Felixer™ grooming trap trial, 2020–23: Feral cat control for threatened fauna conservation in the southern jarrah forests, Western Australia.

Final Report

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Summary

This report details the results of a three-year study aimed at assessing the safety and efficacy of Felixer grooming traps for the control of feral cats (*Felis catus*) in the Upper Warren and Lake Muir area of the Southern Jarrah Forest IBRA subregion in south-western Australia. This area is very important for native vertebrate fauna conservation, supporting many threatened or conservation priority species including at least 10 mammals and three birds for which predation by feral cats is recognised as a key threatening process.

The safety of Felixers (v3.1) for non-target species was assessed with pen trials for numbats, *Myrmecobius fasciatus* and photo-only deployments in the field prior to their use in toxic mode. Over all deployments (in both photo-only and toxic arming status), there was a 0.02% rate of mis-identified targets in conservative targeting mode (1 out of 4,296 detections), and 0.7% in standard targeting mode (28 out of 3,733 detections). The mis-identified targets were woylies, *Bettongia penicillata* (18), yongka, *Macropus fuliginosus* (5), tammar, *Notamacropus eugenii derbianus* (4) and kwara, *Notamacropus irma* (1). Based on their median lethal dose (LD_{50}), adults of these species are not at risk of being killed from a single 8mg dose of 1080 from a Felixer gel.

Up to eight Felixers were deployed in toxic mode in four experimental field trials in four separate areas each covering ~14,000 hectares. An array of 49–50 remote sensor cameras were deployed at the treatment sites and similar-sized reference sites to monitor the activity of feral cats. Felixers identified feral cats as targets 31% of the time they were detected in conservative targeting mode and 42% in standard targeting mode. This was lower than the targeting rate in photo-only mode where it was 52% and 69%, respectively. The reason for this difference is uncertain, however it is likely this is due to behavioural and fate differences of feral cats passing inconsequentially by a Felixer in photo only mode, versus being targeted and killed when the Felixers were in toxic mode.

The Felixers targeted 4–17 feral cats in toxic mode in each trial (9.6–15.1 weeks per trial), which represented 33–100% of the individuals estimated to have passed in front of a Felixer, and a maximum 31–89% being killed of the individuals detected throughout the treatment area prior to the Felixers being deployed in toxic mode. Detection histories of feral cat individuals that could be readily distinguished, demonstrated there is a very high probability that individuals targeted by the Felixers resulted in their death. However, one cat survived (targeted in the face instead of the usual side of the body). There was between a 49% reduction and a 4% increase in the 28-day mean of the feral cat daily detection rate, immediately before- compared with immediately after- the Felixers were deployed in toxic arming status. Comparisons with simultaneously monitored reference sites showed a significant reduction in feral cat detections compared to the reference site in only one of the four trials. Changes in the detections of individual feral cats after Felixer deployment indicate that reinvasion of these areas can occur very rapidly, which may explain the lack of significant change in some trials.

There was substantial spatial and temporal variation in cat detection rates from remote sensor camera arrays (49-50 per site) deployed at comparative reference sites and treatment sites before, during and after the Felixer trials. While there were some slight seasonal differences in feral cat detection rates, any time of year may be suitable for targeting feral cats in the jarrah forest. Feral cat detection rates were also greater closer to farmland, wetter areas and lower elevations in some cases. However, which landscape factors were most important varied between sites and they only explained a very small amount of the variation in feral cat detection rates (<10%).

In conclusion, the use of Felixers does not present a significant risk to non-target species in the Southern Jarrah Forest in either conservative or standard targeting mode. Felixers effectively targeted feral cats with a very high probability that it resulted in the death of the animal. Improvements in the technology deployed in the newest Felixers (v3.2; including Artificial Intelligence image recognition) to improve targeting, and careful deployment of Felixers (including camouflage and careful site selection), are likely to improve targeting rates further. Locating Felixer traps in areas where they will detect the greatest number of feral cats will also improve their efficiency as a control method. This may be helped by improving our understanding of how feral cats use the landscape and using surveillance intelligence to identify areas of relatively high cat activity. Sustaining reductions in feral cat populations using Felixers in areas ~14,000 ha, will require longer term deployment to continue to target feral cats that will move into the areas where cats have been killed.

The use of Felixers as part of integrated feral predator management programs has the potential to significantly improve the conservation of affected threatened species in the Southern Jarrah Forest.

Acknowledgements

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This was a collaborative project between South West NRM (SWNRM), Biodiversity and Conservation Science (BSC) in the Department of Biodiversity, Conservation and Attractions (DBCA) and the Blackwood Basin Group (BBG). We would like to thank Karrie Williamson, Ann Bentley, Per Christensen and Clint Connor from the Blackwood Basin Group for their assistance in project planning and maintenance of the remote camera arrays. Thanks also to Jane Putland and Georgia Fellows for assisting with the photo analysis and John Read for reviewing this report.

DBCA Parks and Wildlife Service (PWS) staff in the Warren Region, Donnelly District and Frankland District assisted with making this project possible by accommodating the field trials around their other operational and management activities in the area, facilitating the closure of roads as well as the administration and approvals processes required for the use of 1080. DBCA Conservation and Ecosystem Management (CEM) purchased and loaned two Felixer (v3.1) grooming traps to the project to be used in conjunction with the six purchased by BCS.

This project was supported by South West NRM, through funding from the Australian Governments National Landcare Program, and funding, equipment (e.g., remote sensor cameras) and staff from DBCA.

These trials were conducted with approval and in accordance with the conditions specified by the DBCA Animal Ethics Committee (AEC; approval # 2020–26A), Australian Pesticides and Veterinary Medicines Authority (APVMA; PER80926), DBCA Feral Cat working Group, the DBCA 1080 risk assessment and approval process, the Department of Health (Permit 29564) and DBCA authorisations to use and possess 1080 (for Marika Maxwell Authority number 473, Adrian Wayne Authority number 1047, and Colin Ward Authority number 1011). These trials were conducted as part of the Biodiversity and Conservation Science approved project (Science Project # 2020/23), "Felixer™ grooming trap trial: Feral cat control for threatened fauna conservation in the southern forests."

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1 Introduction

1.1 Background

Feral cats are one of the most significant threats to native species in Australia with over 100 listed threatened species impacted by feral cats (Legge *et al.*, 2017). Efforts to control feral cats have had mixed success with baiting practices having greater success in arid regions and generally much lower success rates in more temperate areas. This appears to be largely due to the preference of feral cats to take live prey, which are more consistently available in more productive environments with higher rainfall.

The Felixer™ cat grooming trap v3.1 (referred to as 'Felixer' hereafter) is a novel method of controlling feral cats that takes advantage of the compulsive grooming behaviour exhibited by this species. Felixers include an optional auditory lure to attract feral cats and a series of LiDAR sensors at various heights. The combination of sensors that are blocked as an animal passes in front of the Felixer are analysed using a series of algorithms to identify if the animal is a target fox or cat, or a non-target species. If the potential target is identified as fox or cat the Felixer shoots a sticky gel that contains 1080 poison (sodium monofluoroacetate) onto the animal's fur. When a targeted fox or cat then grooms this gel from their fur, they ingest the poison and die.

Under contract to the Department of Agriculture Water and Environment through the National Landcare Program this is a collaborative project principally involving South West NRM (formerly the South West Catchments Council), Department of Biodiversity, Conservation and Attractions (DBCA), and Blackwood Basin Group (BBG) to study the effectiveness of Felixers to reduce feral cat numbers in the Upper Warren and Muir-Byenup areas in Western Australia's south west. Numerous threatened species, which are also threatened by feral cat predation, are found in this area including the woylie (*Bettongia penicillata*), chuditch (*Dasyurus geoffroii*), numbat (*Myrmecobius fasciatus*), Australasian bittern (*Botaurus poiciloptilus*), Australian little bittern (*Ixobrychus dubius*) and malleefowl (*Leipoa ocellata*). Many of these threatened species have suffered large declines in recent times, with predation be feral cats having been identified as a contributing factor (Wayne *et al.*, 2017a; Wayne *et al.*, 2017b). Felixers have previously been tested in the presence of bettongs and chuditch and shown to reliably identify these species as non-targets (Ecological Horizons, 2020, 2018; Read *et al.*, 2019). The Felixers have not yet been tested in areas with numbat populations and we aimed to test if the Felixers would reliably identify numbats as non-targets before their deployment in the field.

The density of feral cats in the Upper Warren area has recently been estimated at 0.06 animals/km^2 (A. Wayne, unpublished data) and around 0.32/km^2 by Legge *et al.* (2017). By comparison, Venning *et al.* (2021) estimated the average density of feral cats on Kangaroo Island to be 0.37/km^2. Population models also estimated that annual cull rates of 0.35 of the population would reduce the feral cat population to 0.1 of its original size over a 10-year period. Alternatively, an initial cull minimum of 0.6 and a minimum 0.5 maintenance cull would reduce the final population to 0.01 of its initial size within 10 years (Venning *et al.* 2021). Region-specific population modelling is needed to better estimate what cull regimes in the southern jarrah forest may be required to sustain a reduction in the feral cat population, however, higher levels of recruitment by immigration will be a significant factor. It is therefore likely that the cull rates in the southern jarrah forest would likely need to be greater than those estimated for Kangaroo Island, to achieve comparable reductions in the population size.

1.2 Felixer effectiveness

Felixers have been tested at several sites to determine their effectiveness at killing resident feral cats. The results of these published studies are summarised below:

Six Felixers were deployed in mostly open farmland over an area of 11.8 km^2 (1,176 ha) on Kangaroo Island for 21 days. Prior to the Felixers being deployed, 14 feral cats were trapped and fitted with VHF and GPS collars to track their movements and test the effectiveness of the Felixers. Feral cat density prior to the Felixer trial was estimated to be 2.98 cats/km^2. Technical issues with some of the Felixers meant that the total Felixer effort was significantly reduced, however, 13 feral cats were targeted by Felixers, eight (8) of which were collared. The estimated feral cat density at the end of the 21-day trial was 1.69 cats/km^2, a reduction of approximately 43%. The eight collared feral cats killed by the Felixers moved between 220 and 2700 m from the Felixer site. The amount of time between being targeted and the cat dying ranged from 1 hour 41 minutes to 25 hours 23 minutes (Hodgens, 2019).

In a separate trial, 20 Felixers were set over a 26 km^2 (2,600 ha) fenced enclosure in arid South Australia for six weeks. Six feral cats were radio collared prior to the deployment of Felixers with two targeted by Felixers and later found dead. Thirty-three (33) feral cats were targeted by the Felixers during the trial, including 22 individually recognisable feral cats that were targeted and then not observed again on monitoring cameras set across the enclosure. Feral cat density was estimated at 1.84 cats/km^2 before the trial and 0.64 cats/km^2 after, a reduction of approximately 63% (Moseby *et al.*, 2020).

1.3 Felixer target specificity

Felixers have been used in the presence of numerous native mammal, reptile and bird species and have been shown to consistently identify these species as non-targets (Ecological Horizons, 2020, 2018; Hodgens, 2019; Moseby *et al.*, 2020; Read *et al.*, 2019, *Table 1*). Early in the development of the Felixers, some native species were identified as false positive targets. In the study where tammar and other species were identified as targets this was found to be the result of a rock blocking one of the sensors. Improvements have been made to the targeting algorithms with only small domestic dogs occasionally mis-identified as targets in recent studies (Dunlop *et al.*, 2019). Felixers have also been shown to consistently identify humans and vehicles as non-targets (Dunlop *et al.*, 2019; Hodgens, 2019; Moseby *et al.*, 2020; Read *et al.*, 2019, *Table 1*).

Table 1. Summary of Felixers ability to identify non-target species as non-targets.

	Common Name	Scientific name	Detected as non-target	Detected as target
Mammals	**Chuditch, Western quoll**	***Dasyurus geoffroii***	**2[1]**	
	Northern quoll	*Dasyurus hallucatus*	226[2]	
	Brushtail possum	***Trichosurus vulpecula***	**2[2], 11[4], >100[5]**	**1[4]**
	Boodie	*Bettongia lesueur*	2[1], 165[2]	
	Bilby	*Macrotis lagotis*	1[5]	
	Red kangaroo	*Osphranter rufus*	9[1]	1[1]
	Euro	*Macropus robustus*	4[2]	
	Tammar wallaby	***Notamacropus eugenii***	**197[3], 1[4]**	**21[3]**
	Kangaroos -species not listed		**181[3], 30[4]**	**8[3]**
	Short-beaked echidna	***Tachyglossus aculeatus***	**12[2]**	
	Rodent – species not listed		**16[1], 1[2], 4[6]**	
Reptiles	Perentie	*Varanus giganteus*	3[2]	
	Yellow spotted monitor	*Varanus panoptes*	4[2]	
	Goanna – species not listed	***Varanus spp.***	**4[4], 3[6]**	
	Lizard - species not listed		**8[1]**	
Birds	**Australian raven**	***Corvus coronoides***	**1[2], 22[4]**	
	Common bronzewing	***Phaps chalcoptera***	**2[2]**	
	Quail -species not listed		2[2]	
	Dove – species not listed		4[2]	
	Magpie-lark	***Grallina cyanoleuca***	**5[2], 16[4]**	
	Willie wagtail	***Rhipidura leucophrys***	**5[2]**	
	Magpie	***Gymnorhina tibicen***	**51[4]**	
	Diamond dove	*Geopelia cuneata*	9[2]	
	Singing Honeyeater	***Lichenostomus virescens***	**20[2]**	
	Birds – species not listed		**34[1], 358[6]**	
Introduced species	**Fox**	***Vulpes vulpes***	**2[1]**	**1[1], 5[3]**
	Rabbit	***Oryctolagus cuniculus***	**32[1],**	
	Cow	***Bos taurus***	**9[2]**	
	Domestic dog	***Canis lupus familiaris***	**17[2], 3[4]**	**3[2]**
	Human	***Homo sapiens***	**79[2], 11[4], 30[6]**	
	Vehicle		**186[1], 164[4], 201[6]**	

References: [1]Ecological Horizons, 2018, [2]Dunlop, 2019a&b, [3]Read *et al.* 2019, [4]Hodgens, 2019, [5]Ecological Horizons 2020, [6]Moseby *et al.* 2020
Bold font indicates species (potential targets) present in the southern jarrah forest.

1.4 Aims

There were four main aims of this project:

- Safety Assessment: Determine the safety of the Felixer for use in the presence of non-target species present in the southern jarrah forest, including numbats and chuditch.
- Test: Determine whether Felixers can reduce feral cat densities by at least 60% at a meso-spatial scale (~14,000 ha) in the southern jarrah forests, Western Australia.
- Optimise: Improve the efficiency and effectiveness of Felixers by refining the deployment design (i.e., adjusting spatio-temporal factors such as density, duration, mobility, location in the landscape)

- Sustain: Identify how to maintain a reduction in feral cat densities to allow for the recovery of native prey species (i.e., investigate the timing, frequency, and spatial scale of Felixers required to overcome recruitment from breeding and immigration).

2 Methods

2.1 Safety assessment

A desktop risk assessment was conducted for the fauna species present in the southern jarrah forest for which there is published information on their tolerance of sodium fluoroacetate (1080) poison (Department of Agriculture *et al.* 2002). The overall risk of a lethal interaction with a Felixer was based on our current understanding of the Felixer, animal morphology and behaviour (movement, terrestrial habitat use, and grooming propensity).

Felixers were initially trialled at Perth Zoo using captive numbats to reduce the amount of time needed to attain the minimum 100 detections to determine safety for this species. Details of these trials were reported separately (Chambers *et al.* 2020), but the results of those trials (793 detections of numbats, 30 detections of humans) have been incorporated into the results here to provide a more comprehensive assessment of the risk to this species. This report also provides an update of the safety assessment reported part way through this project (Wayne *et al.* 2021).

2.2 Study region

We trialled the Felixers in the Southern Jarrah Forest Interim Biogeographic Regionalisation for Australia (IBRA) subregion (JAF02) in the Upper Warren region (including Tone-Perup Nature Reserve) and Lake Muir National Park. This region supports forests and woodlands dominated by jarrah (*Eucalyptus marginata*), marri (*Corymbia calophylla*) and wandoo (*Eucalyptus wandoo*). The area is particularly important for the conservation of threatened plant and animal species including several native mammals including the Critically Endangered woylie (*Bettongia penicillata*) and ngwayir (*Pseudocheirus occidentalis*), the Endangered numbat (*Myrmecobius fasciatus*), the Vulnerable chuditch (*Dasyurus geoffroii*) and quokka (*Setonix brachyurus*), the Conservation dependent wambenger (*Phascogale tapoatafa wambenger*), and Priority 4 species including quenda (*Isoodon fusciventer*), tammar (*Notamacropus eugenii derbianus*), and kwara or western brush wallaby (*Notamacropus irma*). Several of these species, including ngwayir, and others such as dunnarts (*Sminthopsis* spp.) and mootit or bush rat (*Rattus fuscipes*) have undergone significant and sustained declines since the 1990s, while others, such as the koomal (southwestern subspecies of common brushtail possum, *Trichosurus vulpecula hypoleucus*) have increased (Wayne *et al.* 2015; Wayne *et al.* 2017).

The introduced red fox (*Vulpes vulpes*) and feral cat (*Felis catus*) are a significant threat to many native mammals. Other introduced species in the area that are of management interest include pig (*Sus scrofa*), goat (*Capra hircus*) and red deer (*Cervus elaphus*). Fox baiting for conservation purposes began in some areas in 1977 (Burrows and Christensen 2002). It became broadscale, covering most of the study area in 1996 as part of the Western Shield program (Wayne *et al.* 2017; Wyre 2004). Other major management activities in the region include prescribed burning (McCaw *et al.* 2005), timber harvesting in State Forest (Wayne *et al.* 2006; Wayne *et al.* 2016 and references therein) and dieback hygiene (i.e., reducing the spread of the plant pathogen *Phytophthora cinnamomi*). Land uses of the freehold land around the DBCA-managed lands in the southern jarrah forest are primarily agricultural (sheep, cattle, grain, and oil crops), plantation forestry (blue gums and pine), viticultural (wine grapes), and horticultural (fruit tree orchards and vegetables).

