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Warralong Feral Cat Monitoring
2024

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Cover image: Feral cat investigating a bilby burrow on Coongan Station (credit Roy Hill)

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1 Introduction

In 2014, the Department of Biodiversity, Conservation and Attractions (DBCA) collaborated with members of the Warralong community to identify an active bilby population on the Coongan Pastoral Lease. In subsequent years, bilby presence was observed in 2015, 2016, 2018, 2019, 2021, 2022 and 2023 (Dziminski *et al.* 2020; Dziminski *et al.* 2021; Moore 2022a; Moore *et al.* 2023; Harrison *et al.* 2024).

A collaborative project was launched in 2018 to monitor and manage threats to the bilby population at Warralong, involving the Warralong Community, DBCA, Roy Hill (RH), and Greening Australia (GA). In 2019, RH commenced funding Greater Bilby Offset Project 1, which was approved by the Commonwealth Government.

This Offset Project, covers part of the Coongan Pastoral Lease with management activities identified including patch burning, introduced predator control, and introduced herbivore management. Management activities are to be focused on a defined area, the Bilby Land Management Area (BLMA), within which bilbies are known to occur.

In 2022 and 2023 introduced predator management was delivered, involving the aerial deployment of ~5,750 Eradicat® baits within the BLMA. Another aerial deployment of ~11,000 Eradicat® baits was conducted in June 2024 over an expanded area to cover the then known bilby colony areas. To evaluate the effectiveness of this baiting, a before and after control and impact (BACI) monitoring design was implemented to detect changes in feral cat occupancy and activity pre and post baiting. This report summarises findings from the analysis of the 2024 monitoring data (another report describing the population monitoring of bilbies will be compiled separately).

Specific objectives of the analysis were to:

1. Measure the effect of Eradicat® baiting on feral cat occupancy within the BLMA.
2. Measure the effect of Eradicat® baiting on feral cat activity within the BLMA.
3. Measure the effect of Eradicat® baiting on feral cat prey species within the BLMA, including small mammal and reptiles.
4. Provide directions for future feral cat monitoring within the BLMA based on the above.

2 Methods

2.1 Eradicat® baiting

Eradicat® is a toxic bait designed to target feral cats (Algar and Burrows 2004). It contains a lethal dose of the active ingredient, 1080, and has been shown to be effective in reducing feral cat populations (Algar *et al.* 2013; Comer *et al.* 2018; Fancourt *et al.* 2022). Eradicat® baits were successfully deployed across the BLMA at a density of 50 baits per 1 km^2 on the 14th June 2024. This BLMA bait cell was larger than that baited during 2022 and 2023 with an increase from 13,000 ha to 18,712ha. Helicopter Logistics Pty Ltd were responsible for bait delivery, with bait preparation undertaken by licenced personnel from the DBCA Exmouth office.

2.2 Data collection

2.2.1 Camera traps

Camera trap monitoring was conducted at 30 sites spread across the study area using Reconyx PC900 Hyperfire Professional cameras. A total of 20 cameras were positioned inside or bordering the BLMA, and 10 cameras outside the BLMA (Figure 1; Table S1). Camera trap effort was designed to maximise our capacity to measures changes in feral cat occupancy within the BLMA, where Eradicat® baits were deployed.

Camera traps were deployed between 7/02/2024 to 31/10/2024, totalling 267 days. This provided approximately 130 days (18-19 weeks) of camera trap data either side of Eradicat® deployment, which is sufficient to achieve a reasonable level of statistical power to detect changes in feral cat occupancy (Guillera-Arroita and Lahoz-Monfort 2012; Moore 2022b).

Cameras were mounted on 90 cm aluminium fence droppers (Figure 2), and positioned next to tracks to maximise feral cat detectability and statistical power (Moore 2022b).

Animals in camera trap images were identified by trained observers.

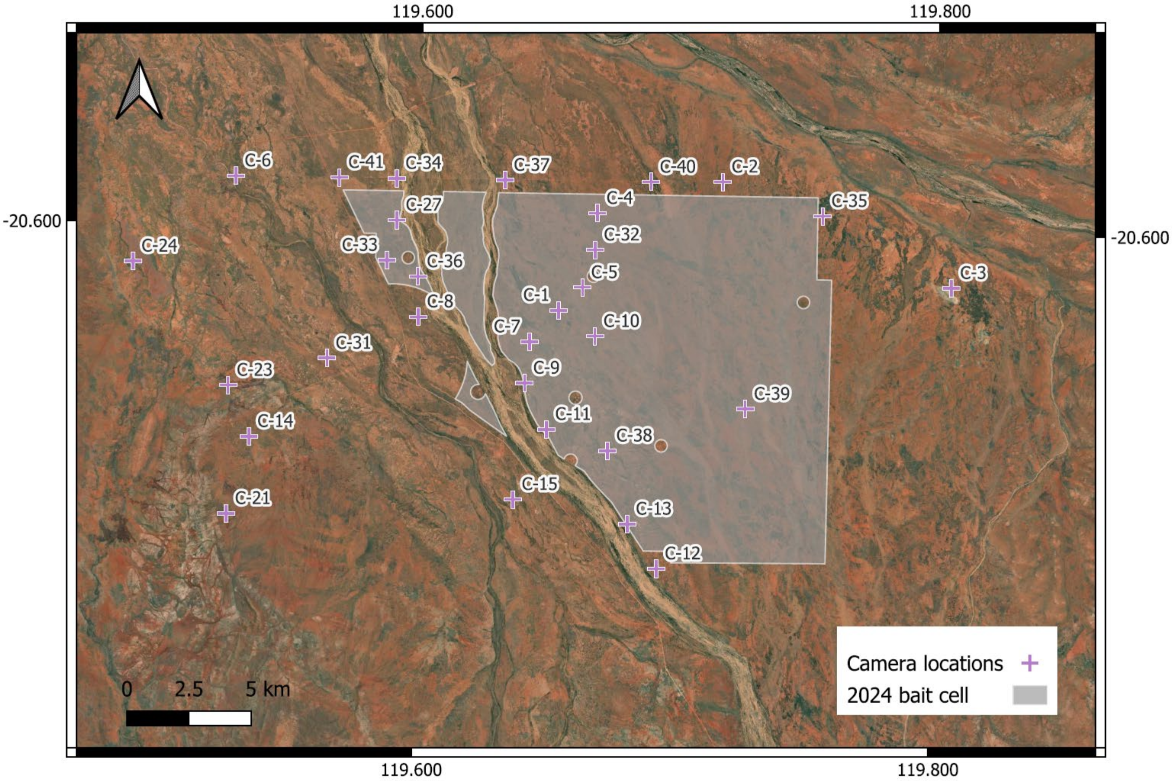

Figure 1. Camera trap locations relative to Eradicat® bait cell in 2024.

