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OFFSET PEST ANIMAL MONITORING
YEAR 1 REPORT
June 2022

DEPARTMENT OF TRANSPORT AND MAIN ROADS

Executive summary

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

Passive infrared cameras (Reconyx Professional HP2X Hyperfire 2) were deployed in mid-February for a total of eight weeks. Generalised linear mixed models were used to estimate activity indices for pest species in each offset cluster. The 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, and it is assumed that these indices are proportional to absolute pest abundance.

Pest species presence was relatively consistent with baseline surveys. Red foxes were recorded in all three clusters, with the greatest activity recorded in Victory Heights, followed by Curra and Woondum. Wild dogs were recorded in Curra and Woondum, with highest activity in Curra. Few feral cat observations were recorded in Curra and Victory Heights, and feral pigs were only recorded in Curra.

The results from the 2022 monitoring event suggest an overall decrease in pest activity across all three offset clusters since baseline surveys. Pest activity indices tended to decrease across the majority of offset clusters, with the exception of feral cats in Victory which remained relatively constant (two independent observations made during baseline and 2022 surveys). The results suggest current pest management efforts are effective in reducing pest activity within the offset clusters.

Ongoing management should be prioritised to target pest species with the highest activity indices, and pest species that did not show as great a decline in activity as others. Compared with control results, these include red foxes and feral cats in Victory Heights and feral cats in Curra.

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	Cooroy to Curra Section D – Detailed Design Offset Management Plan
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.

As per the OMP, TMR engaged Ecosure to undertake quarterly pest control works (commencing October 2021) within the offset properties, 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 the active control program 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 2022, Ecosure commenced the second round of offset pest monitoring, representing Year 1 of the Pest Animal Monitoring Program (i.e. following baseline monitoring). This report provides an overview of methodology and results from Year 1 monitoring (February – April 2022). It also provides a discussion on pest activity levels in comparison to baseline results.

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 on results
- preparing this Year 1 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) and with 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**

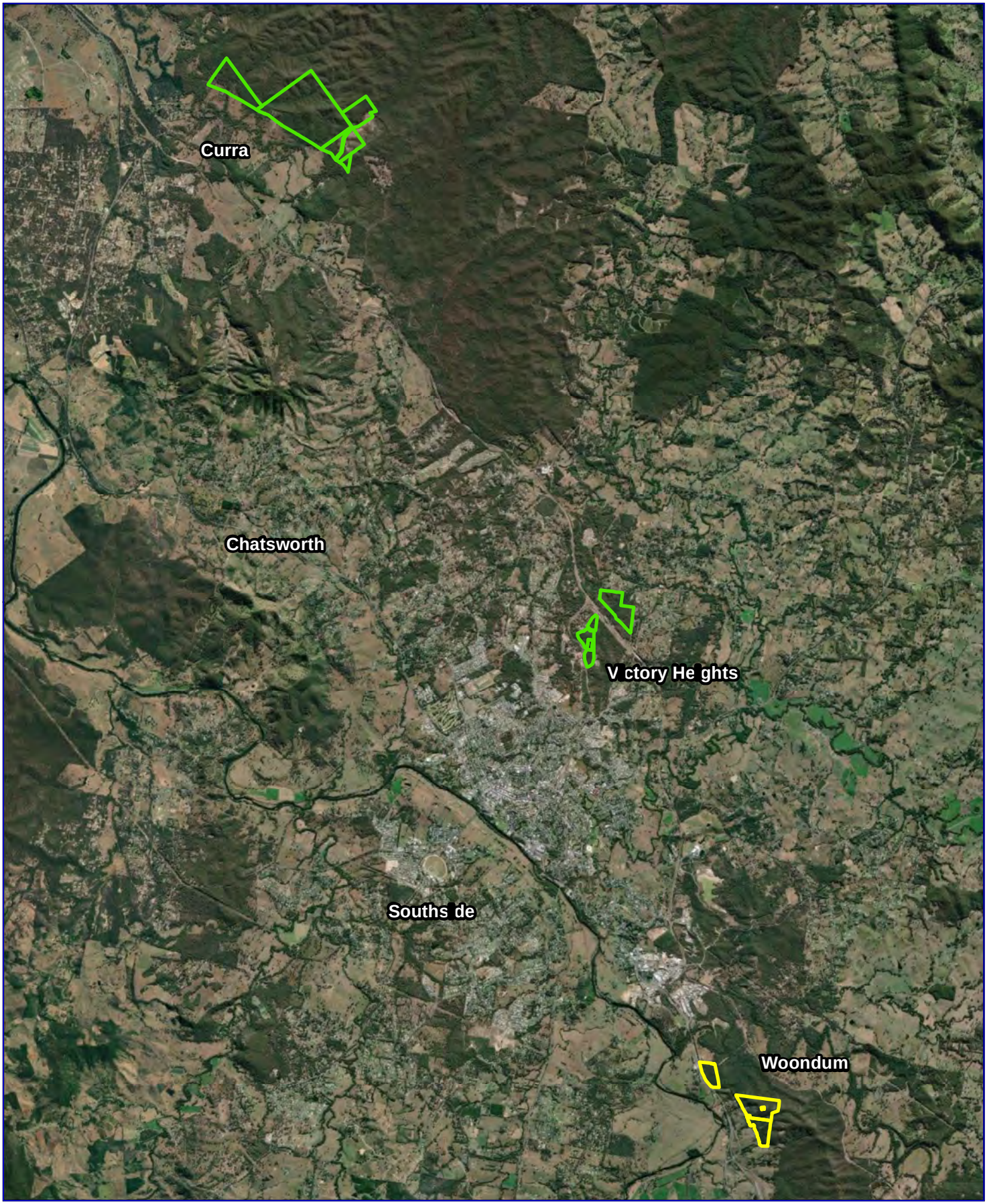

Figure 1: C2CD offset areas

Department of Transport and Main Roads

PR6714 C2CD Offset Pest Animal Control and Survey - Year 1

Offset

- koala offset areas
- koala + black-breasted button-quail offset areas

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Job number: PR6714
Revision: 0
Author: EK
Date: 27/10/2021

0 0.5 1 2
Kilometers

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

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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 6th – 9th of February 2022 and collected 6th – 7th of April 2022 (eight weeks total). Cameras were installed to the same specifications as during baseline surveys (Ecosure 2021), including location (same tree), 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. The following cameras were adjusted slightly, as described:

- Camera 3 – moved within 2 m of baseline location due to fallen tree, track type remained the same
- Camera 46 – changed direction of camera (same tree location) due to lantana thicket covering previous field of view
- Camera 51 – moved within 2 m of baseline location due to fallen tree, track type remained the same
- Camera 53 – moved 5 m down creek bed due to fallen tree
- Camera 57 – moved off track into the bush as baseline location is now too close to active construction
- Camera 63 – moved to nearby dry creek bed within 5 m of baseline creek bed location as baseline location is now in project footprint.

