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OFFSET PEST ANIMAL MONITORING YEAR 2 REPORT

December 2023

DEPARTMENT OF TRANSPORT AND MAIN ROADS

Executive summary

Ecosure monitored vertebrate pests across 13 properties designated to offset the impact of the Bruce Highway Project: Cooroy to Curra Section D (Woondum to Curra) in Gympie. This is the second annual monitoring round following baseline monitoring February – April 2021. The offset properties are located in three main clusters: Curra, Victory Heights, and Woondum. Monitoring aimed to estimate Year 2 levels of pest activity in each offset cluster for comparison to the activity observed in 2021 (baseline) and 2022 (Year 1), as a means of measuring the efficacy of pest management activities.

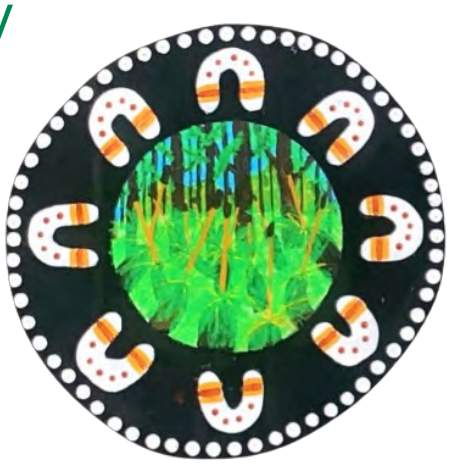
Camera traps were deployed mid-February across 68 sites for a total of eight weeks. Activity indices for pest species in each offset cluster were estimated. Activity indices represent the expected number of detections (red fox/wild dog/feral cat/feral pig) per camera station per day at each offset cluster; it is assumed that these indices are proportional to absolute pest abundance.

Red fox and feral pig activity continued to decline in 2023 at all sites that they had previously been recorded. Feral cat activity remained consistently low at Curra and there were no detections at Victory Heights. Wild dog activity increased substantially at both Curra and Woondum. The increase was likely due to immigration from surrounding properties as several packs of dogs not identified in previous surveys were detected at both sites.

The results from the 2023 monitoring suggest a continued overall decrease in pest activity across all three offset clusters compared to baseline surveys. Pest activity indices decreased or remained consistent across the offset clusters, with the exception of wild dogs in Curra and Woondum which have increased since the 2022 monitoring period. The results suggest current pest management efforts are effective in reducing pest activity within the offset clusters and that management should be maintained to mitigate natural fluctuations in local pest animal populations. Evidence suggests dingoes likely act to reduce impacts of cats and foxes on native species. Understanding the composition of these populations in the local area will inform management approaches in the future. Ecosure recommend DNA collection from live individuals to confirm the degree of dingo DNA present in local populations.

Ongoing management should prioritise pest species with the highest activity indices, species displaying a substantial increase in activity and pest species that have not shown significant decline in activity. Feral cat and red fox activity has declined or remained stable at all sites that have recorded them previously; feral cats were not recorded at Victory Heights in 2023. Wild dog activity has increased since 2022, primarily at Curra but an increase in activity was also detected at Woondum. Feral pigs continue to show a steady decline in activity at Curra.

Acknowledgement of Country



Ecosure acknowledge the Traditional Custodians of the lands and waters where we work. We pay deep respect to Elders past and present who hold the Songlines and Dreaming of this Country. We honour and support the continuation of educational, cultural and spiritual customs of First Nations peoples.

Acronyms and abbreviations

AIC_C	Akaike information criterion analyses adjusted for small samples sizes
BBBQ	Black-breasted button-quail
DAWE	Department of Agriculture, Water, and the Environment
DEE	Department of the Environment and Energy
DES	Department of Environment and Science
DPI	Department of Primary Industries
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GIS	Geographical Information Systems
GLMM	Generalised Linear Mixed Model
HSE	Health Safety and Environment Plan
NSW	New South Wales
OMP	Offset Management Plan Detailed Design for the Cooroy to Curra Section D
PAMS	Pest Animal Management Strategy
the Project	Bruce Highway Project: Cooroy to Curra Section D (Woondum to Curra)
QPWS	Queensland Parks and Wildlife Service
TMR	Department of Transport and Main Roads

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1 Introduction

The Department of Transport and Main Roads (TMR) has commenced construction for the Bruce Highway Project: Cooroy to Curra Section D (Woondum to Curra) (the Project). As part of the conditions of approval (EPBC 2017/7941) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), an Offset Management Plan (OMP) was developed by TMR. This included securing and managing 13 offset properties in the Gympie Region, located in Curra, Victory Heights, and Woondum, for koala (*Phascolarctos cinereus*) and black-breasted button-quail (*Turnix melanogaster*, BBBQ) (Table 1). The OMP outlined several conditions related to the delivery of offsets, including pest management.

Ecosure was engaged by TMR to undertake quarterly pest control works (commencing October 2021) within the offset properties, as described in the detailed OMP, targeting pest species known to threaten koala and BBBQ: red fox (*Vulpes vulpes*), wild dog (*Canis lupus familiaris*), feral pig (*Sus scrofa*), and feral cat (*Felis catus*). In order to assess the efficacy of pest management works over 10 years, Ecosure developed the Pest Animal Monitoring Program (Ecosure 2020) to detect pest activity level changes and allow implementation of the active Control Plan (Ecosure 2021) to be evaluated. Baseline pest animal surveys were conducted across the offset properties in early 2021, in accordance with the Pest Animal Monitoring Program. This established a baseline activity index for each relevant pest species in each offset cluster.

In early 2023, Ecosure commenced the third round of offset pest monitoring, representing Year 2 of the Pest Animal Monitoring Program (i.e. following baseline monitoring). This report provides an overview of methodology and results from Year 2 monitoring (February – April 2023). It also provides a discussion on pest activity levels in comparison to observations recorded during the baseline (2021) and Year 1 (2022) survey periods.

1.1 Scope of works

The scope of the monitoring program included:

- monitoring as per the Pest Animal Monitoring Program (Ecosure 2020):
  - eight-week camera monitoring period
  - 68 cameras deployed across three offset clusters in Gympie (Curra, Victory Heights, Woondum)
  - regular battery and SD card checks.
- analysing camera trap images and conducting statistical analyses
- preparing the Year 2 monitoring report summarising field and statistical methods, results, and supporting maps.

Control works are also undertaken in accordance with the Pest Control Plan (Ecosure 2021). Results of the control program are reported in monthly progress reports and summarised in Section 3.3.

1.2 Site context

Of the three offset clusters, Curra is the largest (approximately 239 ha), followed by Woondum (56 ha) and Victory Heights (46 ha); the total offset area is around 341 ha (Table 1, Figure 1).

Table 1 Offset site details

Cluster location/name	Lot/Plan	Offset focal species	Area (ha)	Total area (ha)
Curra	1MPH23906	koala	27.69	239.44
	3MPH23906	koala	22.97	
	4MPH23906	koala	3.46	
	878MCH1061	koala	144.56	
	889CP864404	koala	40.77	
Victory Heights	19SP299683	koala	26.86	45.58
	1MPH23904	koala	5.85	
	1MPH5670	koala	2.02	
	2MPH14193	koala	7.27	
	763MCH5342	koala	3.58	
Woondum	102SP297908	koala + BBBQ	12.66	56.09
	2SP302526	koala + BBBQ	15.18	
	3SP302524	koala + BBBQ	28.25	
Total				**341.11**