Fox baiting for conservation is conducted on DBCA-managed land throughout the region as part of routine operations (Department of Parks and Wildlife, 2017). This program continued as normal at all four main field sites throughout the duration of these trials. The frequency of aerial and ground baiting (Probaits) varied across the sites with the frequency and quantity of baits being highest at North Perup and least at Tone-Meribup. (*Table 2*)

Table 2. Frequency of Probait (1080 fox baits) baiting events per year within the four main experimental field trial sites. Ground perimeter baiting is usually associated with aerial baiting events and concentrates on baiting the perimeter of DBCA-managed land with adjacent agricultural land. Ground core baiting focusses on baiting transects along internal forest management tracks within North Perup and is conducted monthly.

Field site	Aerial	Ground perimeter	Ground core
North Perup	4	12	12
Lake Muir	3	4	0
Tone-Meribup	S half 3 / N half 4	0	0
Central Perup	4	4	0

2.3 Modelling the appropriate Felixer deployment design for field trials

The design of trial sites, including site size, number and spacing of remote sensor cameras (referred to as 'camera' hereafter), duration of monitoring and the spacing of Felixers were refined using the secrdesign package in project R. The following parameters were used in the simulations:

- *Detector type: proximity*
- *Detection function: Half hazard rate* - This model was found to be the best fit for the data gathered at Boyicup and Balban in the previous camera surveys (A. Wayne, unpublished data).
- *N Distribution: Binomial (fixed)*
- *σ (Sigma, i.e., movement parameter describing decrease in detection over distance): 2000m* – Sigma value modelled from A. Wayne (unpublished data) was 1952m. GPS tracking of 4 feral cats in the Upper Warren area found daily movement distances of 4,084–7,254 m (n=3) and home ranges of 4,578–11,370 hectares indicating that this value is conservative.
- *λ (Lambda, i.e., detection probability at an individual's activity centre): 0.5* - Maximum likelihood estimated lambda value from Boyicup site (A. Wayne, unpublished data)
- *Feral cat density: 0.0006 cats/hectare (0.06/km^2)* - Densities estimated from previous Eradicat trials using spatially explicit capture recapture (A Wayne, unpublished data).

2.3.1 Camera monitoring layout simulation results

To achieve a 10% relative standard error for density estimates of feral cat populations in our study area, camera spacing between ~1600 m and ~2100 m was required depending on the duration of the monitoring (*Figure 1*). The relative standard error decreases with greater camera spacings and is lower at any given camera spacing with more cameras, or a longer monitoring duration (*Figure 1*).

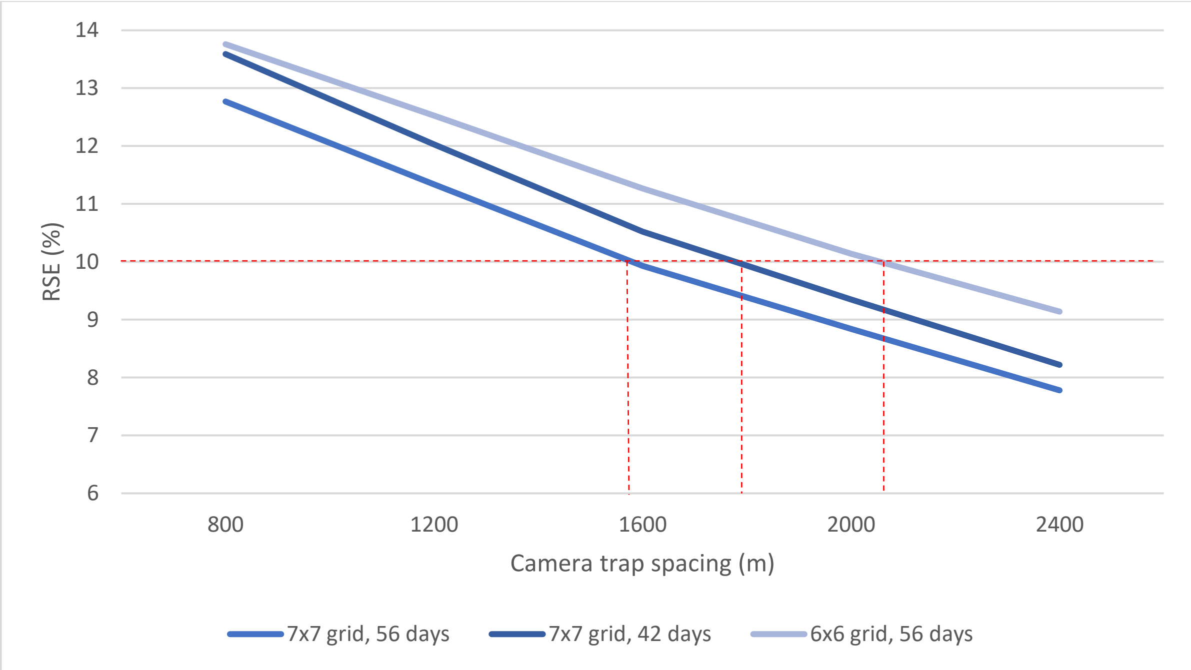


Figure 1. Relationship between camera spacing and relative standard error (RSE) with varying numbers of cameras and monitoring duration.

We aimed for a relative standard error of less than 10% and the power to detect a population size change of approximately 30% as a minimum. To achieve this the following combinations of camera numbers, spacing and durations were identified as possible options (*Table 3*).

Table 3. Combinations of optimal camera number, spacing and monitoring duration

Number of Cameras	Number of Days sampling	Camera Spacing (m)	Site area hectares (based on square grid)	Relative Standard Error (%)	Minimum population size change to detect at P=0.05 (%)	Expected cat population size
49	56	2000	14400	8.84	32.3	9
	42	2400	20736	8.22	30.3	12
36	56	2400	14400	9.5	33.2	9

To be conservative, a combination of 49 cameras at 2000m spacings deployed for 56 days was chosen as the layout that would be used. This gives us a site size of ~15,000 ha.

2.3.2 Felixer layout simulation results

A maximum of eight Felixers were available for use in the trials, and we modelled the following scenarios of deployment:

- 8 Felixers deployed for 28 days in a 4x2 grid: ~4300m spacing.
- 8 Felixers deployed for 28 days in a 3x3 hollow grid (no central Felixer): ~4000m spacing.
- 8 Felixers deployed for 56 days in a 3x3 hollow grid (no central Felixer): ~4000m spacing.
- 4 Felixers set for 56 days in a 2x2 hollow grid: ~6000m spacing.

The results of the modelling indicate that all these layouts can detect all the individuals present at the sites under the expected density (*Table 4*). The number of potential recaptures also indicates that the Felixers should have multiple opportunities to target individual feral cats if they are not identified as a target when near a Felixer the first time.

Table 4. Results of Felixer layout simulations.

Number of Felixers	Felixer layout	Felixer spacing (m)	Deployment duration (days)	Area of Felixer grid (ha)*	Est. cat pop size	Est. cats killed (n)	Est. potential recaptures (r)
8	4x2 grid	4300	28	14792	9	19	131
8	3x3 hollow grid	4000	28	14400	9	19	131
8	3x3 hollow grid	4000	56	14400	9	21	279
4	2x2 grid	6000	56	14400	9	16	134

**Area, in hectares (ha), includes a buffer of 0.5* spacings around Felixer grid.*

To be conservative a 3x3 hollow grid with 4000 m Felixer spacings were used for 56 days initially to determine whether this layout can remove at least 60% of feral cats.

To estimate the effect of varying feral cat density on the value of this survey design we ran scenarios with density at 50% (0.0003 cats/ha) with a corresponding 100% increase to σ (4000 m) and a scenario with density at 200% (0.0012 cats/ha) with a corresponding 50% decrease to σ (1000m). The results are given in *Table 5* and indicate that the survey and Felixer design is likely robust to variance in these parameters.

Table 5. Sensitivity of survey design to changes in density and sigma (σ).

Cat Density (animals/ha)	σ (m)	λ	Relative Standard Error (%)	Minimum population size change to detect at p=0.05 (%)	Estimated number of cats killed by Felixers	Est. potential recaptures (r)
0.0003	4000	0.5	8.6	31.3	26	573
0.0006	2000	0.5	8.9	32.3	21	279
0.0012	1000	0.5	7.6	27.9	19	130

A scenario was also simulated with λ reduced from 0.5 to 0.1 to simulate feral cats showing a level of avoidance of cameras and Felixers with density of 0.0006 cats/hectare and σ of 2000 m. This scenario yielded an estimated 11.9% RSE and 41.8% minimum population size detectable at p=0.05. This scenario also resulted in the number of feral cats estimated to be killed dropping to 16 with 50 potential opportunities for Felixers to identify and target these feral cats. The 16 feral cats potentially killed in this scenario is still greater than the estimated nine (9) cats in this area and therefore the design appears robust to changes in this parameter.

2.4 Felixer trap set up and operating modes

Felixer v3.1 were used in these trials (i.e., earlier model without AI capability). Felixers were set up in accordance with instructions in the Felixer 3.1 Grooming Trap Standard Operating Procedure (Thylation Operations Pty Ltd, 2020). Human safety and security considerations were one of the largest constraints in selecting Felixer locations. Therefore, Felixers were deployed on minor or seldomly used minor unsealed roads and forest tracks that were closed to unauthorized access with Regulation 44 provisions (Conservation and Land Management Regulations, 2002). With security a higher priority, the Felixer deployment locations were not necessarily the best locations for encountering feral cats.

Felixers were set on a flat, compacted surface. A natural or manipulated back drop was used at a maximum range of 4.0 m to optimise sensor detections. Natural vegetation and camouflage were used to conceal the Felixer as much as possible and to guide the feral cat perpendicularly in front of the Felixer at the desired sensor distance (*Figure 2*). The Felixer does not emit light or make sound when operating (other than when the audio lure is enabled), so minimising visual and olfactory cues was important to minimise behavioural changes around the Felixer and maximise targeting opportunities.

The Felixer is powered by an external solar panel in the field and to optimise sun capture, the panel was positioned away from canopy in a Northerly direction with an extension cable of 5–10 m. We also aimed to minimise the visibility of the solar panel from the track in the vicinity of the Felixer. For security purposes, the Felixer was triple locked (two locks on the device) and secured to a fixed object (e.g., tree) with python cables.

Figure 2. Image of a Felixer deployment, showing concealment of the Felixer and the construction of a backdrop using local natural vegetation

2.4.1 Arming status

Felixers can be operated in one of two arming states, 'photo-only' and 'toxic'. In photo-only arming status, the Felixer is essentially acting as a LiDAR sensor-activated camera useful for assessing the safety of the Felixers to non-targets without disrupting any fauna. During our photo-only trials, the Felixers did not contain 1080 gel cartridges. In toxic arming status, the Felixer was loaded with up to eight 1080 cartridges, and if an animal was identified as a target, the Felixer would shoot the contents of a cartridge (2ml of gel containing 8mg 1080) at the animal. There is a 2-minute cooldown period before the Felixer rearms. The same algorithms operate in both arming states with respect to sensing and identifying targets and logging data.

2.4.2 Targeting mode

The Felixer v3.1 can be operated in two targeting modes: 'conservative' and 'standard'. In conservative targeting mode additional safeguards are applied to the sensing algorithms that consider the height, speed, and leg motions of the animal used to discriminate targets from non-target species. This also lowers the chances of successfully targeting feral cats. The conservative targeting mode was used first in this project because it is recommended when there is a high prevalence of non-target species (Thylation Operations Pty Ltd, 2020). In standard targeting mode the identification of target species is maximised with the trade-off that there are more likely to be false positive targeting of wildlife species.

2.5 Felixer deployment

2.5.1 Photo only trials

Photo-only trials of the Felixers were conducted prior to toxic mode trials in both conservative (with and without audio lures activated) and standard target mode.

The purpose of these trials was to test the target specificity of the Felixers with the non-target species found in the study area in controlled conditions. Two initial Felixer trials were conducted in predator-free facilities and were only conducted in photo-only conservative target mode. The first was at the Perth Zoo testing the Felixer with numbats, a species previously untested with the Felixer algorithms. The second trial was within the Perup Sanctuary with the aim of maximising the Felixer interactions with woylies and tammar. Another short trial was conducted around the outside of the Perup Sanctuary in photo-only standard targeting mode with six Felixers, again to maximise the Felixer interactions with the tammar, a species considered most likely to be misidentified as a target.

2.5.2 Experimental field trials in toxic mode

There were four experimental field trials of the Felixers in toxic mode, conducted in four treatment areas (approximately circular with a diameter of 13.5 km; average 14,000 ha, range 11,500–16,000 ha, based on 100% Minimum Convex Polygon (MCP) plus 1650 m buffer (half the average distance between Felixer traps); *Figure 3*) with up to eight Felixers deployed at any one time. The average minimum nearest neighbour distance between Felixers actively deployed across all trials was ~3,300 m (range 1,800–5,400 m). The aim was to deploy the Felixers approximately 4,000 m apart, but this distance varied based on suitable deployment locations and sites likely to have high feral cat activity (see 0 Spatial variables correlated with feral cat detections).

Comparative reference sites were a minimum of 10 km from the treatment sites to increase the likelihood of spatial independence from the treatment sites. Tone-Meribup was the reference site for the first two experimental field trials (treatment sites at North Perup and Lake Muir). Lake Muir was the reference site for the last two trials (treatment sites at Tone-Meribup and Central Perup), having previously been the treatment site, during which only 4 individual feral cats were successfully targeted. Lake Muir had Felixers deployed in toxic mode from 23/08/21–29/10/21. This was ~3.4 months (103 days) prior to the commencement of the third trial, when Lake Muir was the reference site (i.e., disruption to the feral cat population at Lake Muir was likely to have been limited by the time it was used as the reference site in trials 3 and 4).

During the first two experimental field trials in toxic mode (treatment sites at North Perup and Lake Muir, respectively), eight Felixers were set in conservative targeting mode at eight locations. The locations of the Felixers deployed during the last two experimental toxic trials were informed by available intelligence of cat activity from the remote sensor cameras deployed as part of this project (see sections 2.5.3 and 2.5.4 below). At Tone-Meribup, a year of array data and scouts were used. At Central Perup, intelligence from scout cameras was used (given limited period of array deployment before toxic trials began).

At Tone-Meribup (trial 3) eight Felixers were used with one moved partway through the trial to an area of higher feral cat activity (total of nine locations). At the Central Perup site (trial 4) eight Felixers were set in standard targeting mode. Based on intelligence of feral cat activity collected from the Felixers (in photo-only mode) and other scout cameras in the area, two Felixers were moved prior to the toxic stage of the trials commencing (this included moving one Felixer away from a site with particularly high non-target fauna activity and a high risk of false positive targets, mainly from woylies). During the toxic stage of the trial, three other Felixers were moved from locations with no feral cat activity to areas of activity (i.e., a total of 11 locations were used over the duration of the toxic stage of the trial in Central Perup). A total of 38 different Felixer locations of which 36 were used in the toxic stages of the experimental field trials. A summary of the total Felixer effort for each site and by Felixer status is given in *Table 6* and *Table 7*.

2.5.3 Audio lure trials

The Felixer can be programmed to play a variety of pre-recorded or custom audio lures at varying time intervals to attract feral cats. The default audio lure cycle configuration, "Combi Lures #1–4, were used for these trials. This compromised a combination of primarily bird calls, enabled every 3rd night between 18:00–06:00 hrs, with the call repeated at random intervals every few minutes and varying volume level defined by the default program cycle.

Two small trials of the effects of audio lures were conducted during this project: four Felixers (5/03/2021–19/03/2021 at North Perup) in photo-only conservative target mode and similarly with four Felixers (30/03/2022–26/05/22 at Tone-Meribup) in toxic conservative targeting mode. Species detection rates for Felixers with the lure enabled were compared for nights (during the period from 18:00–06:00 hrs) when the lure was playing (n=84) versus not playing (n=186) across both trials. Felixer faults and periods of audio lure inactivity due to low battery power were accounted for when determining Felixer effort.

Paired t-tests investigating the effect of lures on detection rates were done for target species (feral cat and fox) and a selection of non-target species that were either false positive targets with sufficient data (yongka, tammar, woylie), potentially vulnerable to a toxic interaction with a Felixer (chuditch), were a priori expected to be attracted to audio lures (owl) or were relatively abundant (quenda). Comparisons of the target rates of feral cats and foxes were also made between lures on and off using paired t-tests.