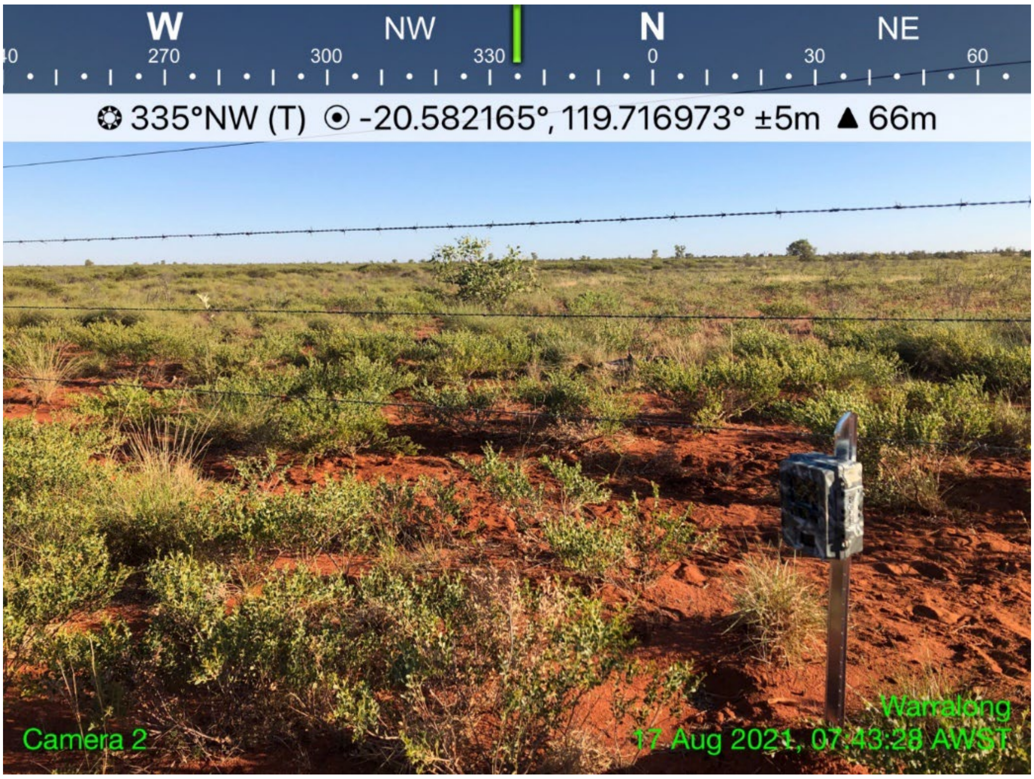

Figure 2. Typical camera trap set up used to detect feral cats as part of the Warralong Greater Bilby Offset Project.

2.2.2 2-ha plot surveys

A total of 31 x 2-ha plots were surveyed across the study area (Figure 3). The standardised 2-ha sign plot technique provides systematically quantified and comparable data and is currently applied broadly in parts of arid and semi-arid Australia (Southwell *et al.* 2022). At each 2-ha plot, trained observers recorded animal sign as well as plot covariates in a 2-ha area and along 100 m of nearby vehicle track. During this survey, data was collected electronically using Fulcrum.

Each 2-ha plot was surveyed eight times in 2024 (February, April, May, June, July August, September, October) (Table S2). This provided four surveys prior to the deployment of Eradicat® baits (conducted on 14 June 2024), and four surveys following the deployment of bait. Ten sign plots were located inside the baited cell (baited), and 20 were located outside (unbaited) (Figure 3; Table S3).