In accordance with baseline surveys, cameras were placed approximately 250 m apart along roads, tracks, and movement corridors where possible, or nearby suitable 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: rapidfire, 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 olfactory lures (tinned tuna). During baseline surveys, audio lures (Cat Caller, Professional Trapping Supplies, Molendinar, Queensland, Australia) were also fixed to three bait stations. However, these devices (the only device of its kind available in Australia) quickly deteriorated and malfunctioned with rainfall and were not deemed suitable for this kind of long-

term monitoring project. As such, they were not deployed during the 2022 monitoring period. This is unlikely to impact the results as audio lures did not account for variation in the baseline data and this was not included as a covariate in statistical modelling. More simply, pest activity did not appear higher or lower at cameras with audio lures compared to those without.

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 one instance, four wild dog individuals hung around camera 27 for over four hours. From around 10:00 pm – 10:30 pm, they were observed running around the camera and waterhole in front of the camera. Technically, some of these observations were separated by more than 5 minutes, so following the 5-minute rule for independent observations, these would ordinarily be classed as independent. However, calculating the activity index based on this rule for this scenario would be inaccurate as it would inflate the real activity. As such, image sequences were analysed to individually identify dogs, and observations were only classed as independent if they were separated by a significant time spent away from the camera, approximately 30 minutes in this case. A sample of these images are provided in Appendix 3.

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

Due to the challenges of deriving an absolute population abundance of pest species within offset clusters, an activity index was used to represent relative pest abundance in each offset cluster (as per Bengsen et al. 2014 and 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 normal error distributions. This differs slightly from the statistical model used to analyse 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 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 (see 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 resulted in a February 2021 commencement. 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 in Ecosure 2020), so this monitoring period was ultimately 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 this year and moving forward), then valid comparisons in species abundance/activity trends can be made.

The biggest limitation of this round of monitoring was the potential impact resulting from the severe flooding event that occurred in late February 2022 (peak flooding on the 28th of February). Severe weather can impact pest activity, as well as detectability. However, given this program runs for eight weeks, and the activity index is a measure of expected pest observations per camera per day, the impact on overall results is expected to be minimal (i.e. potentially a slight reduction in pest activity due to reduced activity/detection during the flooding period). Four cameras located in Curra (camera 1, 3, 6 and 12) were also damaged, presumably by the severe weather event, and had to be removed from the dataset entirely. Similarly, as the activity index is an average measure of expected number of pest observations per camera per day, losing four cameras from the dataset for Curra may slightly reduce accuracy and power of the statistical measure, but does not make it incomparable to baseline data.

Camera 66 was also vandalised and had to be removed from the Victory Heights dataset prior to statistical analyses.

