer 2023 and slightly higher than autumn 2023 (0.37 rk/km/week). Birds and mammals have continued to comprise the majority of road kills in all surveys to date. Notably, the survey method is biased towards larger and long-lasting carcasses, which tend to be birds and mammals. The method also reduces the ability to identify all carcasses confidently, resulting in some individuals being assigned to a size class and fauna group (Ogletree and Mead 2020). The absence of amphibians in July 2023 is consistent with previous surveys and further emphasises the difficulty of identifying road-killed amphibians during vehicle-based surveys.

4.2 Temporal variation in road-kill

The temporal decline in road-kill abundance from 2019-2022 was not evident in 2023. By comparison, the road-kill rate in 2023 was 33% lower than 2019, 7% higher than 2020, 14% higher than 2021, and 27% higher than 2022. The 2023 rate was slightly higher than the rate of 0.3 rk/km/week recorded on three major roads in north-eastern New South Wales (Taylor and Goldingay 2004). There is likely to be a number of reasons for the temporal changes in road-kill rates, including changes in habitat quality, fauna

abundance, weather conditions and time since opening. The peak in 2019 could be due to a combination of drought and the recent opening of the highway, whilst the decline from 2020 to 2022 may be associated with the La Nina weather pattern with the increase recorded in 2023 due to drought.

4.2.1 Temporal changes in mammals

There have been notable changes in the frequency of detection for some fauna groups. For example, road-kill rates for bandicoots have consistently increased, with the highest recorded in 2023. Better climatic conditions since 2021 have likely contributed to an increase in the abundance and movement of bandicoots (Vernes and Pope 2009) and decomposition of mulch applied to batters and bunds has created favourable foraging habitat within the road corridor. Numerous bandicoot diggings have been observed on mulch bunds situated on the road side of exclusion fence (L. Andrews pers obs). Increased abundance of bandicoots combined with favourable feeding habitat in the road corridor means more individuals are accessing the road corridor to forage, resulting in a higher incidence of vehicle strike.

The abundance of macropod records peaked in 2020 (27 road-kills), remained relatively stable between 2021 (15 road-kills) and 2022 (17 road-kills) and decreased substantially in 2023 (4 road-kills). The lower abundance of macropods in 2023 on the back of favourable climatic conditions further supports the hypothesis that the higher road-kill rates recorded in 2019 and 2020 were due to drought (Klocker *et al.* 2006). Reduced grass quality and quantity during drought means individuals move larger distances in search of new growth, which may occur along road-sides, or cause individuals to cross roads more frequently. Nonetheless, it is difficult to confirm if the decrease in vehicle strike is due to a decline in local abundance caused by high mortality between 2019 and 2022, particularly for red-necked wallaby (Bond and Jones 2013). The observed decrease in vehicle strike is likely due to the combined effect of improved climatic conditions and reduced local abundance. If drought influences road-kill rate of macropods an increase would have been expected in the second half of 2023 after monitoring was completed.

4.2.2 Temporal changes in birds

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

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

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

4.2.3 Seasonal changes

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

4.3 Distribution and fenced vs unfenced

The G-test identified no significant difference (P>0.05) in road-kill density between fenced and unfenced sections of the alignment in 2023. This result suggests that fauna that should be blocked by exclusion fence were killed at an equivalent rate between fenced and unfenced sections of the alignment, and is similar to findings in 2021 and 2022. It should be noted that this does not take into account comparable habitat between fenced and unfenced sections of the highway.

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

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

Hot-spot analysis also showed that the fauna fence is effective in the forested northern extent of the project, around Nambucca State Forest, where substantially fewer road-kill records were found. This can be attributed to the continuous nature of the fauna fence in this section, which has limited fence ends or interchanges and features underpasses that facilitate the movement of fauna across the alignment. Results are consistent with Clevenger *et al.* (2001) and Plante *et al.* (2019) who highlighted the effectiveness of longer fences that discourage animals from moving along the fence to the fence ends.

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

Throughout operational monitoring, macropod road-kills mostly occured in unfenced sections of the alignment near Rosehill Road, Upper Warrell Creek and fence ends/interchanges at Bald Hill Road and

south of Mattick Road. This fence end effect is consistent with the findings of other studies (e.g. Clevenger *et al.* 2001, Plante *et al.* 2019 and Song *et al.* 2011), and provide useful information for future road projects.

Data suggest that species likely to be blocked by exclusion fence are killed regardless of whether a drop-down occurs nearby. Whilst the influence of drop-downs on road-kill rate requires further investigation this observation is consistent with drop-down monitoring in northern NSW which showed negligible use by native fauna (Sandpiper Ecological 2019b). Indeed, growth of dense vegetation on batters makes some drop-downs inaccessible to larger species.