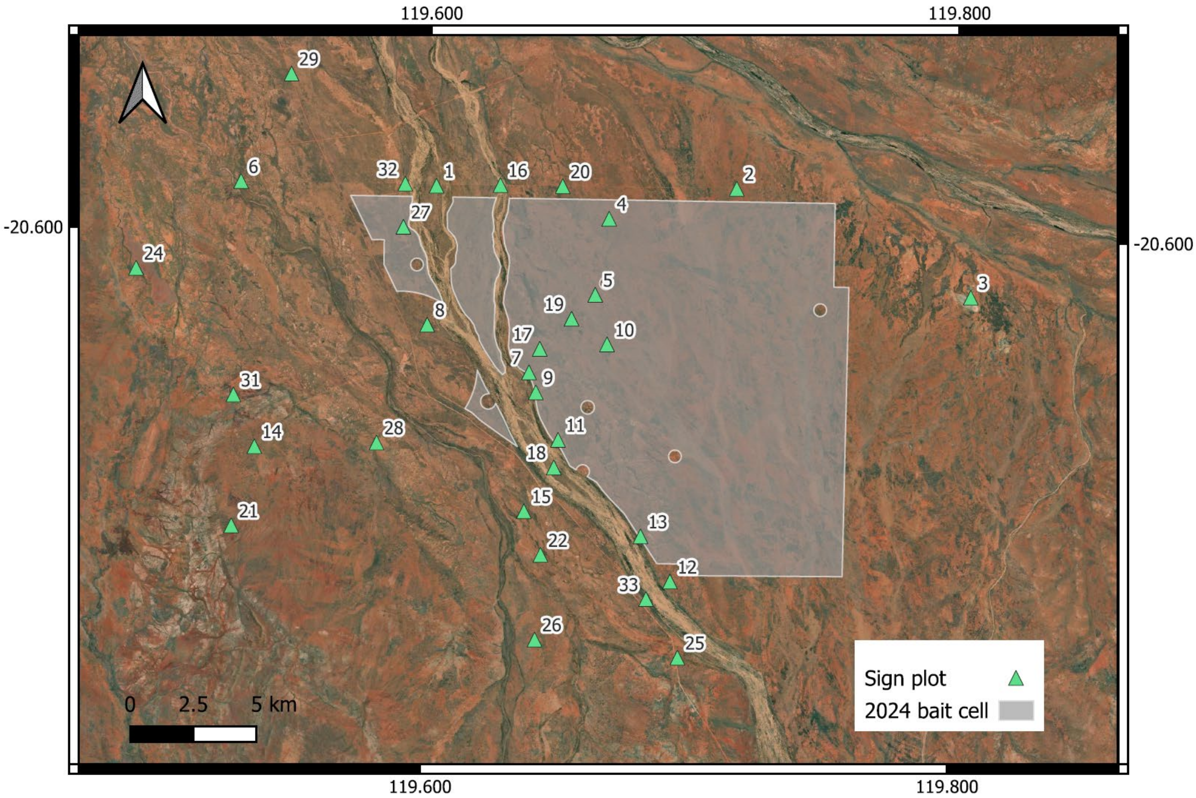

Figure 3. Sign plot survey locations relative to Eradicat® bait cell in 2024.

2.2.3 Occupancy analysis

We used dynamic occupancy models to detect changes in feral cat occupancy in response to Eradicat® baiting. Models were fitted using the package *Unmarked* (Fiske and Chandler 2011) in the R statistical software (R Core Team 2021). Dynamic occupancy models use data from primary periods (pre-baiting and post-baiting), each comprising a series of secondary periods. In this analysis, secondary periods were made up of 14-day blocks of camera trap data, or individual 2-ha plot surveys (following Moore 2022b). These models do not rely on the assumption of a closed system between primary periods, and allow users to estimate initial site occupancy rates, as well as colonisation and extinction probabilities, which account for changes in site occupancy between primary periods, i.e., pre- and post-baiting periods. This approach has previously been used to examine the effect of Eradicat® baiting (Doherty *et al.* 2021).

To determine if the application of Eradicat® reduced feral cat occupancy, we fitted a suite of models with treatment (baited or unbaited) as a predictor for initial occupancy, as well as extinction and colonisation probability. Models were then ranked based on AICc. Evidence for the efficacy of baiting was established if the treatment demonstrates a significant effect on the probability of extinction ($p < 0.05$). Models were fitted separately for camera trap and plot data.

Occupancy predictions were generated by drawing samples from empirical Bayes posterior predictive distribution derived from unmarked models. This is a statistical technique that uses observed data to estimate the distribution of future observations and provides a more accurate prediction of future outcomes.

To test if baiting had any effect on feral cat prey species, we repeated the above analysis for small mammals (rodents, dasyurids) and small to medium sized reptiles (skinks, goannas, small snakes) using both camera trap and 2-ha plot data.

2.2.4 Activity analysis

We used generalised linear models fit with Gaussian distribution to assess changes in cat activity in response to baiting. Models were fit using the package *lme4* (Bates *et al.* 2015) in the R statistical software (R Core Team 2021). Feral cat activity was assessed as the number of detections recorded at a site per 100 trap nights, following previous studies (Doherty and Algar 2015; Moseby *et al.* 2020; Palmer *et al.* 2021). Independent detections were defined as those separated from one another by at least 15 minutes. Models included an interaction term between treatment (baited or unbaited) and period (pre-baiting or post-baiting) as a fixed effect. Evidence for the efficacy of baiting was established if there was significant effect ($p<0.05$) of the interaction terms (treatment*period) on cat activity.

3 Results

In 2024, feral cats were detected 32 times on cameras traps, across 14/30 sites, and detections were more common in the second half of the sampling period (Figure 4). Over the same period, feral cats were detected 48 times during 2-ha plot surveys, across 15/31 plots (Figure 5).

Other species detected during camera and plot surveys included dingos (*Canis familiaris*), brush-tailed mulgara (*Dasycercus blythi*), and sand goannas (*Varanus gouldii*). A single red fox (*Vulpes vulpes*) was also detected once at the eastern extent of the study area at C3.

Cameras failed at 7 sites during the sampling period (C1, C12, C13, C24, C27, C39, C41) either due to stolen SD cards or battery failure. This reduced the total number of sampling occasions across all cameras from 570 to 532 (Figure 4). It is unlikely this reduction in sampling effort had a significant effect on the results.

Detection of all species by camera traps (Figure 6) was considerably lower than previous years, particularly in the period before baiting (Figure 4). This was likely due to disruptions to the cameras, for example, incorrect positioning of camera traps (i.e., angle of focus and field of view resulting from disturbance by cows).

3.1 Occupancy analysis

There were no significant effects of treatment (baited vs unbaited) on extinction or colonisation probability for feral cats, small mammals or for reptiles by either method (camera trap data or sign plot data). Moreover, treatment was not included in the top models for any species group, suggesting there was no detectable effect of baiting on occupancy for any of these species' groups (Table 1, Figure 7, Figure 8).

With high variation in detection rates between methods (Figure 4, Figure 5), predictions of occupancy for feral cats, reptiles, and small mammals varied considerably. In both baited and unbaited sites, occupancy of all species groups increased after baiting according to camera trap data (Figure 7) (although there were very few detections before baiting owing to camera interference). Predictions of occupancy from sign plot data suggest that there are more feral cats in the unbaited area, but this doesn't change following baiting (Figure 8). Predicted occupancy of small mammals and reptiles was high from sign plot data, increasing after baiting in both baited and unbaited sites (Figure 8).