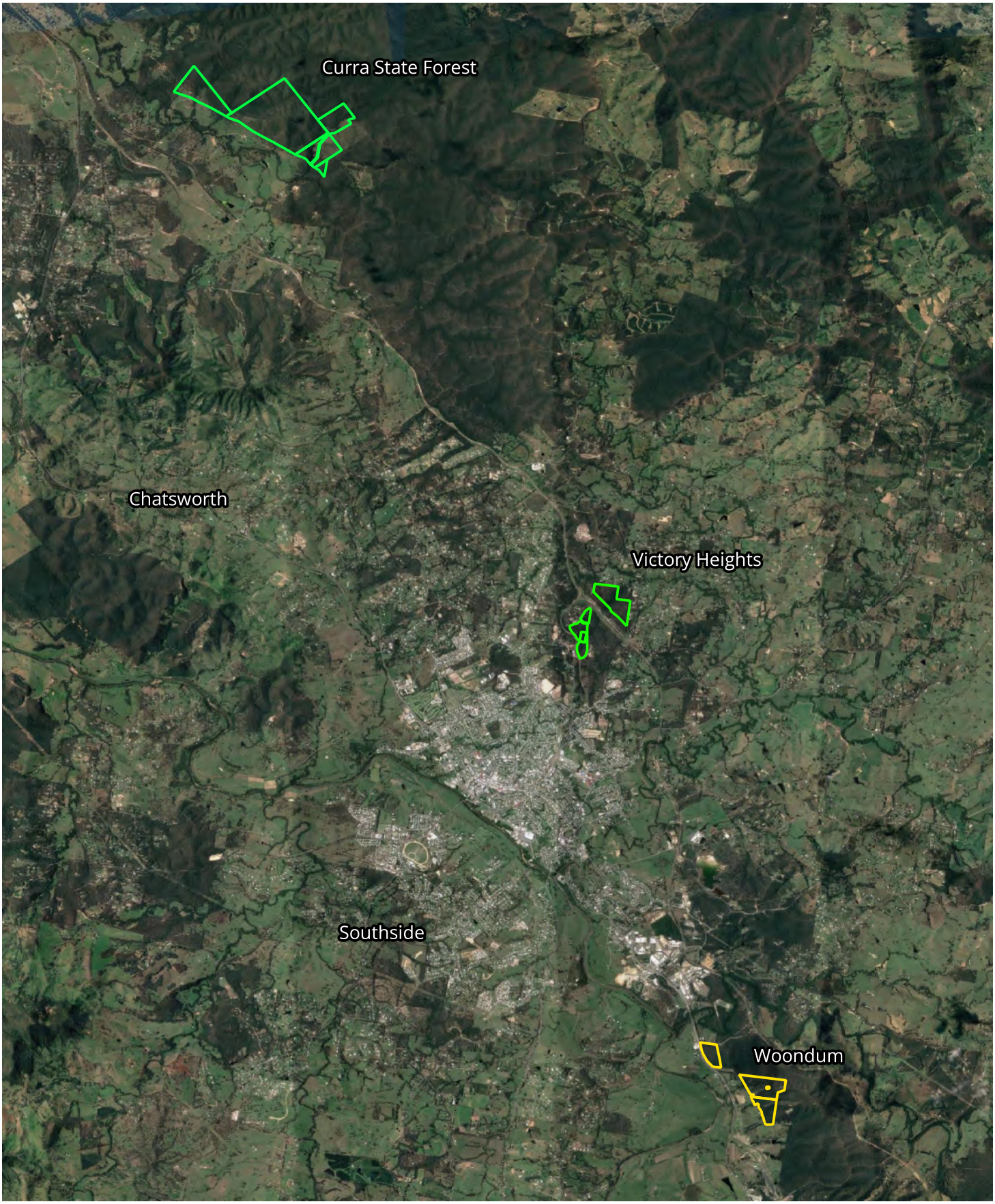

Figure 1: Location of the Bruce Highway Project: Cooroy to Curra Section D (Woondum to Curra) offset sites.

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C2CD Offset Pest Animal Control and Survey - Year 2

Offset

- Koala and clack-breasted button-quail offset area
- Koala offset area

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0 1 2 km

GDA 1994 MGA Zone 56
Projection: Transverse Mercator
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Units: Meter

2 Methods

The following field work, analysis and reporting was undertaken by suitably qualified personnel to meet the Commonwealth Requirements of the OMP. See Appendix 1 for further details on personnel and their roles throughout this project.

2.1 Camera trapping

Sixty-eight passive infrared cameras (Reconyx Professional HP2X Hyperfire 2, Reconyx Inc. Holmen, WI, USA) were deployed between the 15th – 16th of February 2022 and collected on the 13th of April 2022 (eight weeks total). Cameras were installed to the same specifications as the baseline survey (Ecosure 2021), including location (same tree where possible), direction, height, and angle, in order to maintain consistent detectability between different survey periods (see Appendix 2 for camera locations). In some cases, this was not possible, though only small adjustments were made to ensure minimal changes to detectability (Table 2). Additionally, camera 9 malfunctioned and failed to record and camera 68 was damaged by kangaroo and stopped recording on 01/03/2023.

Table 2 Camera location adjustment details.

Camera	Distance moved	Reason
11	20m	Original tree had fallen, a suitable nearby tree was chosen
20	20m	Lantana regrowth obscured camera perspective, a suitable nearby tree was chosen
21	30m	Grass regrowth obscured camera perspective, a suitable nearby tree was chosen
24	5m	Lantana regrowth obscured camera perspective, a suitable nearby tree was chosen
28	5m	Natural regrowth obscured camera perspective, a suitable nearby tree was chosen
39	5m	Fallen tree blocked original tree, a suitable nearby tree was chosen
40	5m	Creek was full, camera was moved to adjacent creek
42	5m	Lantana regrowth obscured camera perspective, a suitable nearby tree was chosen
46	0m	Perspective changed due to lantana
50	10m	Original tree had fallen, a suitable nearby tree was chosen
56	5m	Fallen debris blocked original tree, a suitable nearby tree was chosen
57	10m	Lantana regrowth obscured camera perspective, a suitable nearby tree was chosen
59	5m	Fallen tree blocked original tree, a suitable nearby tree was chosen

In accordance with baseline surveys, cameras were placed approximately 250 m apart along roads, tracks, and movement corridors where possible, or suitable nearby locations. Cameras were attached to stable, permanent tree trunks approximately 30 cm from the road/track edge (where applicable), 50 cm above the ground, approximately 45° to the road/track, and

north/south-facing to avoid direct sunlight. Vegetation in front of the cameras was trimmed to reduce the number of false triggers and maximise pest animal detectability. Cameras were set to capture images with the following settings: rapid fire, no delay, 10 images per trigger, 3.1-megapixel resolution, high-medium sensitivity, night mode: fast shutter or high quality.

To maximise the detection of feral cats in Woondum offset sites, seven camera traps were baited with tinned cat food.

2.2 Data analysis

2.2.1 Image sorting

Camera trap images were analysed over the two-weeks following camera collection. A five-minute window was used to discriminate between independent pest observations i.e. an observation was considered independent if it was separate from the preceding image/s by more than five minutes. In instances where animal behaviour clearly negate this, e.g. animals resting near cameras for extended periods, a single observation was scored. This ensured that calculating the activity index based on this rule would not introduce inaccuracies that may inflate true activity. As such, image sequences were analysed to individually identify pest species where possible. When clusters of images occurred, suggestive of the same individual they were only classed as independent if they were separated by approximately 30 minutes spent away from the camera.

All observations were entered into a database with the corresponding camera number, offset cluster, track type, and bait status used for statistical analyses.

2.2.2 Statistical analyses

An activity index was used to represent relative pest abundance in each offset cluster due to the challenges of deriving an absolute species population abundance within offset clusters (Bengsen et al. 2014; Thompson et al. 2019). The activity index describes the expected number of detections (red fox/wild dog/feral cat/feral pig) per camera station per day at each offset cluster.

Activity indices were calculated using generalised linear mixed models (GLMMs) fit by maximum likelihood (Laplace Approximation) with standard error distributions. This differs slightly from the statistical model used to analyse the baseline results, in which Poisson error distributions were used (Ecosure 2021). Though the Poisson error distribution provided the best fit for the baseline data model, the data are more heavily clustered than expected for a Poisson error distribution, meaning the activity indices may not represent the raw data well. While a normal error distribution technically provides a worse fit for the model, it does ensure that the parameter point estimates (i.e. activity indices) better represent the raw data, which is important when comparing activity between years.

To allow for comparability, activity indices from baseline and past monitoring surveys were re-calculated using a normal error distribution. The R Studio coding scripts for each activity index

calculation are provided in Appendix 4.

2.3 Limitations

Limitations pertinent to the survey design are outlined in the Pest Animal Monitoring Program (Ecosure 2020). The following limitations relate specifically to the implementation of baseline monitoring.

Deployment of cameras for baseline monitoring was originally scheduled for November 2020 but unavoidable delays outside Ecosure control resulted with commencement in February 2021. Ideally, surveys would have been in late-spring/early-summer to coincide with peak activity of foxes and wild dogs. However, red foxes and wild dogs continue to disperse until late May (DAF 2016), so this monitoring period was deemed acceptable for baseline monitoring. While this has the potential to reduce species detectability compared to the more optimal period, if surveys are conducted at the same time each year (as was the case in 2022 and 2023), robust comparisons in species abundance/activity trends can be made.