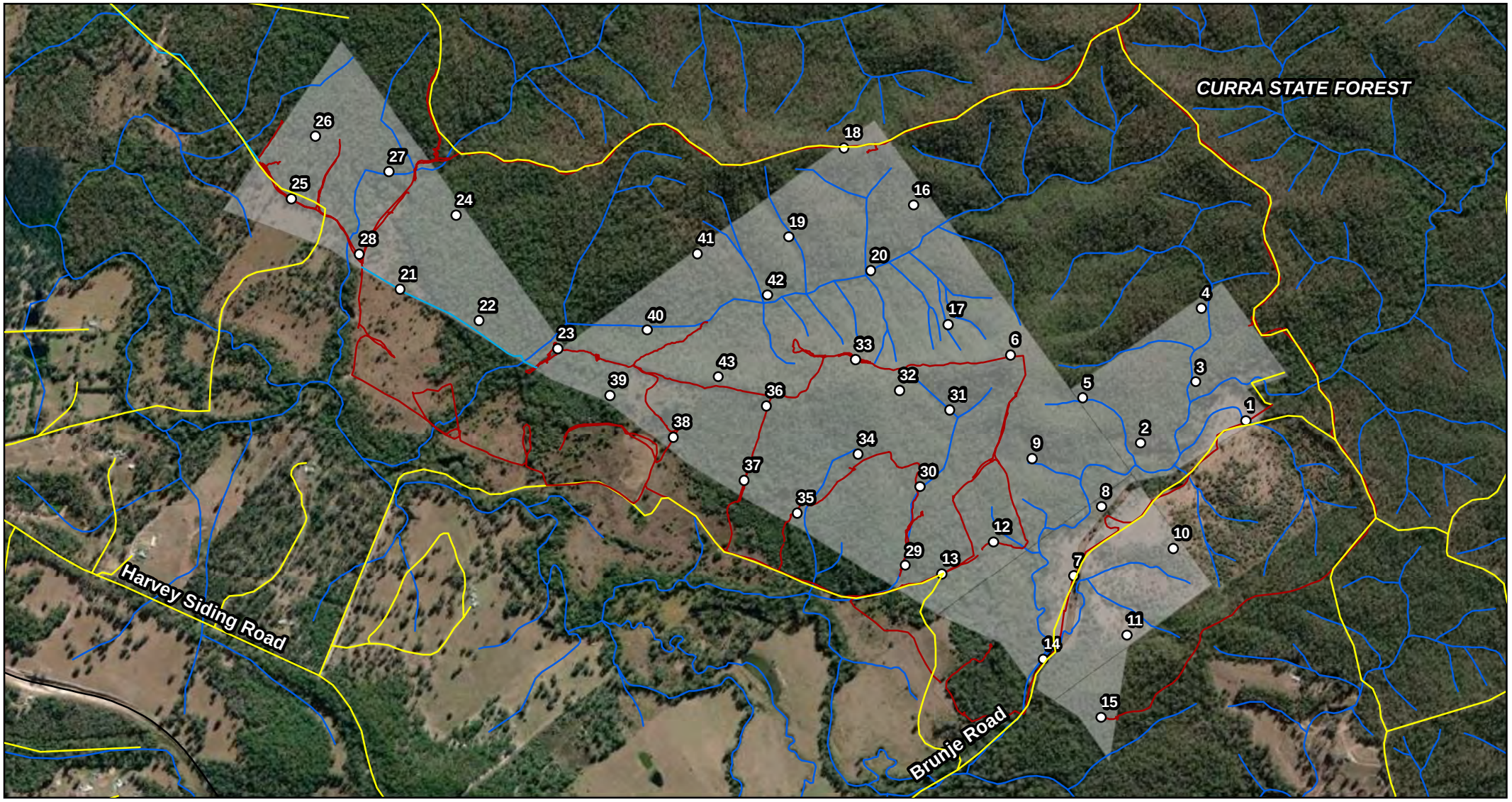

Figure 2: Camera locations in Curra offset sites

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C2CD Offset Pest Animal Control and Survey - Year 1

Offset cluster
Camera locations
Watercourse

Tracks/roads
Existing access track
Proposed access track
Rail network
Road

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Job number: PR6714
Revision: 0
Author: EK
Date: 25/05/2022

0 175 350 700
Metres

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

Data Sources: Ecosure Pty Ltd, 2020; Image Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
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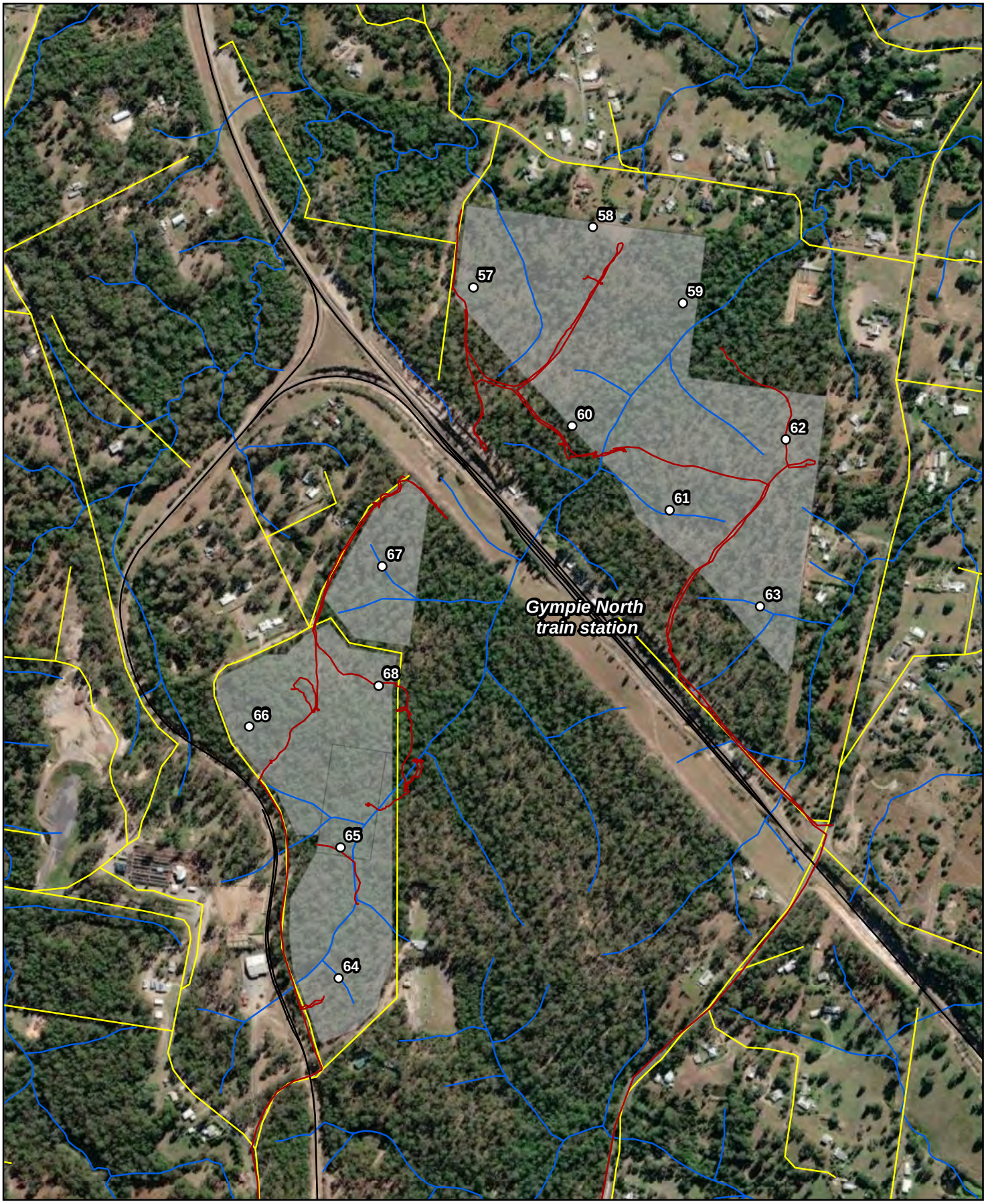

Figure 3: Camera locations in Victory Heights offset sites

Department of Transport and Main Roads

C2CD Offset Pest Animal Control and Survey - Year 1

Camera locations
Offset cluster
Watercourse

Tracks/roads
Existing access track
Rail network
Road

ecosure

Job number: PR6714
Revision: 0
Author: EK
Date: 25/05/2022

0 40 80 160
Meters

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

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PR6714_MP3_VictoryCameraLocations
A4