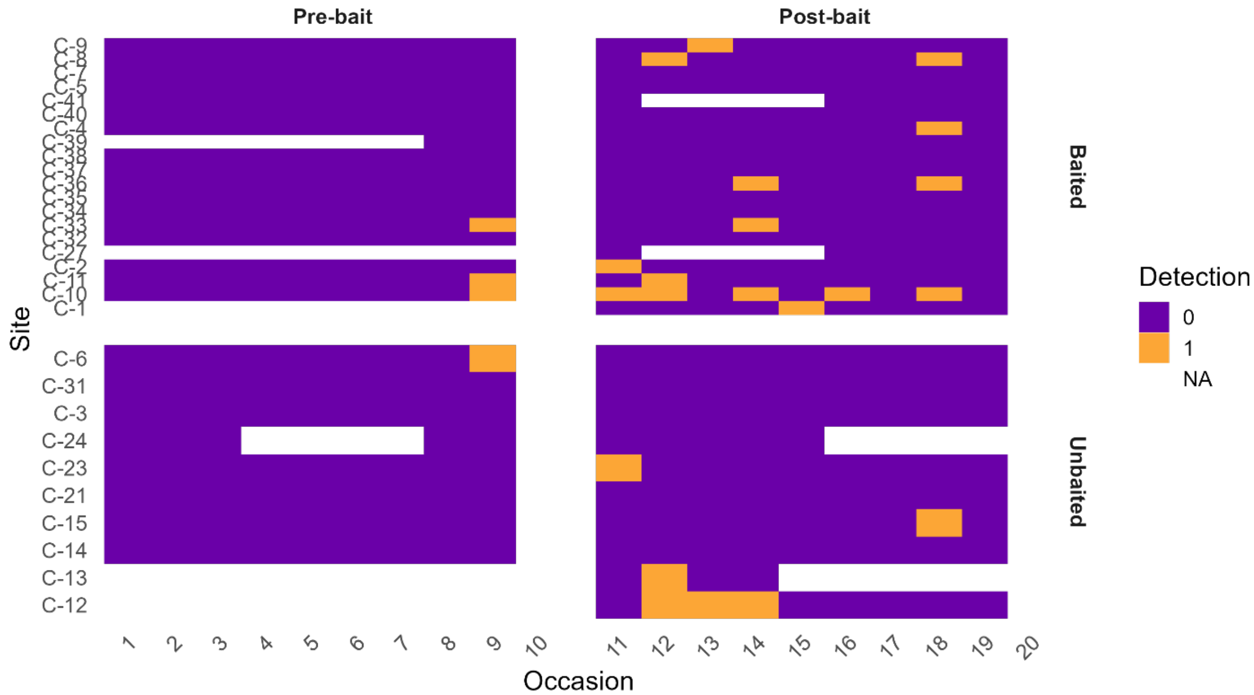

Figure 4. 2024 Raw feral cat occupancy data from camera trap surveys conducted inside (baited) and outside (unbaited) the 2024 bait cell over the Bilby Land Management Area pre and post Eradicat® baiting. White blocks indicate camera (battery/SD card) failures.

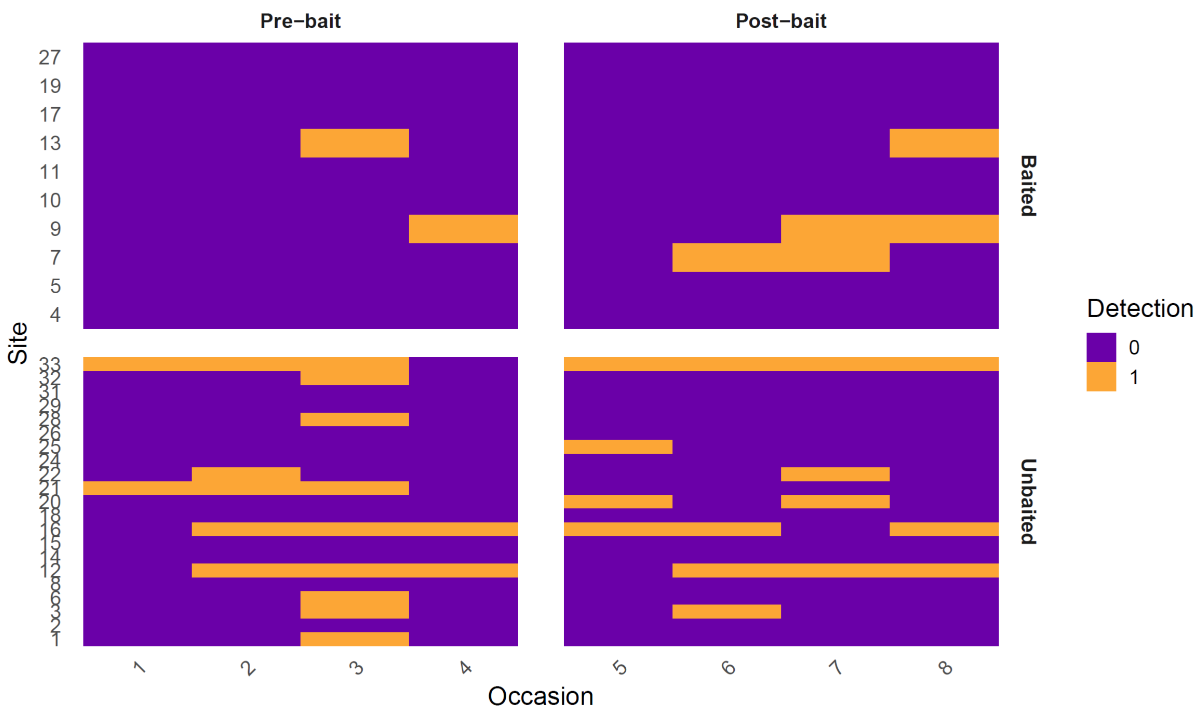

Figure 5. 2024 Raw feral cat occupancy data from 2-ha sign plot surveys conducted inside (baited) and outside (unbaited) the 2024 bait cell over the Bilby Land Management Area, pre and post Eradicat® baiting.