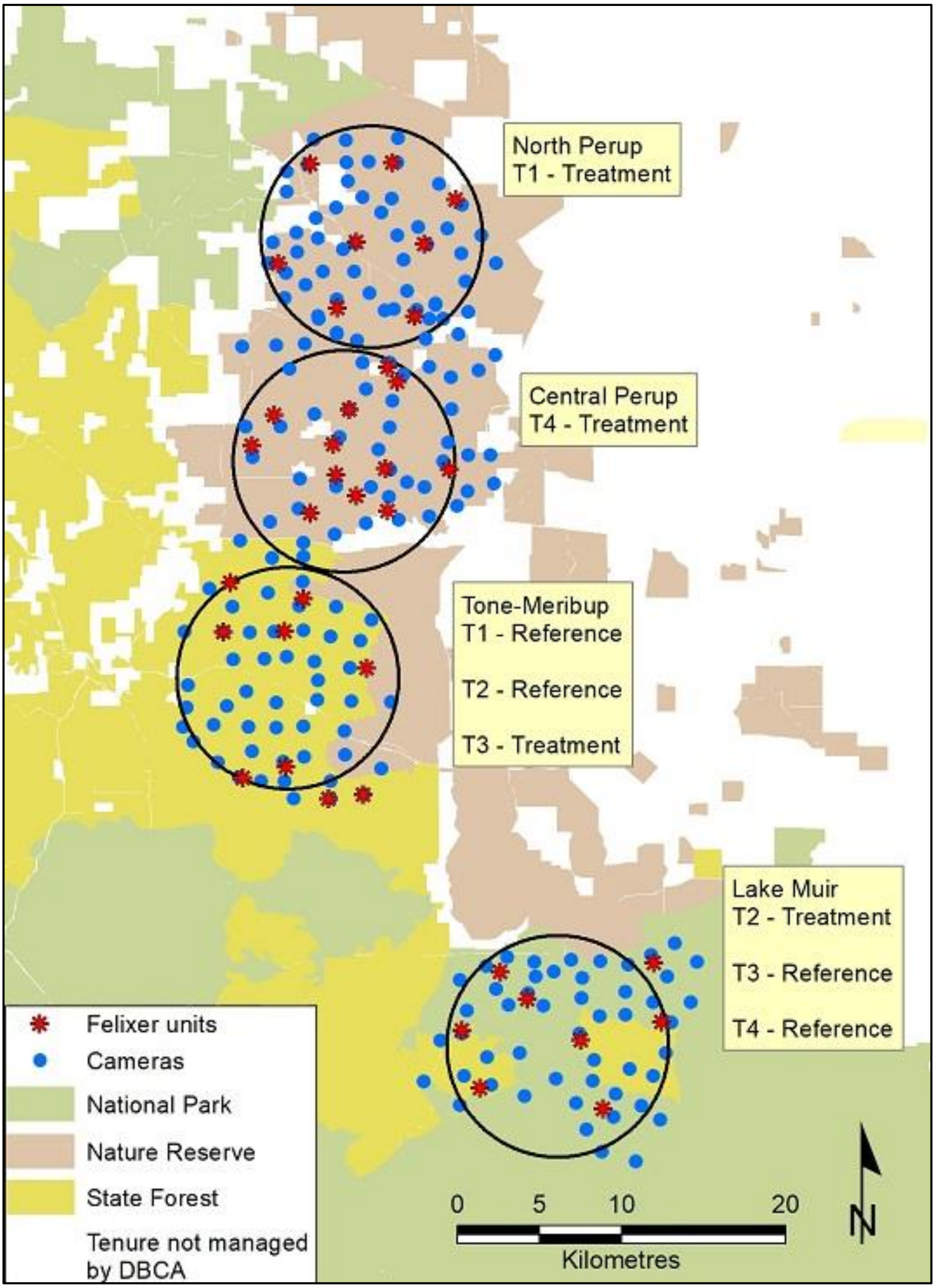


Figure 3 Location of the four experimental field trials of Felixers in the Upper Warren region and Lake Muir-Byenup area (NB: only 8 Felixers were in operation at any one time).

Table 6. Summary of Felixer deployments by targeting mode, arming status and lure use.

Location	Start date	End date	Target mode	Arming status	Lure	# Felixers	Total effort (nights)
Perth Zoo	16/6/20	22/6/20	C	Photo-only	No	2	12
Perup Sanctuary	9/12/20	05/1/21	C	Photo-only	No	2	54
North Perup	5/1/21	25/6/21	C	Photo-only	No	6	720
North Perup	5/3/21	19/3/21	C	Photo-only	Audio	4	56
North Perup	10/5/21	16/8/21	C	Toxic	No	8	653
Lake Muir	23/8/21	29/10/21	C	Toxic	No	8	506
Yackelup	10/1/22	2/2/22	S	Photo-only	No	4	89
Yackelup	10/1/22	2/2/22	C	Toxic	No	2	46
Tone-Meribup	9/2/22	26/5/22	C	Toxic	No	4–8*	616
Tone-Meribup	30/3/22	26/5/22	C	Toxic	Audio	4	227
Central Perup	26/10/22	5/1/23	S	Photo-only	No	8	533
Central Perup	5/1/23	28/3/23	S	Toxic	No	8	648

** 8 Felixers 9/2/22–30/3/22, then 4 Felixers 30/3/22–26/5/22.*
Target mode: C = conservative, S = standard
Grey shaded rows indicate the four main experimental toxic trials.

Table 7. Summary of trial duration and total Felixertrap effort for the permutations of Felixer target modes (Conservative or Standard), arming status (photo-only or toxic), and audio lure activation.

		Trial duration (days)		Felixer effort (nights)	
Target mode	**Audio Lure**	**Photo-only**	**Toxic**	**Photo-only**	**Toxic**
Conservative	No	204	294	786	1821
	Yes	14	57	56	227
Standard	No	94	82	622	648
	Yes	0	0	0	0

2.5.4 Camera deployment in association with Felixers

Reconyx HC600 and P900 cameras were deployed on either side of the Felixers at all sites. These cameras were vital for cat identification and often taxa identification because the image quality from the cameras was much better than from the Felixers. At the first treatment site (North Perup), we were particularly interested in the fauna behaviour in response to the Felixers. The cameras were set within 1–5 m of the Felixer, with a detection zone overlapping the Felixer and concealed as much as possible. One camera was located adjacent to the Felixer, the other was located on the opposite side of the track and facing the Felixer (i.e., the Felixer being within the field of view of the camera). For the subsequent trials, the cameras were moved further away from the Felixers (2.5–30 m, average = 10.8 m) to the most suitable location for concealment and camouflage, to reduce the risk of altered feral cat behaviour in response to the camera and potential reduced target efficiency (e.g., potentially due to the animal pausing within the detection zone of the Felixer upon sighting a camera). This negated the ability to observe animal behaviour at the Felixer and making direct comparison of the images of animals from the Felixers with the comparable images from the cameras.

2.5.5 Camera deployment as scouts for reconnaissance

Some additional cameras were deployed for the purposes of gathering intelligence of feral cat activity within some treatment sites to help identify suitable sites for locating Felixers.
During the trial at Tone-Meribup, 22 scout cameras were deployed within the general areas known to have relatively high feral cat activity (based on the data from the camera array in place for a year) to further refine the best potential locations for the Felixers. This included preferentially placing some scout cameras at various intersections between creek lines and tracks to identify the pathways most regularly used by feral cats. These intersections were targeted because of our understanding that feral cat movements are preferentially associated with the ecotonal boundaries along some creek lines and along some tracks in these forests and that the intersections of these are likely crossing/access points used by feral cats to cross some areas of dense riparian vegetation (e.g., melaleuca thickets). These intersections are also logistically advantageous for providing access for the deployment of Felixers.

There was a greater reliance on the intelligence from the 12 scout cameras deployed at Central Perup (experimental toxic trial 4) because there was less intelligence available from the camera array (<3 months of data and relatively low detection rates of feral cats). All scout cameras were deployed with the same methodology as all other cameras in the project (see methodology for the camara arrays detail below). The scout cameras were also used to provide additional information on feral cat movement and assisted with the identification of individuals detected on the Felixers.

2.6 Analysis of data from Felixers

2.6.1 Distinguishing the results between photo-only and toxic arming states

We report on the photo-only and toxic arming states separately because we expect there may be differences in the detection rates and target rates and because these metrics serve different purposes. There may be differences in the detection and targeting rates between photo-only and toxic arming states due to potential differences in animal behaviour and their interactions with the Felixers depending on whether the Felixer is armed (toxic) or not. In photo-only arming state, individuals remain unaware whether they have been identified as a target and so continue to behave accordingly. In toxic arming state individuals will get startled by the firing and being hit with gel and so may subsequently behave differently around the Felixer including avoidance. This may result in differences in detection and target rates.

Felixers may be moved to reduce the detection rate of non-target species that may be at risk of unwanted targeting (i.e., false positive), by avoiding sites with high activity or abundance of susceptible species (e.g., 'roo pads'). Conversely, Felixers in toxic arming state may be moved to increase the detection rates of target species (feral cat and fox). While this may change the detection rates between deployments in photo-only and toxic arming states, this alone is not expected to change the target rates. In some cases, the photo only trials were conducted in different sites to the toxic trials (e.g., Perth Zoo, Perup Sanctuary in conservative targeting mode and Yackelup in standard targeting mode).

All detections by the Felixers were classified to taxa where possible. 'Blank' detections were recorded when it was clear and we were confident that no animal was present in the image. 'Unidentifiable species' was recorded when an obvious animal shape was observable, but it was not possible to confidently identify the taxa because of poor image quality. Note that very few if any of the 'unidentifiable species' would have been feral cats or foxes, because these generally involved smaller animals such as woylies and quenda or smaller. If it wasn't clear whether there was an animal or not (because of poor image quality) the detection was classified as 'Unidentifiable species' rather than 'blank' (i.e., a conservative approach to recording species detections). Before the Felixer image was recorded as an 'unidentifiable species', images from both adjacent cameras were checked for further evidence.

2.6.2 Description of metrics

'**Detection rate'** is the number of detections at a Felixer divided by the functional Felixer effort (i.e., total Felixer nights removing nights whereby the Felixer was not working) and is generally reported as a species detection rate.

'**Target rate'** is the number of detections identified as a target by the Felixer divided by the number of detections of that same species and can be measured in photo-only and toxic arming status. We used a conservative approach and did not include 'Unidentifiable species' in the calculations such as non-target detection and target rates. This results in inflated false positive target rates because most of these cases are expected to be a non-target species.

'**Felixer effectiveness'** is measured as the number of individuals that were identified as a target by the Felixer as a proportion of the number of individuals that were detected at the Felixer site. This is only reported for Felixer trials in 'toxic' arming status only.

The minimum number of feral cat individuals at each trial site was determined by identifying all distinguishable individuals through distinctive features including their pelt patterns, fur length, posture, movement traits, defining marks and scars, size (age), body shape and gender. Many black feral cats could be distinguished with infrared if captured at night, if the image quality was good and if the pelt pattern was visible (e.g., a good view of the animal's body and its distinctive features). Some deduction of individuals is also used based on the spatial and temporal information from nearby cameras (i.e., cameras set either side of the Felixer and scout cameras elsewhere in the area). The maximum number of individuals is a total of all the distinguishable individuals plus a sum of all remaining feral cat detection events whereby the image was not clear enough for identification (blurry photos, too far away, mist, poor angle, daylight images of black feral cats, etc). Feral cat individual identification was only completed at the Felixer site level, and during the Felixer trial period. Cameras captured many more feral cat detection pre- and post-Felixer deployment at the Felixer sites as well as within the overall trial site area. Hence, more feral cat individuals were known from the trial area, but the quantity is unknown.

Fox individual identification was not attempted due to the difficulty in distinguishing individuals.

2.7 Camera arrays

An array of 49–50 remote sensor cameras (Reconyx HC600, P900 or HP2X) was deployed at each trial site to monitor the population of feral cats and foxes in the area. Cameras were set at ~2,000m intervals on tracks. The general locations of cameras were chosen based on a desktop assessment of track availability to achieve the desired spacing. Actual camera locations were chosen in the field based on the availability of cover to disguise the cameras and track width to ensure passing animals were detected. Cameras were set without lures and took 10 photos when triggered. The cameras were set to rearm immediately after being triggered. Once set, the cameras were checked every four weeks, except when there were access restrictions due to wet conditions (to minimise soil movement risk for dieback hygiene purposes), that postponed some checks.

Images captured by the remote camera arrays were first assessed using a photo image viewer to remove blank photos that were not triggered by an animal, person, or vehicle. Images were then managed using the CPW Photo Warehouse software. A single experienced observer identified each photo to species level where possible. Feral cats were identified to individual level where possible based on coat patterns.

2.8 Analysis of data from camera arrays

Data from the camera arrays was intended to be used to estimate feral cat density using spatially explicit capture recapture (SECR) based on individual identification of feral cats, however more than 50% of detections of feral cats by the cameras were of black cats that could not be accurately identified to individual level. As a result, that data were too sparse to use SECR and therefore detection rates of feral cats were used as a measure of feral cat activity to assess the effect of the Felixer deployments.

To assess if the removal of feral cats from the deployment of Felixers in toxic mode affected the level of cat activity at a site, the mean detection rates of feral cats at each site over a 28-day period were compared before and after deployment of the Felixers. Detections of feral cats were considered independent when they were separated by a minimum of 60 minutes. Results from the Felixer site were compared with those from the same period at the reference site by fitting generalized linear models with 'site' and 'period' (before and after) as fixed factors. The results of these models were used to assess if there was a significant change in feral cat detections and if there were significant differences between the Felixer and reference sites.

Where feral cats could be individually identified and had more than two detections prior to being targeted by a Felixer, the daily probability of detection was calculated for that animal. A probability of the animal still being present in the study area without detection after it was targeted was then calculated as $(1-p)^d$ where p is the daily probability of detection and d is the number of monitoring days post targeting where the individual was not detected.

2.9 Spatial variables associated with feral cat detections

Data from the North Perup, Tone-Meribup and Lake Muir sites were used to assess relationships between spatial variables and the rates of detection of feral cats with the intention of being able to better inform the placement of Felixers in the landscape. The data from these sites were chosen as they covered at least 12 consecutive months and either did not have Felixers deployed in toxic mode, or only had small numbers (maximum 4) feral cats targeted by Felixers over the monitoring period. For each site the following spatial variables were analysed.

Table 8. Spatial variables analysed at the North Perup, Tone-Meribup and Lake Muir sites.

Covariate	Description	Data source
Track type	Describes if tracks were maintained for vehicle use or unmaintained at the time of the trial	Department of Biodiversity, Conservation and Attractions (DBCA)
Track width	Total width of track at camera site, measured between the edges of wheel ruts	Measured on site
Topographic wetness index	Calculated as log_e(specific catchment area / slope) and estimates the relative wetness within a catchment.	CSIRO
Fuel Age	Time (years) since last recorded fire.	DBCA
Elevation	Elevation (m) above mean sea level	Landgate
Distance to Agricultural Land	Distance (m) from camera site to closest boundary with cleared agricultural land.	Landgate
Distance to Hydro Centre Line	Distance (m) from camera site to mapped centre line of surface water feature (creek, wetland, etc)	Landgate/DBCA

The number of cat detections per camera site was used with detections of feral cats considered independent when they were separated by a minimum of 60 minutes. Analysis was completed using the mlmRev and MuMIn packages in project R. The number of detections per camera site in each season was adjusted for survey effort and the number of days in the season to standardise detections across the seasons.

Seasons were defined by the six Noongar seasons which more closely reflect changes in the environment in the south west of Western Australia than the commonly used European four seasons. These seasons are:

- Birak: December–January

- Bunuru: February–March
- Djeran: April–May
- Makaru: June–July
- Djilba: August–September
- Kambarang: October–November

Camera sites with less than 30 days of survey effort in a season were excluded as were outliers with total detections more than five times the mean for that site. Quantitative spatial variables were scaled before analysis.

Associations between the number of feral cat detections at camera points and the spatial variables were assessed using generalized linear mixed models with a gamma distribution and inverse link function based an exploratory analysis of the distribution of the data. Camera site nested within trial site were set as random factors to model data from the three sites combined. Single site models were run using camera site as a random factor. Models were assessed for fit against competing models using AICc values and conditional R^2 values were calculated using the MuMin package to assess total variance explained by the model.

3 Results

3.1 Detection of animals by Felixers

Of the 10,969 detections by Felixers across all trials, 9,521 were triggered by animals; 5,377 of these were from Felixers in conservative target mode and 4,144 of these were in standard targeting mode (*Table 9*). Woylies (24%), koomal (11%), numbats (8%), tammar (8%) and chuditch (5%) were the most detected species on the Felixers across all trials (*Table 9*). Feral cats and red foxes constituted 1.2% and 2.5% of all detections on the Felixers during our trials (*Table 9*). A total of 10% of detections by Felixers were 'Unidentifiable species' – due to poor image quality of the photos from the Felixer and no corroborating evidence from the adjacent cameras (*Table 9*). A total of 5% of detections by Felixers were 'blank' – no information from the photo to determine what triggered the Felixer (*Table 9*). Personnel and vehicle detections (6% and 2% of all detections, respectively) were by field staff associated with the project.

Felixers performed well at detecting animals in front of the Felixer when compared with two adjacent cameras (Reconyx HC600 and PC900) set up next to the Felixers. The best evidence of this is from our first field trials conducted in North Perup, where there were no instances where the cameras detected a feral cat or fox that entered the detection zone of the Felixer that was not also detected by a fully functioning Felixer. However, on a few occasions the Felixer detected feral cats (1 of 37) and foxes (28 of 149) that were not detected by the adjacent cameras that had overlapping detection zones. Note that 10% of the 60 feral cat detections at North Perup were detected on the cameras but not on the Felixer. This is because the feral cat did not walk in front of the Felixer (i.e., showed avoidance behaviour, and/or turned around or moved behind the Felixer).

Table 9. Number of detections by Felixers for taxa in trials conducted in 'conservative' and 'standard' targeting mode (photo-only and toxic trials combined) in the southern jarrah forest, Western Australia.

