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OFFSET PEST ANIMAL MONITORING BASELINE REPORT

July 2021

GYMPIE REGIONAL COUNCIL

Executive summary

Ecosure undertook baseline pest monitoring across 13 offset properties designated to offset the impact of the Bruce Highway Project: Cooroy to Curra Section D (Woondum to Curra) in Gympie. The offset properties are located in three main clusters: Curra, Victory Heights, and Woondum. The monitoring period aimed to estimate baseline levels of pest activity in each offset cluster for comparison in later years following active pest management. Passive infrared cameras (Reconyx Professional HP2X Hyperfire 2) were deployed in mid-February for a total of nine weeks. Cameras were planned to be collected after eight weeks, but inclement weather prevented collection, so an additional week's data was collected.

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.

Red foxes were recorded in all three clusters with greatest activity in Victory Heights, followed by Woondum and Curra. Wild dog activity was highest in Curra followed by Woondum, and none were recorded in Victoria Heights. An activity index for feral cats could only be calculated for Curra, although two detections were made in Victory Heights and one domestic cat was observed in Woondum. Similarly, an activity index for feral pigs could not be accurately calculated for Curra due to the variable nature of data, though groups of 1 – 15 individuals were captured on cameras in Curra; no pigs were detected in Victory Heights or Woondum.

The cameras targeted pest species but also recorded koala and black-breasted button-quail which are species the areas are designed to provide offset habitat for. One koala was detected on a camera in Curra and three black-breasted button-quails were detected on two cameras in Woondum. This highlights the importance of effective pest management to limit predation pressure on these and other endemic species.

Acknowledgements

Ecosure gratefully acknowledges Dr. Andrew Bengsen, Research Scientist for the Department of Primary Industry Vertebrate Pest Research Unit, for expert advice provided throughout this project. In particular, we would like to thank him for his assistance with statistical analyses.

Acronyms and abbreviations

AIC_C	Akaike information criterion analyses adjusted for small samples sizes
BBBQ	Black-breasted button-quail
Council	Gympie Regional Council
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
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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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) (Project). As part of the conditions of approval (EPBC 2017/7941) from the Commonwealth Department of the Environment and Energy (DEE) (now the Department of Agriculture, Water, and the Environment [DAWE]) under the *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, the Department of Transport and Main Roads (TMR) will subcontract specialists to implement pest management within the 13 offset properties to support conservation of the koala and BBBQ.

Management in each offset property will target pest species known to threaten each protected species: red fox (*Vulpes vulpes*) and wild dog (*Canis lupus familiaris*) in koala offset properties; and fox, wild dog, feral pig (*Sus scrofa*), and feral cat (*Felis catus*) in BBBQ offset properties. Gympie Regional Council (Council) engaged Ecosure to undertake baseline pest animal monitoring across the 13 environmental offset properties located within the Gympie region, as part of a contract with TMR. Baseline monitoring was in accordance with the Pest Animal Monitoring Program for the offset properties (Ecosure 2020), which was prepared to guide pest animal monitoring over ten years to detect changes and allow an active control program to be evaluated.

This first round of monitoring aimed to establish a baseline activity index for each relevant pest species in each offset cluster. Although site works had commenced in some areas prior to this survey being undertaken, the survey is considered a baseline for future statistical monitoring. Pest monitoring will occur annually, and baseline data will be used in subsequent years to determine the efficacy of pest management activities.

1.1 Scope of works

The scope of works 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 baseline monitoring report summarising field and statistical methods, results, and supporting maps.

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**

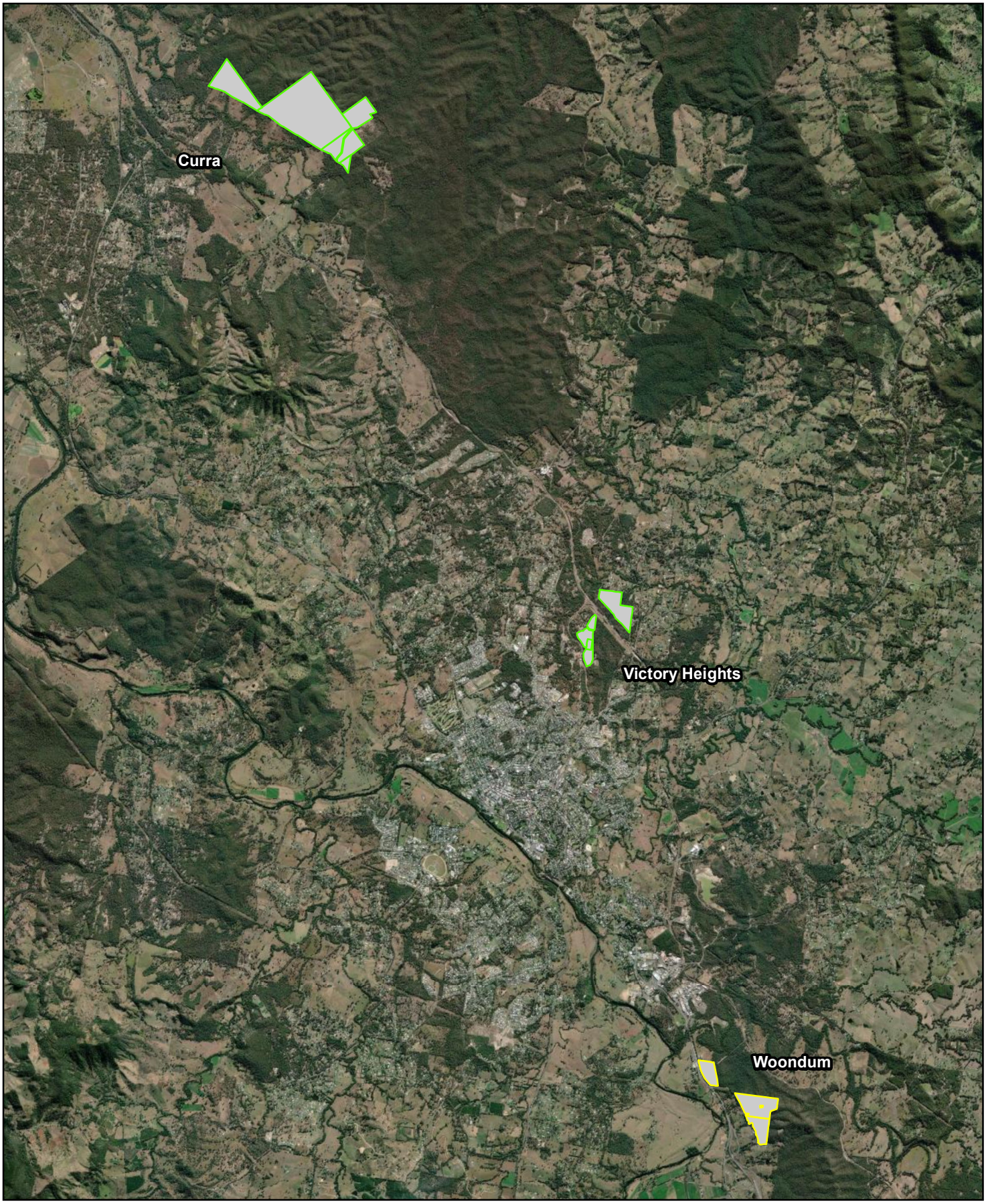

Figure 1: Offset sites

Gympie Regional Council

Offset Pest Animal Monitoring - Baseline Report

koala offset

koala + black-breasted button-quail offset

ecosure

Job number: PR5853
Revision: 0
Author: EK
Date: 27/05/2021

0 0.5 1 2
Kilometers

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

PR5853_MP1_OffsetSites
A4

2 Methods

The following field work, analysis and reporting was undertaken by suitably qualified personnel to meet the Federal 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 installed between 11th – 13th February 2021. Cameras were deployed for nine weeks in total (i.e. one week more than planned, due to heavy rainfall conditions limiting safe accessibility at the end of the eight-week period). The implications of this change for subsequent years are discussed in Section 3.3.