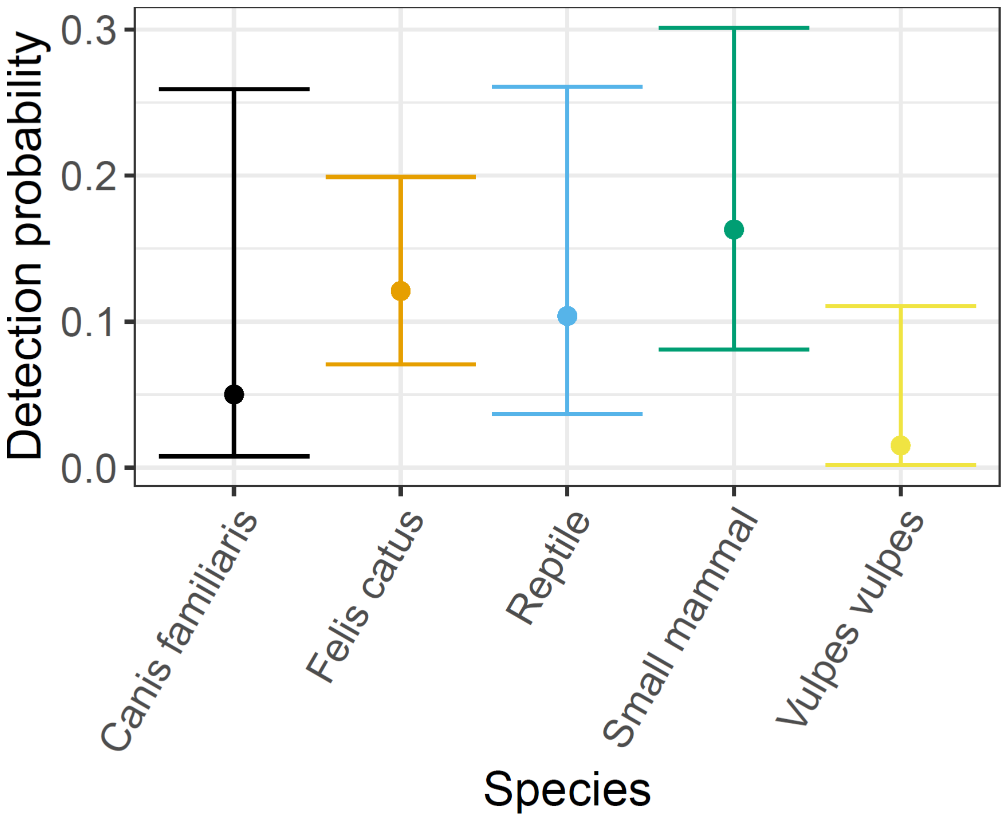

Figure 6. Detection probability of dingos (*Canis familiaris*), feral cats (*Felis catus*), foxes (*Vulpes vulpes*), small mammals, and reptiles from camera traps on Coongan Station in 2024.

Table 1. Occupancy model selection tables. Models with ΔAICc less than 3 are displayed. “Baited” is the reference level of the treatment variable and therefore coefficient estimates of initial occupancy, colonisation and extinction probability represent the effect of a site being unbaited on these parameters.

psi.Int.	col.Int.	ext.Int.	p.Int.	psi.baited	col.baited	ext.baited	df	AICc	delta
Feral cat camera trap occupancy									
-1.06	0.27	-7.07	-2.06				4	192.57	0.00
-1.30	0.41	-8.17	-1.97			+	5	194.48	1.91
-1.07	0.15	-7.23	-2.06		+		5	195.42	2.84
-1.02	0.28	-7.36	-2.06	+			5	195.46	2.89
Small mammal camera trap occupancy									
-9.48	-0.76	-0.61	-1.64				4	102.73	0.00
-9.84	-0.66	-0.73	-1.64		+		5	105.52	2.79
-9.49	-0.76	-0.93	-1.64	+			5	105.63	2.90
-9.79	-0.76	-0.71	-1.64			+	5	105.63	2.90
Reptile camera trap occupancy									
-9.60	-0.62	-0.35	-2.16				4	83.50	0.00
-9.67	-0.25	-0.42	-2.15		+		5	85.35	1.84
-9.34	-0.62	-0.68	-2.16	+			5	86.40	2.90
-9.64	-0.62	-0.42	-2.16			+	5	86.40	2.90
Feral cat plot occupancy									
-0.21	-1.91	-0.73	-0.44				4	200.02	0.00
1.30	-1.82	-0.69	-0.42	+			5	200.41	0.39
-0.21	-1.87	-0.59	-0.43			+	5	202.73	2.71
-0.21	-0.28	-0.73	-0.44		+		5	202.86	2.84
Small mammal plot occupancy									
1.31	-2.79	-1.99	-0.79				4	271.07	0.00
-1.05	-2.19	-1.93	-0.77	+			5	273.02	1.95
1.26	-3.7	-1.93	-0.77		+		5	273.78	2.71
1.29	-2.74	-1.02	-0.78			+	5	273.80	2.73
Reptile plot occupancy									
1.94	1.08	-12.30	1.07				4	296.25	0.00
-1.40	1.07	-11.90	1.07	+			5	297.73	1.48
1.94	-6.40	-11.3	1.07		+		5	298.45	2.20
1.94	1.08	-4.53	1.07			+	5	299.11	2.86