Species name	Common Name	Conservative mode	Standard mode
Capra hircus	Feral Goat	4	1
Felis catus	Feral Cat	105	29
Oryctolagus cuniculus	Rabbit	43	11
Sus scrofa	Feral pig	5	0
Vulpes vulpes	Red Fox	239	39
Bettongia penicillata	Woylie	933	1697
Dasyurus geoffroii	Chuditch	178	325
Isoodon fusciventer	Quenda	216	120
Macropus fuliginosus	Yongka (Western Grey Kangaroo)	160	148
Myrmecobius fasciatus	Numbat	837	31
Notamacropus eugenii	Tammar	608	238
Notamacropus irma	Kwara (Western Brush Wallaby)	30	28
Phascogale tapoatafa	Wambenger (Brush-tailed Phascogale)	8	3
Pseudocheirus occidentalis	Ngwayir (Western Ringtail Possum)	6	9
Setonix brachyurus	Quokka	47	0
Tachyglossus aculeatus	Nyingarn (Short-beaked Echidna)	6	15
Trichosurus vulpecula	Koomal	511	698
	Macropod spp.	57	3
	Bat spp.	2	0
Aegotheles cristatus	Australian Owlet-nightjar	73	0
Aquila audax	Wedge-tailed Eagle	4	1
Barnardius zonarius	Australian Ringneck	7	8
Climacteris rufa	Rufous Treecreeper	4	0
Corvus coronoides	Australian Raven	4	9
Cracticus tibicen dorsalis	Australian Magpie	12	48
Dromaius novaehollandiae	Emu	11	4
Eopsaltria georgiana	White-breasted Robin	10	33
Eopsaltria griseogularis	Western Yellow Robin	5	1
Malurus splendens	Splendid Fairy-wren	23	11
Phaps chalcoptera	Common Bronzewing	47	54
Platycercus icterotis	Western Rosella	6	0
Podargus strigoides	Tawny Frogmouth	5	0
Rhipidura fuliginosa	Grey Fantail	8	7
Strepera versicolor	Grey Currawong	309	78
Turnix varia	Painted Button-quail	5	6
	Owl spp	20	5
	Waterbird spp	0	5
	Bird spp	57	56
Chelodina colliei	Snake-necked Turtle	1	0
Varanus rosenbergi	Southern Heath Goanna	0	1
	Amphibian	30	78
	Invertebrate	4	1
	Personnel	410	244
	Vehicle	158	36
	Unidentifiable species	737	343
	Blank	276	324
Subtotal: Animal*		5377	4144
Grand total		**6221**	**4748**

*Animal subtotal includes animal detections that were 'unidentifiable species'

3.2 Safety assessment

3.2.1 Desktop risk assessment

Eight native taxa were found to have a lethal dose (LD_{50}) lower than the amount of 1080 in a single Felixer gel cartridge (8mg). Three of these were mammals (mardo, wambenger and mootit (southern bush rat)) and five birds (*Table 9*). All of these were deemed to be at very low risk of a lethal interaction directly with a Felixer, based principally on size and shape.

Two non-targets species were identified as being at low risk of a lethal interaction with a Felixer (*Table 10*), but for different reasons. The chuditch may be at low risk because of the possibility of being mis-identified: based on their general size, shape, and quadrupedal movement. However, we understand that the algorithms used by the Felixer are designed to discriminate short-legged native quadrupeds, such as the quolls, from the relatively longer-legged introduced felids and canids. Evidence that this is effective includes other studies around Australia that have shown that none of at least 200 quolls detected by a Felixer have yet been misidentified as a target (*Table 1*; Dunlop *et al.* 2019a&b; John Read pers comm. February 2021). The Felixer with 1080 cartridges have been used to protect reintroduced chuditch in Flinders Ranges National Park (SA) since 2019 without any false positive targeting event (Katherine Moseby pers comm. February 2021). The larger spotted tailed quoll has experienced one false positive targeting in over 4500 interactions monitored by NSW DPI and UTAS (John Read pers comm., February 2021). Nonetheless, based on the tolerance of chuditch to 1080, it is expected that a chuditch would be required to consume most of at least two direct hits of gel (8 mg 1080 each) from a Felixer within 24 hours for it to receive a dose at or above its LD_{50} (9.8 mg 1080 for an average sized adult chuditch; Department of Agriculture *et al.* 2002, *Table 10*). It seems highly unlikely that the same individual chuditch, having been mis-identified as a target once, would be targeted a second time by the same device within 24 hours given that there is a default 120 seconds 'cooldown' period after the Felixer has fired, before it can rearm and fire again at a newly identified target. Furthermore, it is highly unlikely that a chuditch individual, having been hit once by the gel from a Felixer, is going to remain in the vicinity of the Felixer for some considerable period. Given the nearest neighbour spacing between Felixers in the southern jarrah forest is on average 3,300 m apart (1,800–5,400 m), it seems unlikely that the same chuditch would be mis-identified as a target on two separate Felixer within 24 hours.

Based on their size, it is possible that European rabbits could be mis-identified. This has occurred on two occasions from 1,891 detections across other projects (John Read pers comm. February 2021; *Table 10*). An average-sized adult rabbit that consumes at least 8% of a full dose of a Felixer gel cartridge would reach the species' 1080 LD_{50} (*Table 10*). As demonstrated elsewhere (*Table 10*, John Read pers comm.), small domestic dogs are at high risk of being targeted by a Felixer (*Table 10*). Medium-sized dogs or larger are generally large enough to break the top blocking sensor and hence not trigger the Felixer. If a targeted dog is allowed to ingest a significant portion of the 1080 gel on its coat it is at high risk of exceeding the 1080 LD_{50} for the species, depending on its size.

Table 10. Assessment of the potential vulnerability of species likely to encounter a Felixer in the southern jarrah forest, Western Australia.

Species	Common Name	*Mean adult body Wt. (kg)	*LD50 (mg/kg)	*Amount for LD50 (mg)	Approximate number of Felixer gel direct hits required for an LD50 dose	Likelihood of being Felixer target	Likelihood of ingesting a significant amount of gel if targeted	Overall risk of lethal interaction
Anas supercillosa	Black Duck	1.1	18.4	20.24	2.53	Very low	Possible	Very low
Antechinus flavipes	Mardo	0.05	11.8	0.59	0.07	Very low	Possible	Very low
Aquila audax	Wedge-tailed Eagle	4.85	9.1	44.18	5.52	Very low	Possible	Very low
Barnardius zonarius	Port Lincoln Parrot	0.179	10.8	1.93	0.24	Very low	Possible	Very low
Bettongia penicillata	Woylie	1.35	115	155.25	19.41	Possible	Possible	Very low
Chenonetta jubata	Wood Duck	0.82	11.8	9.64	1.21	Very low	Possible	Very low
Dasyurus geoffroii	**Chuditch**	**1.39**	**7.1**	**9.8**	**1.23**	**Possible**	**Possible**	**Low**
Dromaius novaehollandiae	Emu	39.5	102	4029	503.63	Very low	Possible	Very low
Falco berigora	Brown Falcon	0.44	30.1	13.23	1.65	Very low	Possible	Very low
Isoodon obesulus	Quenda	1	18.8	18.8	2.35	Possible	Possible	Very low
Leioa ocellata	Malleefowl	1.8	94	169.2	21.15	Possible	Possible	Very low
Macropus fuliginosus	Yongka	40.5	47	1903.5	237.94	Possible	Possible	Very low
Notamacropus eugenii	Tammar	7	9.4	65.8	8.23	Possible	Possible	Very low
Notamacropus irma	Kwara	8	7.1	56.4	7.05	Possible	Possible	Very low
Ocyphaps lophotes	Crested Pigeon	0.204	23.5	4.78	0.60	Very low	Possible	Very low
Phaps chalcoptera	Bronzewing Pigeon	0.294	37.6	11.05	1.38	Very low	Possible	Very low
Phascogale tapoatafa	Wambenger	0.173	9	1.55	0.19	Very low	Possible	Very low
Platycercus icterotis	Western Rosella	0.06	70.5	4.19	0.52	Very low	Possible	Very low
Purpureicephalus spurius	Red-capped Parrot	0.114	23.5	2.67	0.33	Very low	Possible	Very low
Rattus fuscipes (Max Tolerance)	Mootit (bush rat)	0.145	73.3	10.63	1.33	Very low	Possible	Very low
Rattus fuscipes (Min Tolerance)	Mootit (bush rat)	0.145	22.2	3.22	0.40	Very low	Possible	Very low
Setonix brachyurus	Quokka	3.15	37.6	118.44	14.81	Possible	Possible	Very low
Tiliqua rugosa	Bobtail Skink	0.35	800	280	35.00	Very low	Very low	Very low
Trichosurus vulpecula	Koomal	3	117.5	352.5	44.06	Possible	Possible	Very low
Tyto alba	Barn Owl	0.322	21.8	7.01	0.88	Very low	Possible	Very low
Varanus gouldii	Sand Goanna	1.35	47	63.45	7.93	Very low	Very low	Very low
Varanus rosenburgi	Rosenberg's Goanna	1.55	235	354.25	44.28	Very low	Very low	Very low
INTRODUCED SPECIES								
Canis familiaris	**Dingo/Wild dog**	**14.5**	**0.11**	**1.6**	**0.20**	**Likely**	**Possible**	**High**
Felis catus	**Feral Cat**	**4.4**	**0.35**	**1.54**	**0.19**	**Likely**	**Likely**	**Very High**
Homo sapiens	Human	80	2	160	20.00	Possible	Very low	Very low
Oryctolagus cuniculus	**European Rabbit**	**1.6**	**0.4**	**0.64**	**0.08**	**Possible**	**Possible**	**Moderate**
Sus scrofa	Feral pig	55	1.02	56.1	7.01	Possible	Possible	Very low
Vulpes vulpes	**European Fox**	**6.5**	**0.12**	**0.78**	**0.10**	**Likely**	**Possible**	**High**

* = data from Department of Agriculture *et al.* (2002)

Highlighted fields: Yellow = LD_{50} requires less than 1 Felixer^{TM} gel cartridge (8mg 1080); Overall risk of lethal interaction with a Felixer^{TM} is Blue if Low or Moderate and Red if High to Very high.

3.2.2 Field trials

One animal, a tammar, was mis-identified as a target out of 4,296 detections of identifiable animals when the Felixers were set in conservative targeting mode (0.02%). This was in the Perup Sanctuary during the photo-only trial.

In standard targeting mode, there was a 1.0% (n=2,088) and 0.4% (n=1,645) false positive target rate of non-target animals during photo-only and toxic deployments respectively (*Table 11*). This included 17 woylies (13 in photo only and 4 in toxic mode), 2 tammar (1 in photo only and 1 in toxic mode), 5 yongka (3 in photo only and 2 in toxic mode), and 1 kwara (in photo only mode) during the standard targeting mode trial in Central Perup. In addition, 1 woylie and 2 tammar were identified as targets during the photo-only trial in standard targeting mode in Yackelup.

With the yongka and woylie considered among the species exempt by the APVMA (2023) conditions regarding the false-positive target rates of non-targets, the only non-target species of potential concern that were false positive targets in this study were the tammar and kwara. Therefore, using the APVMA (2023) criteria (Appendix 1), the false positive non-target rates were, 0.47% (1 tammar /211 total non-target animals detected) during the photo-only trial in conservative targeting mode at Perup Sanctuary (maximising detections of woylies and tammar), 1.5% (2 tammar/133 total non-target animals detected) during the photo-only trial at Yackelup (maximising detections of targeting tammar), 0.10% (1 tammar + 1 kwara /1,955) during the photo-only trial in the Central Perup (targeting feral cats), and 0.06% (1 tammar/1,645 not including unidentifiable species foxes or cats) during the toxic trial in the Central Perup (targeting feral cats).

No chuditch were incorrectly identified as a target during any of the deployments of Felixers either in conservative mode (n=178) or standard target mode (n=325).

All four woylies targeted by the Felixers in standard targeting mode were not directly hit by the gel, with the gel making only partial contact with the individual’s tail (based on available photographic evidence from the Felixers and adjacent cameras). These animals were therefore not exposed to full dose of 1080 from the gel.

Table 11. Target identification rate by Felixers for true positives (feral cat and fox) and false positives (non-target native species) that occurred in all trials combined and conducted in 'conservative' and 'standard' targeting mode in both arming states (photo and toxic mode) in the southern jarrah forest, Western Australia.

		Conservative (Photo-only)		Conservative (Toxic)		Standard (Photo-only)		Standard (Toxic)	
Species name	**Common Name**	**Target rate**	**n**	**Target rate**	**n**	**Target rate**	**n**	**Target rate**	**n**
Felis catus	Feral Cat	52.0%	25	31.3%	80	64.7%	17	41.7%	12
Vulpes vulpes	Red Fox	39.2%	97	28.9%	142	20.0%	5	41.2%	34
Bettongia penicillata	Woylie	0.0%	444	0.0%	489	1.4%	987	0.6%	710
Macropus fuliginosus	Yongka	0.0%	59	0.0%	101	3.1%	96	3.8%	52
Notamacropus eugenii	Tammar	0.3%	325	0.0%	283	3.1%	96	0.7%	142
Notamacropus irma	Kwara	0.0%	4	0.0%	26	14.3%	7	0.0%	21
Total non-target false positive target rate (all species)		**0.05%**	**2186**	**0.00%**	**2110**	**1.01%**	**2088**	**0.43%**	**1645**
Total non-exempt^ non-target false positive target rate		**0.05%**	**2186**	**0.00%**	**2110**	**0.19%**	**2088**	**0.06%**	**1645**

False positive target rate (expressed here as a percentage) = all false-positive non-target detections / total non-target detections *100. ^ Fauna regarded as exempt non-target fauna under the APVMA (2023) include Yongka and Woylie.

3.3 Felixer performance

3.3.1 Felixer function

Felixers were not working for a full 24-hour period on 9% of nights they were deployed (18:00hrs to 17:59hrs the following day), across all trials combined (*Table 12*). During another 2% of Felixer nights the Felixers were not fully operational for part of the time (i.e., diurnal hibernation (06:00–18:00 hrs and/or functionality loss of <10% of the night (18:00–06:00 hrs)). Felixer functionality was compromised due to several issues including mechanical malfunction, software errors, insufficient battery power and human error (1.5%, 4.0%, 1.7% and 2.0% Felixer nights respectively; *Table 12*).

Felixers hibernated to save power when battery power was low due to recharging from the solar panel being inadequate. Felixers initially go into hibernation between 06:00 and 18:00 hrs and if the battery has recharged adequately during the day the Felixer would reactivate. But, if the diurnal recharge has been inadequate (<20% battery capacity), the device would remain in hibernation for a further 24 hours. There were 1.7% of nights (n=71) when a Felixer was in hibernation for the entire 24-hour period or >10% of night between 06:00 and 18:00 hrs. There was an additional 1.7% of occasions (n=72) when hibernation was only through the day or <10% of the night, i.e., reduced functionality. When battery power was low the audio lure (if activated) was also disabled. Issues with insufficient battery power were mostly limited to the two trials that occurred over Autumn-Winter and were greatest during May-July. Power issues began in April during the trial at Tone-Meribup (4.4–4.9% lost time) and began in May at North Perup (<4% lost time). Reduced functionality occurred on an additional <5% of Felixer nights at both sites.

To address the power supply issues, larger 26Ah capacity batteries were installed in half of the Felixers on 10 June 2021, as recommended by Thylation. However, this did not make a noticeable difference in the rate of hibernation compared with the Felixers with the original 18Ah batteries. The Felixers is limited by an inbuilt 4 Amp regulator that could not be readily upgraded, therefore the use of higher capacity solar panels would not have solved the power supply issue. Swapping out batteries in the field every 3–5 days with a fully recharged battery was deemed impractical. Greater effort was made to maximise direct sun exposure on the solar panel by careful and strategic placement. Adequate access to direct sunlight became an important criterion for the selection of sites to deploy Felixers after the first field trial in North Perup.

At 4.0% lost time, software faults were responsible for the greatest overall loss of functional Felixer nights. These faults mostly affected the first two trials at North Perup and Lake Muir before these issues were resolved in collaboration with Thylation and their technicians. Software faults involved, 1) the Felixer not reactivating after entering hibernation mode (36 Felixer nights lost), 2) infra-red flash fault resulting in no illumination of night images (83 Felixer nights lost), and 3) a variety of error messages - software faults that caused complete Felixer disfunction (48 Felixer nights lost).

Table 12. Summary of Felixer performance in relation to the causes of lost time incidents for all trials.

									% Lost time (nights)					% Partial*
Location	**Start date**	**End date**	**Target mode**	**Arming status**	**Lure**	**# Felixers**	**Total Felixer effort (# trap nights)**	**Total # of functional Felixer nights**	**Mechanical**	**Software**	**Power**	**Human Error**	**Total**	
Perth Zoo	16-Jun-20	22-Jun-20	Conservative	Photo-only	No	2	12	12	0	0	0	0	0	0
Perup Sanctuary	09-Dec-20	05-Jan-21	Conservative	Photo-only	No	2	54	54	0	0	0	0	0	0
North Perup	05-Jan-21	25-Jun-21	Conservative	Photo-only	No	6	720	619	1.8	11.5	0.7	0	14.0	0.3
North Perup	05-Mar-21	19-Mar-21	Conservative	Photo-only	Audio	4	56	56	0	0	0	0	0	0
North Perup	10-May-21	16-Aug-21	Conservative	Toxic	No	8	653	459	6.4	6.7	4.0	12.6	29.7	5.2
Lake Muir	23-Aug-21	29-Oct-21	Conservative	Toxic	No	8	506	464	0	7.9	0	0.4	8.3	0
Yackelup	10-Jan-22	02-Feb-22	Standard	Photo-only	No	4	89	89	0	0	0	0	0	0
Yackelup	10-Jan-22	02-Feb-22	Conservative	Toxic	No	2	46	46	0	0	0	0	0	0
Tone-Meribup	09-Feb-22	26-May-22	Conservative	Toxic	No	8	616	586	0	0	4.9	0	4.9	4.9
Tone-Meribup	30-Mar-22	26-May-22	Conservative	Toxic	Audio	4	227	214	1.3	0	4.4	0	5.7	2.2
Central Perup	26-Oct-22	5-Jan-23	Standard	Photo-only	No	8	533	533	0	0	0	0	0	0
Central Perup	5-Jan-23	28-Mar-23	Standard	Toxic	No	8	648	645	0.5	0	0	0	0.5	0.2
Total (all trials combined)							**4160**	**3777**	**1.5**	**4.0**	**1.7**	**2.0**	**9.2**	**1.7**

*% Partial = % nights with reduced functionality due to diurnal hibernation &/or functionality loss of <10% of the night (18:00–06:00hrs).
Grey shaded rows indicate the four main experimental toxic trials.

