



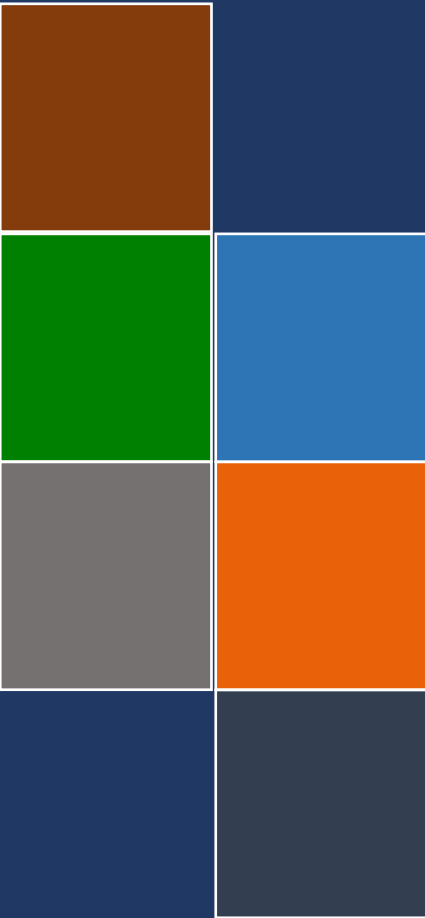
Transport for
New South Wales

Warrell Creek to Nambucca Heads

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

Transport for New South Wales | April 2023





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

Road-kill monitoring – operational phase
Year four (2022)

Document Distribution

Date	Version	Status	Sent to	Represent	Delivered Format	Dispatched By
19/1/23	A	Draft	D. Rohweder	SES	MSW	L. Andrews
21/2/23	B	Draft	J. Sheehan	TfNSW	MSW	L. Andrews
19/04/23	C	Final	J. Sheehan	TfNSW	MSW/PDF	L. Andrews

Project Team:

Dr D. Rohweder (Project management, reporting)

Mr L. Andrews (Reporting and fieldwork)

Ms A. English (Fieldwork)

Report prepared for:

Transport for New South Wales



Cover Photo: N/A

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

Table of contents

1.	Introduction	1
2.	Methods	2
2.1	Study area	2
2.2	Road-kill surveys	3
2.3	Data summary and analysis	4
2.3.1	Statistical analysis.....	4
2.4	Exclusion fence inspection	5
3.	Results	5
3.1	October 2022 sample	5
3.1.1	Weather condition	5
3.1.2	Road-kill survey	6
3.1.3	Distribution of road-kill	7
3.2	Annual results and operational monitoring	11
3.2.1	Annual species richness and abundance.....	11
3.2.2	Temporal comparisons.....	11
3.2.2	Spatial comparison – fenced vs. unfenced.....	13
3.2.3	Spatial comparison – Distribution of road-kill.....	15
3.4	Exclusion fence inspection	20
4.	Discussion	21
4.1	October 2022	21
4.2	Temporal variation	21
4.3	Distribution and fenced vs unfenced	22
4.4	Threatened fauna	23
5.	Conclusion and recommendations	23
6.	References	24
	Appendix A – Field data	26

List of tables

Table 1: Fauna groups included in comparison of fenced and unfenced sections of alignment.	5
Table 2: Weather conditions were recorded at 9am on each sample day in October 2022. Relative humidity and temperature data were obtained from the Bureau of Meteorology Coffs Harbour Airport (station 059151) with rainfall data from the Bellwood station (059150).	6
Table 3: Species of vertebrate fauna recorded during year four (2022) road-kill surveys along the WC2NH alignment. For a full road-kill summary of all surveys to date, see Appendix A, Table A2. RK=Roadkill. Chelidae spp. = Freshwater turtles.	6
Table 4: The number of road-killed fauna recorded in fenced and unfenced sections of the WC2NH alignment during the October (spring) 2022 sample period. Includes sub-totals for fauna that the fauna fence should stop under normal circumstances (excluded) and fauna that would not be stopped by the fauna fence (not excluded).	7
Table 5: G-test summary statistics on the number of road-kill in fenced versus unfenced sections of the WC2NH alignment during operational monitoring (years 1-4). Note, only fauna that should be blocked by exclusion fence under normal circumstances has been included.	14
Table 6: Issues identified and their priority for action from the exclusion fence inspection at WC2NH, 2022. *Trees or branches recorded on the fence were between 100mm to 200mm.	21
Table 7: Recommendations based on findings of the year 4 operational phase road-kill monitoring program.	24

List of figures

Figure 1: Location of the WC2NH alignment.	2
Figure 2: Location of road-killed fauna recorded in 2022 along the WC2NH alignment (northern extent). Note: only October (spring) 2022 records are labeled. Other road-kill fauna include summer, autumn, and winter records from year four surveys at WC2NH, 2022.	9
Figure 3: Location of road-killed fauna recorded in 2022 along the WC2NH alignment (southern extent). Note: only October (spring) 2022 records are labeled. Other road-kill fauna includes summer, autumn, and winter records from year four surveys at WC2NH, 2022.	10
Figure 4: Mean (+SD) number of road-kill per kilometer per week (n=16) recorded during operational phase monitoring (2019-2022).	12
Figure 5: Mean (+SD) number of road-kill per kilometer per week (n=16) recorded for all fauna groups during operational phase monitoring (2019-2022)	12
Figure 6: Annual comparison in the mean (+SD) number of road-kill per kilometer per week (n=16) recorded in fenced (10.86km) versus unfenced (8.89km) sections of the WC2NH alignment during operational monitoring. Only includes fauna that, under normal circumstances, would be blocked by the exclusion fence (see Table 1).	13
Figure 7: Annual comparison in the mean (+SD) number of road-kill per kilometer per week (n=16) along the WC2NH alignment in fenced (10.86km) and unfenced (8.89km) sections. Only includes fauna groups that, under normal circumstances, would be blocked by the exclusion fence (see Table 1).	14
Figure 8: Heat map analysis of all road-killed fauna during operational monitoring surveys (2019-2022) at WC2NH.	16
Figure 9: Heat map analysis of road-killed fauna that, under normal circumstances would be blocked by fauna fence (see Table 1) during operational monitoring surveys (2019-2022) at WC2NH. Overlaid red dots indicate the location of road-killed individuals recorded between 2019 and 2022.	17
Figure 10: The location of road-killed fauna recorded during 2022 surveys in relation to known hot spots at WC2NH (northern extent). Hot spots have been determined by heat map analysis (2019-2022) of road-killed	

fauna, as seen in Figure 9. Note only include fauna which, under normal circumstances, are blocked by exclusion fence (see Table 1)..... 18