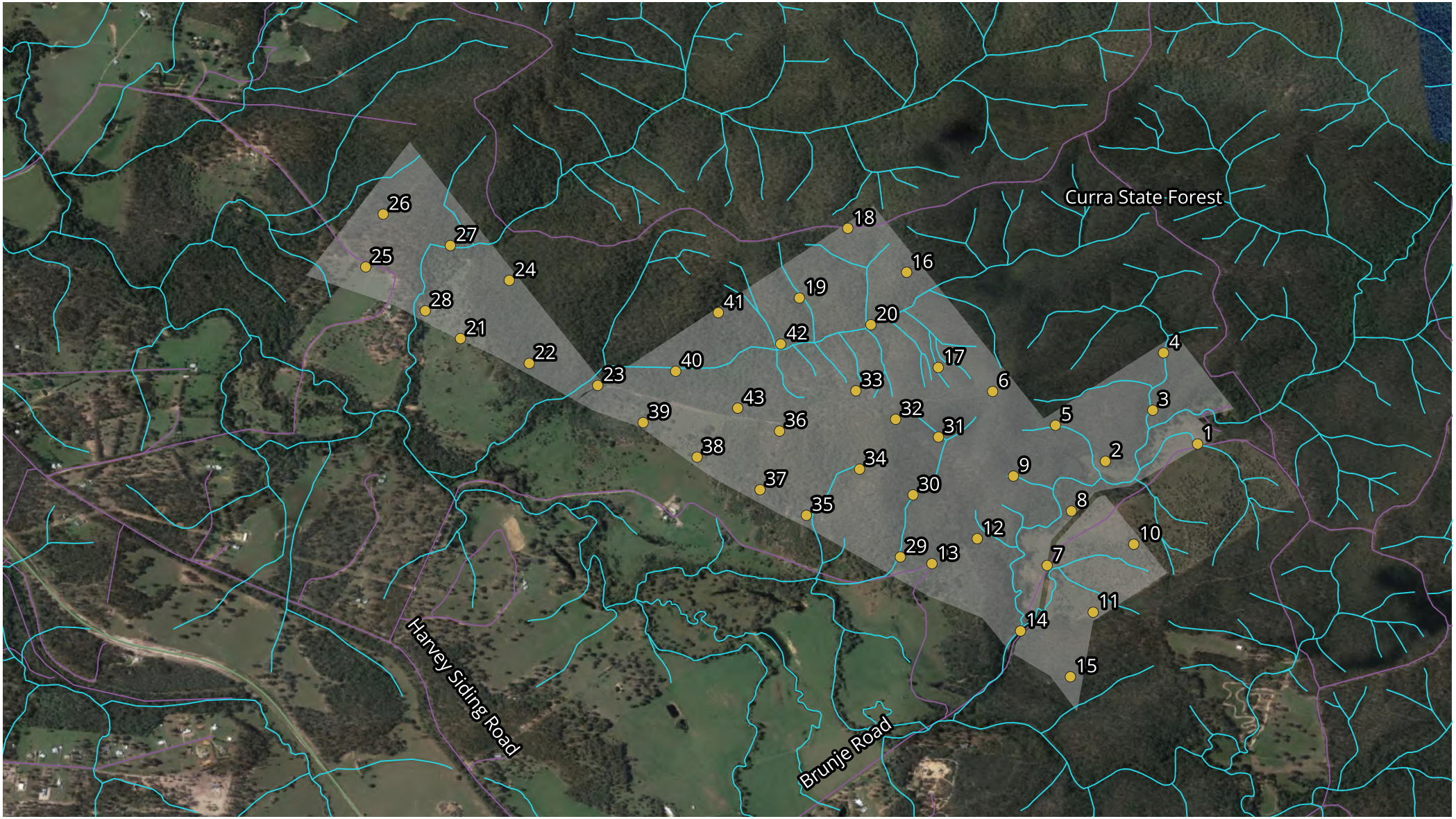

Figure 2: Camera locations in Curra offset site

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Camera location
Offset cluster
Watercourse
Road
Rail

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0 250 500 750 m

GDA 1994 MGA Zone 56
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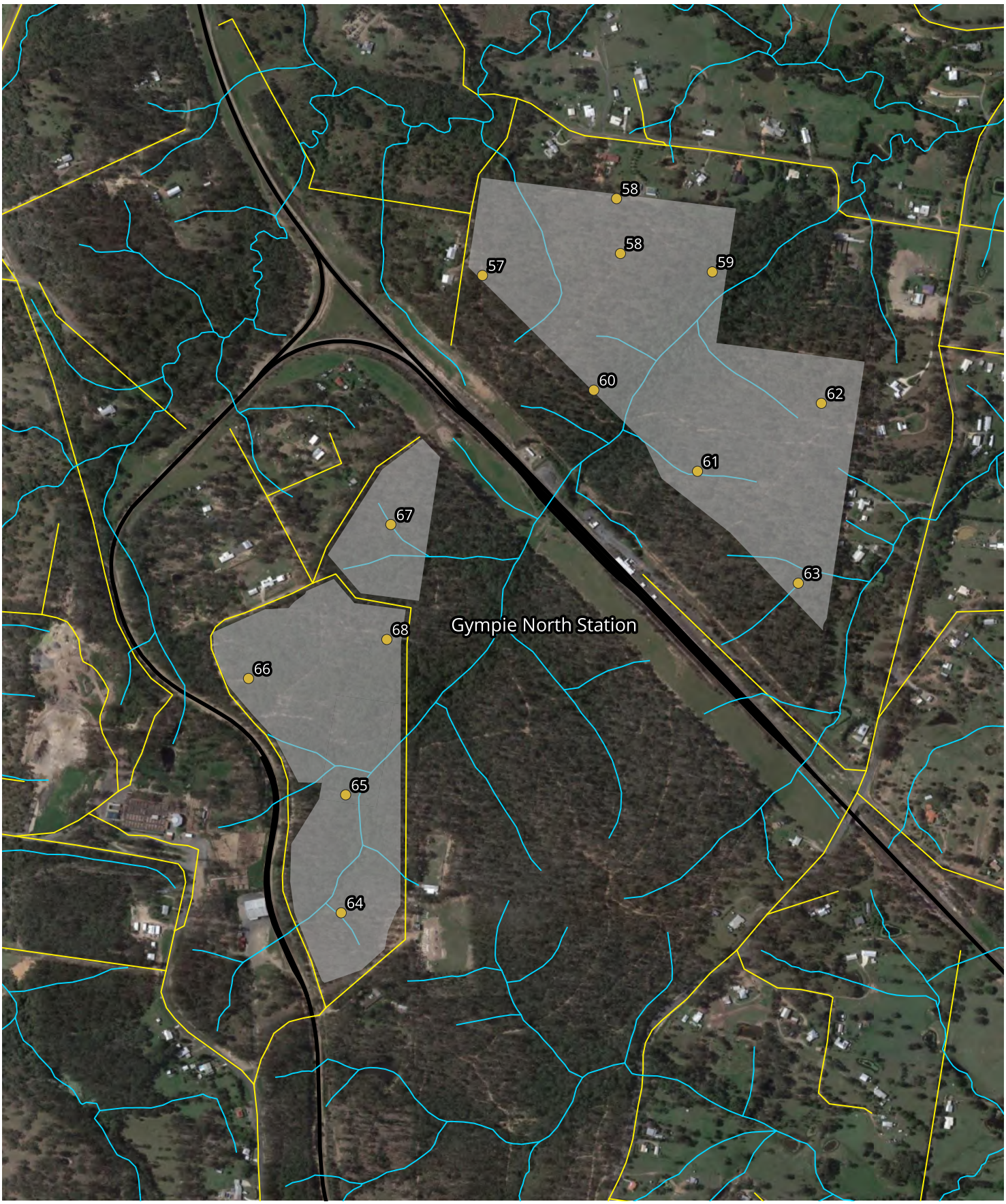

Figure 3: Camera locations in Victory Heights offset sites

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Camera locations
Roads
Offset cluster
Rail
Watercourses