Mechanical faults included faulty equipment, such as assembly faults with Anderson plug attachments for the solar panels when purchased (55 Felixer nights lost; contact terminals installed incorrectly), cartridge magazine recall (14 Felixer nights lost), mechanical seizure of internal parts (6 Felixer nights lost).

Human error faults resulted from damaged or loose power supply connections e.g., dislodged solar panel Anderson plug from the Felixer (14 Felixer nights lost) and damaged internal computer during battery replacement (68 Felixer nights lost). Felixer faults resulted in a total of 13% and 14% fewer target opportunities for feral cats and foxes, respectively, across all trials combined (*Table 12*). Ten of the 17 missed opportunities of targeting a feral cat were in toxic target mode (*Table 12*). Similarly, 32 out of the 39 missed opportunities of targeting a fox were in toxic target mode (*Table 12*).

3.3.2 Audio lures

Detection probability and detection rates may be influenced by the use of the audio lures in the Felixers. However, there was no evidence that the default audio lure had a significant effect on the detection rates for any species based on the combined results of the two small trials conducted at North Perup and Tone-Meribup (*Table 12*; total of 270 functional Felixer nights, 84 with lure on and 186 lure off). All 11 detections of owls in our lure trial occurred when the audio-lures were active, resulting in a detection rate of 8% (*Table 16*). This is substantially greater than the 0.4% owl detection rate (14 detections from 3495 functional Felixer nights) observed across all other Felixer trials in the field conducted with no audio lure. There also was no significant difference in the target rate of feral cats and foxes between periods of lure on versus lure off (p=0.23 and p= 0.1, respectively, one tailed paired t=tests, df=7; *Table 16*). As with the detection rate tests, these results are limited by the small sample sizes.

3.3.3 Felixer targeting rates

While feral cats were detected at most Felixer trap locations, only half the locations resulted in one or more cats being targeted while the Felixers were in toxic mode. More specifically, feral cats were detected at 79% of the 38 Felixer deployment locations (36 in toxic arming status) used in these trials, with an average six detections per location (range 0–20). When the Felixers were in toxic arming status, at least one feral cat was detected at 69% of the 36 Felixer locations (range 0–9 detections), and feral cats were targeted at 50% of locations (range 0–3 feral cats targeted per location; *Table 13*). The results were particularly low at the first trial site, North Perup, where feral cats were detected at only 38% of Felixer locations during the toxic stage of trial and feral cats were only targeted at 25% of Felixer locations. In the preceding photo-only trial at the same site the proportion of Felixer sites where feral cats were detected and targeted feral cats at was approximately double (*Table 13*).

Feral cat detection rates (i.e., the total number of detections at a Felixer divided by the total number of functional Felixer trap nights) were low (mean = 3.7%, SD = 1.4%, range 1.9–5.6%; *Table 14*). Target rates for feral cats (i.e., the proportion of cats targeted when detected by a Felixer) were on average 41.3% (SD=16.3%, range 17.0–68.8%), but varied considerably between sites, and Felixer arming status and targeting modes. Target rates were greater when the Felixers were in photo-only arming state compared with toxic mode. As expected, targeting rates were higher with the Felixers in standard targeting mode trials compared with conservative mode. The target rate in standard targeting mode was 68.8% in photo-only, but only 41.7% in toxic arming state. This rate was only slightly higher than the 31.3% target rate achieved in toxic conservative targeting mode.

Detection rates for foxes were higher overall and more variable between trials (mean = 13.4%, SD=8.7%, range 0.8–23.2%; *Table 15*) compared to those for cats (*Table 14*). Fox target rates were similar to those of feral cats (mean = 34.6%, SD = 17.1%, range 0–55.6%) and followed similar trends with higher target rates when the Felixers were in photo-only compared with toxic arming status, and higher target rates in standard targeting mode compared with the conservative targeting mode trials.

Felixers were not moved during Trials 1 (North Perup) and 2 (Lake Muir), but in Trial 3 (Tone-Meribup) and 4 (Central Perup) the Felixers were moved to optimise feral cat target opportunities identified through intelligence from the camera array and scout cameras. In all but one case (5/6 sites) when Felixers were moved to another site, no additional feral cat activity was identified on the retained cameras at the original Felixer location. At one site a feral cat was detected 50 days after the Felixer had been relocated. Feral cats were detected by the Felixers at five of the six new locations and targeted at three sites (Felixer effort at the new locations was on average 52 Felixer nights (range 27–82)).

There was no consistent pattern to the timing of targeting events of feral cats by Felixers, which was highly variable between locations (*Figure 5. Feral cat detection events (Felixer and camera combined), detections by Felixers only and cats targeted by Felixers at a) Tone-Meribup and b) Central Perup in both photo-only and toxic arming status*.*Figure 4*, *Figure 5*). On average feral cats were targeted by a Felixer, 40 days after the toxic stage of the trials began (range 1–89 days). In some cases, once the previously identified feral cats at that location were targeted in toxic arming status, no other feral cats were detected for the remainder of the trial. Whilst for other locations there were ongoing feral cat target detections with apparently new feral cats visiting the Felixer location after the removal of previously known individuals (i.e., consistent with new individuals potentially moving into or through previously occupied territories).

The tally of detected and targeted feral cats was generally steady over time, except at Central Perup (experimental trial 4) where the target rate slowed after the Felixers were activated in toxic arming mode. The difference between the accumulation tally of targeted feral cats to the sum of feral cat visits in the vicinity of the Felixer ('sum events' in *Figure 4 and 5*), graphically demonstrate the lost opportunities to target feral cats. At North Perup, where these lost opportunities were greatest, this was largely due to do faults with the Felixers and increasing power issues that began in May (*Table 12*). This is illustrated by the reduced number of functional Felixers over time (i.e., orange bars in *Figure 4*). The incidence of reduced Felixer functionality, generally reduced over successive trials (*Figure 5. Feral cat detection events (Felixer and camera combined), detections by Felixers only and cats targeted by Felixers at a) Tone-Meribup and b) Central Perup in both photo-only and toxic arming status*.*Figure 4*, *Figure 5*). Except for Tone-Meribup, the number of functioning Felixers gradually reduced over time as the number of power issues increased through April - June. In the final trial at Central Perup, compromises to Felixer performance were negligible. At Lake Muir, the detection efficiency was much improved compared to North Perup, however, the target efficiency was the poorest of all sites (see also *Table 12*).

Table 13. Proportion of Felixer locations where feral cats were detected and targeted while in photo-only and toxic arming status in conservative and standard targeting modes.

Arming status	Site	Targeting mode	Number of Felixer locations	Felixer effort (nights) (mean and range)	% locations with detections	% locations with targets	Detections per location (mean and range)	Targets per location (mean and range)
Photo-only	North Perup	Conservative	8	84.4 (2–125)	63%	63%	3.1 (0–8)	1.6 (0–6)
	Central Perup	Standard	8	65.7 (63–71)	50%	50%	1.2 (0–9)	0.8 (0–6)
	Total		**16**	**75.1 (2–125)**	**56%**	**56%**	**2.5 (0–9)**	**1.5 (0–6)**
Toxic	North Perup	Conservative	8	55.9 (17–85)	38%	25%	1.5 (0–8)	0.5 (0–3)
	Lake Muir	Conservative	8	58.0 (45–67)	88%	38%	2.6 (0–9)	0.5 (0–2)
	Tone-Meribup	Conservative	9	88.9 (48–107)	100%	100%	5.0 (0–5)	1.9 (1–3)
	Central Perup	Standard	11	59.3 (27–83)	55%	36%	1.2 (0–4)	0.4 (0–2)
	Total		**36**	**65.6 (17–107)**	**69%**	**50.0%**	**2.6 (0–9)**	**0.8 (0–3)**

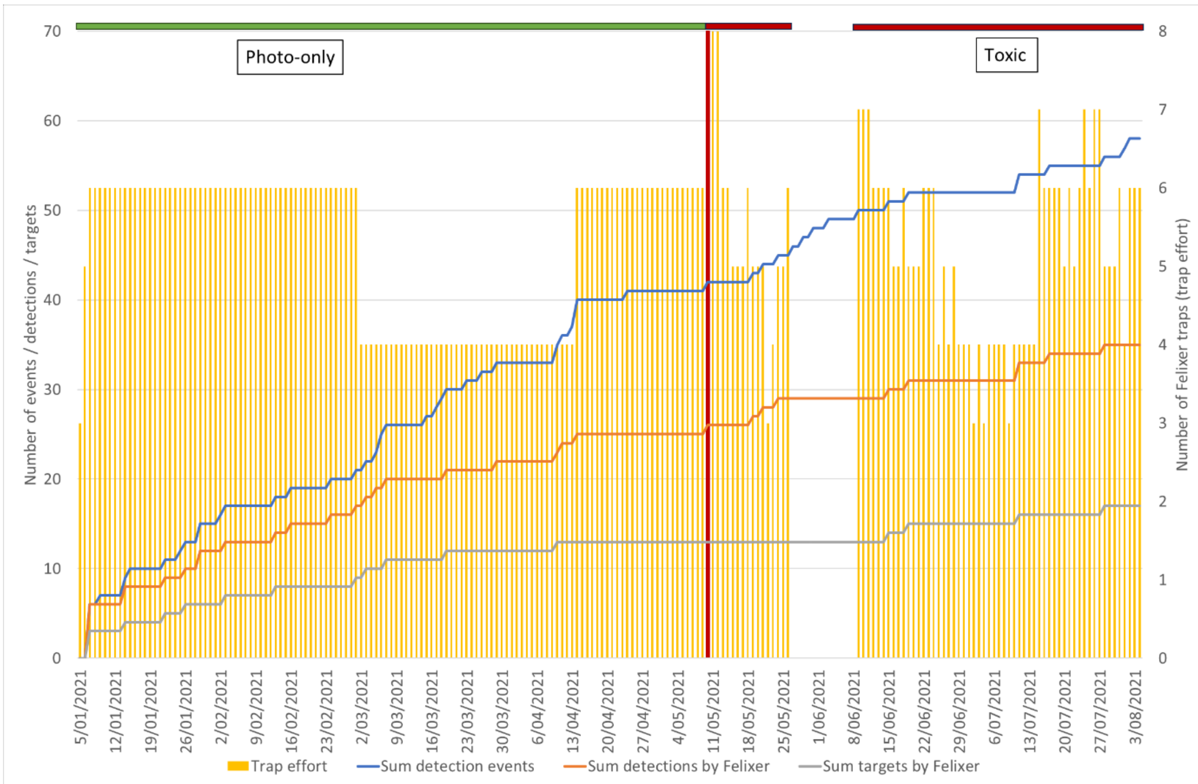
Grey shaded rows indicate the four main experimental toxic trials.

Table 14. Feral cat detection rate (# detections/ # functional Felixer trap nights) and target rate (# target identifications/# detections) by Felixers during the main experimental field trials.

Location	Start date	End date	Target mode	Arming status	Lure	Total trap nights	Detections	Targets	Misses	Missed opportunities	Detection rate	Target rate
North Perup	5/1/21	25/6/21	C	Photo-only	No	619	23	12	11	7	3.7%	52.2%
North Perup	5/3/21	19/3/21	C	Photo-only	Audio	56	2	1	1	0	3.6%	50.0%
North Perup	10/5/21	16/8/21	C	Toxic	No	459	12	4	8	6	2.6%	33.3%
Lake Muir	23/8/21	29/10/21	C	Toxic	No	464	23	4	19	1	4.5%	17.0%
Tone-Meribup	09/2/22	26/5/22	C	Toxic	No	586	33	14	19	0	5.6%	42.4%
Tone-Meribup	30/3/22	26/5/22	C	Toxic	Audio	214	12	3	9	1	5.6%	25.0%
Central Perup	26/10/22	5/3/23	S	Photo-only	No	533	16	11	5	0	3.0%	68.8%
Central Perup	5/1/23	28/3/23	S	Toxic	No	645	12	5	7	0	1.9%	41.7%
Conservative Photo-only Subtotal						**675**	**25**	**13**	**12**	**7**	**3.7%**	**52.0%**
Conservative Toxic Subtotal						**1723**	**80**	**25**	**55**	**8**	**4.6%**	**31.3%**
Standard Photo-only Subtotal						**533**	**16**	**11**	**5**	**0**	**3.0%**	**68.8%**
Standard Toxic Subtotal						**645**	**12**	**5**	**7**	**0**	**1.9%**	**41.7%**

Grey shaded rows indicate the four main experimental toxic trials.

a) North Perup



b) Lake Muir

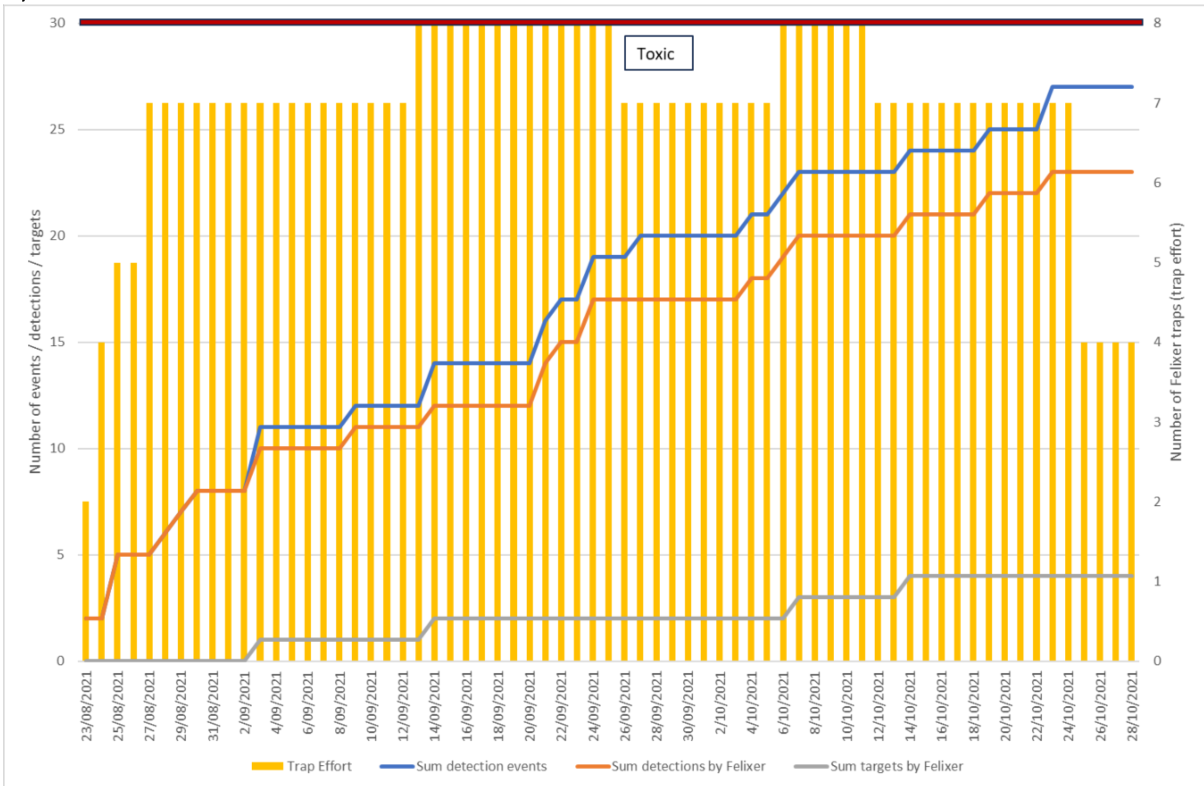
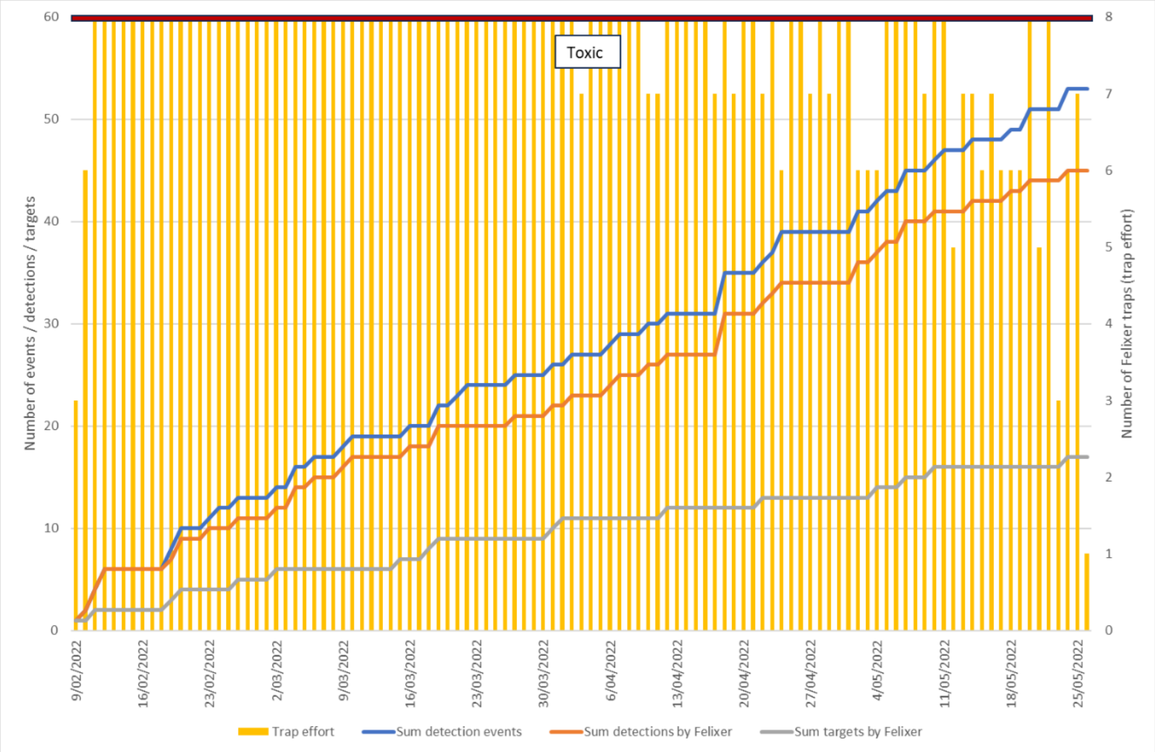