Cameras were placed approximately 250 m apart along roads, tracks, and movement corridors where possible (Figure 2, Figure 3, Figure 4, Appendix 2). Where not possible, cameras were placed in the most suitable location and 'site type' (e.g. track, bush, open area) was recorded for statistical analyses. 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 lures. The lures consisted of olfactory (mixture of tinned tuna, pure tuna oil, and sardines) and audio lures (Cat Caller, Professional Trapping Supplies, Molendinar, Queensland, Australia). Due to a short supply of audio lure devices available in Australia, only three of the seven cameras baited with olfactory lures also had an audio lure (Figure 4).

2.2 Limitations

The 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 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 (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, then valid comparisons in species abundance/activity trends can be made.

The delayed deployment of cameras also raised concerns regarding the potential impact of Project clearing on pest activity. Ideally, baseline monitoring would have been completed prior to any clearing/construction works to avoid any visual or noise impacts to pest animal behaviour (e.g. avoiding certain areas). However, C1 (south) works commenced in October 2020, prior to camera deployment. While on site, the noise disturbance from construction work appeared minimal, suggesting little impact. Ultimately, the location and scale of Project clearing was considered unlikely to significantly impact pest animal activity in the offset properties.

2.3 Data analysis

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

2.3.2 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 Poisson error distributions. Multiple models were run for each species to determine the model that was best supported by the data. In all models, the response variable was ‘count’, i.e. the number of red fox/wild dog/feral cat/feral pig observations recorded at each camera station on each day (including counts of ‘0’), and the fixed variable was ‘site’. Different random effects, and combinations thereof, were attempted in each model. Attempted models included:

- basic GLMM model with no random effects
- simple GLMM model with ‘camera’ as a random effect
- simple GLMM model with ‘camera’ and ‘date’ as random effects
- GLMM model with ‘camera’ nested in ‘track type’ as a random effect
- GLMM model with ‘camera’ nested in ‘bait’ as a random effect
- splitting data into three 23-day periods, then running basic models with ‘period’ as a fixed effect.

Akaike information criterion analyses (adjusted for small samples sizes; AIC_C) were used to

determine which model best fit the data for each pest species. AIC_C determined the following models for each species:

- wild dog: **GLMM model with 'camera' nested in 'track type' as a random effect**
  - Technically, the best-fit model was a simple GLMM model with 'camera' and 'date' as random effects. However, this result suggests that some days were more likely to have dog detections than others which may cause issues with repeatability in future years. For simplicity, repeatability and consistency with the red fox and feral cat models, the second-best model (bolded and underlined above) was adopted.
- red fox: **GLMM model with 'camera' nested in 'track type' as a random effect**
- feral cat: **GLMM model with 'camera' nested in 'track type' as a random effect**
- feral pig: see section 3.1.

The R Studio coding scripts for each activity index calculation are provided in Appendix 3.

2.3.2.1 Track type

The AIC_C emphasised the importance of accounting for 'track type' as a random variable in the models, likely due to the impact it has on species detectability, particularly of red foxes and wild dogs (Read et al. 2015, Wysong et al. 2020). Cameras were placed preferentially along movement corridors including tracks and dry creek beds. Where these locations were not available, cameras were strategically placed by field ecologists. Six 'track types' were recorded (in descending order):

- track (26 cameras)
- bush (21 cameras)
- dry creek bed (16 cameras)
- open area (4 cameras)
- small clearing (1 camera).

The influence of 'track type' on the results is discussed in Section 3.3.1.

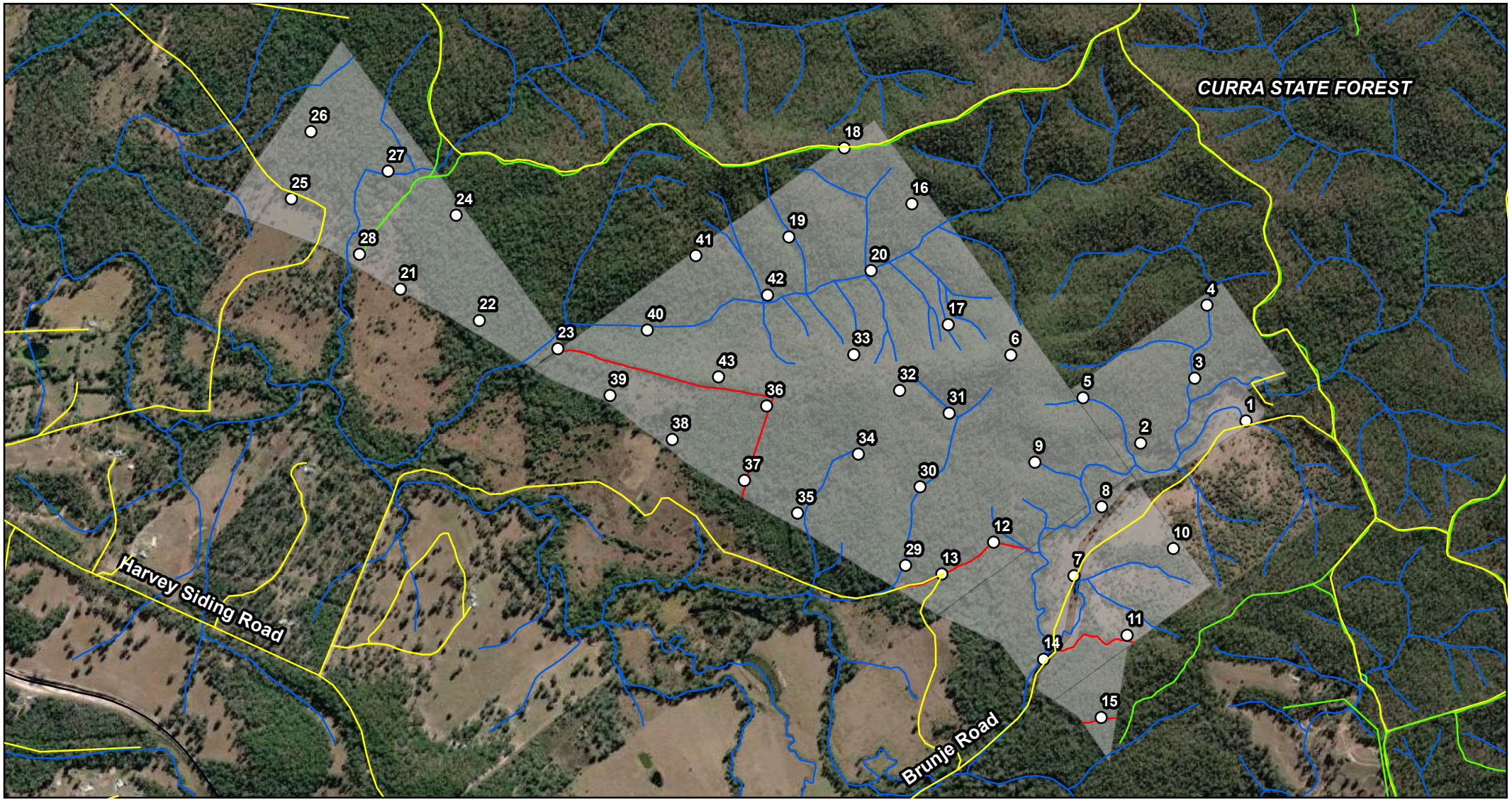

Figure 2: Camera locations in Curra offset sites

Gympie Regional Council

Offset Pest Animal Monitoring - Baseline Report

Offset cluster
Watercourse
Rail network
Potential tracks
QPWS access road
Camera locations
Road