Figure 11: The location of road-killed fauna recorded during 2022 surveys in relation to known hot spots at WC2NH (southern extent). Hot spots have been determined by heat map analysis (2019-2022) of road-killed fauna, as seen in Figure 9. Note only include fauna which, under normal circumstances, are blocked by exclusion fence (see Table 1)..... 19

List of plates

Plate 1: Work vehicle with signage, flashing amber light and indicators. 3

Plate 2: Thick grass protruding through and over the fauna fence north of Mattick Road (Top). Acacia spp. overhanging fauna fence adjacent to old coast road (Bottom)..... 20

1. Introduction

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

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

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

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

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

The aim of road-kill monitoring is to:

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

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

2. Methods

2.1 Study area

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

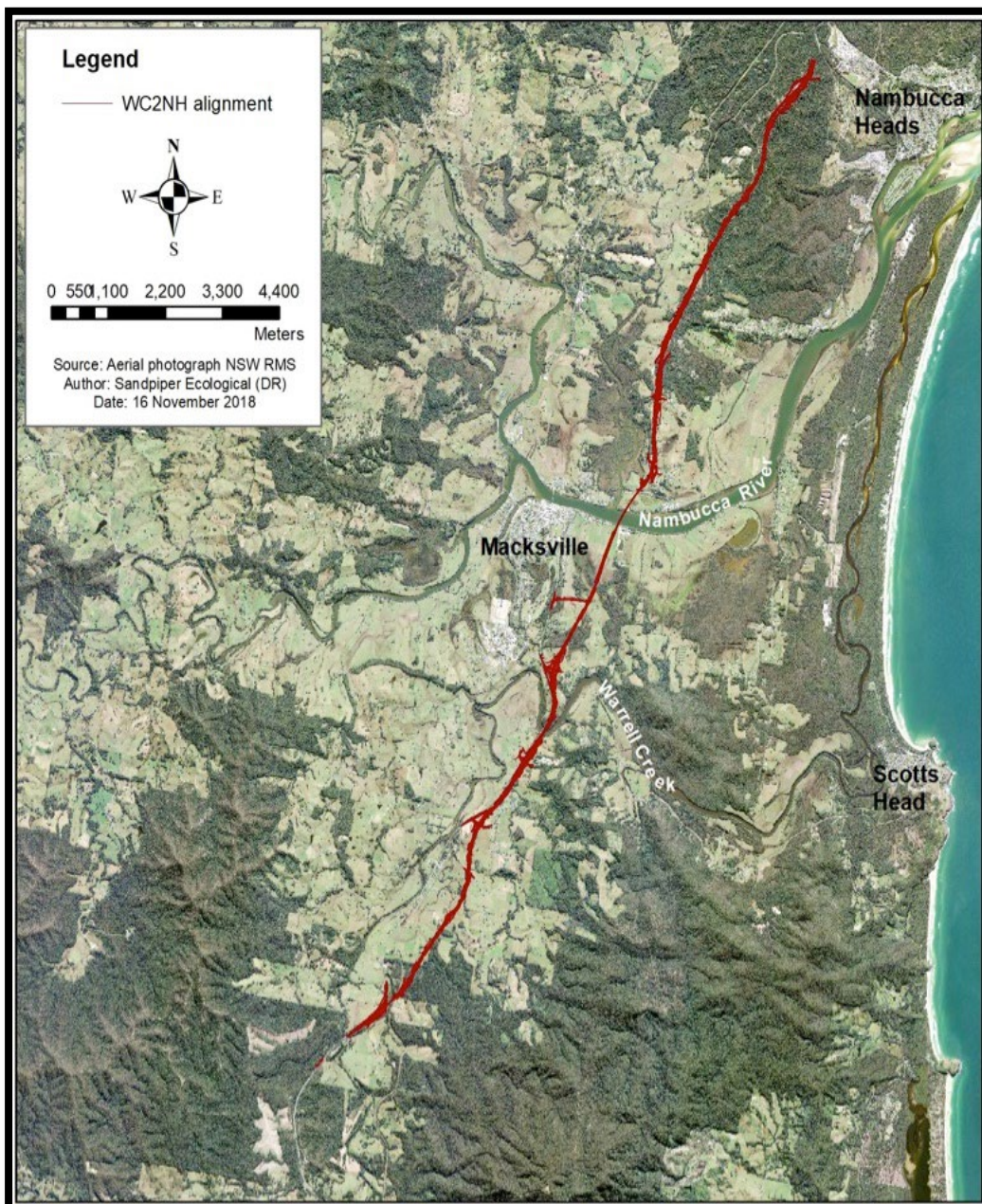


Figure 1: Location of the WC2NH alignment.

2.2 Road-kill surveys

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

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



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

Data collected on each road-kill included:

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

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

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

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

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

2.3 Data summary and analysis

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

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

2.3.1 Statistical analysis

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

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

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

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

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

2.4 Exclusion fence inspection

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

3. Results

3.1 October 2022 sample

3.1.1 Weather condition

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

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

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

3.1.2 Road-kill survey

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

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

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

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

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

3.1.3 Distribution of road-kill

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

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

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

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

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

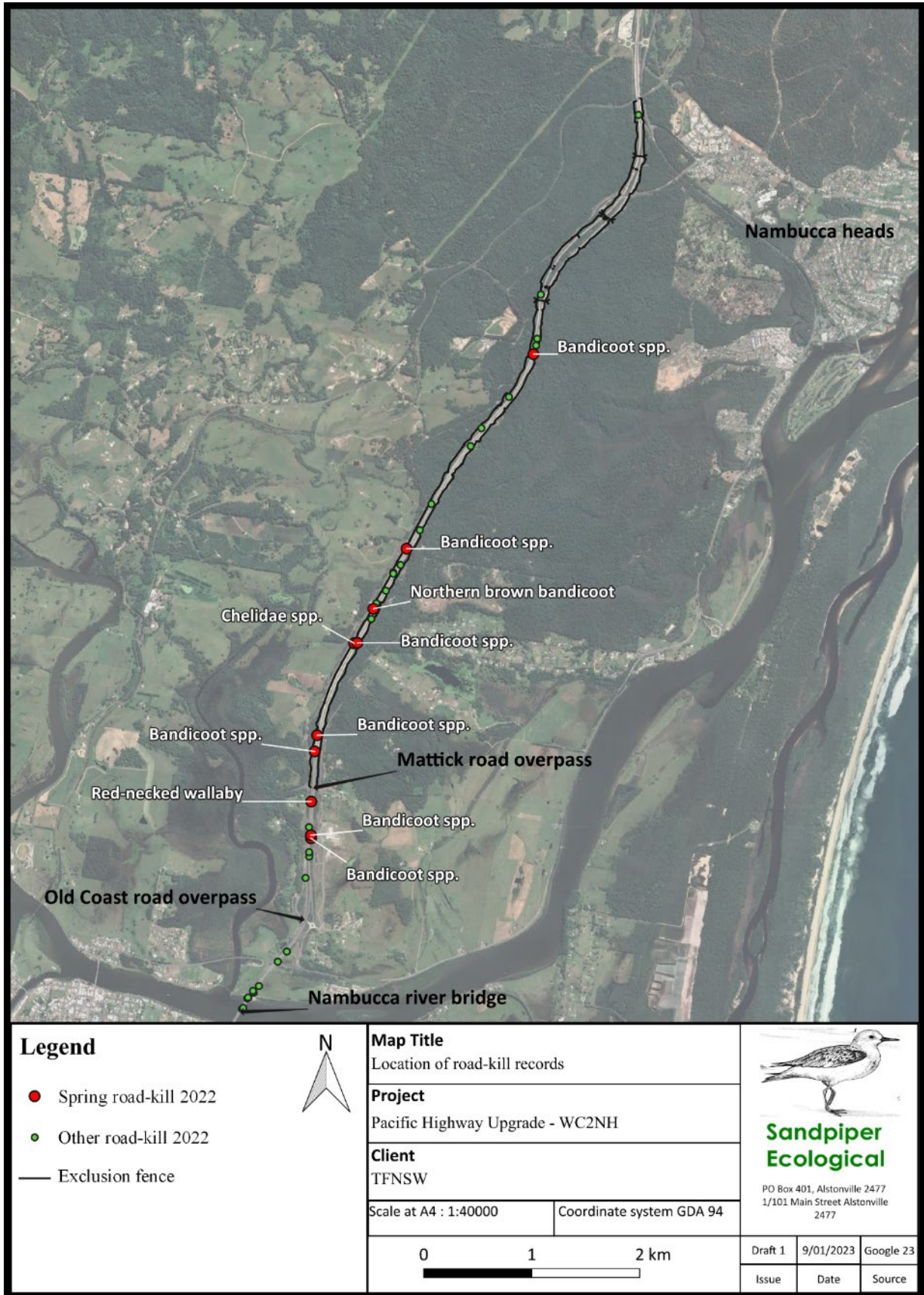


Figure 2: Location of road-killed fauna recorded in 2022 along the WC2NH alignment (northern extent). Note: only October (spring) 2022 records are labeled. Other road-kill fauna include summer, autumn, and winter records from year four surveys at WC2NH, 2022.

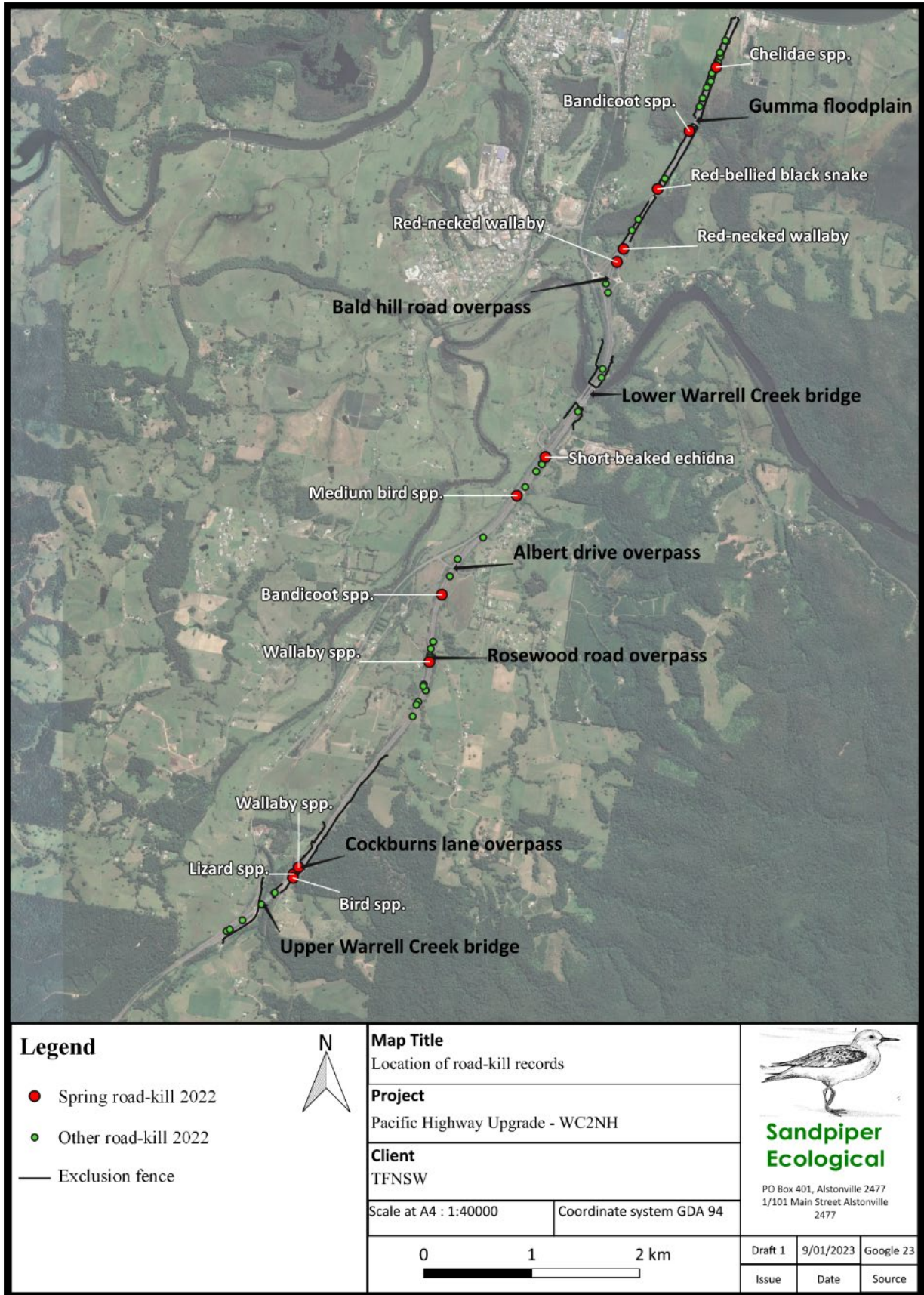


Figure 3: Location of road-killed fauna recorded in 2022 along the WC2NH alignment (southern extent). Note: only October (spring) 2022 records are labeled. Other road-kill fauna includes summer, autumn, and winter records from year four surveys at WC2NH, 2022.