Figure 4. Feral cat detection events (Felixer and camera combined), detections by Felixers only and cats targeted by Felixers at a) North Perup and b) Lake Muir in both photo-only and toxic arming status. Trap effort is the number of fully operational Felixers per night

c) Tone-Meribup



d) Central Perup

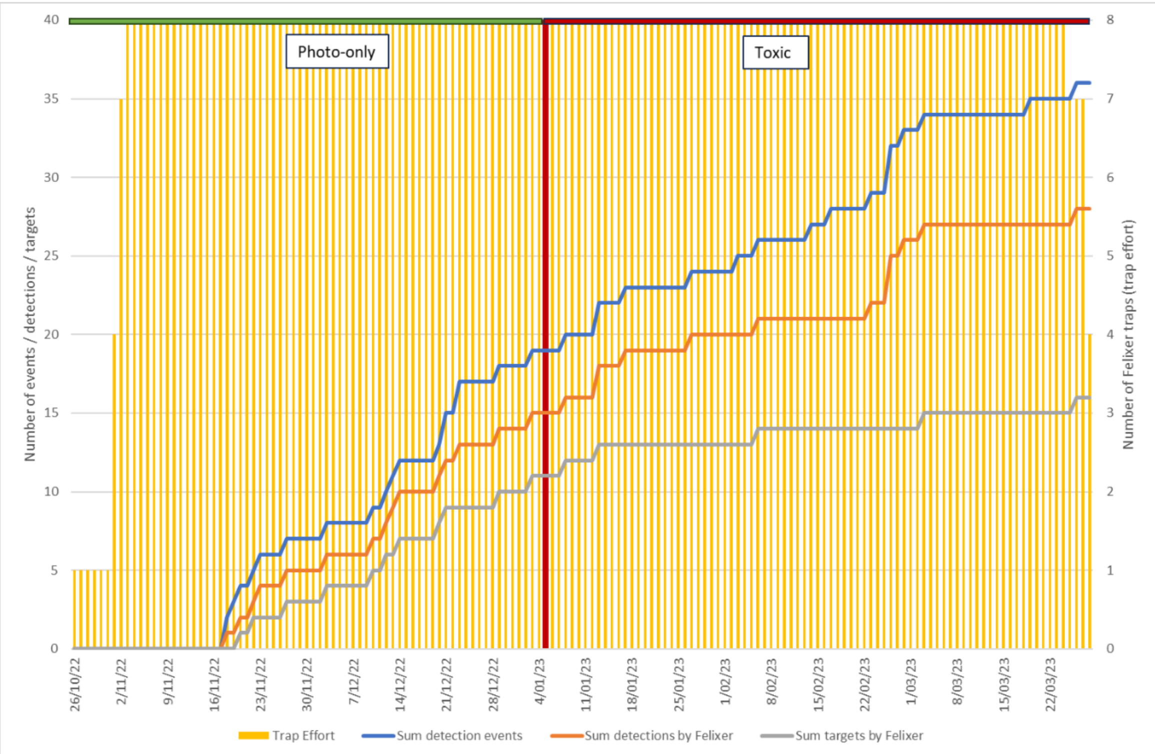


Figure 5. Feral cat detection events (Felixer and camera combined), detections by Felixers only and cats targeted by Felixers at a) Tone-Meribup and b) Central Perup in both photo-only and toxic arming status.

Table 15. Fox detection rate (# detections/ # functional Felixer trap nights) and target rate (# target identifications/# detections) by Felixers during the four main experminetal trials.

Location	Start date	End date	Target mode	Arming status	Lure	Total trap nights	Detections	Targets	Misses	Missed opportunities	Detection rate	Target rate
North Perup	5/1/21	25/6/21	C	Photo-only	No	619	89	33	56	7	18.4%	37.1%
North Perup	5/3/21	19/3/21	C	Photo-only	Audio	56	9	5	4	0	23.2%	55.6%
North Perup	10/5/21	16/8/21	C	Toxic	No	459	50	17	33	31	19.6%	34.0%
Lake Muir	23/8/21	29/10/21	C	Toxic	No	464	5	0	5	0	1.9%	0.0%
Tone-Meribup	09/2/22	26/5/22	C	Toxic	No	586	51	18	33	0	11.6%	35.3%
Tone-Meribup	30/3/22	26/5/22	C	Toxic	Audio	214	30	7	23	1	21.5%	23.3%
Central Perup	26/10/22	5/3/23	S	Photo-only	No	533	2	1	1	0	0.8%	50.0%
Central Perup	5/1/23	28/3/23	S	Toxic	No	645	34	14	20	0	10.1%	41.2%
Conservative Photo-only Subtotal						**675**	**98**	**38**	**60**	**7**	**18.8%**	**38.8%**
Conservative Photo-only Subtotal						**1723**	**136**	**42**	**94**	**32**	**12.4%**	**30.9%**
Conservative Toxic Subtotal						**533**	**2**	**1**	**1**	**0**	**0.8%**	**50.0%**
Standard Toxic Subtotal						**645**	**34**	**14**	**20**	**0**	**10.1%**	**41.2%**

Grey shaded rows indicate the four main experimental toxic trials.

Table 16. Comparison of the detection and targeting rates by Felixers of selected fauna when the default audio lure was active and not active between 18:00 and 06:00 hr. Results combined from two sites, North Perup and Tone-Meribup, 4 Felixers at each. n = number of detections, p = p-value from a one tailed paired t-test (7 degrees of freedom).

Species		Detection rate lure on (%)	Detection rate lure off (%)	n	p	Target rate lure on (%)	Target rate lure off (%)	n	p
Felis catus	Feral Cat	4	3	8	0.31	1	2	4	0.23
Vulpes vulpes	Red Fox	5	13	29	0.10	2	6	10	0.10
Bettongia penicillata	Woylie	34	32	49	0.39				
Dasyurus geoffroii	Chuditch	7	17	19	0.13				
Isoodon fusciventer	Quenda	10	10	43	0.41				
Macropus fuliginosus	Yongka	8	6	15	0.33				
Notamacropus eugenii	Tammar	10	11	21	0.40				
	Owl spp.	8	0	11	0.09				

3.3.4 Felixer effectiveness

On average between 44% (SD=9.6) and 58% (SD = 15.8) of the feral cat individuals detected by the Felixers were ultimately targeted by the Felixer, during the three main field trials conducted in toxic arming status with conservative targeting mode (*Table 17*). The one experimental toxic trial in standard targeting mode (Central Perup) targeted 100% of the feral cat individuals (n=5) detected by the Felixers. Data from the camera array indicated that another individual feral cat was within proximity (<20m) of a Felixer but did not enter the detection zone in front of the Felixer and was therefore not detected or targeted by the Felixer in both the trial at Lake Muir and Central Perup, and another two individual feral cats were in the vicinity but not detected during the trial at North Perup. It was more difficult to quantify the maximum number of individuals detected in front of the Felixers at Tone-Meribup with any confidence because there were a greater number of detections of unidentifiable black cats, however it was less than 34 individuals.

While many of the targeted individuals were large adult males, there were insufficient quality images to determine the gender of all targeted individuals, so it was not possible to quantify the proportion of targeted animals that were large males.

Table 17. Felixer effectiveness (proportion of individuals detected by the Felixers that were ultimately targeted by the Felixer) for feral cats during the four experimental toxic trials in the Upper Warren region and Lake Muir, Western Australia.

Site	**Targeting mode**	**Felixer effort (nights)**	**Number detections at site**	**Number individuals detected (range)**	**Number individuals targeted**	**% individuals targeted (range)**
North Perup	Conservative	459	19	6–8	4	50–67
Lake Muir	Conservative	464	27	10–12	4	33–40
Tone-Meribup	Conservative	800	53	25–34	17	50–68
Central Perup	Standard	645	16	5	5	100

3.3.5 False negative identification of target species

Many of the detections of feral cats and foxes that were not identified as a target were due to the animals moving too quickly through the Felixer detection zone (11.2% and 27.0%, respectively; *Table 18*) or in the case of feral cats the information from the bottom sensor was not consistent with the algorithms used to discriminate a target (19.4%). Animals moving too slowly through the Felixer detection zone were more common for feral cats (8.2%) than foxes (4.7%). This typically occurred when the individual was curious and investigated either the Felixer or the area opposite the Felixer or was noticeably startled. Triggering of only one of the left or right sensors was also relatively common for feral cats (9.0%) and foxes (17.3%; *Table 18*).

During the first trial at North Perup it is likely that the close proximity of the cameras to the Felixers reduced the targeting rate of feral cats. At North Perup, a total of nine (45%) of the false negative target events for feral cats was due to a 'slow' determination by the Felixer. We think this is due to the feral cats detecting or being distracted by the cameras, which may make a sound that may be perceivable when the camera is activated. In the subsequent trials the cameras were moved further away from the Felixers, which resulted in only two (3.3 % of 60 false detections) additional 'slow' determinations for subsequent feral cat detections by Felixers. Other changes made after the initial trial at North Perup that may have also contributed to the reduction in the rate of 'slow' determinations included further improvements to the concealment of the Felixer, minimisation of site disturbance and an increased use of pre-existing backdrops to the Felixer detection zone.

Table 18. Summary of the Felixer determinations based on sensor algorithms of feral cat and fox detection events, detailing the reasons why an animal was or was not identified as a target, based on 134 and 278 detections of feral cat and fox, respectively.

Logged detection (object)	Description	Cat Conservative	Cat Standard	Fox Conservative	Fox Standard
BOTTOM	ONLY BOTTOM sensor triggered.	6.7%	3.8%	0.0%	2.6%
FAST	A target detection where the calculated speed of the object is faster than the maximum expected cat/fox speed. Firing on fast targets is not recommended due to low chance of a solid hit.	14.3%	27.2%	0.0%	25.6%
LEFT	Only Left sensor triggered	2.9%	6.7%	10.3%	12.8%
MULTI	Both left and right sensor triggered but distance between them more than default 30cm.	5.7%	7.1%	0.0%	2.6%
RIGHT	Only right sensor triggered	4.8%	10.0%	3.4%	7.7%
SLOW	A target detection where the calculated speed of the object is slower than the safety threshold. This is typically to manage grazing kangaroos.	10.5%	5.4%	0.0%	0.0%
TOP	TOP blocking sensor triggered. This ignores all other sensor readings.	1.0%	2.5%	0.0%	0.0%
NO BOTTOM	The bottom sensor was not triggered at all. The algorithm expects to see motion across the bottom indicating that cat/fox legs have walked through it	16.2%	3.8%	31.0%	10.3%
TARGET FIRE FAULT		1.9%	0.0%	0.0%	0.0%
TARGET_PHOTO ONLY	Both left and right triggered, distance ≤ default 30cm	12.4%	16.3%	37.9%	2.6%
TARGET_FIRE TOXIC	Both left and right triggered, distance ≤ default 30cm	23.8%	17.2%	17.2%	35.9%

3.4 Camera arrays

A total of 90,147 camera nights (not including nights lost due to malfunction) resulted in 6,099 independent detections of feral cats and 5,949 detections of foxes across the four main trial sites (*Table 19*). Quantifying the number of individual feral cats at each site was difficult given that more than 50% of detections were of indistinguishable black cats. Nonetheless, the conservative minimum number of feral cat individuals (i.e., number of distinguishable cats + 1) detected on the camera arrays prior to the deployment of Felixers in toxic arming mode were 7, 13, 19 and 4 for North Perup, Lake Muir, Tone-Meribup and Central Perup, respectively (note trap effort varied between sites; see Table 19). A summary of the detections of other selected species is provided in Appendix 2.

Table 19. Total independent detections of feral cats and foxes by the camera arrays at each of the four main experimental field trial sites.

Site	Trial/s	Trap effort before*	Trap effort during*	Trap effort after*	Total trap effort	Cats	Foxes
North Perup	1	5842	4822	7352	18,016	404	1529
Tone-Meribup	1,2,3	18581	5128	3030	26,739	2331	1428
Lake Muir	2,3,4	6859	3385	26996	37,240	3246	2146
Central Perup	4	1915	3999	2238	8,152	118	828
Total					**90,147**	**6099**	**5949**

*Functional remote sensor camera trap effort (trap nights) before, during and after the toxic deployment of Felixers

3.5 Effects of Felixer targeting of feral cats

Seven identifiable individual feral cats were targeted by the Felixers with at least two detections from the camera array prior to being targeted. Only one of these seven feral cats was detected after being targeted by the Felixers. The probability that these six individuals were still present at the study site but were not detected varied from 0.41 to 1.25×10^{-12} (*Table 20*). The one individual that was detected again after being targeted was hit in the face with the gel from the Felixer where all other feral cats targeted were hit on the body.

Table 20. Detection probabilities for identifiable individual feral cats that were targeted by the Felixers and the probability that these feral cats were still alive and present at the study site, but were not detected after being targeted.

		Before targeting			After targeting	
Site	**Individual**	**Monitoring days**	**Number of days detected**	**Daily detection probability**	**Monitoring days**	**Probability of presence without detection**
Tone-Meribup	Ginger	402	33	0.082	121	3.15×10^{-5}
Tone-Meribup	Mer09	392	74	0.189	131	1.25×10^{-12}
Tone-Meribup	Target	412	25	0.061	111	0.0010
Tone-Meribup	Mer15	210	2	0.010	93	0.41
Tone-Meribup	Mer12	348	61	0.175	40	0.0004
Central Perup	CP Tabby04	39	5	0.128	70	0.0001

Across the four trials the change in the 28-day mean for feral cat detections before and after the Felixers were deployed in toxic arming status varied between a 49% reduction and a 4% increase (*Table 21*). Interactions between treatment and period (before and after Felixer deployment) were only significant in toxic trial 1 (p=0.019, *Table 21*, *Figure 6*).

Table 21. Change in mean daily feral cat detections at Felixer treatment and reference sites over 28 days before and after Felixers were deployed in toxic arming status for the four experimental field trials.

		Before		**After**		**% change**
	Site	**Mean**	**Std Err**	**Mean**	**Std Err**	
Trial 1	Felixer (North Perup)	1.43	0.22	1.10	0.22	-23%
	Reference (Tone-Meribup)	3.43	0.44	4.92	0.54	+43%
Trial 2	Felixer (Lake Muir)	4.29	0.39	4.43	0.39	+3%
	Reference (Tone-Meribup)	4.08	0.48	4.86	0.49	+19%
Trial 3	Felixer (Tone-Meribup)	4.59	0.45	2.32	0.37	-49%
	Reference (Lake Muir)	5.28	0.48	2.94	0.38	-44%
Trial 4	Felixer (Central Perup)	0.82	0.24	0.86	0.23	+4%
	Reference (Lake Muir)	5.01	0.38	4.08	0.42	-18%

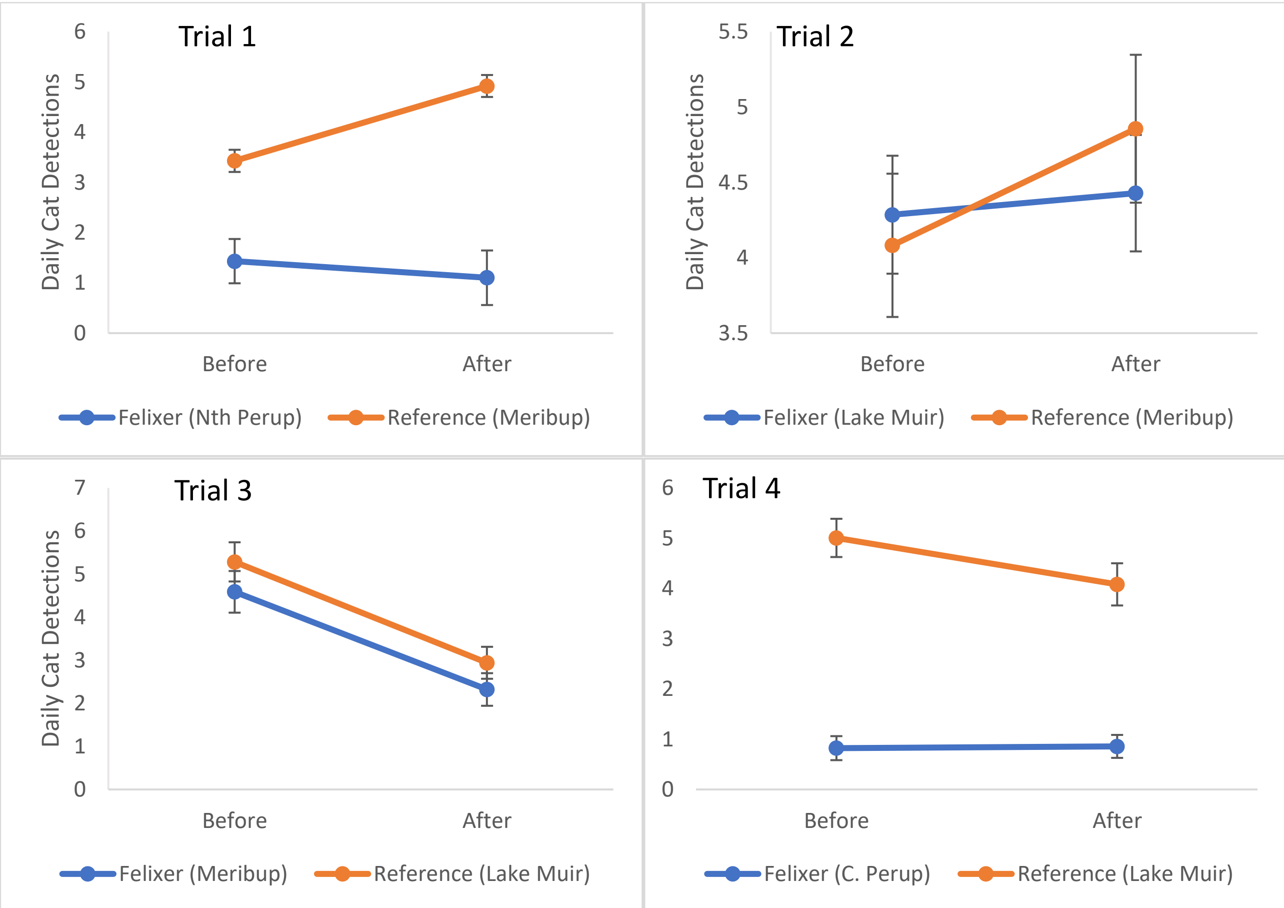


Figure 6. Changes in feral cat detection rates (mean ± standard error) over 28 days before and after Felixers were deployed in toxic arming status for the four experimental field trials.