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0 100 200 300 m

GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
Units: Meter

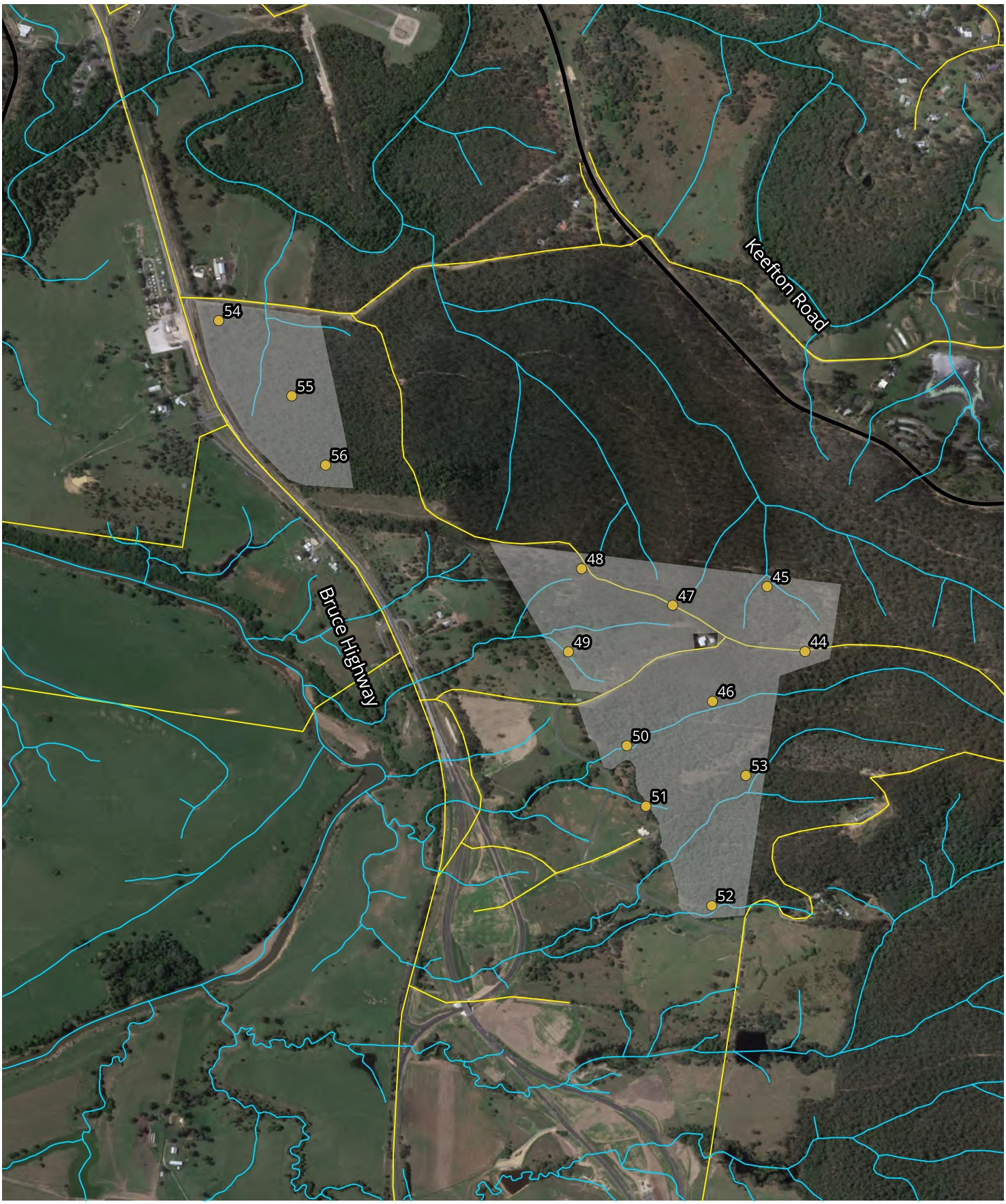

Figure 4: Camera locations in Woondum offset sites

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Camara locations — Roads

Offset cluster — Rail

Watercourses

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Date: 24/05/2023

0 100 200 300 m

GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
Units: Meter

3 Results

3.1 Pest species detection trends

Red foxes were recorded in all three offset clusters, which is consistent with past results (Table 3). The highest activity was detected in Curra, followed by Victory Heights and Woondum. This differs from past years which identified substantially higher activity in Victory Heights. Red fox activity appears to be decreasing in all three offset clusters in comparison to the baseline surveys (Figure 5), with similar activity recorded in 2022 and 2023. The largest decrease was observed in Curra, followed by Victory Heights and Woondum.

Wild dogs were detected in Curra and Woondum, but not in Victory Heights, which is consistent with baseline results (Table 3). Analyses indicate that wild dog activity decreased between 2021 and 2022 but increased in 2023 at both sites and is now higher than pre-control baseline activity (Figure 5). This activity increase is driven by the arrival of a novel pack of at least seven individuals which were observed using tracks regularly in the last week of data collection.

Feral cats were only detected at Curra with much lower activity than wild dogs and red foxes (Table 2, Figure 5). Analyses suggests that feral cat activity has increased marginally in 2023 but has remained broadly consistent with 2022 levels and remains lower than during the baseline survey (Figure 5). Given the low total detections of feral cats (seven detections in 2023) comparing activity indices can be problematic and potentially driven by data stochasticity rather than being reflective of genuine trends. Several feral cats observed in Curra during 2023 appear to be the same individuals observed during 2022 (Appendix 3), likely a reflection of low abundance and persistent residence within Curra (see Appendix 3 for feral cat images).

Feral pigs were only recorded in Curra, which is consistent with past surveys (Table 2, Figure 5). During previous surveys, feral pigs were only occasionally detected in Curra, though the sporadic nature of detections and high variability of group sizes (1 – 15 individuals) across the survey periods means that the data are limited. Feral pig activity continued to decline and is now lower than in 2022 and the baseline survey. Notably, the average group size has continued to reduce, with only lone individuals observed during the 2023 survey.

The spatial distribution of pest animal activity within each offset cluster shows (Figure 6 – Figure 8). Note, these maps show total number of pest observations on each camera over the entire monitoring period.

Table 3 Activity indices calculated for each pest species in each offset cluster.

Offset cluster	Pest activity indices (estimated no. of observations/camera/day)											
	red fox			wild dog			feral cat			feral pig		
	2021	2022	2023	2021	2022	2023	2021	2022	2023	2021	2022	2023
Curra	0.0455	0.0126	0.0158	0.0306	0.0214	0.0605	0.0047	0.0022	0.0039	0.0168	0.0108	0.0016
Victory Heights	0.0906	0.0831	0.0190	0	0	0	0.0027	0.0030	0	0	0	0
Woondum	0.0349	0.0326	0.0130	0.0170	0.0039	0.0161	0	0	0	0	0	0