3.2 Annual results and operational monitoring

3.2.1 Annual species richness and abundance

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

3.2.2 Temporal comparisons

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

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

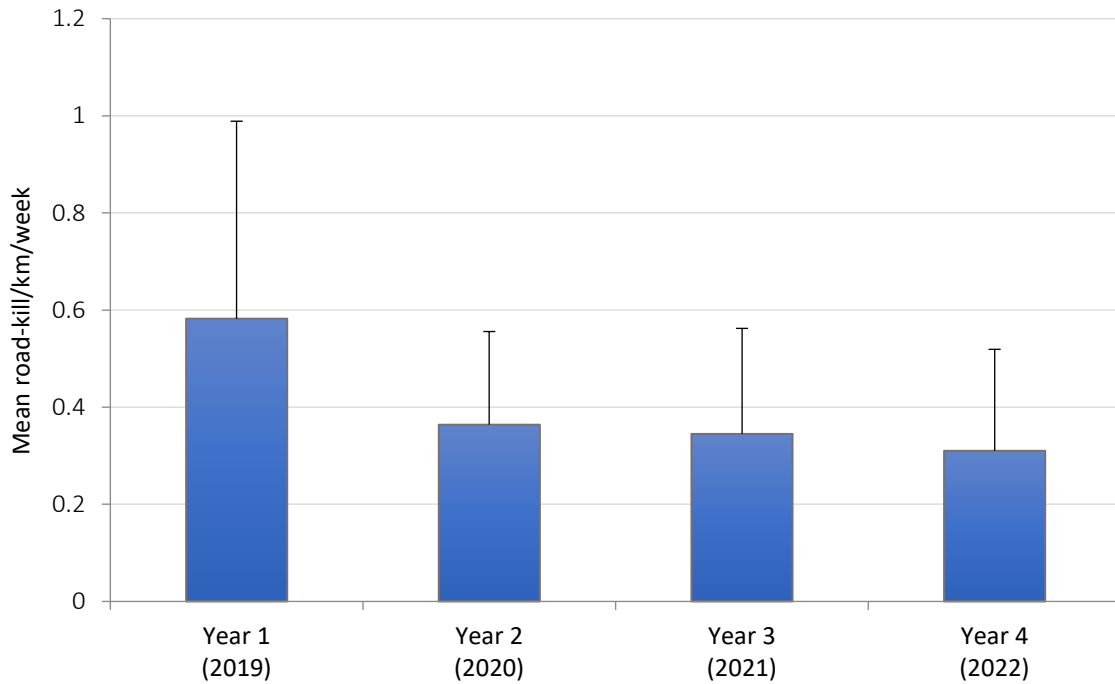


Figure 4: Mean (+SD) number of road-kill per kilometer per week (n=16) recorded during operational phase monitoring (2019-2022).

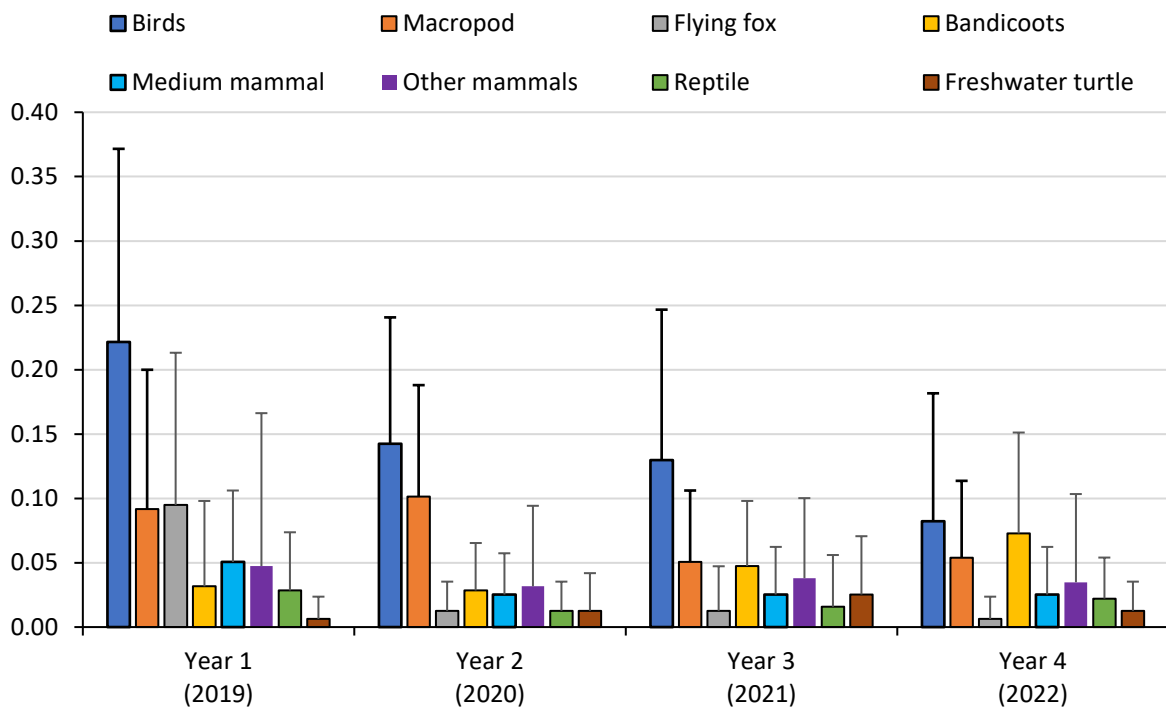


Figure 5: Mean (+SD) number of road-kill per kilometer per week (n=16) recorded for fauna groups during operational phase monitoring (2019-2022). Other mammals = combined microbat spp., echidna, feral predators, and small mammal spp.