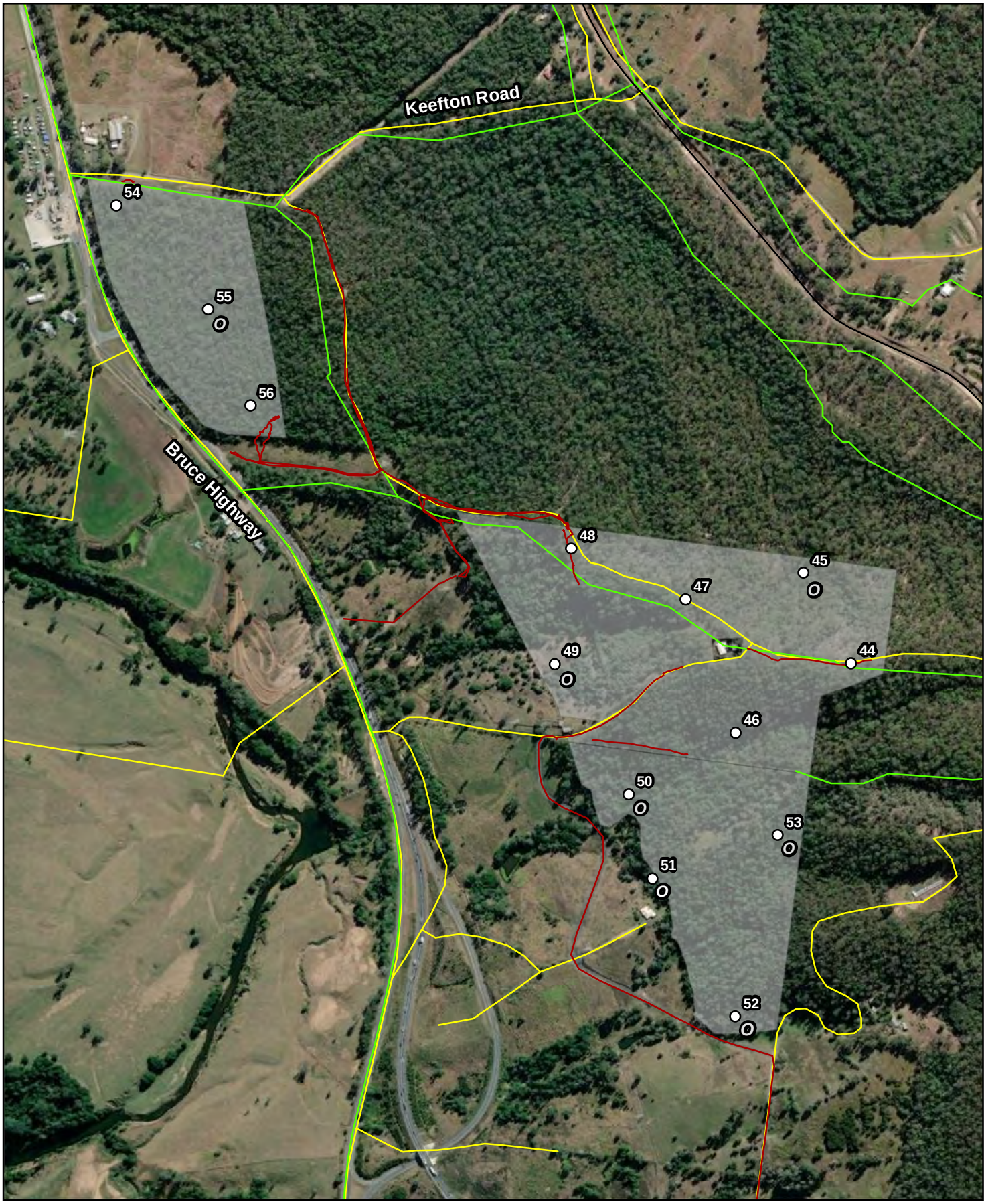

Figure 4: Camera locations in Woondum offset sites

Department of Transport and Main Roads

C2CD Offset Pest Animal Control and Survey - Year 1

Offset cluster
Camera locations
Watercourse
olfactory lure

Tracks/roads
Existing access track
Road
QPWS access road
Rail network

ecosure

Job number: PR6714
Revision: 0
Author: EK
Date: 25/05/2022

0 40 80 160
Meters

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

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PR6714_MP4_WoondumCameraLocations
A4

3 Results

3.1 Statistical results

Foxes were recorded in all three offset clusters, with the greatest activity detected in Victory Heights, followed by Woondum and Curra, which is consistent with baseline results (Table 2). Red fox activity appears to have decreased in all three offset clusters since baseline surveys (Figure 5), with the greatest decrease in Curra, followed by Victory and Woondum.

Wild dogs were detected in Curra and Woondum, but not in Victory Heights, which is consistent with baseline results (Table 2). Statistical analyses suggest a decrease in wild dog activity in Curra and Woondum compared to baseline activity (Table 2, Figure 5).

Feral cats were detected in Curra and Victory Heights, though to a far lesser extent than wild dogs and foxes. Statistical analyses suggest a decrease in feral cat activity between 2022 and baseline surveys in Curra (Figure 5). An accurate activity index could not be derived for feral cats in Victory Heights previously as there was insufficient data to use the statistical model (i.e. Poisson distribution). While baseline data does not fit a normal distribution model well, an activity index using this new model has been derived retrospectively, for the purpose of comparison. The 2022 activity index appears to have slightly increased, though the same number of independent observations were made this year compared to last year, suggesting that activity has remained the same. Feral cats observed in Victory Heights and Curra in baseline surveys do not appear to be the same individuals observed in each area during 2022 surveys (Appendix 3), likely a reflection of low detectability and/or movement in/out of offset areas. However, one individual observed in Curra during baseline surveys was observed in Victory Heights during 2022 surveys, showing movement between offset areas (see Appendix 3 for feral cat images).

Feral pigs were only recorded in Curra this year, which is consistent with baseline results. During baseline surveys, feral pigs were only occasionally detected in Curra, though the sporadic nature of detections and high variability of group sizes (1 – 15 individuals) meant the data were not suitable for estimating a reliable activity index with Poisson error distribution modelling. Activity indices have been calculated using normal distribution modelling, allowing for a comparison between baseline and 2022 surveys. Feral pig activity appears to have decreased in 2022 compared to baseline surveys. Notably, the group sizes were significantly reduced, with only a maximum of two individuals observed throughout the 2022 survey period.

Activity indices discussed above are provided in Table 2 and Figure 5, with both 2021 and 2022 results displayed for comparison between baseline and Year 1 monitoring. Maps displaying the spatial distribution of pest animal activity within each offset cluster are provided in Figure 6 – Figure 8. Note, these maps show total number of pest observations on each camera over the entire monitoring period.