4.4 Threatened fauna

Since WC2NH became operational, five threatened species have been recorded as road-kill (grey-headed flying fox, masked owl, black bittern, eastern grass owl and koala). Overall, the number of grey-headed flying fox mortalities has declined since 2019. This trend is likely a result of improved foraging conditions associated with higher rainfall, and less visitation to roadside trees to forage. Vehicle strike is not identified as a major threat to grey-headed flying foxes (DotEE 2017) and Scheelings and Frith (2015) found that only 2.4% of individuals presented at Victoria clinics were due to a vehicle strike.

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

5 Conclusion and recommendations

The temporal decline in road-kill recorded in 2021 and 2022 was not evident in 2023, however, numbers remain substantially lower than 2019. In 2023, bandicoots were a major contributor to road-kill for species that the fauna fence should exclude. This result is likely due to higher abundance, ability to move through small gaps in the fence, especially around open drains, and suitable foraging habitat within the road corridor. During the five years of monitoring, most road-killed fauna that the fauna fence should exclude were found around fence ends and interchanges, emphasising the importance of ensuring that fence extents are consistent on both sides of the alignment and minimising the number of fence ends. No modifications of exclusion fencing design, location or extent are recommended (Table 7), however, the records of road-killed koalas highlight the importance of ongoing fence inspections and maintenance to maximise effectiveness and reduce the likelihood of threatened species accessing the road corridor (Table 8).

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

Potential problem	Contingency/Corrective Action	Proposed action
High rates of fauna road mortality.	Modify exclusion fencing design, location or extent depending on the species and location of mortalities.	No corrective action is warranted. Year five monitoring remains substantially lower than 2019.

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

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

5.1 Lessons learnt from road-kill monitoring

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

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

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Appendix A – Field data

Table A1: Road-kill summary of all fauna recorded to date during operational phase monitoring at WC2NH (2018-2023). * denotes threatened species; ** = stage 2a only; Sum = summer; Aut = autumn; Win = winter; Spr = spring.

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Sum 23	Aut 23	Win 23	Total
Birds																								
Australian magpie	6	1	0	1	0	0	0	2	2	1	0	0	1	0	0	2	0	0	0	0	0	0	0	16
Grey butcherbird	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pied butcherbird	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Magpie-lark	2	0	1	0	1	0	1	0	1	0	1	1	0	1	0	1	1	3	0	0	0	1	3	18
Australian white ibis	0	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	4
Cattle egret	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3
Little pied cormorant	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	3
Buff-banded rail	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Purple swamphen	3	0	2	2	0	1	0	2	3	0	1	1	0	3	1	1	0	0	0	0	0	0	0	20
Wonga pigeon	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
White-headed pigeon	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Crested pigeon	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
Galah	7	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Rainbow lorikeet	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Eastern grass owl*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Australian boobook	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4
Masked owl*	1	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4
Eastern barn owl	0	0	11	3	0	1	5	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	25
Tawny frogmouth	1	3	1	2	0	6	0	4	0	1	0	1	1	1	1	0	0	0	1	0	1	1	0	25