3.2.2 Spatial comparison – fenced vs. unfenced

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

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

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

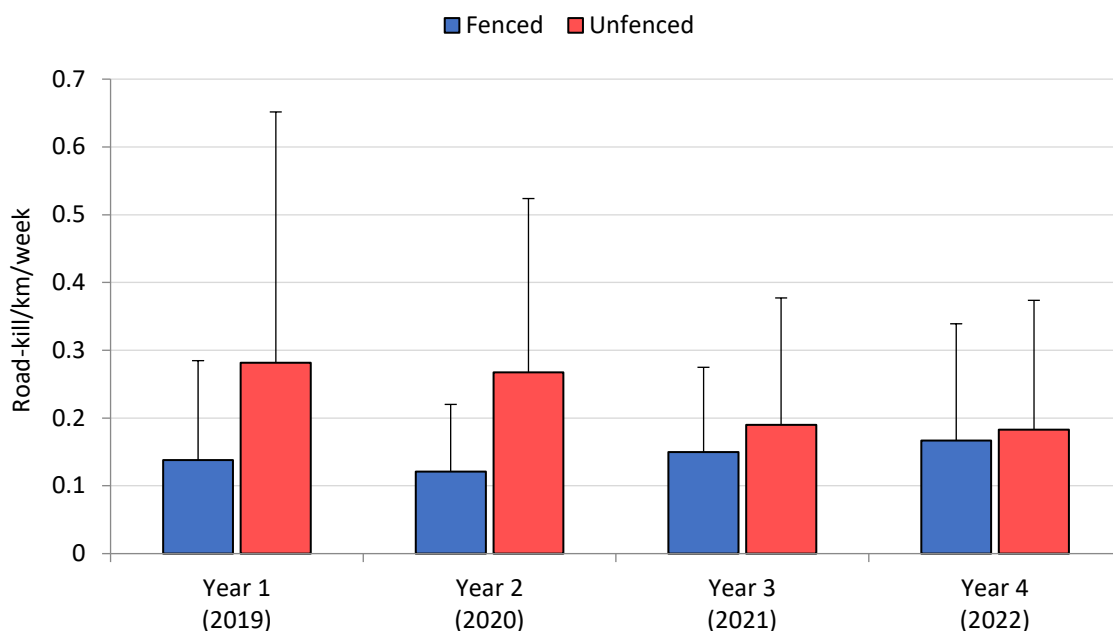


Figure 6: Annual comparison in the mean (+SD) number of road-kill per kilometer per week ($n=16$) recorded in fenced (10.86km) versus unfenced (8.89km) sections of the WC2NH alignment during operational monitoring. Only includes fauna that, under normal circumstances, would be blocked by the exclusion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

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

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

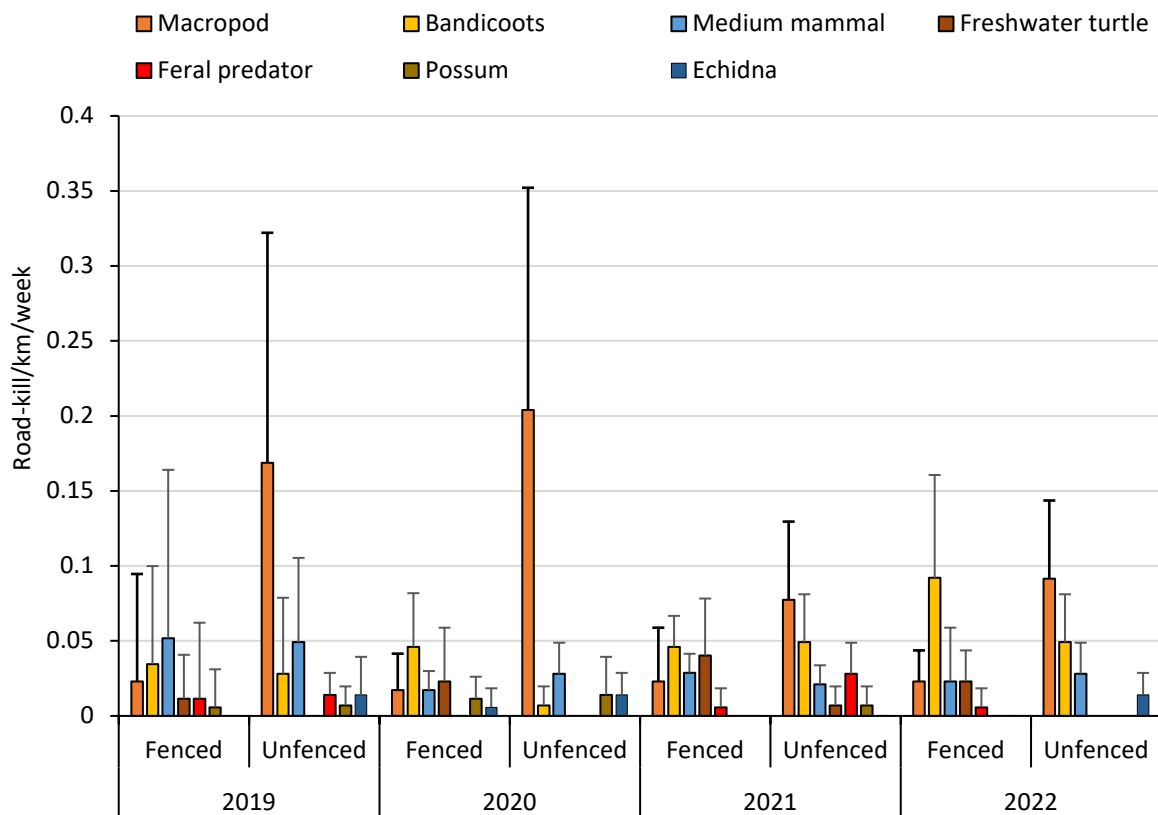


Figure 7: Annual comparison in the mean (+SD) number of road-kill per kilometer per week (n=16) along the WC2NH alignment in fenced (10.86km) and unfenced (8.89km) sections. Only includes fauna groups that, under normal circumstances, would be blocked by the exclusion fence (see Table 1).