ecosure

Job number: PR5853
Revision: 0
Author: EK
Date: 27/05/2021

0 175 350 700
Metres

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

PR5853_MP2_CurraCameraLocations
A4

Figure 3: Camera locations in Victory Heights offset sites

Gympie Regional Council

Offset Pest Animal Monitoring - Baseline Report

Offset cluster
Rail network
QPWS access road
Road
Watercourse
Potential tracks
Camera locations

ecosure

Job number: PR5853
Revision: 0
Author: EK
Date: 14/06/2021

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Meters

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

PR5853_MP3_VictoryCameraLocations
A4

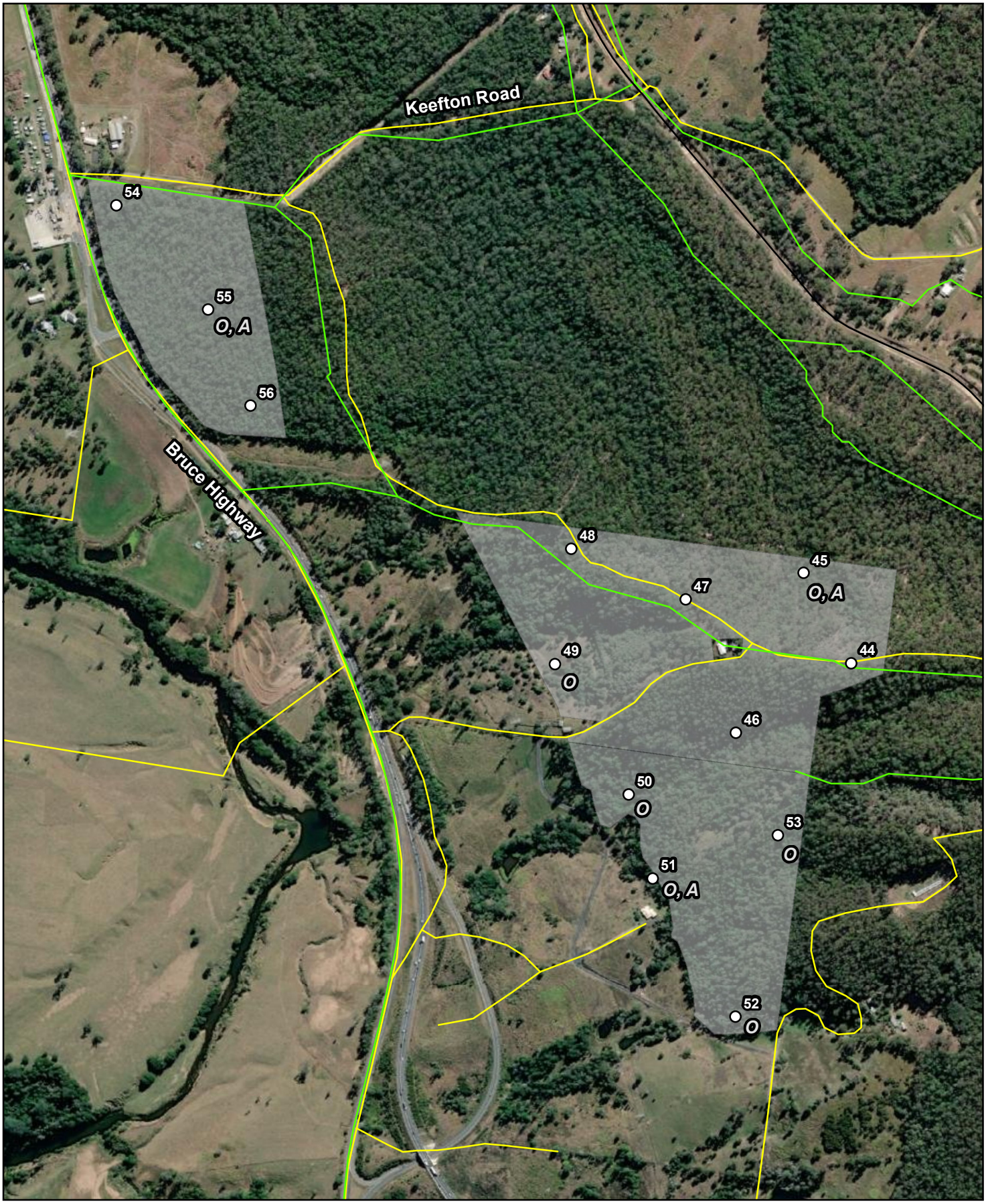

Figure 4: Camera locations in Woondum offset sites

Gympie Regional Council

Offset Pest Animal Monitoring - Baseline Report

Offset cluster
Road
QPWS access road
Watercourse
Rail network
Camera locations
O=olfactory lure
A=audio lure

ecosure

Job number: PR5853
Revision: 0
Author: EK
Date: 27/05/2021

0 40 80 160
Meters

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

PR5853_MP4_WoondumCameraLocations
A4

3 Results

3.1 Statistical analysis

Red foxes

Foxes were recorded in all three offset clusters, with the greatest activity detected in Victory Heights, followed by Woondum and Curra (Table 2, Figure 5).

Wild dogs

Wild dogs were detected in Curra and Woondum, but not in Victory Heights. Activity was greatest in Curra, followed by Woondum and Victory Heights (Table 2, Figure 5). A number of domestic dogs were observed in Victory Heights and Curra. Because the domestic dogs were always observed either on-leash or accompanied by their owners, they were not considered a threat to koala and BBBQ in these areas. If domestic dogs are observed in future years roaming any offset cluster off-leash or unaccompanied, they will be considered a threat and included in the statistical analyses for 'dog' pest activity.

Feral cats

Feral cats[1] were detected in Curra, though to a far lesser extent that wild dogs and foxes (Table 2, Figure 5). Only two independent detections (two different individuals) were recorded in Victory Heights, meaning there was insufficient data to accurately calculate an activity index for feral cats in Victory Heights.

One domestic cat was recorded on one occasion in Woondum. Despite the cat being confirmed domestic (wearing a collar), it is important to note that domestic cats pose the same threat to BBBQ and should be managed appropriately (kept indoors by owners or pounded). All cats (domestic and feral) were therefore included in baseline activity index analyses and will be included in future analyses. As there was only one observation in Woondum, there was insufficient data to accurately calculate an activity index for feral cats in Woondum.

Feral pigs

Feral pigs were occasionally detected in Curra, though the sporadic nature of detections and the high variability of group sizes (1 – 15 individuals) meant the data were not suitable for estimating a reliable activity index. As feral pigs were not a target pest species in Curra (koala offsets), further statistical analysis was not conducted at this stage (but can be in future if required).