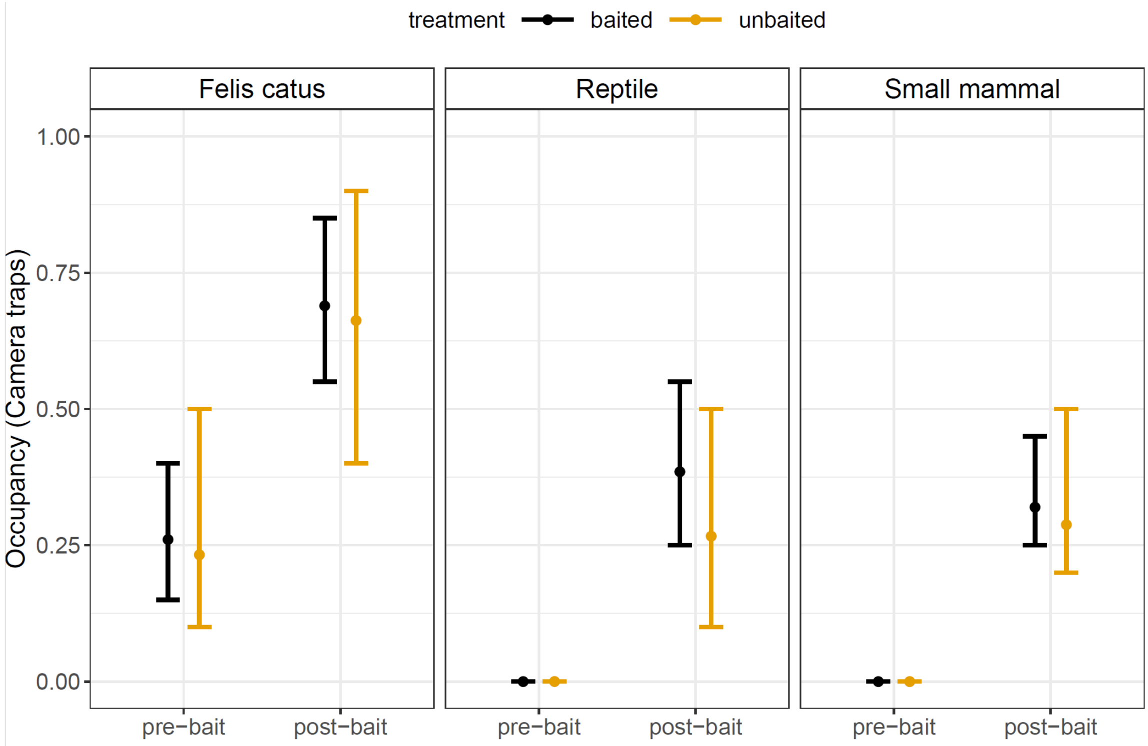

Figure 7. Predicted occupancy of feral cats (*Felis catus*), reptiles, and small mammals based on camera trap data collected inside (baited) and outside (unbaited) the 2024 bait cell over the BLMA, pre and post Eradicat® baiting. Error bars represent 95% confidence intervals.

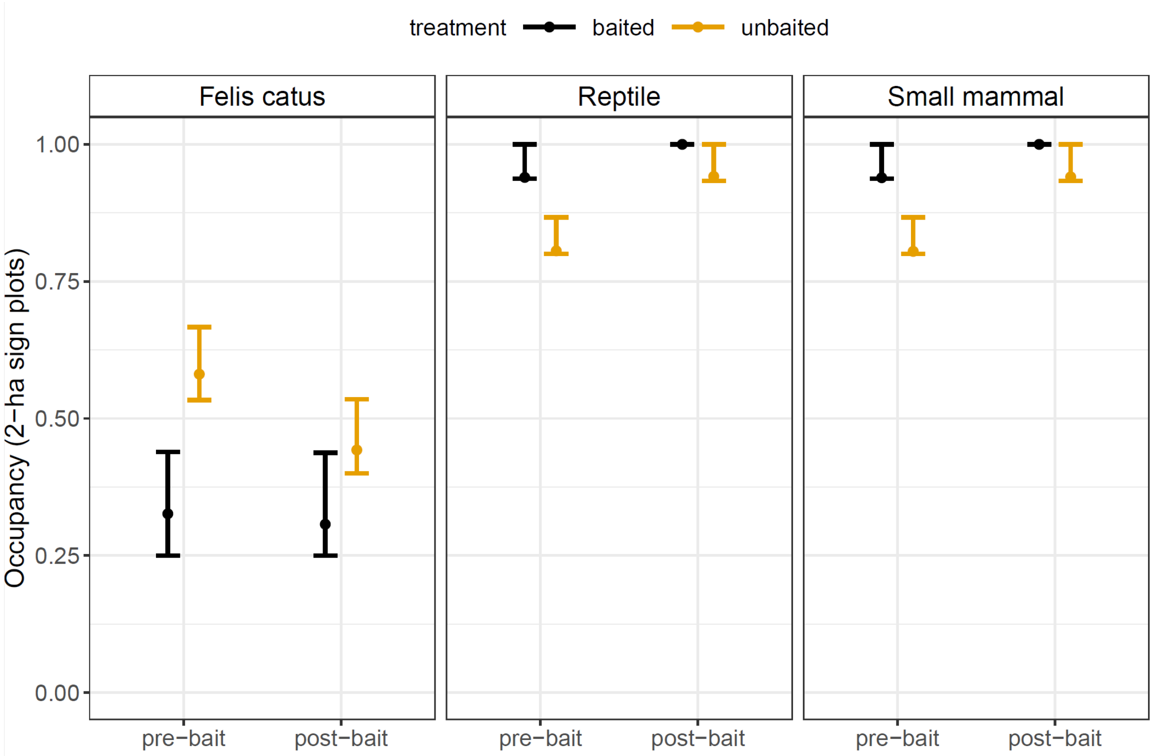

Figure 8. Predicted occupancy of feral cats (*Felis catus*), reptiles, and small mammals based on 2-ha sign plot data collected inside (baited) and outside (unbaited) the 2024 bait cell over the BLMA, pre and post Eradicat® baiting. Error bars represent 95% confidence intervals.

3.2 Activity analysis

Feral cat activity increased later in the year, after baiting had occurred (Figure 9). This small increase in activity occurred in both baited and unbaited areas and is likely owing to a lack of detections before baiting from camera disturbance. Results from the generalised linear model indicated that there was no detectable differences in feral cat activity between baited and unbaited areas (Figure 10, Table 2).

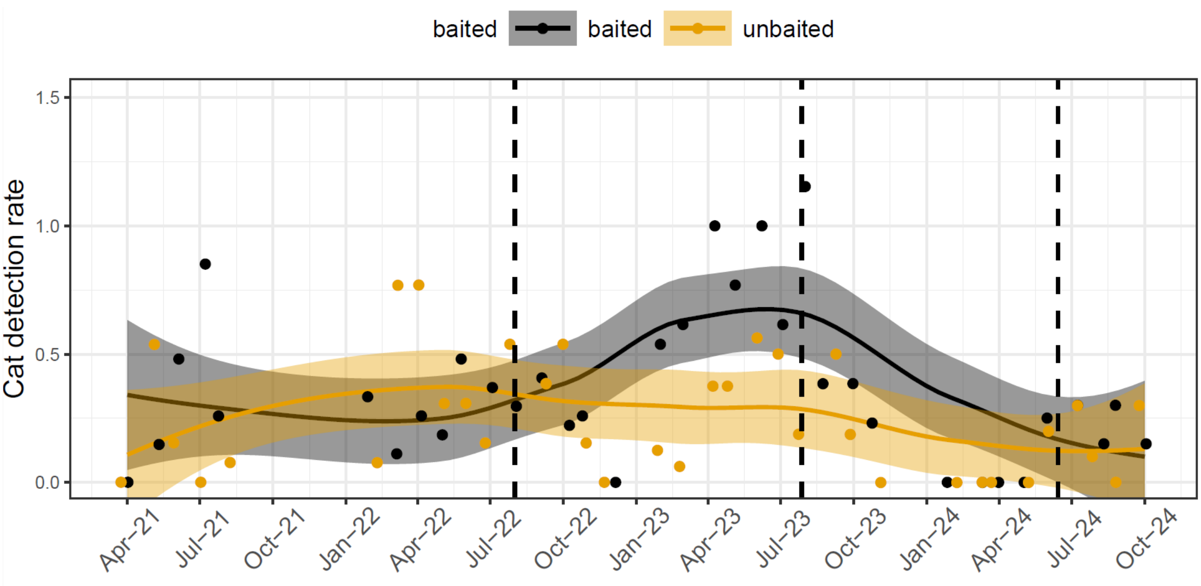

Figure 9. Averaged monthly detection rate for feral cats inside (baited) and outside (unbaited) the BLMA. Shading represent 95% confidence intervals from smooth function. Dark dashed vertical line indicated time of baiting.