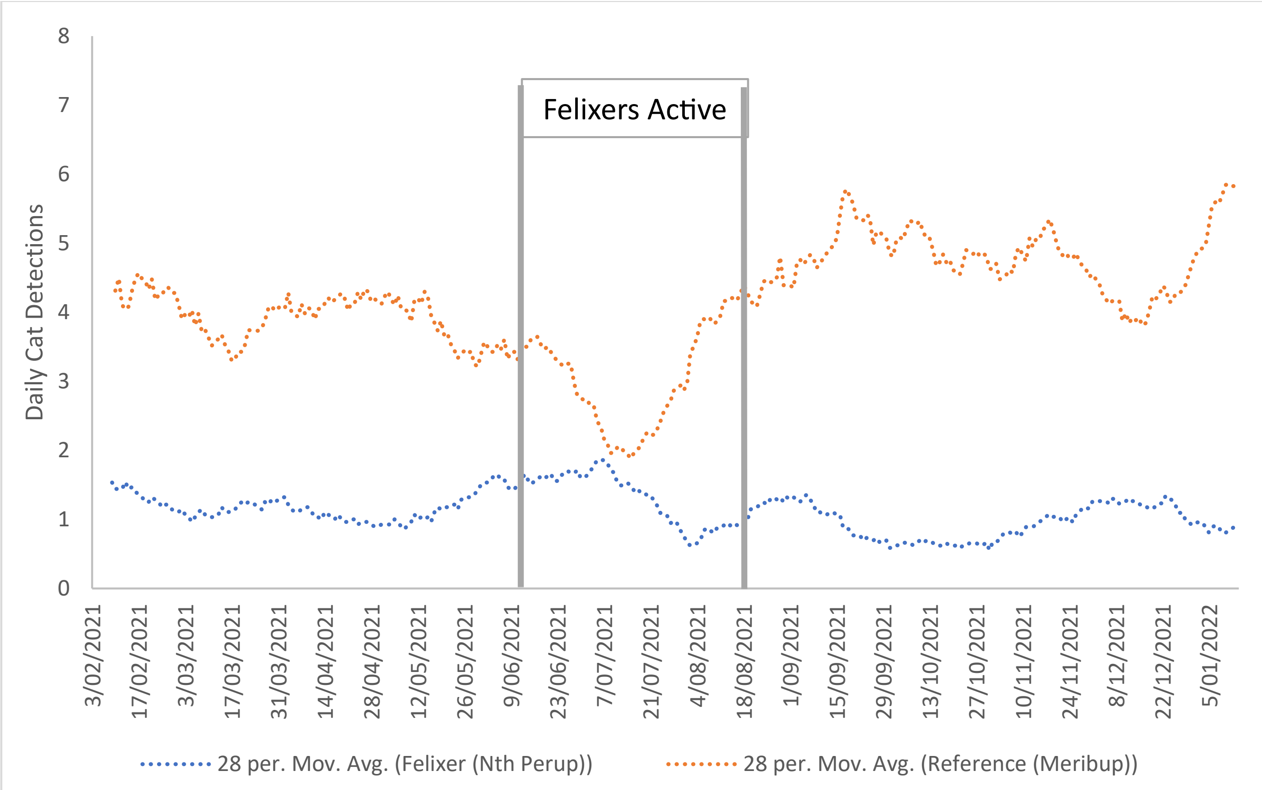


Figure 7. Changes in detection rates of feral cats at the Felixer treatment and reference sites before, during, and after Felixer deployment in toxic arming status in experimental trial 1.

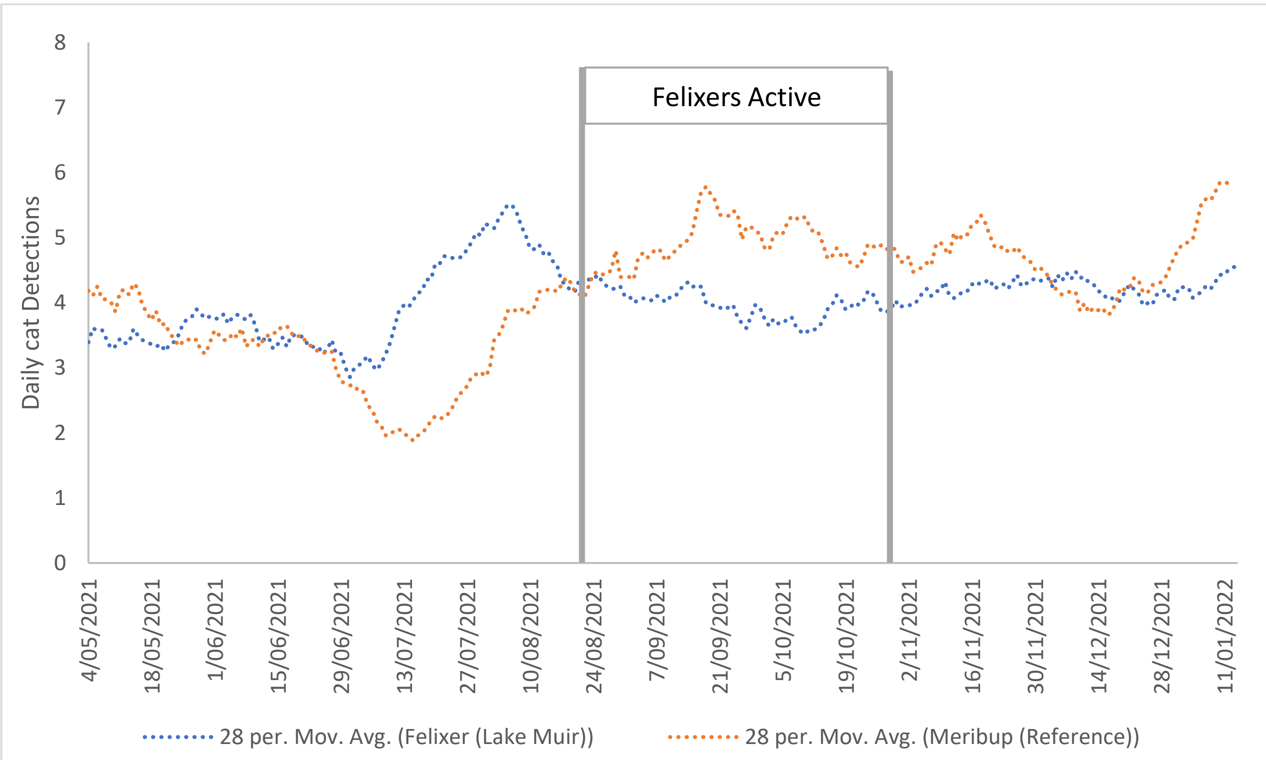


Figure 8. Changes in detection rates of feral cats at the Felixer treatment and reference sites before, during, and after Felixer deployment in toxic arming status in experimental trial 2.

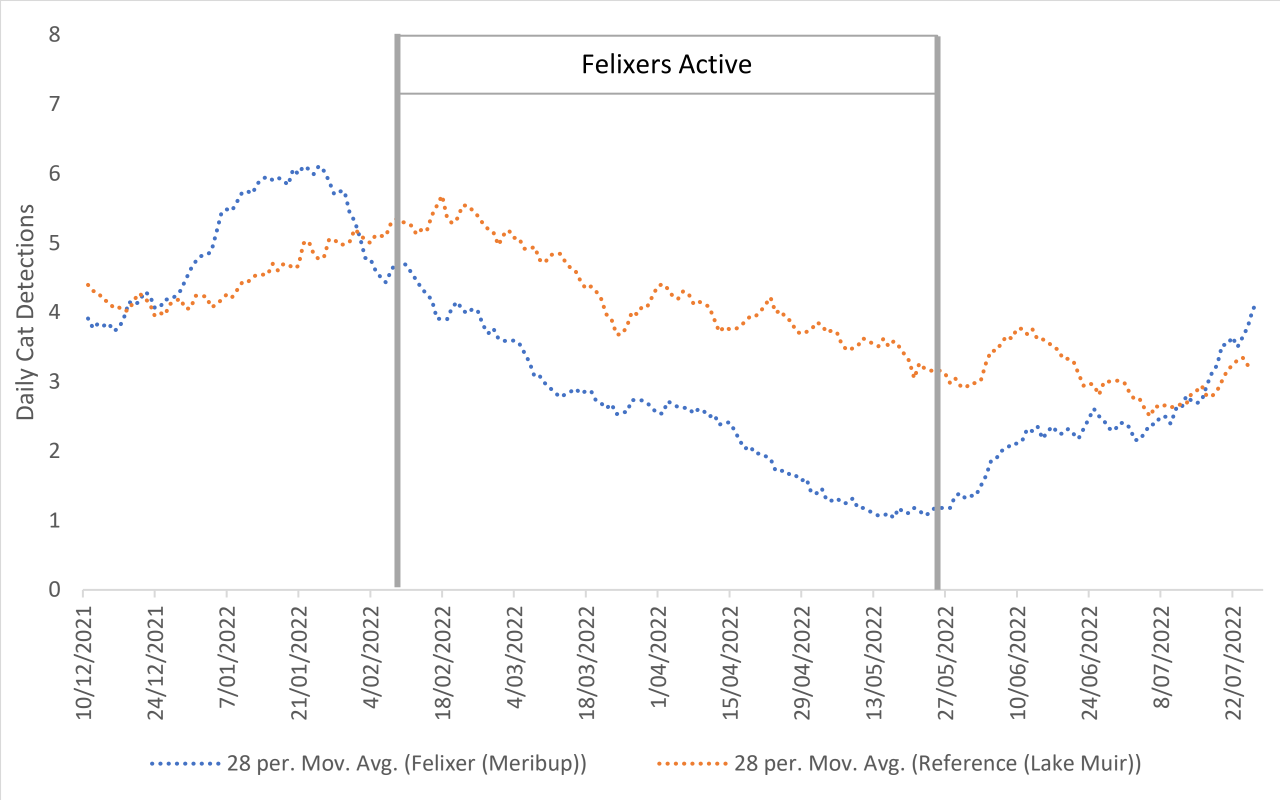


Figure 9. Changes in detection rates of feral cats at the Felixer treatment and reference sites before, during, and after Felixer deployment in toxic arming status in experimental trial 3.

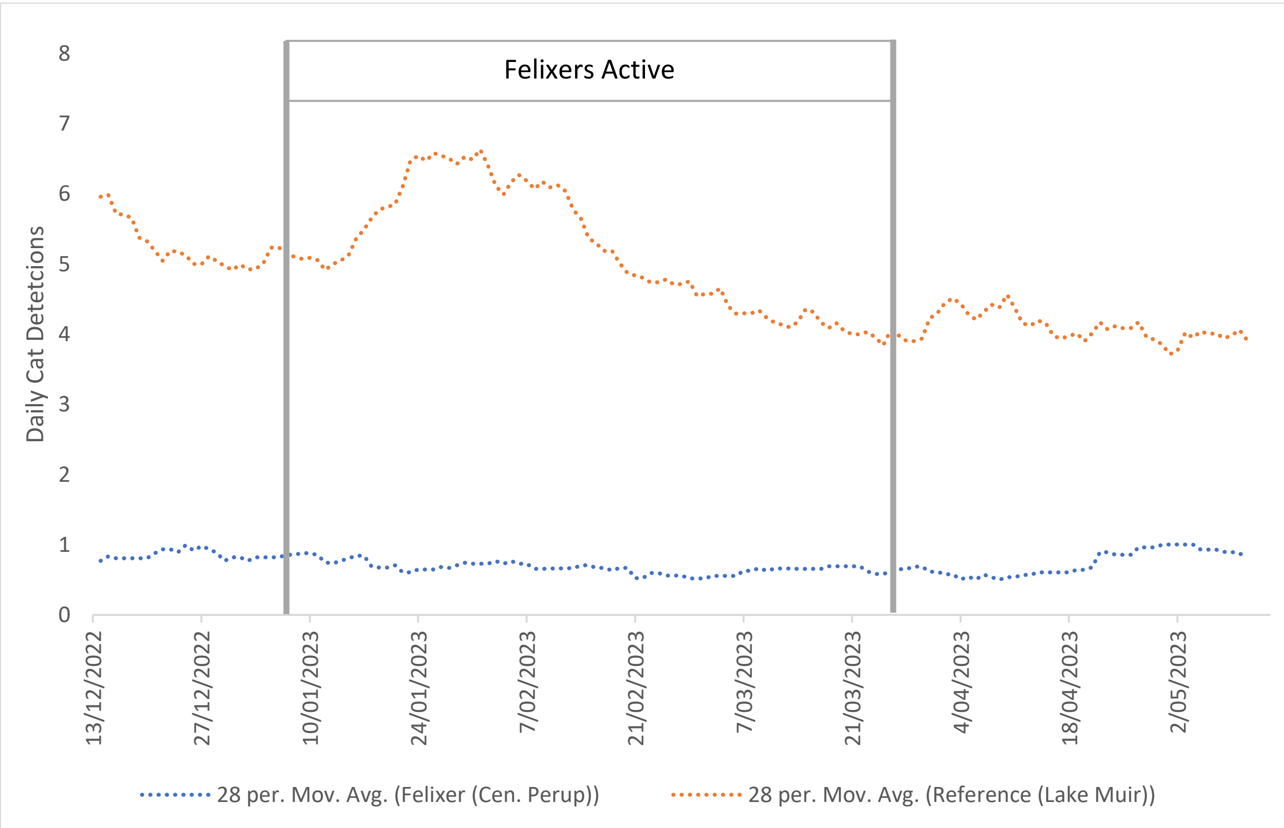


Figure 10. Changes in detection rates of feral cats at the Felixer treatment and reference sites before, during, and after Felixer deployment in toxic arming status in experimental trial 4.

3.6 Effects of Felixer targeting on foxes

Changes in the detections rate for foxes before and after Felixers were deployed did not show any consistent pattern across the four trials. At Felixer locations changes in fox detections varied between a 24% reduction and 381% increase, while at the reference site the change in detections ranged from a 28% reduction to 100% increase (*Table 22*, *Figure 11*). Significant interactions were found between site treatment, and period (before and after Felixer deployment in toxic arming status) in Trials 2 and 4, however the change in fox detections rates increased at Felixer sites rather than decreasing as expected.

Table 22. Changes in mean daily fox detections over 28 days before and after Felixers were deployed in toxic arming status for the four experimental field trials.