Table 2 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	2021	2022	2021	2022	2021	2022
Curra	0.04554	0.0127	0.03061	0.02148	0.00472	0.00224	0.01685204	0.01086
Victory Heights	0.09069	0.08315	0	0	0.00273	0.00306	0	0
Woondum	0.03497	0.03265	0.01707	0.00398	0	0	0	0

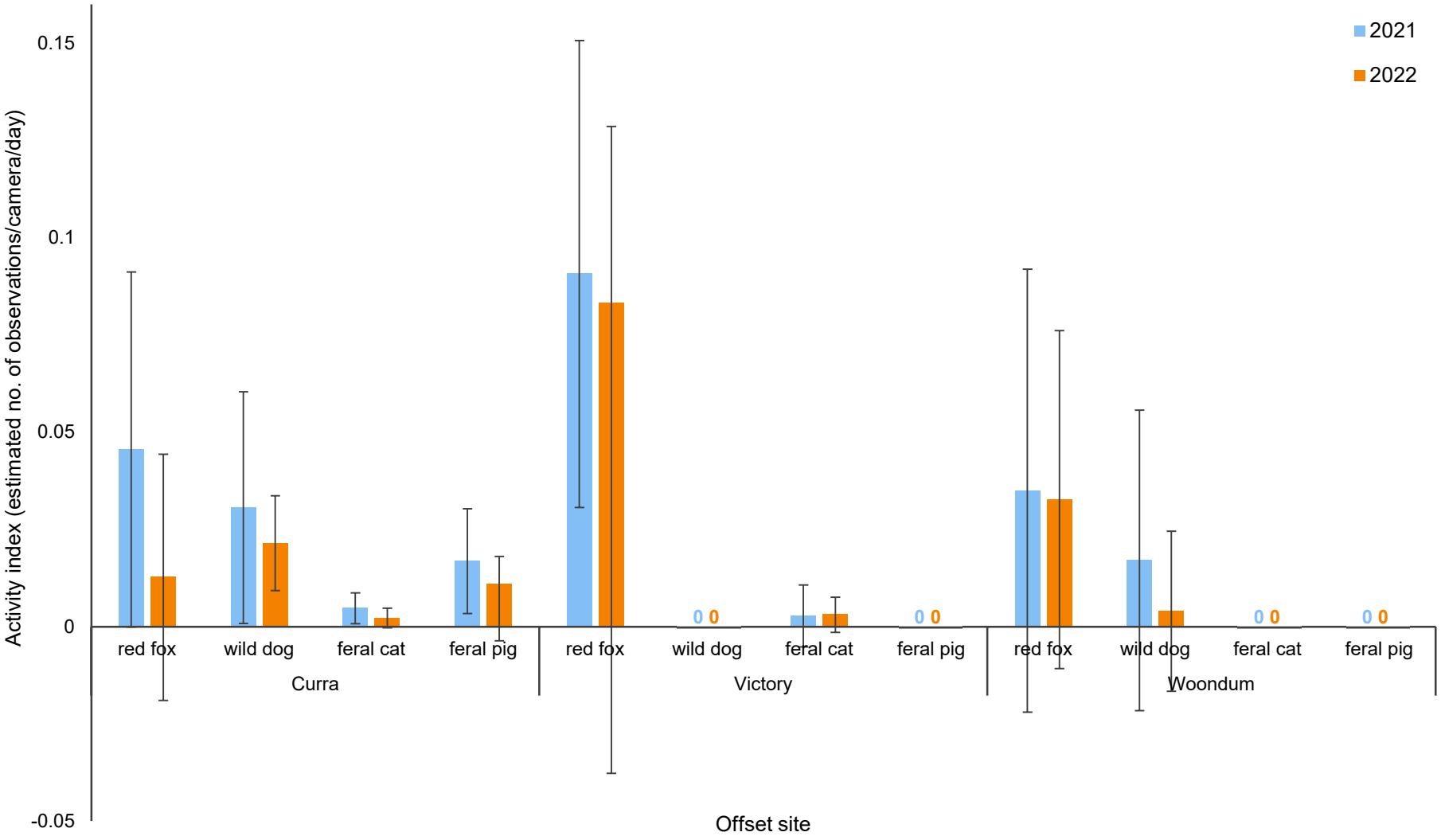

Figure 5 Pest activity indices estimated from statistical analyses (raw data provided in Appendix 5).