3.2.3 Spatial comparison – Distribution of road-kill

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

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

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

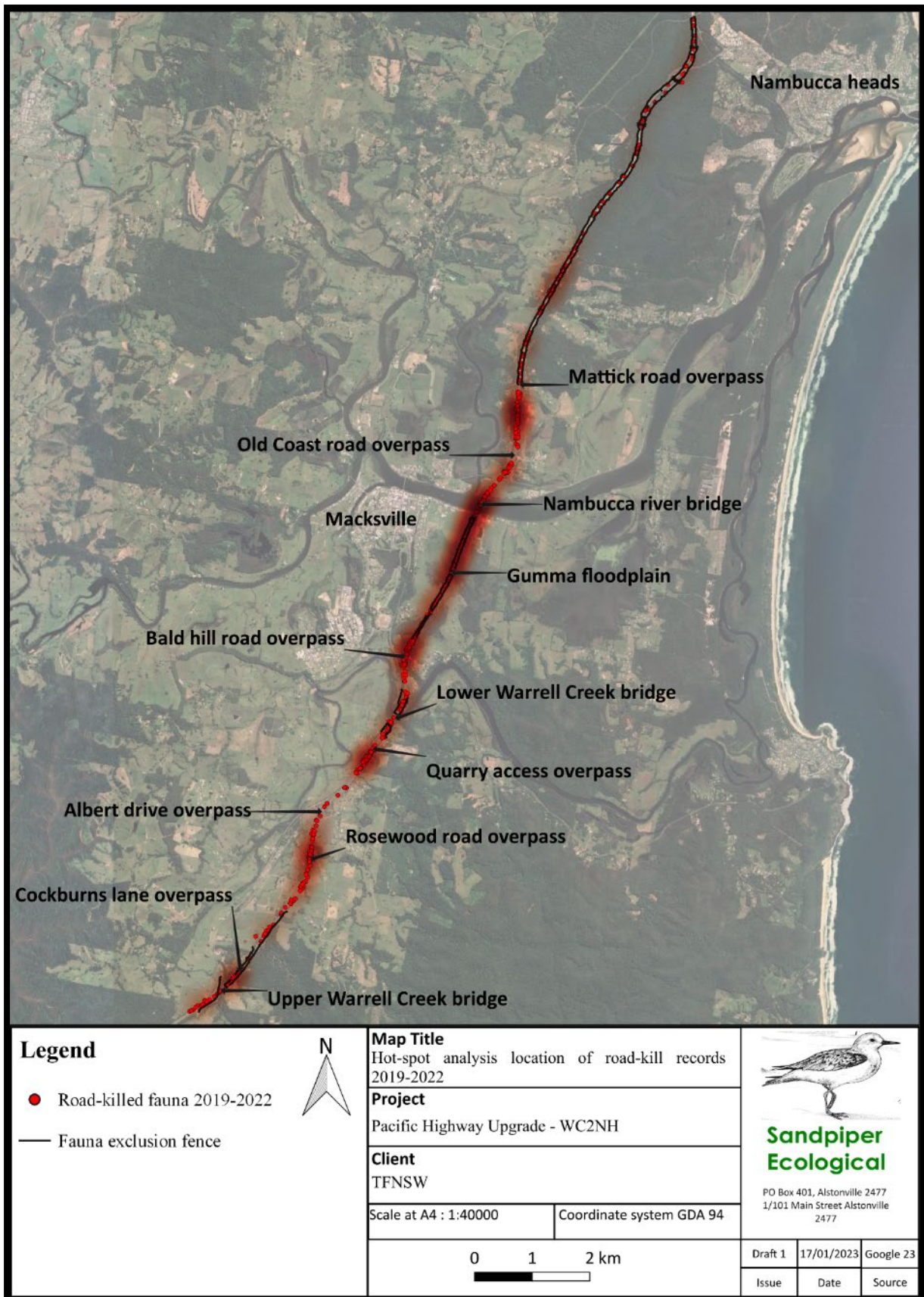


Figure 8: Heat map analysis of all road-killed fauna during operational monitoring surveys (2019-2022) at WC2NH.

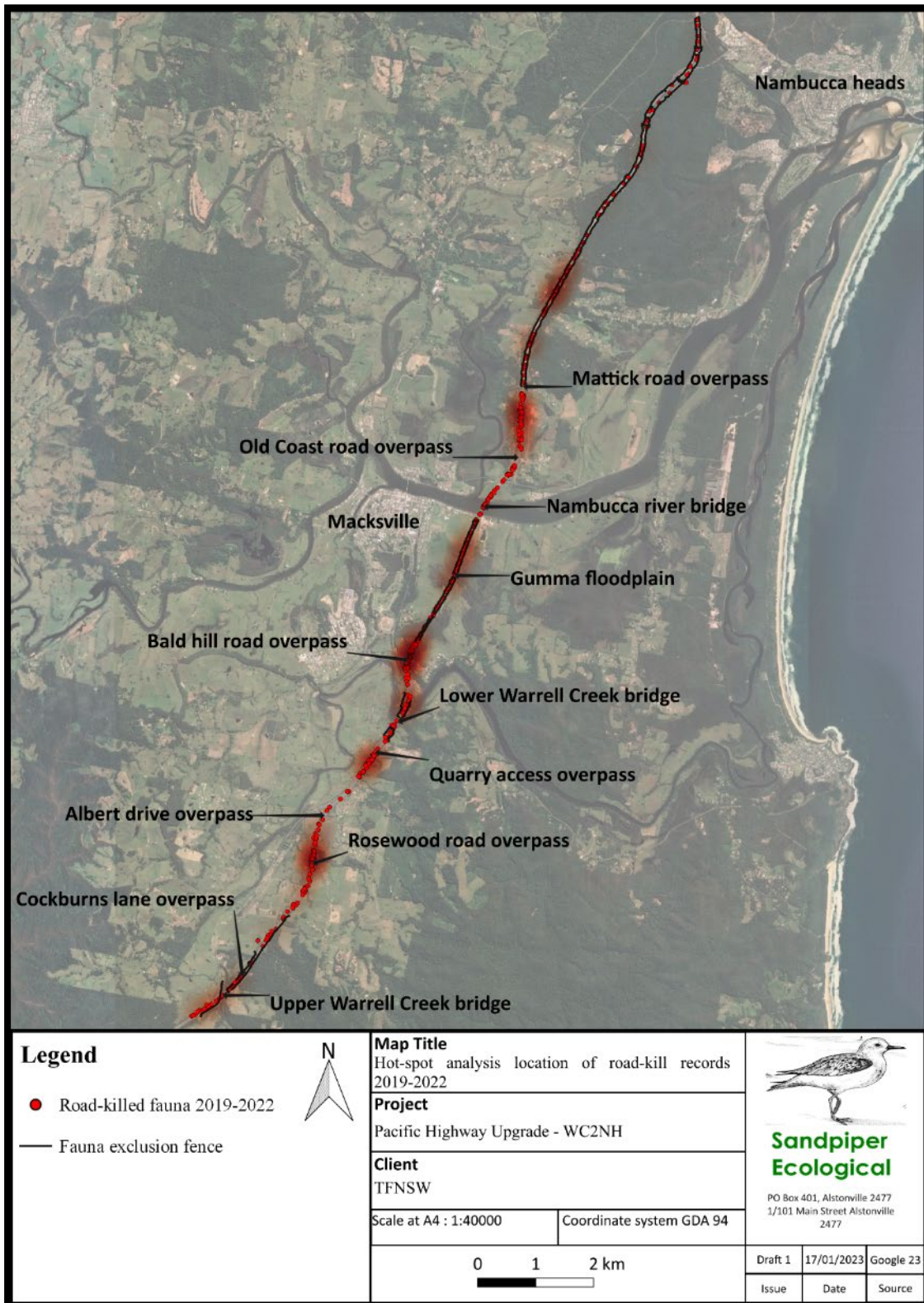


Figure 9: Heat map analysis of road-killed fauna that, under normal circumstances would be blocked by fauna fence (see Table 1) during operational monitoring surveys (2019-2022) at WC2NH. Overlaid red dots indicate the location of road-killed individuals recorded between 2019 and 2022.