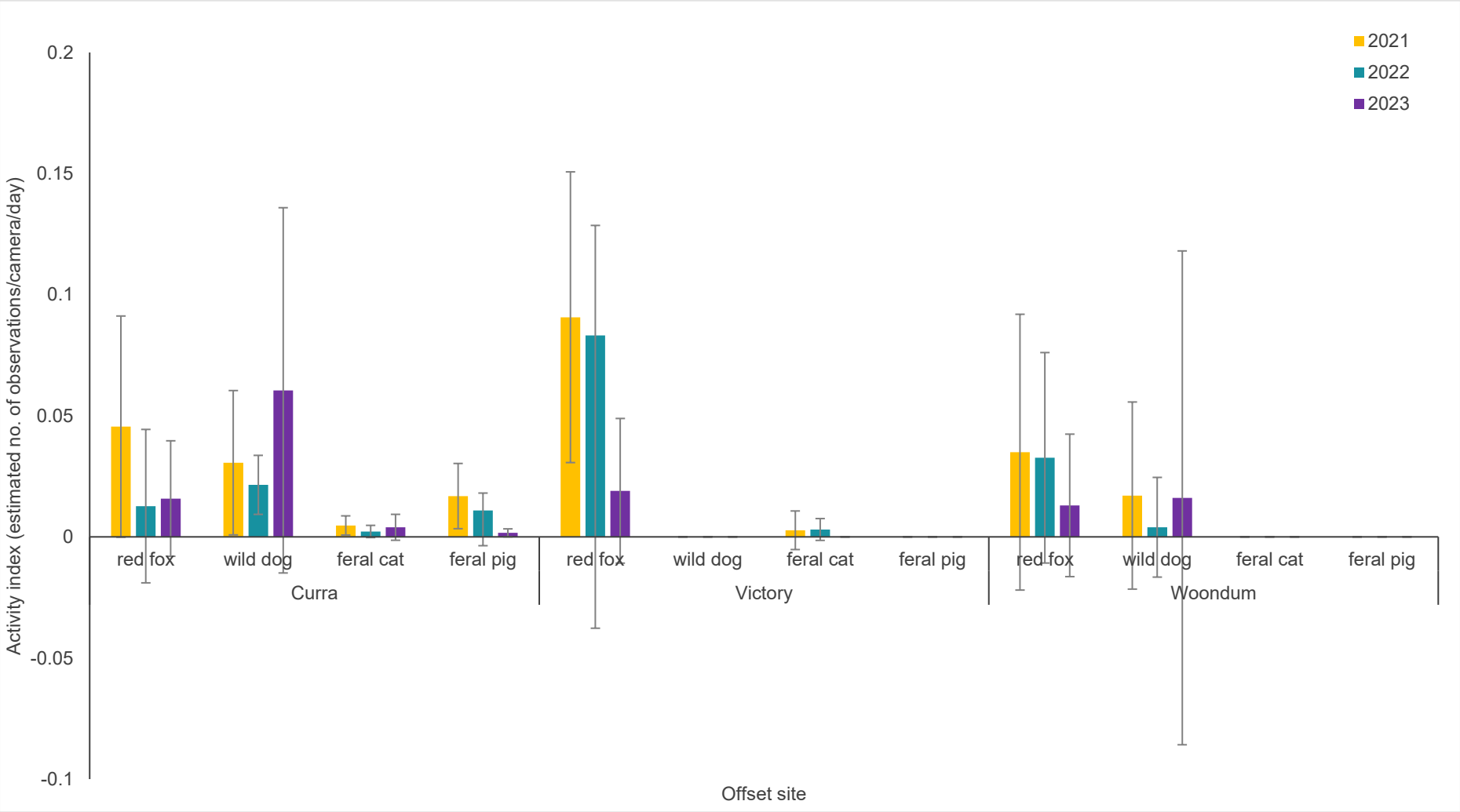

Figure 5 Pest activity indices estimated from camera traps deployed for 8-weeks in February 2023. GLMM were used to calculate the activity index. The index estimates the number of observations of each pest species per camera per day. The data are presented with standard error bars showing confidence intervals (raw data provided in Appendix 5).

Figure 6: Pest animal observations in Curra offset properties

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0 500 1,000 m

GDA 1994 MGA Zone 56
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Figure 7: Pest animal observations in Victory Heights offset properties

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Species
- Feral cat
- Feral pig
- Red fox
- Wild dog

No. of observations
- 1 - 2
- 2 - 10
- 10 - 20
- 20 - 49

- Watercourses
- Roads
- Rail
- Offset site

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0 100 200 m

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Figure 8. Pest animal observations in Woondum offset properties

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Species
- Feral cat
- Feral pig
- Red fox
- Wild dog

No. of observations
- 1 - 2
- 2 - 10
- 10 - 20
- 20 - 49

- Watercourses
- Roads
- Rail
- Offset site

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Date: 06/06/2023

0 100 200 300 m

GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
Units: Meter

3.2 Summary of pest control works

Control program results are detailed in monthly reports with an overall summary to date in Table 4.

Camera monitoring during control periods showed limited red fox, feral cat and wild dog presence. The pack of wild dog/dingoes at Curra was not seen during control periods prior to annual monitoring and only over several days towards the end of this monitoring period. This suggests it is a pack dispersing/moving through the landscape and demonstrates how significantly monitoring results can be influenced by uncommon, landscape-scale movements beyond the boundaries of the offset properties. The number of animals removed during control, as shown in Table 4, should be used as a success measure when interpreting monitoring results.

Table 4 Summary of pest animals humanely euthanased. Before and after monitoring periods

Offset cluster	Period	Species							
		red fox		wild dog		feral cat		feral pig	
		Before	After	Before	After	Before	After	Before	After
Curra	Baseline*	0	0	0	0	0	0	0	0
	Year 1**	0	2	0	5	0	0	8	15
	Year 2***	1	1	1	0	0	0	2	1
Victory Heights	Baseline	0	0	0	0	0	0	0	0
	Year 1	0	0	0	0	0	0	0	0
	Year 2	0	0	0	0	0	0	0	0
Woondum	Baseline	0	0	0	0	0	0	0	0
	Year 1	0	2	0	0	0	0	0	0
	Year 2	0	0	0	0	0	0	0	0
Year 2 Total		1	3	1	0	0	0	2	1
Grand Total		6		6		0		29	

*Baseline monitoring. Before = before baseline monitoring (i.e., before February 2021); After = after baseline monitoring (i.e. April 2021 – October 2021).

**Year 1. Before = before Year 1 monitoring (i.e. October 2021 – January 2022); After = after Year 1 monitoring (i.e. April-October 2022).

*** Year 2 monitoring. Before = before Year 2 monitoring (i.e. October 2022 – January 2023); After = after year 2 monitoring (i.e. April-June 2023)

4 Discussion & recommendations

Results from the 2023 monitoring event suggest relatively low pest activity at all offset sites with the exception of wild dogs at Curra and to a lesser extent Woondum. Both sites experienced an increase in recorded activity between 2022 and 2023. Feral pig and red fox activity has either continued to decline or remained consistently low at all offset sites. A negligible increase to red fox activity was detected at Curra but likely does not indicate an increase in overall abundance. Feral cat activity has remained stable and low at Curra; there were no detections at either Victory Heights or Woondum. The observed changes in pest activity between years may be due to several factors, including (but not limited to):

- active pest management on the offset properties, and by surrounding landholders, reducing abundance of pests
- natural immigration and emigration of pest animals from the surrounding landscape
- sampling error resulting from methodological limitations of camera trapping i.e. detections are opportunistic and can reflect changes in target species behaviour.

Given the lack of experimental control sites in this study (i.e. monitoring and no management), the potential impact of each of these factors on the pest activity within each offset cluster cannot be determined. It is likely that a combination of factors contributed to the changes in pest activity. However, the removal of a total of 5 wild dogs, 5 red foxes and 36 feral pigs from the landscape since the program commenced is likely to have contributed substantially to the general decrease in pest activity.

The increase in wild dog activity at Curra and Woondum may indicate the need for targeted on-ground control at the site. Packs of dogs observed on camera traps in the last week of survey appear to contain a significant number of sub-adult and young adult animals not identified in previous surveys, suggesting that immigration may be occurring from surrounding areas. The effect on activity indices of a single group of animals highlights the impact that natural animal movement within the broader landscape has on monitoring results. In also highlights the limitation of relying on activity indices alone when monitoring population dynamics without relevant context such as individual movement data or the maturity of the observed individuals. It is for this reason that management success should be assessed within the broader context rather than activity indices alone which can be biased by local events or data stochasticity.

A growing body of research is suggesting that wild dog populations are likely to express a high proportion of dingo ancestry (Cairns et al. 2021). This is also true for wild dogs in the Gympie region as Cairns et al. (2021) recovered purity rates of from 65% - 75% and >75% in local populations. Research also suggests that dingo presence likely acts to mitigate the impacts of other feral predators, particularly cats and foxes while predating small sensitive species at much lower rates than either cats or foxes (Glen et al. 2007 Brook et al. 2012, Gordon et al. 2015). We recommend DNA collection from live individuals (for example, using methods in Lobo et al. 2015) to confirm this and inform future management at the site.The lowest response in activity indices given control efforts continues to be feral cats in Curra. Efforts

should be increased in Curra for all species, particularly dogs given the increase in recorded activity in 2023. Pest control should continue at all sites including review of additional/alternative control options that may be incorporated for future pest management activities.

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Appendix 1 Suitably qualified personnel

The following personnel were involved in the on-ground field work, statistical analyses, and reporting for this project.