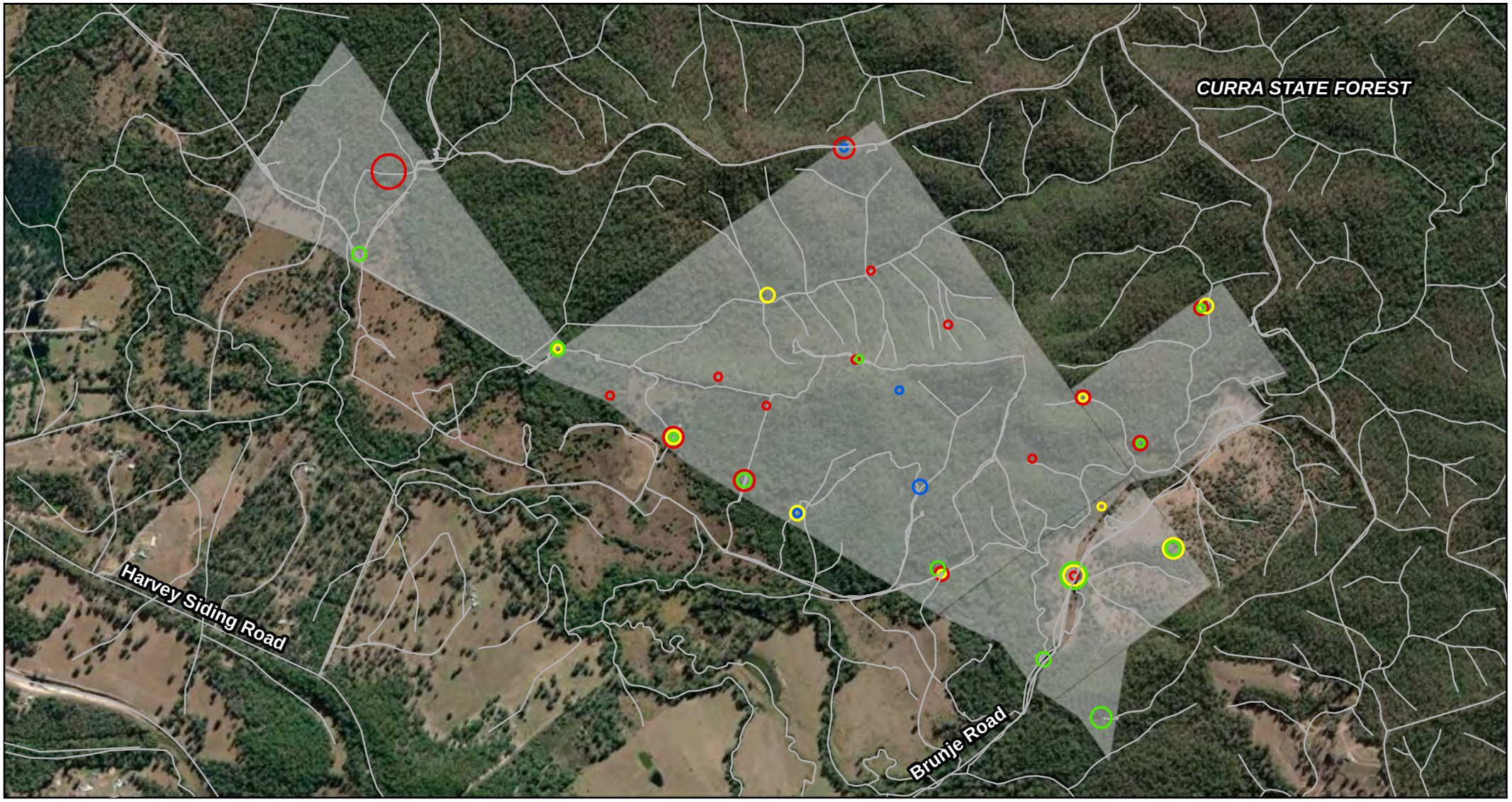

Figure 6: Pest animal observations in Curra offset properties

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C2CD Offset Pest Animal Control and Survey - Year 1

Total no. of independent observations

- 1
- 2 - 3
- 4 - 7
- 8 - 9
- 10 - 28

- feral pig
- feral cat
- red fox
- wild dog
- Movement corridors
- Offset cluster

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Job number: PR6714
Revision: 0
Author: EK
Date: 23/06/2022

0 175 350 700
Metres

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

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Figure 7: Pest animal observations in Victory Heights offset properties

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C2CD Offset Pest Animal Control and Survey - Year 1

Offset cluster
Movement corridor
feral cat
red fox

Total no. of independent observations

1
2 - 3
4 - 7
8 - 9
10 - 28

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Job number: PR6714
Revision: 0
Author: EK
Date: 25/05/2022

0 40 80 160
Meters

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

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PR6714_MP3_VictoryCameraLocations
A4