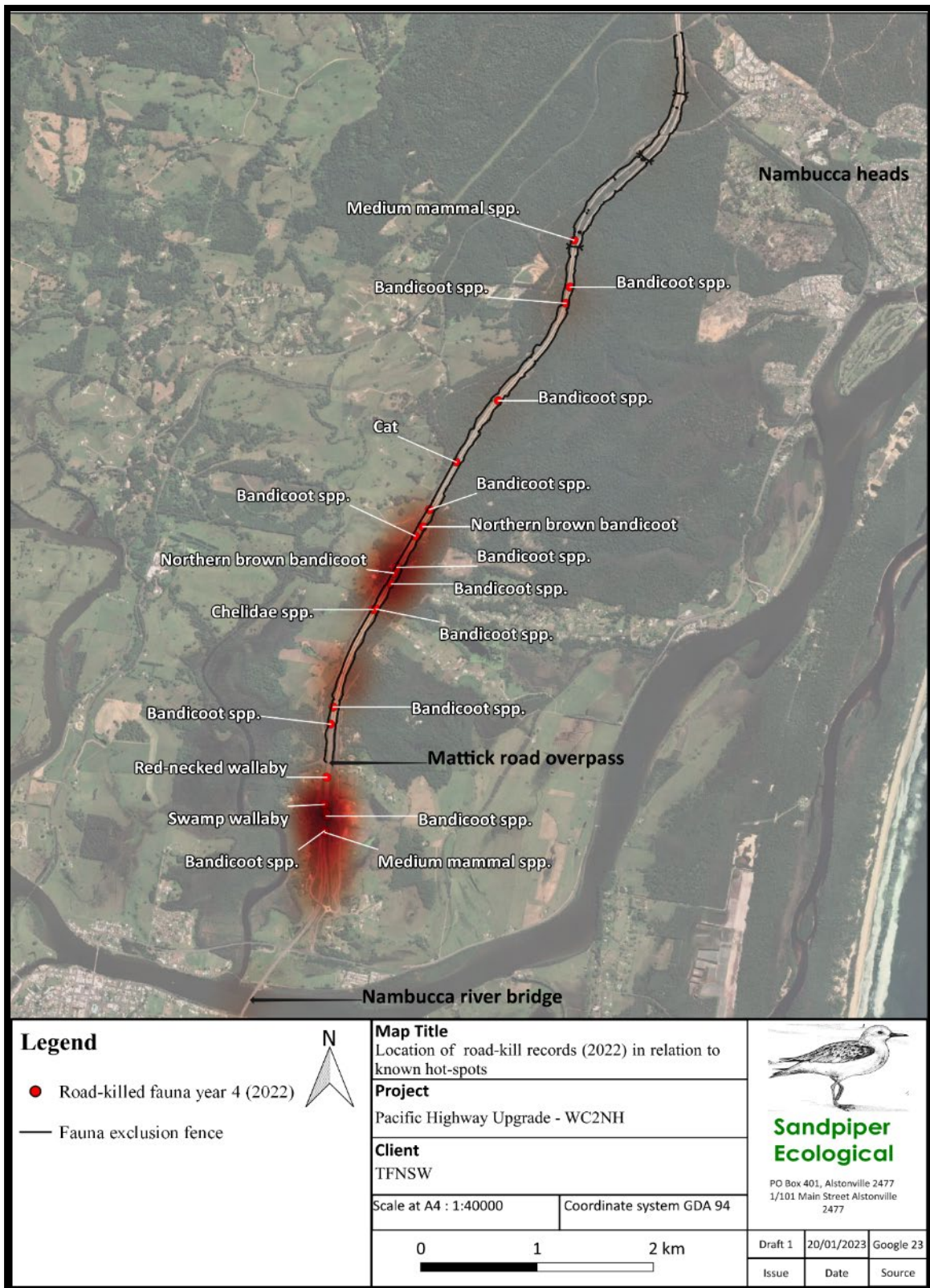


Figure 10: The location of road-killed fauna recorded during 2022 surveys in relation to known hot spots at WC2NH (northern extent). Hot spots have been determined by heat map analysis (2019-2022) of road-killed fauna, as seen in Figure 9. Note only include fauna which, under normal circumstances, are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