Table 2 and Figure 5 provide a summary of activity indices from statistical analyses. See Appendix 3 for R Studio analysis coding and Appendix 4 for raw data.

[1] Cats are assumed feral based on appearance and/or absence of a collar, but may include roaming domestic cats. Only collared cats are recorded as domestic.

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
Curra	0.01418319	0.006889129	0.000937033	*N/A*
Victory Heights	0.03871399	0	*Insufficient data**	0
Woondum	0.01894089	0.003664208	*Insufficient data***	0

** two individual feral cats observed*
*** one domestic cat observed*

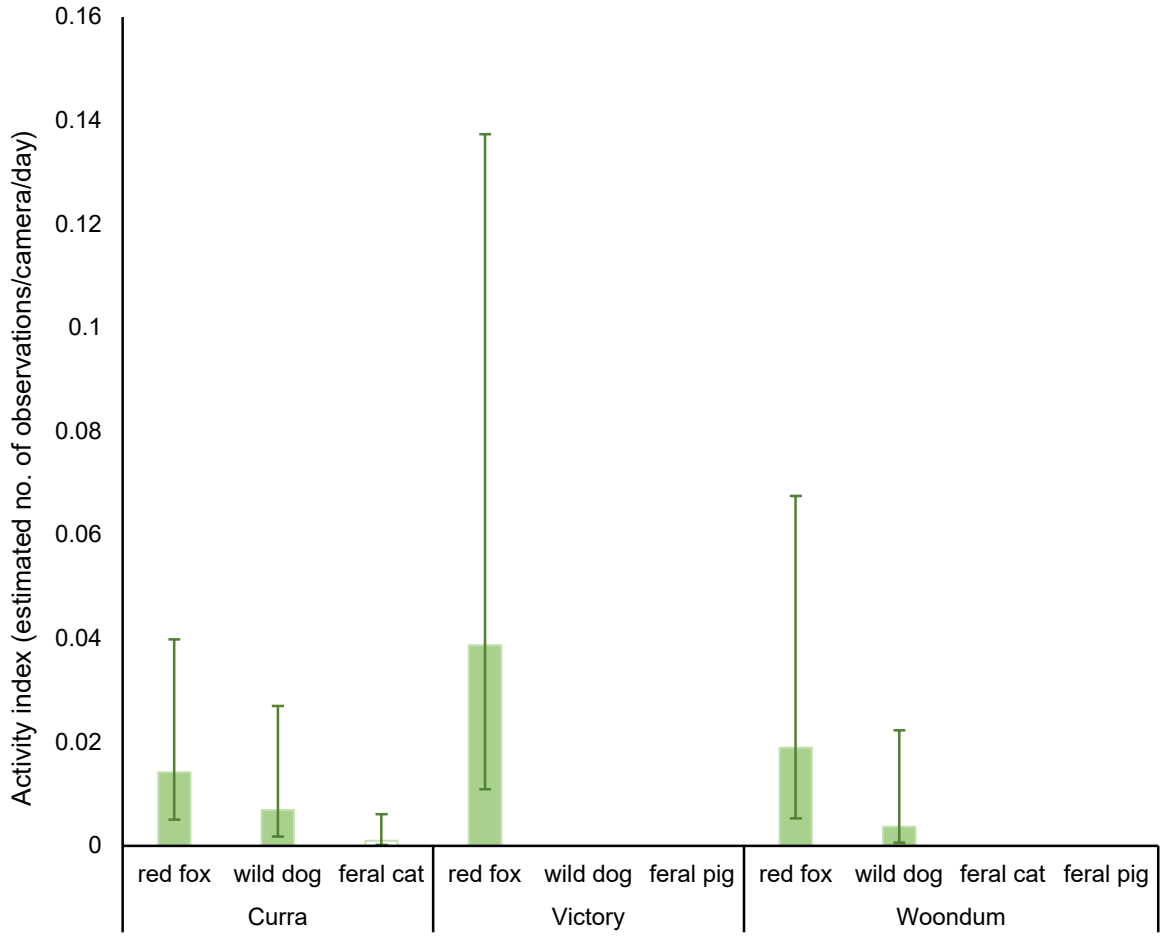

Figure 5 Pest activity indices estimated from statistical analyses, excluding species/sites with insufficient data (i.e. feral pigs in Curra and cats in Victory Heights and Woondum).

3.2 Summary of observations (non-statistical results)

Figure 6 summarises the number of independent pest observations in each offset cluster over the nine-week monitoring period. These data cannot be used in statistical analyses but do provide a clear representation of the raw data collected.

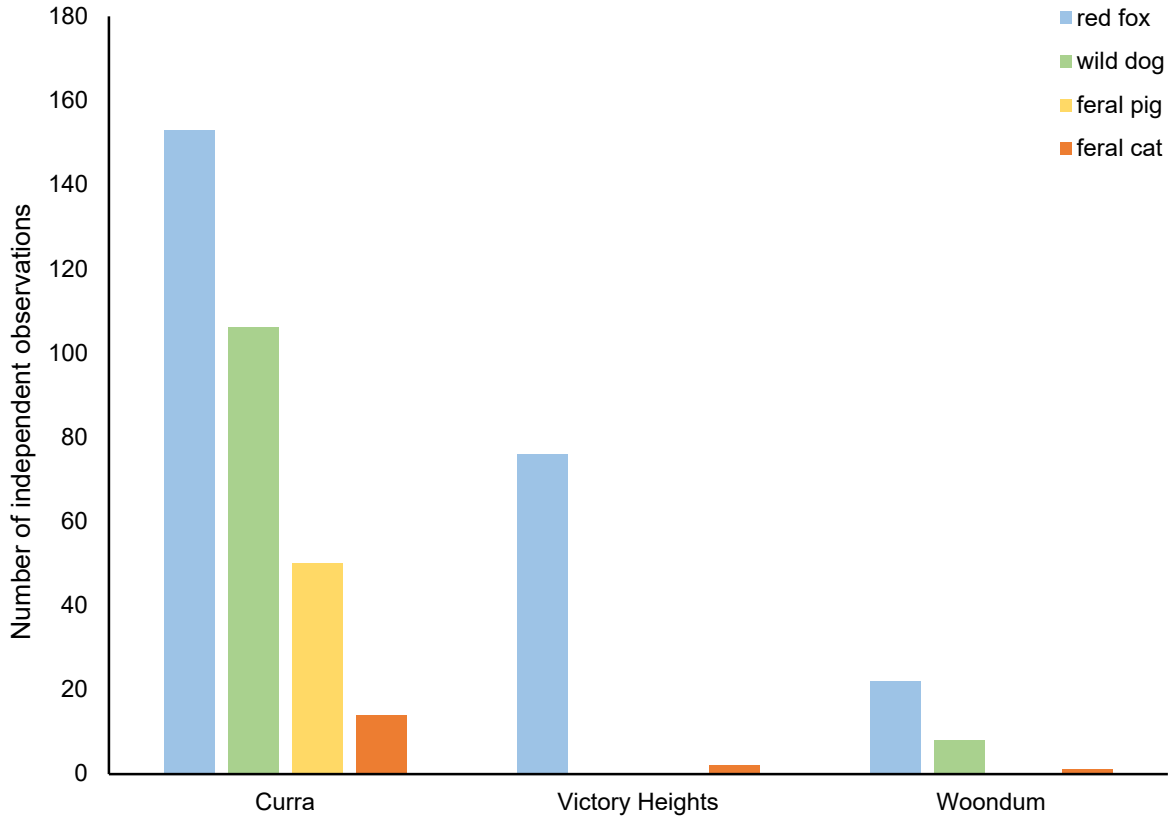

Figure 6 Total number of independent pest observations in each offset cluster.