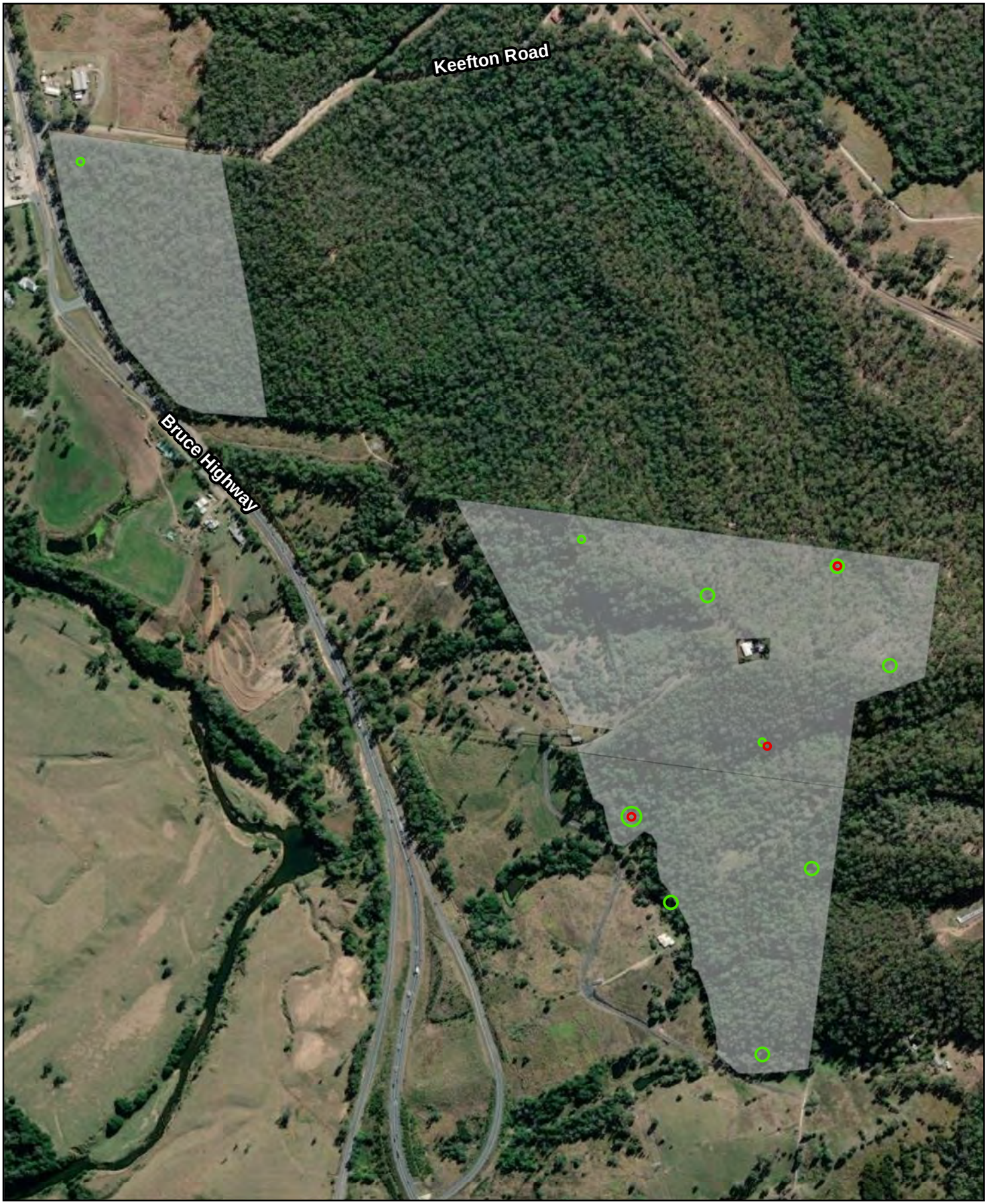

Figure 8: Pest animal observations in Woondum offset properties

Department of Transport and Main Roads

C2CD Offset Pest Animal Control and Survey - Year 1

Offset cluster
Movement corridors
red fox
wild dog

Total no. of independent observations
1
2 - 3
4 - 7
8 - 9
10 - 28

ecosure

Job number: PR6714
Revision: 0
Author: EK
Date: 25/05/2022

0 40 80 160
Meters

GDA 1994 MGA Zone 56
Projection: Transverse Mercator
Datum: GDA 1994
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3.2 Summary of control works to date

Control program results are detailed in monthly reports with an overall summary to date in Table 3. Camera monitoring during control periods showed limited pest animal activity October 2021 – January 2022, potentially associated with seasonal variation, weather and reduced pest abundance attributed to successful control programs on adjacent land. Pest observations increased again in early 2022, which is also reflected in higher numbers of animals removed from the offset sites. As shown in Table 3, the majority of pest animals removed in Year 1 were from after the Year 1 monitoring event (i.e. after mid-April). As such it is expected that if monitoring occurred in May 2022 activity indices would be further reduced compared with those in Section 3.1.

Table 3 Summary of pest animals humanely euthanased in Year 1. Before = before Year 1 monitoring (i.e. October 2021 – January 2022); After = after Year 1 monitoring (i.e. April-May 2022).

	Species							
	red fox		wild dog		feral cat		feral pig	
Offset cluster	Before	After	Before	After	Before	After	Before	After
Curra	0	2	0	3	0	0	8	15
Victory Heights	0	0	0	0	0	0	0	0
Woondum	0	1	0	0	0	0	0	0
Sub-total	0	3	0	3	0	0	8	15*
Grand Total	3		3		0		23*	

*plus 24 unborn fetal pigs

4 Discussion & recommendations

Results from the 2022 monitoring event suggest an overall decrease in pest activity across all three offset clusters. Cumulatively, the largest activity declines were observed in Curra, particularly in red fox activity. Alternatively, negligible differences were observed in feral cat activity in Victory Heights (i.e. two independent observations recorded in both survey periods) and red fox activity in Woondum (i.e. only very small decrease in activity index). 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
- major flooding event impacting the movement and behaviour of pest animals
- natural immigration and emigration of pest animals from the surrounding landscape.

Given the lack of control sites in this study, the potential impact of each of these factors on the pest activity within each offset cluster cannot be determined. In this natural system, it is likely that all these factors contributed to changes in pest activity. However, active pest management is likely to have contributed significantly to the decrease in pest activity, particularly given the number of pest animals that are known to have been removed from the offset sites since October 2021.

Pest management should continue to target all species in all offset clusters. The lowest success when comparing activity indices with control results are:

- foxes in Victory Heights
- feral cats in Victory Heights and Curra.

Efforts should be increased in Victory Heights and for cats at all sites, including review of additional/alternative control options that may be incorporated in Year 2.

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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 recently 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***	Doctor of Philosophy, University of Queensland, 2022 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	Latitude	Longitude	Offset cluster	Site type	Bait status
1	-26.066899	152.634122	Curra	track	no
2	-26.067526	152.630774	Curra	bush	no
3	-26.065781	152.632533	Curra	dry creek bed	no
4	-26.063671	152.632715	Curra	dry creek bed	no
5	-26.066217	152.628958	Curra	dry creek bed	no
6	-26.06499	152.626674	Curra	track	no
7	-26.071314	152.628655	Curra	track	no
8	-26.069335	152.629536	Curra	bush	no
9	-26.067957	152.627346	Curra	dry creek bed	no
10	-26.070543	152.631802	Curra	open area	no
11	-26.073013	152.630328	Curra	open area	no
12	-26.07034	152.626114	Curra	track	no
13	-26.071246	152.624468	Curra	track	no
14	-26.073694	152.627687	Curra	track	no
15	-26.075359	152.6295	Curra	track	no
16	-26.060701	152.623603	Curra	bush	no
17	-26.064119	152.624697	Curra	dry creek bed	no
18	-26.059061	152.62141	Curra	track	no
19	-26.061593	152.619652	Curra	dry creek bed	no
20	-26.062564	152.622249	Curra	dry creek bed	no
21	-26.063065	152.607335	Curra	open area	no
22	-26.063968	152.609834	Curra	bush	no
23	-26.06477	152.612321	Curra	track	no
24	-26.060952	152.609108	Curra	bush	no
25	-26.060464	152.603892	Curra	open area	no
26	-26.058674	152.604659	Curra	bush	no
27	-26.0597	152.606991	Curra	dry creek bed	no

Camera	Latitude	Longitude	Offset cluster	Site type	Bait status
28	-26.062058	152.606056	Curra	track	no
29	-26.071003	152.62332	Curra	track	no
30	-26.068748	152.623781	Curra	track	no
31	-26.066565	152.624743	Curra	dry creek bed	no
32	-26.066001	152.623149	Curra	bush	no
33	-26.065104	152.621749	Curra	track	no
34	-26.067813	152.621838	Curra	bush	no
35	-26.069491	152.619906	Curra	track	no
36	-26.06643	152.618929	Curra	track	no
37	-26.068561	152.618223	Curra	track	no
38	-26.06731	152.615988	Curra	track	no
39	-26.066119	152.613973	Curra	bush	no
40	-26.064255	152.615155	Curra	dry creek bed	no
41	-26.06207	152.616761	Curra	bush	no
42	-26.063266	152.618973	Curra	dry creek bed	no
43	-26.065596	152.61741	Curra	bush	no
44	-26.246316	152.714756	Woondum	bush	no
45	-26.244706	152.713819	Woondum	bush	yes
46	-26.247548	152.712466	Woondum	bush	no
47	-26.24517	152.711482	Woondum	track	no
48	-26.244266	152.709228	Woondum	track	no
49	-26.246322	152.708902	Woondum	small clearing	yes
50	-26.248756	152.710112	Woondum	bush	yes
51	-26.250145	152.71082	Woondum	bush	yes
52	-26.252607	152.71245	Woondum	bush	yes
53	-26.249603	152.713346	Woondum	dry creek bed	yes
54	-26.238126	152.700249	Woondum	bush	no
55	-26.23999	152.702059	Woondum	bush	yes
56	-26.241703	152.702895	Woondum	bush	no