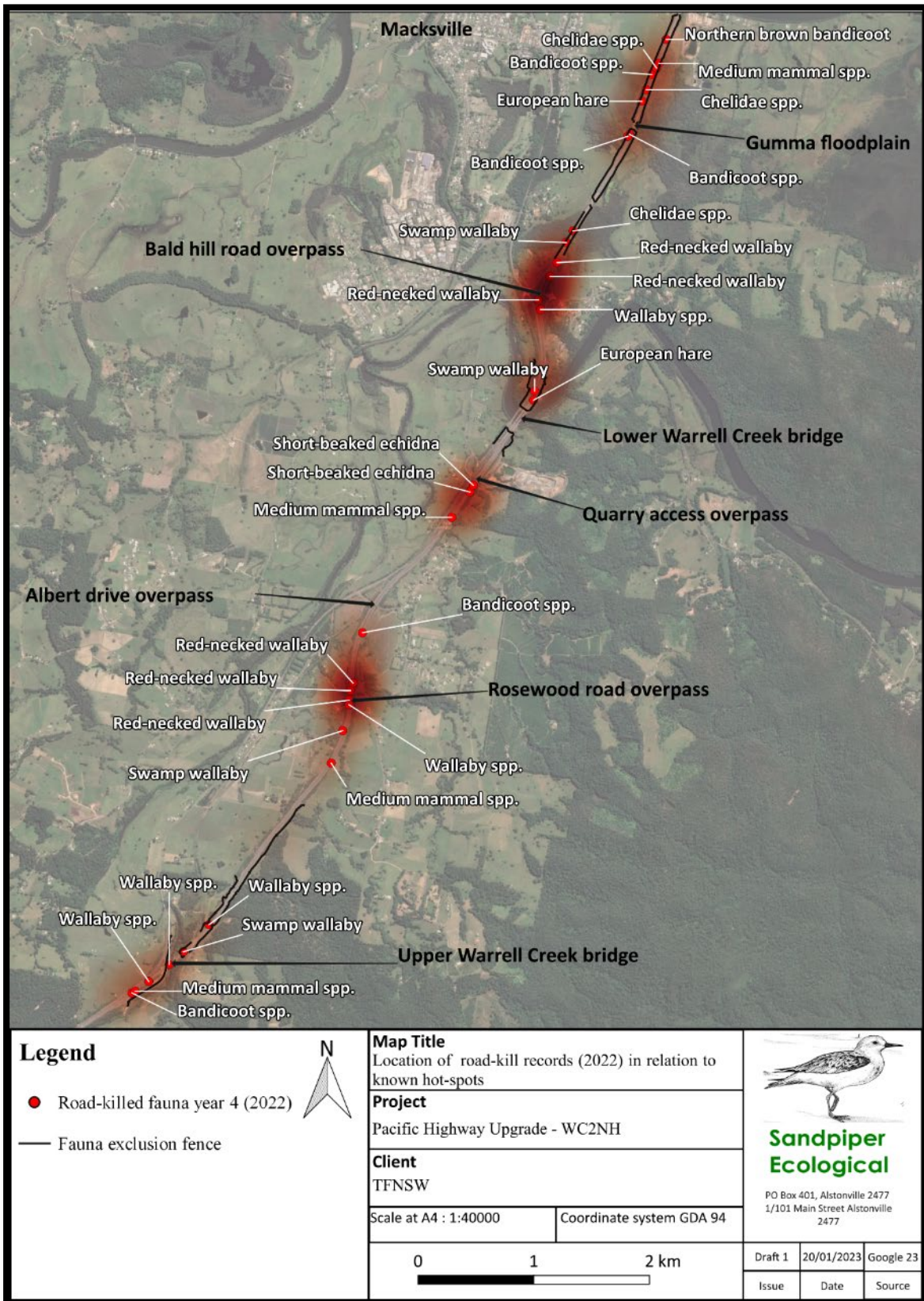


Figure 11: The location of road-killed fauna recorded during 2022 surveys in relation to known hot spots at WC2NH (southern extent). Hot spots have been determined by heat map analysis (2019-2022) of road-killed fauna, as seen in Figure 9. Note only include fauna which, under normal circumstances, are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

3.4 Exclusion fence inspection

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

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



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

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

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

4. Discussion

4.1 October 2022

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

4.2 Temporal variation

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

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

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

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

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

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

4.3 Distribution and fenced vs unfenced

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

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

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

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

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

4.4 Threatened fauna

Since WC2NH became operational four threatened species have been recorded as road-kill (grey-headed flying-fox, masked owl, black bittern and eastern grass owl), with no additional threatened species recorded in 2022. Overall, the number of grey-headed flying fox mortalities has declined since 2019. This trend is likely a result of improved foraging conditions associated with higher summer and autumn rainfall between 2020 and 2022, and less visitation to roadside trees to forage. Vehicle strike is not identified as a major threat to grey-headed flying foxes (DotEE 2017). Scheelings and Frith (2015) found that 2.4% of individuals presented at Victoria clinics were due to a vehicle strike, and 84.6% of these were euthanised.

5. Conclusion and recommendations

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

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

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

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

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

6. References

- Bond, A. R., & Jones, D. N. (2013). Roads and macropods: interactions and implications. *Australian Mammalogy*, *36*(1), 1-14.
- Carvalho, N. C., Bordignon, M. O. & Shapiro, J. T. (2014). Fast and furious: a look at the death of animals on the highway MS-080, southwestern Brazil. *Iheringia, Ser. Zool*: **104**,
- Taylor, B. D., & Goldingay, R. L. (2004). Wildlife road-kills on three major roads in north-eastern New South Wales. *Wildlife Research*, *31*(1), 83-91.
- Department of the Environment and Energy (2017). *Draft recovery plan for the grey-headed flying-fox Pteropus poliocephalus*. Commonwealth of Australia.
- Geolink (2018a). *Road-kill monitoring report: WC2NH Stage 2A*. Report prepared for NSW Roads and Maritime Services.
- Geolink (2018b). *Road-kill monitoring summary report: autumn (April) 2018*. Letter report prepared for NSW Roads and Maritime Services.
- Geolink (2018c). *Road-kill monitoring summary report: winter (July) 2018*. Letter report prepared for NSW Roads and Maritime Services.
- Geolink (2018d). *Road-kill monitoring report - initial 12 weeks WC2NH Stage 2B*. Report prepared for NSW Roads and Maritime Services.
- Grant, R., Halliday, T. & Chadwick, E. (2013). Amphibians' response to the lunar synodic cycle – a review of current knowledge, recommendations, and implications for conservation. *Behavioural Ecology*: **24**, 53-62.
- Higgins, P. J. (1999). *Handbook of Australasian, New Zealand and Antarctic birds, vol 4 parrots to dollarbird*. Oxford University press, Melbourne.
- Klocker, U., Croft, D. B. & Ramp, D. (2006). Frequency and causes of kangaroo-vehicle collisions on an Australian outback highway. *Wildlife Research*: **33**, 5-15.
- Loss, S. R., Will, T., & Marra, P. P. (2014). Estimation of bird-vehicle collision mortality on U.S. roads. *The Journal of Wildlife Management*: <https://doi.org/10.1002/jwmg.721>
- McDonald, J. H. (2013). *Handbook of biological statistics*. Sparky House Publishing, Baltimore, Maryland.

- Mizuta, T. (2014). Moonlight-related mortality: lunar conditions and road-kill occurrence in the Amami woodcock *Scolopax mira*. *The Wilson Journal of Ornithology*: **126**, 544-552.
- Ogletree, K. A., & Mead, A. J. (2020). What roadkills did we miss in a driving survey? A comparison of driving and walking surveys in Baldwin County, Georgia. *Georgia Journal of Science*, 78(2), 8.
- RMS (2018). *Warrell Creek to Nambucca Heads Stage 2 Ecological Monitoring Program*. Report prepared by NSW Roads and Maritime Services.
- Sandpiper Ecological (2015). *Pacific Highway Upgrade: Nambucca to Urunga – underpass monitoring year one construction phase*. Report prepared for Lend Lease Engineering.
- Sandpiper Ecological (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 (2019a). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2019*. Report prepared for Transport for NSW.
- Sandpiper Ecological (2019b). *Escape structure monitoring – autumn 2019*. Letter report prepared for NSW Roads and Maritime Services.
- Sandpiper Ecological (2020). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2020*. Report prepared for Transport for NSW.
- Sandpiper Ecological (2021). *Pacific Highway Upgrade Warrell creek to Nambucca Heads: operational phase road-kill monitoring – annual report 2021*. Report prepared for Transport for NSW.
- Santori, C., Spencer, R. J., Van Dyke, J. U., & Thompson, M. B. (2018). Road mortality of the eastern long-necked turtle (*Chelodina longicollis*) along the Murray River, Australia: an assessment using citizen science. *Australian Journal of Zoology*, 66(1), 41-49.
- Scheelings, T., F. & Frith, S. E. (2015). Anthropogenic factors are the major cause of hospital admission of a threatened species, the grey-headed flying-fox (*Pteropus poliocephalus*), in Victoria Australia. *PLoS One*: **10**, e0133638
- Vernes, K., & Pope, L. C. (2009). Reproduction in the northern brown bandicoot (*Isodon macrourus*) in the Australian Wet Tropics. *Australian Journal of Zoology*, 57(2), 105-109.

Appendix A – Field data

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

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

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

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

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

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

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

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

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