3.2.1 Curra offset cluster

All four focal pest species (wild dog, red fox, feral cat, and feral pig) were captured on cameras within the Curra offset cluster. A total of 323 independent pest observations were made in Curra over the nine-week monitoring period: 153 red fox, 106 wild dog, 50 feral pig, and 14 feral cat observations (Figure 6).

Cattle and one domesticated donkey (captured wearing a harness) were also observed. Four wild dogs were frequently observed roaming together (Figure 7 a, b), often as a pack though sometimes in pairs or alone. The pack consisted of three tan/white dogs and one black/tan (sable colouration) dog. Notably, the pack was captured stalking and hunting an adult swamp wallaby around 2:00 am on the 2nd of March on camera 14 (Lot/Plan 1/MPH23906) (Figure 8).

a)

b)

Figure 7 Pack of four wild dogs frequently observed on cameras within the Curra offset sites.

Figure 8 Pack of wild dogs stalking and hunting an adult swamp wallaby (sequence from left – right, top – bottom)

A koala was captured walking along a cleared track at 11:18 pm on the 1st of April on camera 33 (Lot/Plan 878/MCH1061) (Figure 9). This same camera also captured a feral cat, feral dogs, and red foxes on other nights, emphasising the importance of undertaking pest management in this offset area to conserve koalas. Notably, a wild dog was captured travelling in the same direction approximately 1.5 hours after the koala (Figure 10).

Figure 9 Koala captured on camera 33 in Curra offset site.

Figure 10 Wild dog captured on camera 33, 1.5 hours after the koala was captured.

3.2.2 Victory Heights offset cluster

Foxes and cats were captured on cameras within the Victory Heights offset cluster (Figure 11 a, b and Figure 12 a, b). A total of 78 independent pest observations were made in Victory Heights over the nine-week monitoring period: two feral cat and 76 red fox observations (Figure 6). No wild dogs or feral pigs were observed over the monitoring period.

a)

b)

Figure 11 Feral cats in Victory Heights offset sites captured on a) camera 58 and b) camera 67.

a)

b)

Figure 12 Red foxes in Victory Heights offset sites captured on camera 58.

3.2.3 Woondum offset cluster

Foxes and wild dogs were captured on cameras within the Woondum offset cluster. A total of 31 independent pest observations were made in Woondum over the nine-week monitoring period: 22 red fox, eight wild dog, and one domestic cat observation (Figure 6). Most wild dog observations only included one individual, although three individuals were captured on the 13th of April on camera 48 (Figure 13 a, b). Notably, camera 49 captured a wild dog carrying a medium-sized prey in its mouth (prey item unidentifiable due to image quality) (Figure 14).

The domestic cat captured on camera 45 (Lot/Plan 3/SP302524) (Figure 15) is assumed to belong to a resident/s from one of the Woondum Road properties. It was captured on a 'bush' camera baited with an olfactory and audio lure, though was not captured on any other camera, baited or not baited, over the nine-week monitoring period.

Two BBBQs were captured on camera 55 (Lot/Plan 102/SP297908) on the 16th of February, and one BBBQ was captured on camera 50 (Lot/Plan 2/SP302526) on the 14th of March (Figure 16 a, b).

a)

b)

Figure 13 Three wild dogs captured on camera 48 in Woondum offset cluster.

Figure 14 Wild dog carrying medium-sized prey in its mouth on camera 49 in Woondum offset cluster.

a)

b)

Figure 15 Domestic cat captured on camera 45 in Woondum offset cluster.

a)

b)

c)

Figure 16 Black-breasted button-quails observed in Woondum offset sites; a) camera 55 b) camera 50.

3.3 Spatial analysis

3.3.1 Track type

All GLMM models included 'track type' as a random variable to account for variability in the results due to 'track type'. Based on basic (non-statistical) analyses, the majority of pest animals were captured on cameras placed along movement corridors, particularly tracks (Table 3). These results are as expected for foxes and wild dogs known to prefer travelling along established movement corridors. It also provides insight into feral cat movement, suggesting that they too prefer to travel along established corridors in these offset properties.

Table 3 Pest animal observations per track type.

Pest animal	Track type				
	track	bush	dry creek bed	open area	small clearing
wild dog	97	3	12	0	2
red fox	206	24	14	5	2
cat (domestic & feral)	13	3	1	0	0
feral pig	43	6	1	0	0
Grand total	**359**	**36**	**28**	**5**	**4**

3.3.2 Spatial mapping

Maps displaying the spatial distribution of pest animal activity within each offset cluster are provided below (Figure 17, 18, and 19).

Fox and wild dog activity was distributed relatively evenly across the Curra offset properties, with the majority of observations from cameras placed along movement corridors (Figure 17). Feral pigs were mainly captured on cameras on the eastern portion of the offset cluster, while feral cats appeared to occupy the middle portion of the Curra cluster (Figure 17).

Fox activity was evenly distributed across the Victory Heights offset properties (Figure 18). Only two cat observations were made over the nine-week monitoring period: one on the north-east boundary of the cluster and one near the western boundary. The proximity of these observations to surrounding houses may suggest they are domestic cats that are free to roam the offset properties, or they are feral cats that have access to anthropogenic food sources.

Wild dogs were only observed in the northern portion of the eastern Woondum cluster (Figure 19), while foxes appeared relatively evenly distributed across the entire cluster. The domestic cat was observed in the north-eastern corner of the eastern Woondum offset cluster approximately 190 m from the closest house (Figure 19).