Name & role	Qualifications	Relevant experience
Jess Bracks Principal Wildlife Biologist ***Project Manager, Reviewer***	Bachelor of Applied Science in Animal Studies (Wildlife Biology), University of Queensland, 2005	Jess is a Wildlife Biologist with 15 years' practical experience in the veterinary, zoo and consulting industries. She is passionate about driving pragmatic wildlife management policy; balancing the needs of community and conservation. Jess is often invited to advise on policy for local, state and federal government. Jess has played pivotal roles in facilitating various multi-stakeholder groups with a focus on coordinated and strategic wildlife management and pest animal management at regional and national levels. Jess has prepared numerous pest animal management plans and programs and is often involved in on-ground monitoring and management.
Ellie Kirke Wildlife Biologist ***Field work, statistical analyses, reporting***	Master of Wildlife Health and Conservation, Murdoch University, current Bachelor of Science (Zoology, Ecology) (Honours), University of Queensland, 2018	Ellie is a Wildlife Biologist with experience monitoring wildlife populations across Australia, including in the Northern Territory, Queensland, and Victoria. Ellie is well-versed in various fauna monitoring techniques including the use of cage, Elliott, pitfall and harp traps, motion sensing cameras and sound monitoring devices (e.g. call-playback). She has participated in various camera trapping programs for threatened and invasive species, including northern quolls, new holland mice, fox, feral cat, deer, and feral pigs in Victoria, South East Queensland, and Groote Eylandt. Ellie has conducted multiple koala surveys in the Otway Ranges using distance-sampling techniques to monitor population changes following mass die-off events resulting from over-abundance. She has also undertaken trials of new pig trapping technology with the Conservation Ecology Centre in Victoria.
Andrew Bengsen Vertebrate Pest Specialist, NSW DPI ***Statistical analysis, reviewer***	PhD (Wildlife Biology), University of Queensland, 2010 Bachelor of Science (Honours) (Zoology and Tropical Ecology), James Cook University, 2003	Andrew has over 15 years' experience in pest animal management and research and has been with the Vertebrate Pest Research Unit since 2011. Most of his current research aims to improve the management of introduced large herbivores by understanding the effects of different management tools, strategies and policies on herbivore populations and damage. He has a strong interest in developing and promoting wildlife survey and analysis methods that can provide the best quality information for managers and decision-makers.
Tegan Dinsdale Ecologist ***Field work***	Bachelor of Science (Honours), University of Adelaide, 2020 Bachelor of Science (Animal Behaviour), Flinders University, 2019	Tegan Dinsdale is a Graduate Wildlife Ecologist who began working with Ecosure in 2021. She has gained extensive knowledge in animal behaviour, conservation and ecology through her studies, as well as practical experience in conducting flora and fauna surveys and research in South Australia and internationally. Tegan has experience in animal handling, camera trapping, conducting flora and fauna surveys, scientific report writing, and data analysis.
Adam Stone Ecologist ***Field work***	Master of Environmental Management, University of Queensland 2017 Bachelor of Science, Queensland University of Technology 2012	Adam Stone has worked as an ecologist in both academic and consulting positions since 2012. He specialises in the ecology of volant (flying) vertebrates, terrestrial fauna trapping and conservation-oriented management. Adam has worked across a diverse range of environmental and biodiversity related fields in a variety of Australia's landscapes. He has worked on a diverse range of projects including Surveying and describing new species of Antechinus, assessing the impact of Red Deer on Australian native vegetation, marine turtle and bird monitoring and, microbat behavioural studies.

Appendix 2 Camera locations

Camera ID	Latitude	Longitude	Offset cluster	track type	Bait status
1	-26.0669	152.6341	Curra	track	no
2	-26.0675	152.6308	Curra	bush	no
3	-26.0658	152.6325	Curra	dry creek bed	no
4	-26.0637	152.6327	Curra	dry creek bed	no
5	-26.0662	152.629	Curra	dry creek bed	no
6	-26.065	152.6268	Curra	track	no
7	-26.0713	152.6287	Curra	track	no
8	-26.0693	152.6295	Curra	bush	no
9	-26.068	152.6273	Curra	dry creek bed	no
10	-26.0705	152.6318	Curra	open area	no
11	-26.0729	152.6305	Curra	open area	no
12	-26.0703	152.6261	Curra	track	no
13	-26.0712	152.6245	Curra	track	no
14	-26.0737	152.6277	Curra	track	no
15	-26.0754	152.6295	Curra	track	no
16	-26.0607	152.6236	Curra	bush	no
17	-26.064	152.6247	Curra	dry creek bed	no
18	-26.0591	152.6214	Curra	track	no
19	-26.0616	152.6197	Curra	dry creek bed	no
20	-26.0624	152.622	Curra	dry creek bed	no
21	-26.0629	152.6075	Curra	open area	no
22	-26.064	152.6098	Curra	bush	no
23	-26.0648	152.6123	Curra	track	no
24	-26.0609	152.6091	Curra	bush	no
25	-26.0605	152.6039	Curra	open area	no
26	-26.0587	152.6047	Curra	bush	no
27	-26.0597	152.607	Curra	dry creek bed	no

Camera ID	Latitude	Longitude	Offset cluster	track type	Bait status
28	-26.062	152.6059	Curra	track	no
29	-26.071	152.6233	Curra	track	no
30	-26.0688	152.6239	Curra	track	no
31	-26.0666	152.6247	Curra	dry creek bed	no
32	-26.066	152.6231	Curra	bush	no
33	-26.065	152.6215	Curra	track	no
34	-26.0678	152.6218	Curra	bush	no
35	-26.0695	152.6199	Curra	track	no
36	-26.0664	152.6189	Curra	track	no
37	-26.0686	152.6182	Curra	track	no
38	-26.0673	152.616	Curra	track	no
39	-26.0662	152.6139	Curra	bush	no
40	-26.0644	152.6152	Curra	bush	no
41	-26.0621	152.6168	Curra	bush	no
42	-26.0638	152.619	Curra	dry creek bed	no
43	-26.0656	152.6174	Curra	bush	no
44	-26.2463	152.7148	Woondum	bush	no
45	-26.2447	152.7138	Woondum	bush	yes
46	-26.2475	152.7125	Woondum	bush	no
47	-26.2452	152.7115	Woondum	track	no
48	-26.2443	152.7092	Woondum	track	no
49	-26.2463	152.7089	Woondum	small clearing	yes
50	-26.2488	152.71	Woondum	bush	yes
51	-26.2501	152.7108	Woondum	bush	yes
52	-26.2526	152.7124	Woondum	bush	yes
53	-26.2494	152.7134	Woondum	dry creek bed	yes
54	-26.2381	152.7002	Woondum	bush	no
55	-26.24	152.7021	Woondum	bush	yes
56	-26.2417	152.7029	Woondum	bush	no

Camera ID	Latitude	Longitude	Offset cluster	track type	Bait status
57	-26.1536	152.6803	Victory Heights	open area	no
58	-26.1526	152.6824	Victory Heights	track	no
59	-26.1538	152.684	Victory Heights	track	no
60	-26.1559	152.682	Victory Heights	bush	no
61	-26.1574	152.6838	Victory Heights	dry creek bed	no
62	-26.1562	152.686	Victory Heights	track	no
63	-26.159	152.6855	Victory Heights	dry creek bed	no
64	-26.1651	152.6777	Victory Heights	dry creek bed	no
65	-26.1629	152.6777	Victory Heights	track	no
66	-26.1609	152.676	Victory Heights	track	no
67	-26.1583	152.6785	Victory Heights	dry creek bed	no
68	-26.1603	152.6784	Victory Heights	track	no

Appendix 3 Sample camera images

The following images provide a sample of wild dog/dingo images (184 in total) captured on camera 23 (Curra) on the 15/03/2023. This pack of 7 dogs/dingoes was observed traversing tracks throughout Curra. Images were reviewed to identify individuals.