Camera	Latitude	Longitude	Offset cluster	Site type	Bait status
57	-26.153633	152.680199	Victory Heights	bush	no
58	-26.152634	152.68241	Victory Heights	track	no
59	-26.153902	152.684067	Victory Heights	track	no
60	-26.155947	152.682017	Victory Heights	bush	no
61	-26.157351	152.683811	Victory Heights	dry creek bed	no
62	-26.156175	152.685955	Victory Heights	track	no
63	-26.158961	152.685479	Victory Heights	dry creek bed	no
64	-26.165126	152.677682	Victory Heights	dry creek bed	no
65	-26.162948	152.677722	Victory Heights	track	no
66	-26.160936	152.676041	Victory Heights	track	no
67	-26.158272	152.678504	Victory Heights	dry creek bed	no
68	-26.160261	152.678434	Victory Heights	track	no

Appendix 3 Sample camera images

The following images provide a sample of wild dog images (230 in total) captured on camera 27 (Curra) on 3/04/2022. Images were reviewed to individually identified wild dogs.


2022-04-03 10:08:13 AM M 2/10
22°C
HF2 PRO COVERT
BECONYX


2022-04-03 10:12:48 AM M 1/10
23°C
HF2 PRO COVERT
BECONYX


2022-04-03 10:14:14 AM M 4/10
23°C
HF2 PRO COVERT
BECONYX


2022-04-03 10:21:43 AM M 1/10 23°C
HF2 PRO COVERT
RECONYX


2022-04-03 10:26:00 AM M 1/10 23°C
HF2 PRO COVERT
RECONYX


2022-04-03 10:26:23 AM M 1/10 23°C
HF2 PRO COVERT
RECONYX

Feral cat individuals identified during baseline surveys and 2022 surveys.

Baseline surveys	2022 surveys
Curra	
Camera 15 (multiple dates)  Camera 39, 10/04/2022 	Camera 18, 3/03/2022 
Camera 18, 31/03/2022 (likely same individual as observed on camera 64 in Victory Heights in 2022) 	Camera 30, 15/02/2022  Camera 32, 19/02/2022 

Baseline surveys		2022 surveys
Camera 18, 1/03/2022 	Camera 33, 5/03/2022 	
Victory Heights		
Camera 58, 10/04/2022 		Camera 64, 25/03/2022 (likely same indivudal as seen in Curra during baselines on camera 18) 
Camera 67, 26/03/2022 		Camera 65, 19/02/2022 

Appendix 4 Statistical analysis coding

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

```
library(ggplot2)
library(lme4)

Pest_data_R_2022$camera = factor(Pest_data_R_2022$camera)
head(Pest_data_R_2022)

dog <- subset(Pest_data_R_2022, Pest_data_R_2022$common == "wild dog")
fox <- subset(Pest_data_R_2022, Pest_data_R_2022$common == "red fox")
cat <- subset(Pest_data_R_2022, Pest_data_R_2022$common == "feral cat")
pig <- subset(Pest_data_R_2022, Pest_data_R_2022$common == "feral pig")

## Models below are giving high variances for some sites
## Have a look and see if some species are absent from some sites
library(tidyverse)
spp_sum <- Pest_data_R_2022 %>%
  group_by(site, common) %>%
  summarise(n = n(),
            count = sum(count))
spp_sum

## There were no wild dog detections at Victory, so remove that site from dog
dog <- dog %>%
  filter(site != "victory")
## Also, no cats at Woondum
cat <- cat %>%
  filter(site != "woondum")
## 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)

#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 ~ site-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)
```

Repeat for 2021 data

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

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

## There were no wild dog detections at Victory
dog21a <- dog21a %>%
  filter(site != "victory")
## No feral cats observed at Woondum
cat21a <- cat21a %>%
  filter(site != "woondum")
## Pigs were only detected at Curra
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
```

Appendix 5 Statistical output summary

		Activity index		Lower confidence interval		Upper confidence interval	
Site	**Pest animal**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Curra	red fox	0.04554	0.0127	-0.00012	-0.01898	0.09119	0.04437179
	wild dog	0.03061	0.02148	0.00081	0.0093	0.06041	0.03366065
	feral cat	0.00472	0.00224	0.00076	-0.00028	0.00867	0.004759674
	feral pig	0.01685	0.01086	0.00339	-0.00364	0.03032	0.01808742
Victory Heights	red fox	0.09069	0.08315	0.03067	-0.03771	0.15071	0.12859176
	wild dog	0	0	0	0	0	0
	feral cat	0.00273	0.00306	-0.00523	-0.00145	0.0107	0.007565813
	feral pig	0	0	0	0	0	0
Woondum	red fox	0.03497	0.03265	-0.02196	-0.0108	0.09191	0.07609865
	wild dog	0.01707	0.00398	-0.02156	-0.0166	0.05569	0.02456006
	feral cat	0	0	0	0	0	0
	feral pig	0	0	0	0	0	0

Revision History

Revision No.	Revision date	Details	Prepared by	Reviewed & approved by
00	27/05/2022	Offset Pest Animal Monitoring – Year 1 Report	Ellie Kirke, Wildlife Biologist	Jess Bracks, Principal Wildlife Biologist
01	23/06/2022	Offset Pest Animal Monitoring – Year 1 Final Report	Ellie Kirke, Wildlife Biologist	Jess Bracks, Principal Wildlife Biologist

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Report compiled by Ecosure Pty Ltd

ABN: 63 106 067 976

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

PR6714_C2CD Offset Pest Animal Survey - Year 1 Final Report

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

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