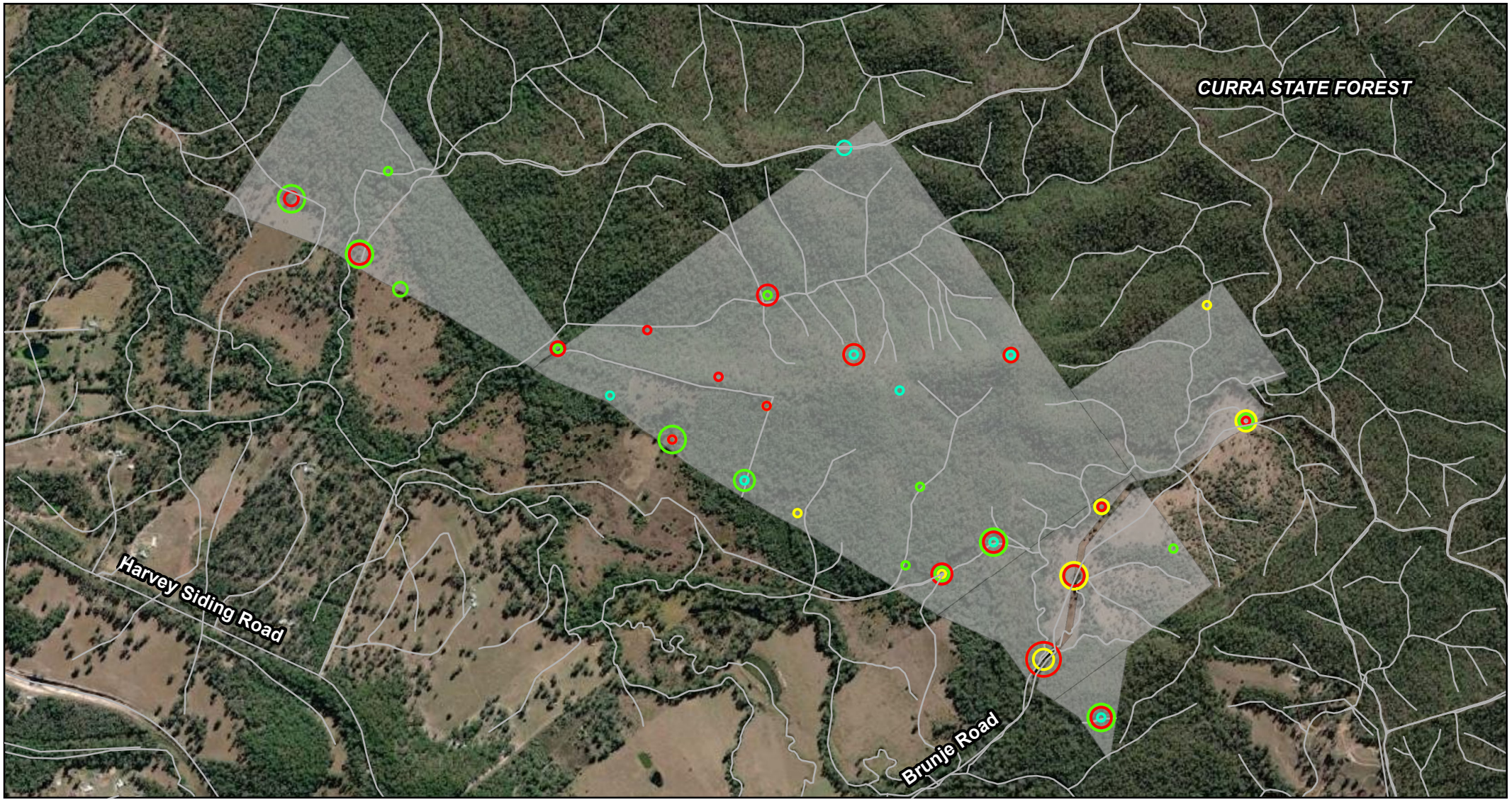

Figure 17: Pest animal activity in Curra offset properties

Gympie Regional Council

Offset Pest Animal Monitoring - Baseline Report

Offset cluster

Movement corridors

feral cat

feral pig

red fox

wild dog

No. of independent observations x count per observation

1 - 2

3 - 6

7 - 11

12 - 16

17 - 21

ecosure

Job number: PR5853
Revision: 0
Author: EK
Date: 9/07/2021

0 175 350 700
Metres

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

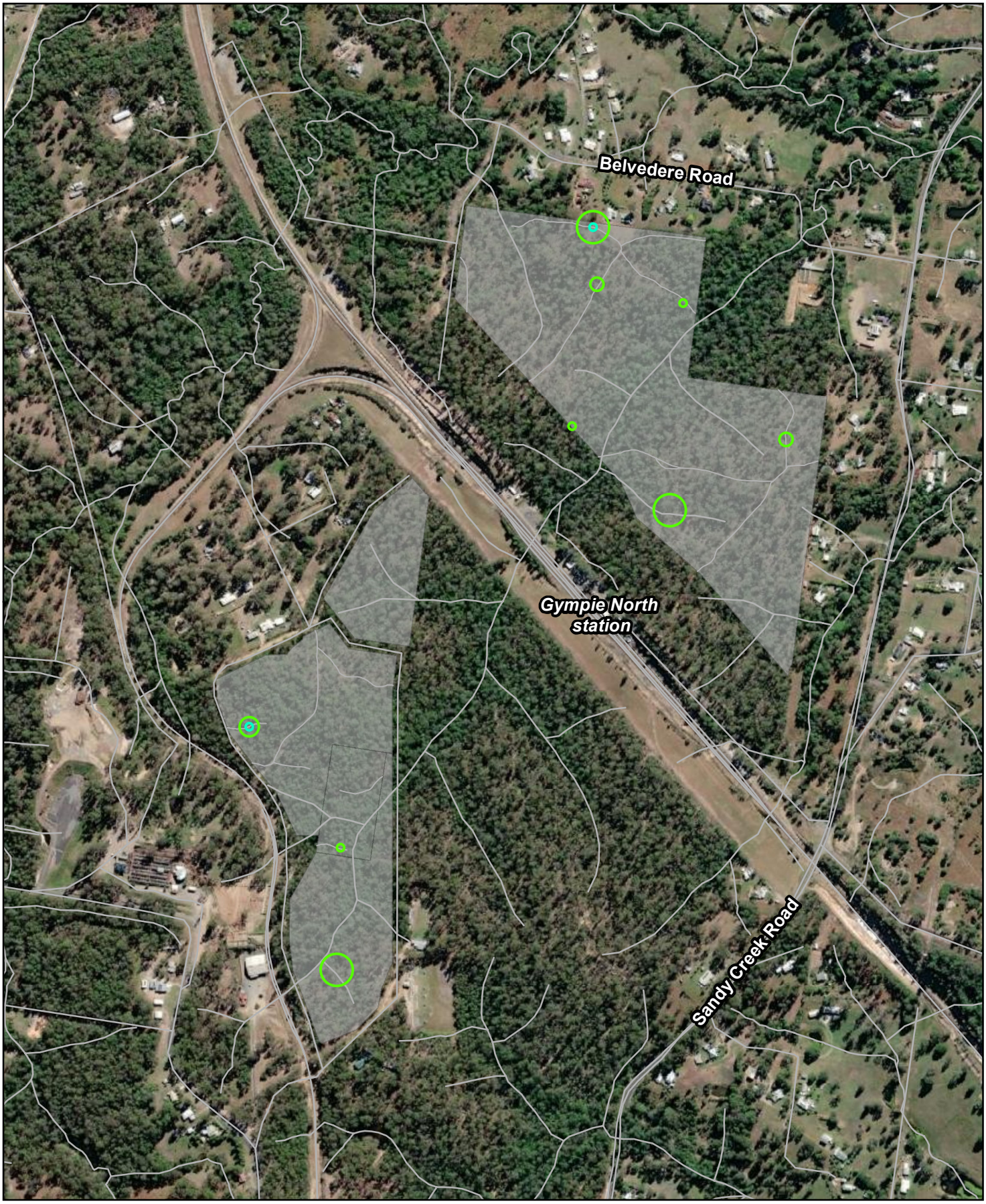

Figure 18: Pest animal activity in Victory Heights offset cluster

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Offset Pest Animal Monitoring - Baseline Report

Offset cluster
Movement corridors
feral cat
red fox

No. of independent observations x count per observation

1 - 2
3 - 6
7 - 11
12 - 16
17 - 21

ecosure

Job number: PR5853
Revision: 0
Author: EK
Date: 9/07/2021

0 40 80 160
Meters

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

PR5853_MPX_PestActivity_VictoryHeights
A4

Figure 19: Pest animal activity in Woondum offset properties

Gympie Regional Council

Offset Pest Animal Monitoring - Baseline Report

Offset cluster
Movement corridors
domestic cat
red fox
wild dog

No. of independent observations x count per observation

1 - 2
3 - 6
7 - 11
12 - 16
17 - 21

ecosure

Job number: PR5853
Revision: 0
Author: EK
Date: 9/07/2021

0 40 80 160
Meters

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

4 Discussion

Results from the baseline monitoring period confirmed the presence of red fox in all three offset clusters, wild dogs in Curra and Woondum, cats in Curra (feral), Victory Heights (feral) and Woondum (domestic), and pigs in Curra. Although present, feral pigs and cats were not a target pest species in Curra.