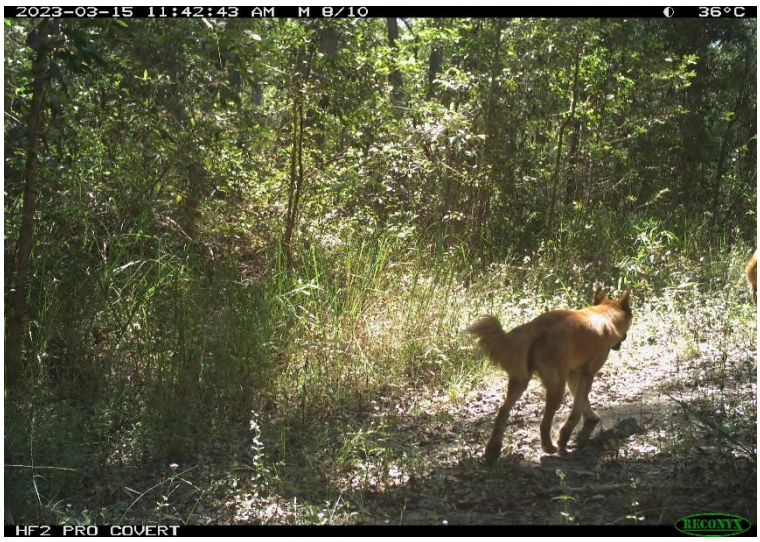

2023-03-15 11:42:40 AM M 3/10
36°C
HF2 PRO COVERT
RECONYX


2023-03-15 11:42:40 AM M 4/10
36°C
HF2 PRO COVERT
RECONYX


2023-03-15 11:42:41 AM M 5/10
36°C
HF2 PRO COVERT
RECONYX


2023-03-15 11:42:42 AM M 6/10
36°C
HF2 PRO COVERT
RECONYX


2023-03-15 11:42:43 AM M 7/10
36°C
HF2 PRO COVERT
RECONYX


2023-03-15 11:42:43 AM M 9/10
36°C
HF2 PRO COVERT
RECONYX

Feral cat individuals identified across multiple monitoring periods.

2022 survey	2023 survey
Camera 18, 3/03/2022 	Camera 18 and 25, 01/03/2023. Likely the same individual recorded during baseline surveys and in 2022  

2022 survey		2023 survey
Camera 18, 1/03/2022 		Camera 19 08/03/2023. Likely the same individual on Camera 33 in 2022, also noting different sock patterns to the individual on Camera 18 in 2022 so two individuals. 
Camera 15 (multiple dates) 	Camera 39, 10/04/2022 	Camera 1. 06/03/2023. Likely same individual on Camera 15 in 2022 

Appendix 4 Statistical analysis coding

The following script is the input code used to analyse 2021 (baseline), 2022 and 2023 data in R Studio. The 2021, 2022 and 2023 databases are names 'Pest_data_R_2021', 'Pest_data_R_2022' and 'Pest_Data_R_2023', respectively.

```
library(ggplot2)
library(lme4)

### Comments and edits by AB 2023-04-27

#  { AB:
 Pest_data_R_2021 <- read.csv("Pest_data_R_2021.csv")
 Pest_data_R_2022 <- read.csv("Pest_data_R_2022.csv")
 Pest_data_R_2023 <- read.csv("Pest_data_R_2023.csv")
 head(Pest_data_R_2023)
# }

Pest_data_R_2023$camera = factor(Pest_data_R_2023$camera)


Pest_data_R_2021$camera = factor(Pest_data_R_2021$camera)
head(Pest_data_R_2021)

dog <- subset(Pest_data_R_2023, Pest_data_R_2023$common == "wild dog")
fox <- subset(Pest_data_R_2023, Pest_data_R_2023$common == "red fox")
cat <- subset(Pest_data_R_2023, Pest_data_R_2023$common == "feral cat")
pig <- subset(Pest_data_R_2023, Pest_data_R_2023$common == "feral pig")


library(tidyverse)
spp_sum <- Pest_data_R_2023 %>%
  group_by(site, common) %>%
  summarise(n = n(),
            count = sum(count))
spp_sum

## There were no wild dog detections at Victory, so site removed
dog <- dog %>%
  filter(site != "Victory Heights")
## Cats were only detected at Curra
cat <- cat %>%
  filter(site == "Curra")
## Pigs were only detected at Curra
pig <- pig %>%
```

```
  filter(site == "Curra")

#activity indices for wild dogs
dog1 <- lmer(count ~ site-1 + (1|track/camera), data = dog)
dog1_sum <- summary(dog1)
print(dog1_sum)

plot(dog1)

#expected number of dog detections per camera per day
gi_dog1 <- coefficients(dog1_sum)[, "Estimate"]
print(gi_dog1)

#confidence intervals for the estimates
lo_dog1 <- coefficients(dog1_sum)[, "Estimate"] - 1.96 * coefficients(dog1_sum)[, "Std. Error"]
up_dog1 <- coefficients(dog1_sum)[, "Estimate"] + 1.96 * coefficients(dog1_sum)[, "Std. Error"]
print(lo_dog1)
print(up_dog1)


#activity indices for red foxes
fox1 <- lmer(count ~ site-1 + (1|track/camera), data = fox)
fox1_sum <- summary(fox1)
print(fox1_sum)

#expected number of fox detections per camera per day
gi_fox1 <- coefficients(fox1_sum)[, "Estimate"]
print(gi_fox1)

#confidence intervals for the estimates
lo_fox1 <- coefficients(fox1_sum)[, "Estimate"] - 1.96 * coefficients(fox1_sum)[, "Std. Error"]
up_fox1 <- coefficients(fox1_sum)[, "Estimate"] + 1.96 * coefficients(fox1_sum)[, "Std. Error"]
print(lo_fox1)
print(up_fox1)


#activity indices for feral cat
cat1 <- lmer(count ~ 1 + (1|track/camera), data = cat)
cat1_sum <- summary(cat1)
print(cat1_sum)

#expected number of cat detections per camera per day
gi_cat1 <- coefficients(cat1_sum)[, "Estimate"]
print(gi_cat1)

#confidence intervals for the estimates
```

```
lo_cat1 <- coefficients(cat1_sum)[, "Estimate"] - 1.96 * coefficients(cat1_sum)[, "Std. Error"]
up_cat1 <- coefficients(cat1_sum)[, "Estimate"] + 1.96 * coefficients(cat1_sum)[, "Std. Error"]
print(lo_cat1)
print(up_cat1)


#activity indices for feral pig ----
pig1 <- lmer(count ~ 1 + (1|camera), data = pig)

pig1_sum <- summary(pig1)
print(pig1_sum)

#expected number of pig detections per camera per day
gi_pig1 <- coefficients(pig1_sum)[, "Estimate"]
print(gi_pig1)

#confidence intervals for the estimates
lo_pig1 <- coefficients(pig1_sum)[, "Estimate"] - 1.96 * coefficients(pig1_sum)[, "Std. Error"]
up_pig1 <- coefficients(pig1_sum)[, "Estimate"] + 1.96 * coefficients(pig1_sum)[, "Std. Error"]
print(lo_pig1)
print(up_pig1)

 pig %>%
   group_by(camera) %>%
   summarise(count = sum(count)) %>%
   as.data.frame()

 pig2 <- lm(count ~ 1, data = pig)
 (pig2_sum <- summary(pig2))

 gi_pig2 <- coefficients(pig2_sum)[, "Estimate"]
 gi_pig2

 lo_pig2 <- coefficients(pig2_sum)[, "Estimate"] - 1.96 * coefficients(pig2_sum)[, "Std. Error"]
 up_pig2 <- coefficients(pig2_sum)[, "Estimate"] + 1.96 * coefficients(pig2_sum)[, "Std. Error"]

 cat(paste0("Random effects estimate = ", gi_pig1, " (", lo_pig1, ", ", up_pig1, ")"))
 cat(paste0("Simple linear estimate = ", gi_pig2, " (", lo_pig2, ", ", up_pig2, ")"))
 # The estimate and it's error is exactly the same as the random effects model
 # The simple linear model provides the same result with fewer assumptions and
 # parameters and is therefore preferable to the random effects model in this case

 # This is reflected in the AIC metric for each model (lower is better, all else being equal)
 AIC(pig1)
 AIC(pig2)
#}
```

```
sites <- rep(unique(Pest_data_R_2023$site), 4)
ggdat <- data.frame(site = sites,
                    species = c(rep("dog", 3),
                                rep("fox", 3),
                                rep("cat", 3),
                                rep("pig", 3)),
                    value = c(gi_dog1,NA,
                              gi_fox1,
                              gi_cat1[1], NA, gi_cat1[2],
                              gi_pig1, NA, NA),
                    ci_lo = c(lo_dog1,NA,
                              lo_fox1,
                              lo_cat1[1], NA, lo_cat1[2],
                              lo_pig1, NA, NA),
                    ci_up = c(up_dog1,NA,
                              up_fox1,
                              up_cat1[1], NA, up_cat1[2],
                              up_pig1, NA, NA),
                    year="2022")

ggplot(ggdat) +
  geom_point(aes(x=site, y=value)) +
  geom_linerange(aes(x=site, ymin=ci_lo, ymax=ci_up)) +
  facet_wrap(~species, scales='free')


## BELOW IS SCRIPT FROM LAST YEAR

## Repeat for 2021 data ----

dat21 <- Pest_data_R_2021

dog21a <- subset(dat21, dat21$common == "wild dog")
fox21a <- subset(dat21, dat21$common == "red fox")
cat21a <- subset(dat21, dat21$common == "feral cat")
pig21a <- subset(dat21, dat21$common == "feral pig")

spp_sum <- dat21 %>%
  group_by(site, common) %>%
  summarise(n = n(),
            count = sum(count))
spp_sum

dog21a <- dog21a %>%
```

```
  filter(site != "victory")
cat21a <- cat21a %>%
  filter(site != "woondum")
pig21a <- pig21a %>%
  filter(site == "curra")

#activity indices for wild dogs 2021 ----
dog21 <- lmer(count ~ site-1 + (1|track/camera), data = dog21a)
(dog21_sum <- summary(dog21))

#expected number of dog detections per camera per day
gi_dog21 <- coefficients(dog21_sum)[, "Estimate"]
print(gi_dog21)

#confidence intervals for the estimates
lo_dog21 <- coefficients(dog21_sum)[, "Estimate"] - 1.96 * coefficients(dog21_sum)[, "Std. Error"]
up_dog21 <- coefficients(dog21_sum)[, "Estimate"] + 1.96 * coefficients(dog21_sum)[, "Std. Error"]
lo_dog21
up_dog21

#activity indices for red foxes 2021 ----
fox21 <- lmer(count ~ site-1 + (1|track/camera), data = fox21a)
(fox21_sum <- summary(fox21))

#expected number of fox detections per camera per day
gi_fox21 <- coefficients(fox21_sum)[, "Estimate"]
gi_fox21

#confidence intervals for the estimates
lo_fox21 <- coefficients(fox21_sum)[, "Estimate"] - 1.96 * coefficients(fox21_sum)[, "Std. Error"]
up_fox21 <- coefficients(fox21_sum)[, "Estimate"] + 1.96 * coefficients(fox21_sum)[, "Std. Error"]
lo_fox21
up_fox21

# activity indices for feral cats 2021 ----
# We can drop the 'track' effect again which has a variance of 0 and causes a poor fit
cat21 <- lmer(count ~ site-1 + (1|camera), data = cat21a)
(cat21_sum <- summary(cat21))

#expected number of cat detections per camera per day
gi_cat21 <- coefficients(cat21_sum)[, "Estimate"]
gi_cat21

#confidence intervals for the estimates
lo_cat21 <- coefficients(cat21_sum)[, "Estimate"] - 1.96 * coefficients(cat21_sum)[, "Std. Error"]
up_cat21 <- coefficients(cat21_sum)[, "Estimate"] + 1.96 * coefficients(cat21_sum)[, "Std. Error"]
```

```
lo_cat21
up_cat21


#activity indices for feral pig ----
pig21 <- lmer(count ~ 1 + (1|camera), data = pig21a)

pig21_sum <- summary(pig21)
print(pig21_sum)

#expected number of pig detections per camera per day
gi_pig21 <- coefficients(pig21_sum)[, "Estimate"]
gi_pig21

#confidence intervals for the estimates
lo_pig21 <- coefficients(pig21_sum)[, "Estimate"] - 1.96 * coefficients(pig21_sum)[, "Std. Error"]
up_pig21 <- coefficients(pig21_sum)[, "Estimate"] + 1.96 * coefficients(pig21_sum)[, "Std. Error"]
lo_pig21
up_pig21

## First, put the estimates into a dataframe
sites <- rep(unique(dat21$site), 4)
ggdat21 <- data.frame(site = sites,
                      species = c(rep("dog", 3),
                                  rep("fox", 3),
                                  rep("cat", 3),
                                  rep("pig", 3)),
                      value = c(gi_dog21,NA,
                                gi_fox21,
                                gi_cat21[1], NA, gi_cat21[2],
                                gi_pig21, NA, NA),
                      ci_lo = c(lo_dog21,NA,
                                lo_fox21,
                                lo_cat21[1], NA, lo_cat21[2],
                                lo_pig21, NA, NA),
                      ci_up = c(up_dog21,NA,
                                up_fox21,
                                up_cat21[1], NA, up_cat21[2],
                                up_pig21, NA, NA),
                      year = "2021")

ggplot(ggdat21) +
  geom_point(aes(x=site, y=value)) +
  geom_linerange(aes(x=site, ymin=ci_lo, ymax=ci_up)) +
  facet_wrap(~species)
```

```
## Plot both years together ----

ggdat_both <- rbind(ggdat, ggdat21) %>%
  arrange(species, site, year)
pd2 <- position_dodge2(width = 0.5)

ggplot(ggdat_both) +
  geom_point(aes(x=site, y=value, colour=year), position=pd2) +
  geom_linerange(aes(x=site, ymin=ci_lo, ymax=ci_up, colour=year), position=pd2) +
  facet_wrap(~species, scales='free')
```