Table 2. Generalised linear model selection table for the effect of baiting (baited or unbaited) and session (before or after bait drop) on cat activity.

Intercept.	baited	Session	baited.Session	df	AICc	delta
0.105		+		4	170.0	0
0.106	+	+		5	173.2	3.15

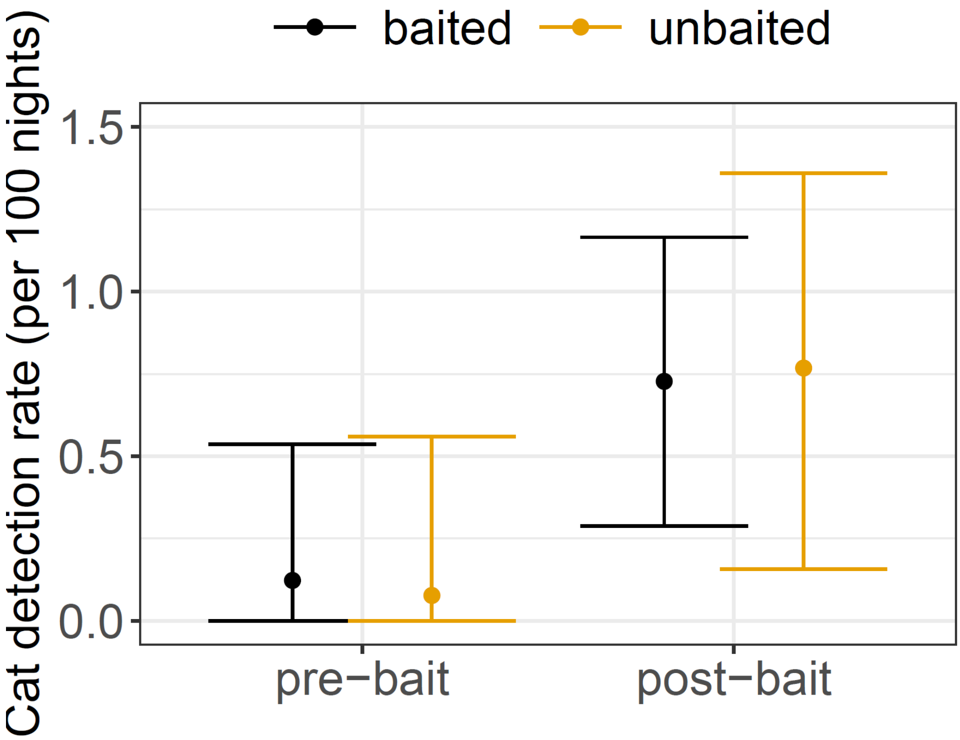

Figure 10. Predicted feral cat detection rate (per 100 trap nights) from generalised linear model using data from camera trap surveys inside and outside the 2024 bait cell over the BLMA area, pre and post Eradicat® baiting. Error bars represent 95% confidence intervals.

4 Discussion

Results from this analysis suggest Eradicat® baiting did not have a detectable effect on feral cat occupancy (measured using both camera trap and sign plot data), or on the feral cat detection rate. Further, we did not find any significant effect of baiting on feral cat prey species (reptiles and small mammals). This is the third consecutive year where an effect of baiting has not been detected.

Detection rates of fauna by camera traps was uncharacteristically low in 2024, likely due to interference with camera functioning by cows (they are known to rub against the poles supporting cameras, shifting the field of view of the camera). The greatest power to detect changes in feral cat occupancy by this project comes from the camera trap data, as there are more occasions, and usually higher detection probabilities compared to sign plots. In 2024, the analysis of camera trap data was substantially hindered by the lack of cat detections in the period before baiting. Given that sign plots still detected cats consistently during this time, we can be confident that this reduction in detections by cameras is the result of equipment malfunction (e.g., cameras not deployed correctly or disturbed) rather than a true drop in cat occupancy. When the cameras are performing optimally, we have moderate power (approximately 70%; Moore 2022b) to detect changes in cat occupancy of 30%. With this lowered detection probability, however, our ability to detect changes in cat occupancy drops substantially. The unexpected low performance of the camera trap array during the period pre-baiting (i.e., very few cat detections) highlights the value of using a combination of complementary survey techniques. With the sign plot data, we were still unable to detect any effect of baiting on the occupancy of feral cats and their prey.

The efficacy of Eradicat® baiting in reducing feral cat impacts in arid and semi-arid Australia has yielded mixed results. While some recent studies have reported positive outcomes (Comer *et al.* 2018; Lohr and Algar 2020; Algar *et al.* 2020; Moseby *et al.* 2021; Fancourt *et al.* 2022), including in the Pilbara (Comer *et al.* 2018), others have found no effect (Wysong *et al.* 2020; Doherty *et al.* 2021; Palmer *et al.* 2021) or inconsistent effects (Comer *et al.* 2020). The effectiveness of Eradicat® baiting can be largely driven by deployment design and local environmental factors. There are a number of potential explanations for why we did not observe an effect of baiting on feral cat occupancy or activity in this analysis.

Firstly, if the change in cat occupancy resulting from baiting was small (i.e., less than 30%), we may have simply lacked the power to detect it with this current study design. Improving the power of the camera array to detect changes in occupancy could help to reveal more subtle changes in cat occupancy in future years, for example, by increasing the number of independent (>2km apart) camera sites.