Red fox activity indices were highest in Victory Heights, followed by Woondum and Curra offset clusters. Wild dog activity indices were highest in Curra, following by Woondum offset cluster. An activity index for feral cats could only be calculated for Curra, though two detections confirmed their presence in Victory Heights and one domestic cat was detected in Woondum. An activity index for feral pigs could not be accurately calculated for Curra due to the highly variable nature of data, though groups of 1 – 15 individuals were captured on cameras.

Given the proximity between cameras and length of survey period, the lack of detection in some offset clusters likely represent an absence of certain pest species at this point in time. However, monitoring was limited to one point in time (late summer/early autumn), and seasonal variation in pest movement may alter activity indies in these offset areas at different times of the year. For example, wild dog activity generally peaks in spring and early summer when wild dogs are dispersing after the breeding season (McNeill et al. 2016, DAF 2016, North Coast Local Land Services 2019). Thus, wild dog activity indices calculated during baseline monitoring is likely lower than the peak activity through the year. Similarly, fox densities have been shown to peak in summer (Coman et al. 1991), with cubs emerging from dens in late spring and dispersing from family territory in late summer to early winter (Gentle 2006, DSEWPC 2010). Unlike wild dogs and foxes, feral cats and feral pigs do not generally have a peak activity season/month as breeding is generally dictated by environmental conditions and resource availability (Mitchell & Balough 2007). Given the variable nature of pest movement, it is reasonable to assume that activity in offset areas may differ throughout the year. Therefore, the lack of detection during this baseline monitoring period does not confirm absence during the rest of the year, nor does it provide a definitive activity level for all times of the year. This factor, along with additional survey limitations discussion in Section 2.2 and Ecosure 2020, should be considered when developing the pest management strategy.

In addition, home ranges of these pest species can differ according to resource availability, meaning that shifts in resource availability may impact the movement of pests into and/or out of offset areas. Pest management efforts should consider the dynamic nature of pest species movement to ensure efficient and effective control.

The detection of offset target species (i.e. koala in Curra and BBBQ in Woondum) emphasises the importance of undertaking effective pest management within offset sites.

Data collected from the 2021 survey will be compared after monitoring in 2022, and one-tailed z-tests will be used to determine how pest abundance (i.e. pest activity index) has changed. 2022 monitoring will replicate the 2021 survey using the exact camera placement, time of year, and statistical analyses. However, cameras will be deployed for the planned eight weeks, rather than nine weeks. As the activity indices are an estimated no. of observations / camera

/ day, the additional week of data collection may have improved the accuracy of the results but would not have introduced any bias. Therefore, assuming all other factors remain the same, direct comparisons can be made between baseline monitoring (nine weeks), 2022 monitoring (eight weeks), and subsequent years.

Results of this baseline monitoring will assist planning effective control, which will be detailed in a Pest Animal Management Strategy (PAMS) (planned for development). Pest management needs to consider potential movement of pest species in response to seasonal and environmental variables and be carefully timed to avoid potential inadvertent impacts (e.g. mesopredator release, which has the potential to have a negatively impact BBBQ population). The Pest Animal Management Strategy should consider research that can inform the program, for example genetic samples from wild dogs to determine dingo purity, and predator scat analyses to determine prey species. It should also ensure that control actions are targeted to locations of known pest animal activity at the time of planned control, highlighting the need for monitoring (cameras, tracks/scats etc) as part of the PAMS.

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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. For a more extensive list of personnel involved in the design of the pest monitoring program, see Ecosure 2020.

Name & role	Qualifications	Relevant experience
Jess Bracks Principal Wildlife Biologist ***Reviewer***	Bachelor of Applied Science in Animal Studies (Wildlife Biology), University of Queensland, 2005	Jess is a Wildlife Biologist with 14 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***	Masters 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.
Hannah Thomas Ecologist ***Field work***	Bachelor of Advanced Science (Honours) (Ecology), University of Queensland, 2018	Hannah is an Ecologist with experience working in a range of ecosystems across Australia. Hannah's experience includes both fauna and flora surveys in the NT, SA, NSW, VIC and Christmas Island. Prior to her role at Ecosure Hannah was a field ecologist with Australian Wildlife Conservancy, based at Mallee Cliffs National Park. Hannah has experience in conducting threatened mammal translocations, telemetry monitoring and targeted monitoring of threatened mammals and birds. She also completed two internships, with the Conservation Ecology Centre and Australian Wildlife Conservancy, where she conducted numerous koala surveys using the distance sampling method.
Bob Johnston Ecologist ***Field work***	Bachelor of Environmental Science, Southern Cross University, 2012	Bob has more than six years' experience as an Ecologist with experience in fauna spotter catching and ecological surveys, including Koala SAT and transect surveys. He has trained with Dr Steve Phillips (Biolink), including formal training on Spot Assessment Technique (SAT) surveys and assisting on koala research projects. He has also carried out aquatic and terrestrial habitat assessments, bird surveys, koala surveys, fauna trapping using Elliott, pitfall, and harp traps, spotlighting and flying-fox dispersal.

Appendix 2 Camera locations

Camera	Latitude	Longitude	Offset cluster	Site type	Bait status
1	-26.0669	152.6341	Curra	track	no
2	-26.0675	152.6308	Curra	bush	no
3	-26.0657	152.6325	Curra	dry creek bed	no
4	-26.0636	152.6329	Curra	dry creek bed	no
5	-26.0662	152.629	Curra	dry creek bed	no
6	-26.065	152.6267	Curra	track	no
7	-26.0713	152.6287	Curra	track	no
8	-26.0693	152.6295	Curra	bush	no
9	-26.0681	152.6274	Curra	dry creek bed	no
10	-26.0705	152.6318	Curra	open area	no
11	-26.073	152.6303	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	152.6235	Curra	bush	no
17	-26.0641	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	-26.0626	152.6222	Curra	dry creek bed	no
21	-26.0631	152.6073	Curra	open area	no
22	-26.064	152.6098	Curra	bush	no
23	-26.0648	152.6123	Curra	track	no
24	-26.061	152.6091	Curra	bush	no
25	-26.0605	152.6039	Curra	open area	no
26	-26.0585	152.6045	Curra	bush	no
27	-26.0597	152.607	Curra	dry creek bed	no

Camera	Latitude	Longitude	Offset cluster	Site type	Bait status
28	-26.0621	152.6061	Curra	track	no
29	-26.071	152.6233	Curra	track	no
30	-26.0687	152.6238	Curra	track	no
31	-26.0666	152.6247	Curra	dry creek bed	no
32	-26.066	152.6231	Curra	bush	no
33	-26.065	152.6217	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	-26.0674	152.6159	Curra	track	no
39	-26.0661	152.614	Curra	bush	no
40	-26.0643	152.6152	Curra	dry creek bed	no
41	-26.0621	152.6167	Curra	bush	no
42	-26.0633	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	-26.2486	152.7103	Woondum	bush	yes
51	-26.2501	152.7108	Woondum	bush	yes
52	-26.2526	152.7124	Woondum	bush	yes
53	-26.2494	152.7133	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	Latitude	Longitude	Offset cluster	Site type	Bait status
57	-26.154	152.6801	Victory Heights	track	no
58	-26.1526	152.6824	Victory Heights	track	no
59	-26.1539	152.6841	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	-26.1593	152.6856	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 Statistical analysis coding