Appendix 5 Statistical output summary

		Activity index			Lower confidence interval			Upper confidence interval		
Site	**Pest animal**	**2021**	**2022**	**2023**	**2021**	**2022**	**2023**	**2021**	**2022**	**2023**
Curra	red fox	0.0455	0.0127	0.0158	-0.0001	-0.0190	0.0238	0.0912	0.0444	0.0238
	wild dog	0.0306	0.0215	0.0605	0.0008	0.0093	0.0754	0.0604	0.0337	0.0754
	feral cat	0.0047	0.0022	0.0040	0.0008	-0.0003	0.0054	0.0087	0.0048	0.0054
	feral pig	0.0169	0.0109	0.0017	0.0034	-0.0036	0.0016	0.0303	0.0181	0.0016
Victory Heights	red fox	0.0907	0.0832	0.0190	0.0307	-0.0377	0.0299	0.1507	0.1286	0.0299
	wild dog	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	feral cat	0.0027	0.0031	0.0000	-0.0052	-0.0015	0.0000	0.0107	0.0076	0.0000
	feral pig	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Woondum	red fox	0.0350	0.0327	0.0130	-0.0220	-0.0108	0.0294	0.0919	0.0761	0.0294
	wild dog	0.0171	0.0040	0.0161	-0.0216	-0.0166	0.1019	0.0557	0.0246	0.1019
	feral cat	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	feral pig	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Revision History

Revision No.	Revision date	Details	Prepared by	Reviewed by	Approved by
00	05/06/2023	Offset Pest Animal Monitoring – Year 2 Report	Adam Stone, Wildlife Biologist	John Martin, Senior Wildlife Biologist	Jess Bracks, Principal Wildlife Biologist
01	12/12/2023	Offset Pest Animal Monitoring – Year 2 Report	Adam Stone, Wildlife Biologist	John Martin, Senior Wildlife Biologist	Jess Bracks, Principal Wildlife Biologist

Distribution List

Copy #	Date	Type	Issued to	Name
1	12/12/2023	Electronic	Department of Transport and Main Roads	Cameron Vacher
2	12/12/2023	Electronic	Ecosure	Administration

Citation: Ecosure, 2023, *Offset Pest Animal Monitoring – Year 2 Report*, Report to Department of Transport and Main Roads, Brisbane

Report compiled by Ecosure Pty Ltd

ABN: 63 106 067 976

admin@ecosure.com.au www.ecosure.com.au

PR6714-RE.C2CD Offset Pest Animal Survey - Year 2

Adelaide
PO Box 145
Pooraka SA 5095
P 1300 112 021
M 0407 295 766

Brisbane
PO Box 675
Fortitude Valley QLD 4006
P 07 3606 1030

Coffs Harbour
PO Box 4370
Coffs Harbour Jetty NSW 2450
P 02 5621 8103

Gladstone
PO Box 5420
Gladstone QLD 4720
P 07 4994 1000

Gold Coast
PO Box 404
West Burleigh QLD 4219
P 07 5508 2046

Rockhampton
PO Box 235
Rockhampton QLD 4700
P 07 4994 1000

Sunshine Coast
PO Box 1457
Noosaville QLD 4566
P 07 5357 6019

Sydney
PO Box 880
Surry Hills NSW 2010
P 1300 112 021

Townsville
PO Box 2335
Townsville QLD 4810
P 1300 112 021