The success of a baiting program depends predominantly on the uptake of Eradicat® baits by cats. This can be compromised if cats do not encounter baits, or if they choose not to eat the baits. The effective baiting density could have been reduced in the BLMA if bait uptake by non-target species (such as varanids) was high. Previous research has shown that non-target uptake of baits can be high. For example, 22% of feral cat baits were removed by non-target species at Peron Peninsula (Algar *et al.* 2007), 14–57% at Arid Recovery (Moseby and Hill 2011), 71% at Kangaroo Island (Hohnen *et al.* 2019), 94% at Dryandra (Friend *et al.* 2020), and 90% at Charles Darwin Reserve (Doherty *et al.* 2021). Although the density of non-target species in some of these aforementioned areas may be higher than that at Warralong, reptile occupancy was close to 100% in our study area (Figure 8), which suggests that non-target uptake of baits by varanids could be high at Warralong.

The relatively small size of this baited area (~18,712 ha) could have impacted baiting efficacy. Feral cat home-ranges are thought to range between 500 and 3,400 ha in the Pilbara (Williamson *et al.* 2021), and it is possible that the baited area only overlaps with a small number of cats, limiting its efficacy (especially if any of these cats are bait averse). High reinvasion rates by feral cats may also comprise the success of baiting, and similar findings have been observed elsewhere (Algar *et al.* 2013). For example, after 4 years of annual aerial baiting in the Fortescue Marsh (~86,900 ha), there was a 30% mortality of radio-collared cats, but no change in feral cat capture rates, suggesting that the baiting program had a limited effect in reducing the overall cat population (Clausen *et al.* 2015). However, if reinvasion had obscured the overall impact of baiting in our study area, a reduction in feral cat activity would still have been anticipated immediately following bait deployment, which was not observed (Figure 9).

Studies have shown that cat personality can play an important role in baiting efficacy, where shy cats may be unlikely to take a bait, regardless of environmental conditions (Algar *et al.* 2011). Moreover, bait aversion can occur if cats consume a sub-lethal dose of 1080 (e.g., a bait that has decomposed in the landscape) (Fancourt *et al.* 2021; Palmer *et al.* 2021). When such individuals exist in a population, baiting alone is unlikely to be effective. Conducting baiting in conjunction with other complementary cat control methods, such as shooting, trapping, or Felixer feral cat grooming traps™ could help to reduce cat occupancy in this case (Lohr and Algar 2020).

5 Future directions

- Great care should be taken to ensure that camera traps are operating as desired throughout the study period to maximise statistical power to detect changes in cat occupancy. The employment of a local project officer (e.g. based in Warralong community or with the sub-lessee of Coongan Station) could facilitate more regular servicing of cameras to ensure their functionality.

- The overall power of the sampling design can be increased by increasing the number of independent (>2km apart) camera sites (provided they are located along tracks).

- Baits should continue to be deployed when the likelihood of uptake by feral cats is highest – typically following a period of low rainfall, and in the cooler months, when prey availability is low (Algar *et al.* 2007). A bait uptake experimental trial may help to elucidate any issues with non-target species.

- Implementing targeted feral cat control measures in conjunction with broad scale baiting has been demonstrated to be effective at further reducing feral cat occupancy (Comer *et al.* 2020; Lohr and Algar 2020; Algar *et al.* 2020). Implementing targeted control methods (e.g. trapping, shooting, Felixer feral cat grooming traps™) in priority locations (bilby activity areas or feral cat hot spots) may complement the baiting and increase the effectiveness of the feral cat control program at Warralong. Involving local stakeholders such the Warralong community and Outback Beef (sub-lessee of Coongan Station) in these targeted efforts may encourage local buy-in.

- Increasing the size of the baiting cell from that baited in 2024 may see an improvement in the effectiveness of the baiting program. Incorporating the current location of known bilby colonies inside an expanded baited area may help known colonies and other undiscovered colonies benefit from any positive effects of baiting.

- Habitat improvement through methods such as strategic burning, can be an effective way to reduce the impact of feral cats on native prey species (Doherty *et al.* 2022). Fire management activities have been proposed for Warralong (Burrows *et al. 2019*) with a perimeter burn implemented in 2020. Small patch burns are conducted by the pastoral station sub-lessee (Outback Beef) via an aerial program. Cat activity can increase in recently burned areas (Moore *et al.* 2024), and burning should be coupled with ongoing cat control.

- To evaluate the effectiveness of the management program, it is important to continue regular monitoring of feral cat occupancy, activity, and prey populations by camera and plot surveys. Inclusion of plot surveys is also recommended, as they offer an alternative method for monitoring feral cat occupancy and are essential for detecting changes in bilby populations, along with other prey species (reptiles, small mammals).

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7 Supplementary material

Table S1 – Camera treatment relative to 2024 baiting cell.

Camera	Treatment
C-1	baited
C-10	baited
C-11	baited
C-2	baited
C-27	baited
C-32	baited
C-33	baited
C-34	baited
C-35	baited
C-36	baited
C-37	baited
C-38	baited
C-39	baited
C-4	baited
C-40	baited
C-41	baited
C-5	baited
C-7	baited
C-8	baited
C-9	baited
C-12	unbaited
C-13	unbaited
C-14	unbaited
C-15	unbaited
C-21	unbaited
C-23	unbaited
C-24	unbaited
C-3	unbaited
C-31	unbaited
C-6	unbaited

Table S2 – 2024 plot surveys

#Survey	Dates
1	07/02/2024 – 08/02/2024
2	03/04/2024 – 04/04/2024
3	01/05/2024 – 02/05/2024
4	05/06/2024 – 07/06/2024
5	08/07/2024 – 10/07/2024
6	14/08/2024 – 15/08/2024
7	12/09/2024 – 17/09/2024
8	30/10/2024 – 31/10/2024

Table S3 – Sign plot treatment relative to 2024 bait cell.

Plot ID	Treatment
01	unbaited
02	unbaited
03	unbaited
04	baited
05	baited
06	unbaited
07	baited
08	unbaited
09	baited
10	baited
11	baited
12	unbaited
13	baited
14	unbaited
15	unbaited
16	unbaited
17	baited
18	unbaited
19	baited
20	unbaited
21	unbaited
22	unbaited
24	unbaited
25	unbaited
26	unbaited
27	baited
28	unbaited
29	unbaited
31	unbaited
32	unbaited
33	unbaited