The following R Studio script was used to analyse the pest data for baseline surveys. Input coding is displayed in blue font and preceded by '>', while output is displayed in black font.

```
> library(ggplot2)
> library(lme4)
> #activity indices for wild dogs in Curra and Woondum
> dog1 <- glmer(count ~ site-1 + (1|track/camera), family="poisson", data = dog)
> dog1_sum <- summary(dog1)
> print(dog1_sum)
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']
 Family: poisson  ( log )
Formula: count ~ site - 1 + (1 | track/camera)
   Data: dog

     AIC      BIC   logLik deviance df.resid
   994.5   1019.5   -493.2    986.5     3860

Scaled residuals:
    Min      1Q  Median      3Q     Max
-0.5256 -0.1383 -0.0647 -0.0504 16.7698

Random effects:
 Groups       Name        Variance Std.Dev.
 camera:track (Intercept) 2.118    1.455
 track        (Intercept) 1.255    1.120
Number of obs: 3864, groups:  camera:track, 56; track, 5

Fixed effects:
             Estimate Std. Error z value Pr(>|z|)
sitecurra    -4.9778     0.6964  -7.148 8.81e-13 ***
sitewoondum  -5.6091     0.9213  -6.088 1.14e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            sitcrr
```

```
sitewoondum 0.544
> #expected number of dog detections per camera per day
> gi_dog1 <- exp(coefficients(dog1_sum)[, "Estimate"])
> print(gi_dog1)
  sitecurra sitewoondum
0.006889129 0.003664208
> #confidence intervals for the estimates
> lo_dog1 <- exp(coefficients(dog1_sum)[, "Estimate"] - 1.96 * coefficients(dog1_sum)[, "Std. Error"])
> up_dog1 <- exp(coefficients(dog1_sum)[, "Estimate"] + 1.96 * coefficients(dog1_sum)[, "Std. Error"])
> print(lo_dog1)
  sitecurra sitewoondum
0.001759477 0.000602185
> print(up_dog1)
  sitecurra sitewoondum
 0.02697399  0.02229617

> #activity indices for red foxes in all offset clusters
> fox1 <- glmer(count ~ site-1 + (1|track/camera), family="poisson", data = fox)
> fox1_sum <- summary(fox1)
> print(fox1_sum)
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']
 Family: poisson  ( log )
Formula: count ~ site - 1 + (1 | track/camera)
   Data: fox

     AIC      BIC   logLik deviance df.resid
  1690.9   1723.0   -840.4   1680.9     4573

Scaled residuals:
    Min      1Q  Median      3Q     Max
-0.5365 -0.2110 -0.1245 -0.0748 13.6641

Random effects:
 Groups       Name        Variance Std.Dev.
 camera:track (Intercept) 1.5763   1.2555
 track        (Intercept) 0.8394   0.9162
Number of obs: 4578, groups:  camera:track, 67; track, 5
```

```
Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
sitecurra    -4.2557     0.5269  -8.077 6.64e-16 ***
sitevictory  -3.2516     0.6460  -5.033 4.83e-07 ***
sitewoondum  -3.9664     0.6485  -6.116 9.59e-10 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Correlation of Fixed Effects:
            sitcrr stvctr
sitevictory 0.651
sitewoondum 0.572  0.449
> #expected number of fox detections per camera per day
> gi_fox1 <- exp(coefficients(fox1_sum)[, "Estimate"])
> print(gi_fox1)
sitecurra sitevictory sitewoondum
 0.01418319  0.03871399  0.01894089
> #confidence intervals for the estimates
> lo_fox1 <- exp(coefficients(fox1_sum)[, "Estimate"] - 1.96 * coefficients(fox1_sum)[, "Std. Error"])
> up_fox1 <- exp(coefficients(fox1_sum)[, "Estimate"] + 1.96 * coefficients(fox1_sum)[, "Std. Error"])
> print(lo_fox1)
  sitecurra sitevictory sitewoondum
0.005049778 0.010912998 0.005313353
> print(up_fox1)
  sitecurra sitevictory sitewoondum
 0.03983597  0.13733837  0.06751994

> #activity indices for cats in Woondum
> cat1 <- glmer(count ~ 1 + (1|track/camera), family="poisson", data = cat)
> cat1_sum <- summary(cat1)
> print(cat1_sum)
Generalized linear mixed model fit by maximum likelihood (Laplace Approximation) ['glmerMod']
 Family: poisson  ( log )
Formula: count ~ 1 + (1 | track/camera)
   Data: cat

     AIC      BIC   logLik deviance df.resid
   166.4    184.4    -80.2    160.4     2964
```

```
Scaled residuals:
    Min      1Q  Median      3Q     Max
-0.2650 -0.0310 -0.0284 -0.0273 12.2129

Random effects:
 Groups       Name        Variance Std.Dev.
 camera:track (Intercept) 3.51312  1.8743
 track        (Intercept) 0.07987  0.2826
Number of obs: 2967, groups:  camera:track, 43; track, 5

Fixed effects:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -6.9745     0.9541   -7.31 2.68e-13 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> #expected number of cat detections per camera per day
> gi_cat1 <- exp(coefficients(cat1_sum)[, "Estimate"])
> print(gi_cat1)
[1] 0.0009370326
> #confidence intervals for the estimates
> lo_cat1 <- exp(coefficients(cat1_sum)[, "Estimate"] - 1.96 * coefficients(cat1_sum)[, "Std. Error"])
> up_cat1 <- exp(coefficients(cat1_sum)[, "Estimate"] + 1.96 * coefficients(cat1_sum)[, "Std. Error"])
> print(lo_cat1)
[1] 0.000144785
> print(up_cat1)
[1] 0.006064371
```

Appendix 4 Statistical output summary

Site	Pest animal	Activity index	Lower confidence interval	Upper confidence interval
Curra	red fox	0.01418319	0.005049778	0.03983597
	wild dog	0.006889129	0.001759477	0.02697399
	feral cat	0.000937033	0.000144785	0.006064371
	feral pig	N/A		
Victory Heights	red fox	0.03871399	0.010912998	0.13733837
	wild dog	0	0	0
	feral cat	N/A		
	feral pig	0	0	0
Woondum	red fox	0.01894089	0.005313353	0.06751994
	wild dog	0.003664208	0.000602185	0.02229617
	feral cat	N/A		
	feral pig	0	0	0

Revision History

Revision No.	Revision date	Details	Prepared by	Reviewed by	Approved by
00	11/06/2021	Offset Pest Animal Monitoring – Baseline Report DRAFT	Ellie Kirke, Wildlife Biologist	Jess Bracks, Principal Wildlife Biologist	Phil Shaw, Managing Director
01	1/07/2021	Offset Pest Animal Monitoring – Baseline Report DRAFT R1	Ellie Kirke, Wildlife Biologist	Jess Bracks, Principal Wildlife Biologist	
02	9/07/2021	Offset Pest Animal Monitoring – Baseline Report	Ellie Kirke, Wildlife Biologist	Jess Bracks, Principal Wildlife Biologist	

Distribution List

Copy #	Date	Type	Issued to	Name
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2	9/07/2021	Electronic	Ecosure	Administration

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