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Sum 23	Aut 23	Win 23	Total
Australian owlet-nightjar	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Laughing kookaburra	3	0	2	1	0	2	0	3	1	1	2	1	0	0	0	2	2	0	0	0	1	0	1	22
Forest kingfisher	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Australian wood duck	20	0	0	2	2	0	1	2	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	30
Pacific black duck	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Whistling kite	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Black-shouldered kite	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Torresian crow	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Pied currawong	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	3
Black-faced cuckoo-shrike	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Noisy miner	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	4
Dollarbird	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Green catbird	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
Australasian figbird	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
White-faced heron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Black bittern*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Eastern yellow robin	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pheasant coucal	0	0	0	0	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	1	5
Masked lapwing	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Welcome swallow	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Red-browed finch	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cormorant spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Raptor spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Duck spp.	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Corvus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Sum 23	Aut 23	Win 23	Total
Tyto spp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	3
Small bird	0	0	0	0	0	0	0	2	0	0	0	0	0	1	1	0	1	2	2	0	2	1	1	13
Medium bird	0	0	0	1	2	2	2	2	6	1	1	0	0	2	0	2	0	0	0	0	0	0	0	21
Unidentifiable bird	5	4	1	0	3	0	0	0	0	0	2	2	1	0	2	2	2	7	0	2	4	5	4	46
Total birds	53	8	22	17	18	16	13	25	16	11	8	9	10	12	8	11	6	14	4	2	11	10	14	318
Mammals																								
Short-beaked echidna	0	0	0	3	0	0	0	2	0	1	2	1	0	0	0	0	0	1	0	1	1	0	0	12
Black flying-fox	2	1	0	0	7	1	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	15
Grey-headed flying-fox*	0	0	0	0	8	0	0	5	2	0	0	0	0	2	0	0	0	0	0	0	0	1	0	18
Pteropus spp.	0	0	0	0	3	8	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	15
Short-eared brushtail possum	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Common brushtail possum	0	0	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Trichosurus spp.	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3
Common ringtail possum	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Koala *	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Eastern grey kangaroo	0	0	0	3	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	6
Red-necked wallaby	0	0	6	0	8	2	8	3	7	1	8	3	1	1	4	2	1	0	3	3	1	0	2	64
Swamp wallaby	2	1	0	1	0	1	1	0	0	1	1	2	1	0	2	1	1	0	4	0	0	0	0	19
Wallaby spp.	0	0	0	0	0	2	0	0	3	0	0	2	0	1	0	1	2	1	0	2	0	0	0	14
Macropod spp.	3	0	2	1	1	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	10
Northern brown bandicoot	1	0	1	0	1	1	1	2	2	3	3	0	1	2	2	1	0	0	2	1	1	0	0	25
Long-nosed bandicoot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
Bandicoot spp.	0	0	0	0	0	1	0	4	0	0	0	1	0	2	4	2	4	3	4	9	8	5	6	53
Chalinolobus spp. (microbat)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Microbat spp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	3

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Sum 23	Aut 23	Win 23	Total
Swamp rat	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Rodent spp.	0	0	0	0	0	2	0	0	0	0	0	1	0	0	1	1	1	1	2	0	3	4	2	18
Small mammal	0	0	0	0	2	0	0	0	0	0	1	0	1	3	0	0	0	1	0	0	1	1	0	10
Medium mammal	0	0	0	2	4	2	4	5	2	2	2	0	0	2	4	2	2	3	1	0	1	3	2	43
Large mammal	0	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4
Unidentified Mammal	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Total mammals	9	2	10	17	37	20	17	23	18	13	20	10	5	16	18	10	12	11	17	16	18	14	15	348
Reptiles																								
Common blue-tongued skink	1	0	0	2	1	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	1	0	0	8
Carpet python	1	0	0	2	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	7
Common tree snake	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Eastern long-neck turtle	1	0	0	6	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	10
Macquarie river turtle	5	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
Unidentified *Chelidae* spp.	6	0	0	0	0	0	0	1	0	0	0	1	2	4	1	0	0	1	1	2	0	1	0	20
Red-bellied black snake	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
Eastern water dragon	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Eastern bearded dragon	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2
Lace monitor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Blackish blind snake	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Small eyed snake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Yellow-faced whipsnake	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Unidentified reptile	0	0	0	0	0	0	0	2	0	1	0	0	0	2	0	0	2	3	0	0	1	1	2	14
Lizard spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
Total reptiles	17	3	0	12	2	2	1	5	2	2	0	4	4	7	1	0	2	4	1	4	3	4	2	82
Frogs																								

Species	Sum 17/18**	Aut 18 **	Win 18 **	Spr 18	Sum 19	Aut 19	Win 19	Spr 19	Sum 20	Aut 20	Win 20	Spr 20	Sum 21	Aut 21	Win 21	Spri 21	Sum 22	Aut 22	Win 22	Spr 22	Sum 23	Aut 23	Win 23	Total
Green tree frog	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Striped marsh frog	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Medium frog	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Large frog	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Total frogs	5	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Introduced species																								
Cat	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	3
Dog	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	2
European fox	3	1	1	2	1	1	2	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	1	15
European hare	2	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	1	0	0	0	0	8
Rabbit	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Black rat	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	4
House mouse	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rock pigeon	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Domestic goose	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Total introduced species	8	1	2	5	2	2	2	0	0	1	0	2	1	2	2	1	4	0	1	0	0	1	1	38
Grand total	**92**	**14**	**34**	**55**	**59**	**40**	**33**	**53**	**36**	**27**	**28**	**25**	**20**	**37**	**29**	**22**	**24**	**29**	**23**	**22**	**32**	**29**	**32**	**795**
Rk/week/km	**1.16**	**0.18**	**0.43**	**0.70**	**0.75**	**0.51**	**0.42**	**0.67**	**0.46**	**0.34**	**0.35**	**0.32**	**0.25**	**0.47**	**0.37**	**0.28**	**0.30**	**0.37**	**0.29**	**0.28**	**0.41**	**0.37**	**0.41**	**0.44**

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

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

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

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

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