		Before		After		
Trial	**Site**	**Mean**	**Std Err**	**Mean**	**Std Err**	**% change**
Trial 1	Felixer (North Perup)	5.61	0.17	4.25	0.47	-24%
	Reference (Tone-Meribup)	3.04	0.12	2.20	0.27	-28%
Trial 2	Felixer (Lake Muir)	2.04	0.16	2.39	0.36	+18%
	Reference (Tone-Meribup)	2.71	0.11	0.95	0.19	-65%
Trial 3	Felixer (Tone-Meribup)	0.97	0.19	4.68	0.45	+381%
	Reference (Lake Muir)	1.76	0.15	3.53	0.45	+100%
Trial 4	Felixer (Central Perup)	1.85	0.34	8.43	0.83	+354%
	Reference (Lake Muir)	2.71	0.19	2.32	0.28	-15%

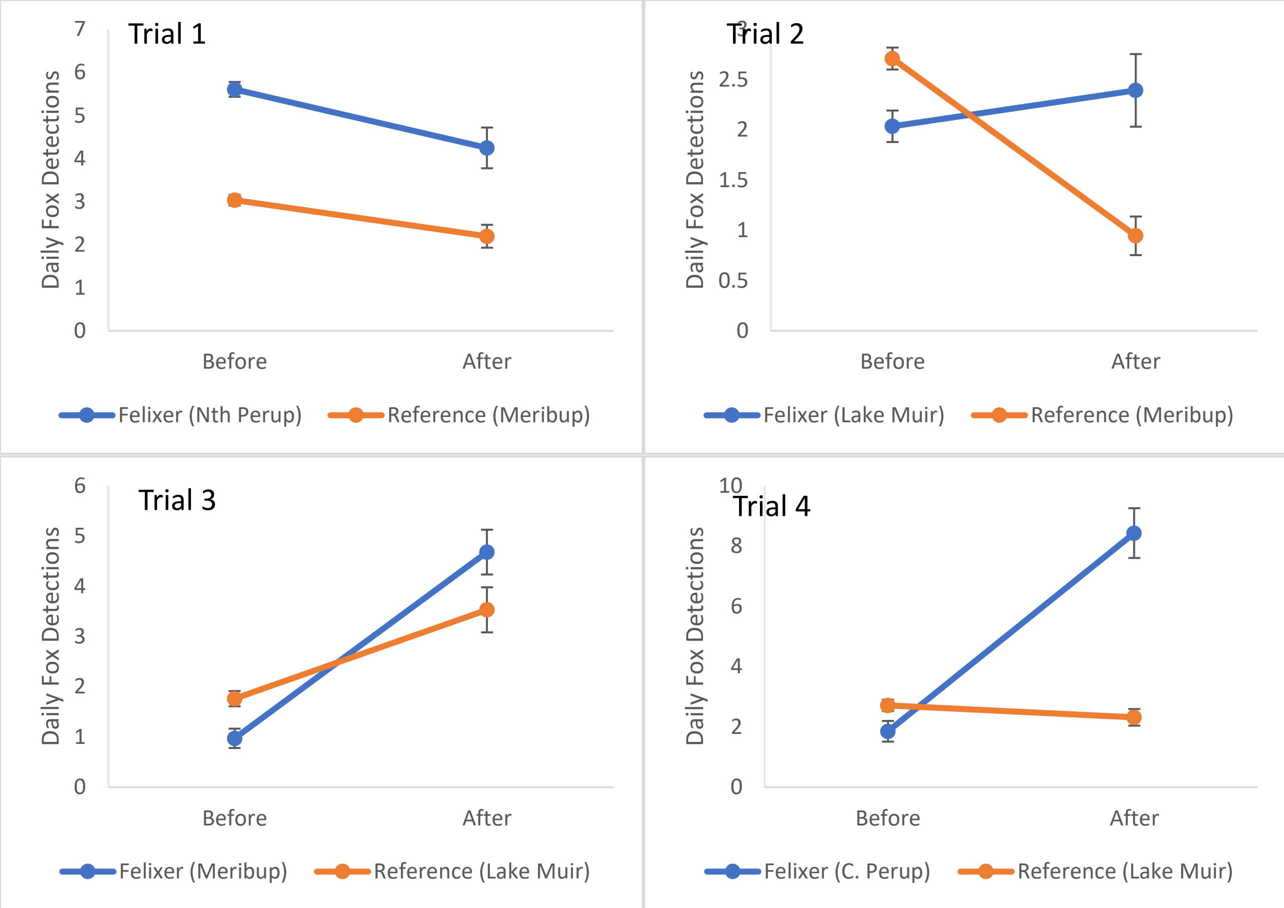


Figure 11. Changes in daily fox detection rates (mean ± standard error) over 28 days before and after Felixers were deployed in toxic arming status for the four experimental field trials.

3.7 Spatial Optimisation of Felixer Placement

None of the spatial variables tested were strongly associated with feral cat detections consistently across all three sites. The best fitting model tested involving all three sites combined, was one with season as the only factor (*Table 23*); this model had a conditional R^2 value of 0.059. Significantly more feral cats were detected in Bunuru (February to March) compared with Kambarang (October to November) and Birak (December to January, *Table 24*).

Table 23. Model fit results from generalized linear mixed models assessing the number of feral cat detections across North Perup, Tone-Meribup and Lake Muir.

Model (Fixed Factors)	AIC	LogLikelihood	ΔAIC
Season	5477.7	-2729.8	0
Elevation*Season	5481.2	-2725.6	3.5
Topographic wetness* Season	5482.4	-2726.2	4.7
Distance to Hydro*Season	5482.8	-2726.4	5.1
Fuel Age*Season	5483.3	-2726.7	5.6
Distance to Ag Land*Season	5487.6	-2728.8	9.9
Topographic wetness	5488.8	-2739.4	11.1
Null model	5490.2	-2741.1	12.5
Topographic wetness*Fuel Age*Season	5495.3	-2720.7	17.6
Topographic wetness*Track Type*Season	5501.3	-2723.6	23.6
Topographic Wetness*Distance to Ag Land*Season	5503.3	-2724.6	25.6

Table 24. Fixed effect estimates for the best fitting season only model.

Predictors	Estimates	CI	p
(Intercept)	1.45	1.21–1.73	**<0.001**
Season [Djeran]	0.99	0.97–1.00	0.092
Season [Makaru]	0.99	0.98–1.01	0.252
Season [Djilba]	1.01	0.99–1.02	0.49
Season [Kambarang]	0.97	0.96–0.99	**<0.001**
Season [Birak]	0.98	0.97–1.00	**0.028**

When the data for each site was analysed separately feral cat detections at North Perup were associated with distance to agricultural land, interacting with season where the negative relationship between distance to agricultural land and detections was strongest in Makaru (June-July) and weakest in Bunuru (February-March, *Table 25* and *Table 26*, *Figure 12* R^2=0.098).

Table 25. Generlized linear model fitting results for daily feral cat detections at the North Perup site.

Model	AIC	LogLikelihood	ΔAIC
Distance to Ag Land*Season	825.9	-399.0	
Null model (Site Only)	827.7	-410.9	1.8
Season	829.2	-406.6	3.3
Topographic wetness	829.6	-410.8	3.7
Distance to Hydro*Season	832.5	-402.2	6.6
Elevation*Season	833.2	-402.6	7.3
Topographic wetness*Season	838.4	-405.2	12.5
Fuel Age*Season	838.6	-405.3	12.7
Topographic wetness*Track Type*Season	842.9	-395.5	17

Table 26. Model results for the distance to agricultural land interacting with season as fixed factors and camera site as a random factor.

Predictors	**Estimate**	**CI**	**p**
(Intercept)	1.82	1.67–1.98	**<0.001**
Distance to Ag Land	1	0.92–1.08	0.988
Season [Djeran]	0.99	0.93–1.05	0.776
Season [Makaru]	0.97	0.91–1.03	0.265
Season [Djilba]	0.98	0.92–1.04	0.535
Season [Kambarang]	1.01	0.94–1.08	0.804
Season [Birak]	1.06	0.99–1.14	0.114
Distance to Ag × Season [Djeran]	1.01	0.95–1.07	0.695
Distance to Ag × Season [Makaru]	1.1	1.03–1.17	**0.002**
Distance to Ag × Season [Djilba]	1.05	0.99–1.11	0.136
Distance to Ag × Season [Kambarang]	1.05	0.99–1.12	0.129
Distance to Ag × Season [Birak]	1.08	1.00–1.16	**0.046**

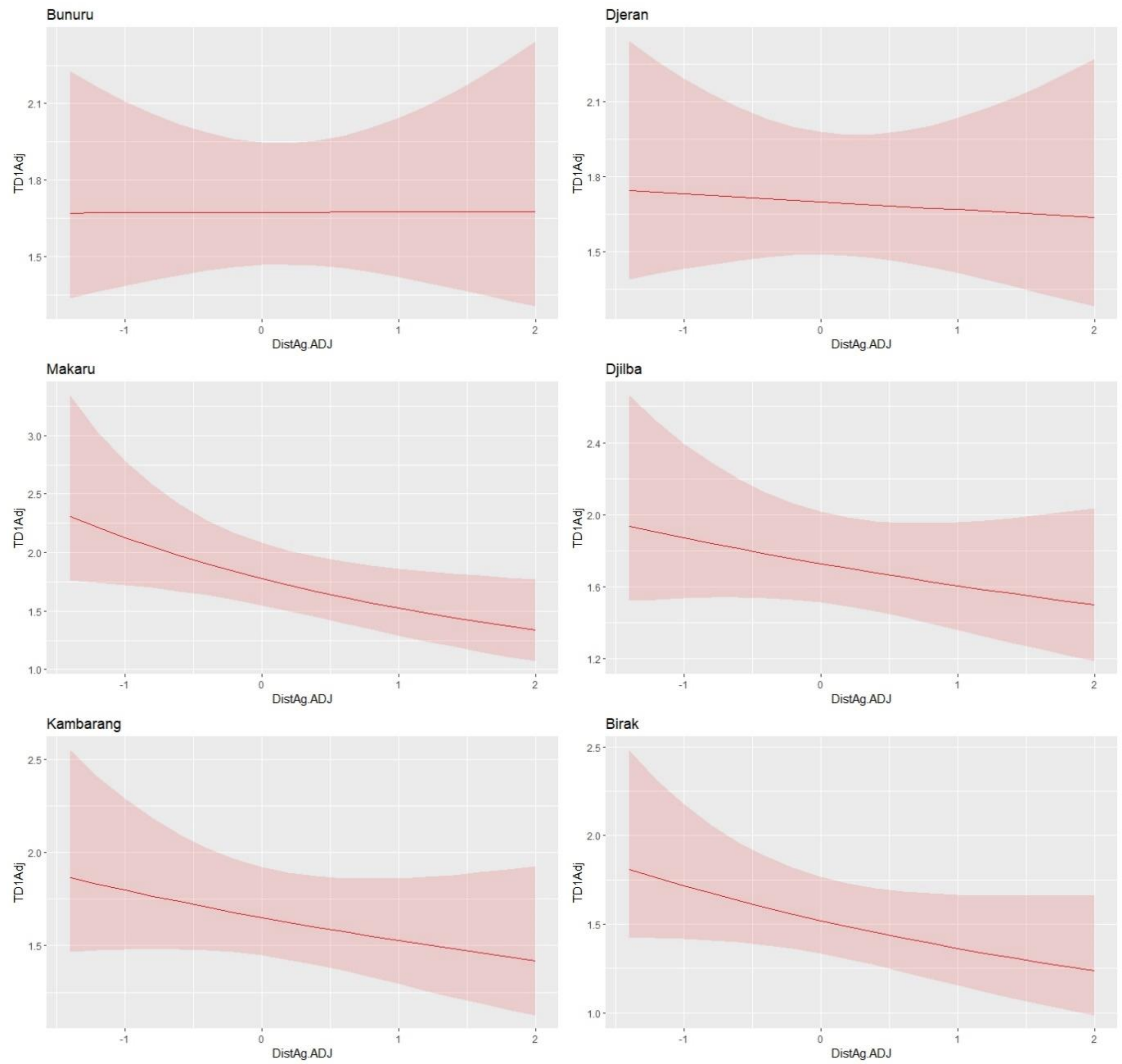


Figure 12. Relationship between distance to agricultural land and feral cat detections at the North Perup Site over the 6 noongar seasons.

At Tone-Meribup detections were positively associated with topographic wetness (R^2=0.043) and negatively correlated with elevation (R^2=0.042) both interacting with season, although these associations were weak with a season only model having some support from the data (ΔAIC=1.2, *Table 27* and *Table 28*). At the Lake Muir site, detections were most negatively associated with distance to hydrographic features (*Table 29* and *Table 30*), although this model was only able to explain 1.7% of the variation in feral cat detections.

Table 27. Generalized linear model fit results for daily feral cat detections at the Tone-Meribup site.

Model	AIC	LogLikelihood	ΔAIC
Topographic wetness*Season	1236.7	-604.3	
Elevation*Season	1237.4	-604.7	0.7
Season	1237.9	-610.9	1.2
Distance to Ag Land*Season	1238.8	-605.4	2.1
Distance to Hydro*Season	1240.6	-606.3	3.9
Fuel Age*Season	1240.6	-606.3	3.9
Topographic wetness*Fuel Age*Season	1245.4	-596.7	8.7
Topographic wetness	1248.8	-620.4	12.1
Topographic Wetness*Distance to Ag * Season	1249.4	-598.7	12.7
Topographic wetness*Track Type* Season	1251.4	-599.7	14.7
Null model (Site Only)	1253.4	-623.7	16.7

Table 28. Coefficients for model containing topographic wetness interacting with season to predict feral cat detections at Tone-Meribup site.

Predictors	Estimates	CI	p
(Intercept)	1.33	1.25–1.41	**<0.001**
Topographic Wetness	0.94	0.89–0.99	**0.019**
Season [Djeran]	1.02	0.97–1.06	0.466
Season [Makaru]	1.07	1.01–1.12	**0.014**
Season [Djilba]	0.98	0.95–1.02	0.314
Season [Kambarang]	0.99	0.95–1.03	0.744
Season [Birak]	0.97	0.94–1.00	0.076
Topographic Wetness × Season [Djeran]	1.03	0.98–1.07	0.216
Topographic Wetness × Season [Makaru]	1.00	0.95–1.04	0.840
Topographic Wetness × Season [Djilba]	0.99	0.96–1.03	0.671
Topographic Wetness × Season [Kambarang]	0.98	0.95–1.01	0.264
Topographic Wetness × Season [Birak]	1.01	0.97–1.04	0.716

Table 29. Generalized linear model fit results for daily cat detections at the Lake Muir site.

Model	AIC	LogLikelihood	ΔAIC
Distance to Hydro *Season	3325.7	-1648.8	
Season	3330.7	-1657.4	5.0
Fuel Age * Season	3337.8	-1654.9	12.1
Topographic wetness * Season	3338.4	-1655.2	12.7
Elevation *Season	3339.3	-1655.6	13.6
Null model (Site Only)	3351.6	-1672.8	25.9
Topographic wetness	3353.0	-1672.5	27.3
Topographic wetness*Fuel Age*Season	3353.7	-1650.8	28.0
Topographic wetness*Track Type* Season	3354.9	-1651.4	29.2

Table 30. Coefficients for model with distance to hydrology interacting with season to predict feral cat detections at Lake Muir site.

Predictors	Estimate	CI	p
(Intercept)	1.12	1.07–1.17	**<0.001**
Distance to Hydro	1	1.00–1.00	**0.001**
Season [Djeran]	0.98	0.95–1.01	0.274
Season [Makaru]	0.99	0.96–1.02	0.369
Season [Djilba]	1.02	0.98–1.06	0.264
Season [Kambarang]	0.98	0.95–1.01	0.138
Season [Birak]	0.98	0.95–1.02	0.322
Distance to Hydro × Season [Djeran]	1	1.00–1.00	0.753
Distance to Hydro × Season [Makaru]	1	1.00–1.00	0.655
Distance to Hydro × Season [Djilba]	1	1.00–1.00	0.84
Distance to Hydro × Season [Kambarang]	1	1.00–1.00	0.457
Distance to Hydro × Season [Birak]	1	1.00–1.00	0.85

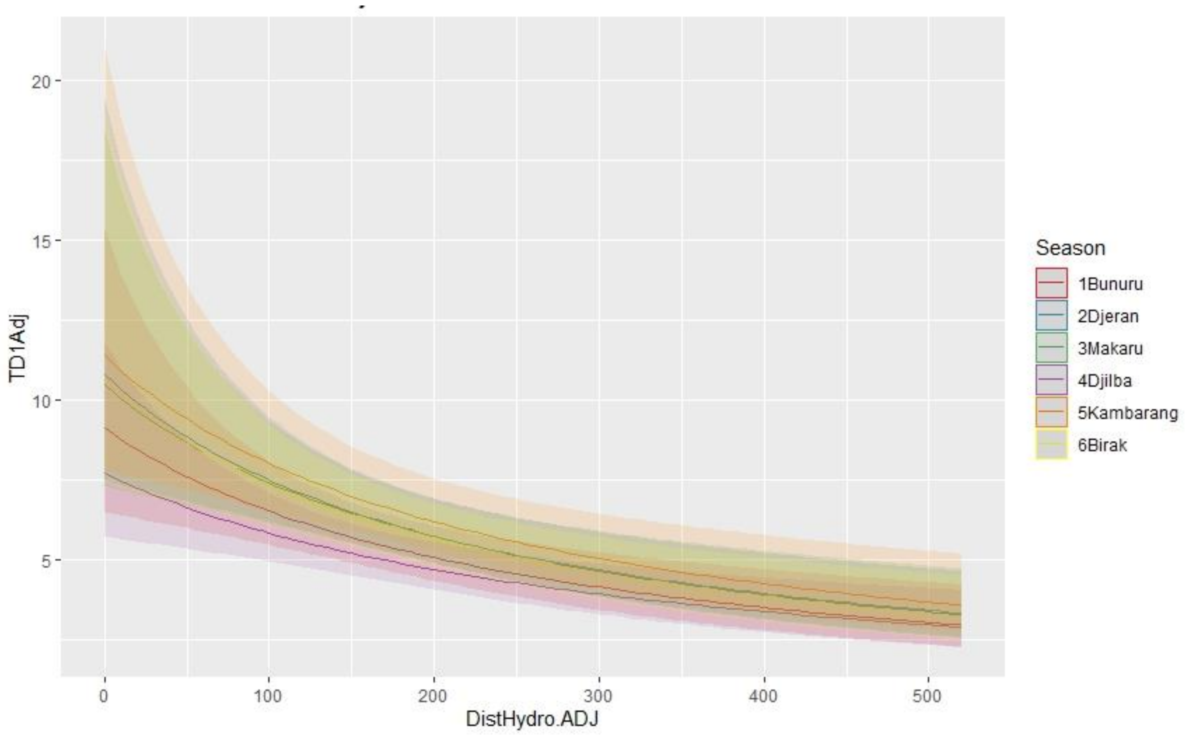


Figure 13. Relationship between feral cat detections and distance to hydrographic features across different seasons at Lake Muir site.

3.8 Circadian detection patterns for the feral cat and fox

3.8.1 Circadian patterns from the Felixers

Most feral cat detections (81%) and target events (89%) were between 1700 hrs and 0359 hrs (*Figure 14*). Conversely, 18% of detections and 11% or target events were between 06:00 and 17:59 hrs (when Felixers may hibernate, when power supply is low). While the proportion of fox detections (77%) and target events (78%) between 1700 hrs and 0359 hrs were similar to that of feral cats, foxes remained relatively more active than feral cats between 0400 hrs to 0759 hrs and were not detected at all between 1000 hrs sand 1559 hrs (*Figure 15*).

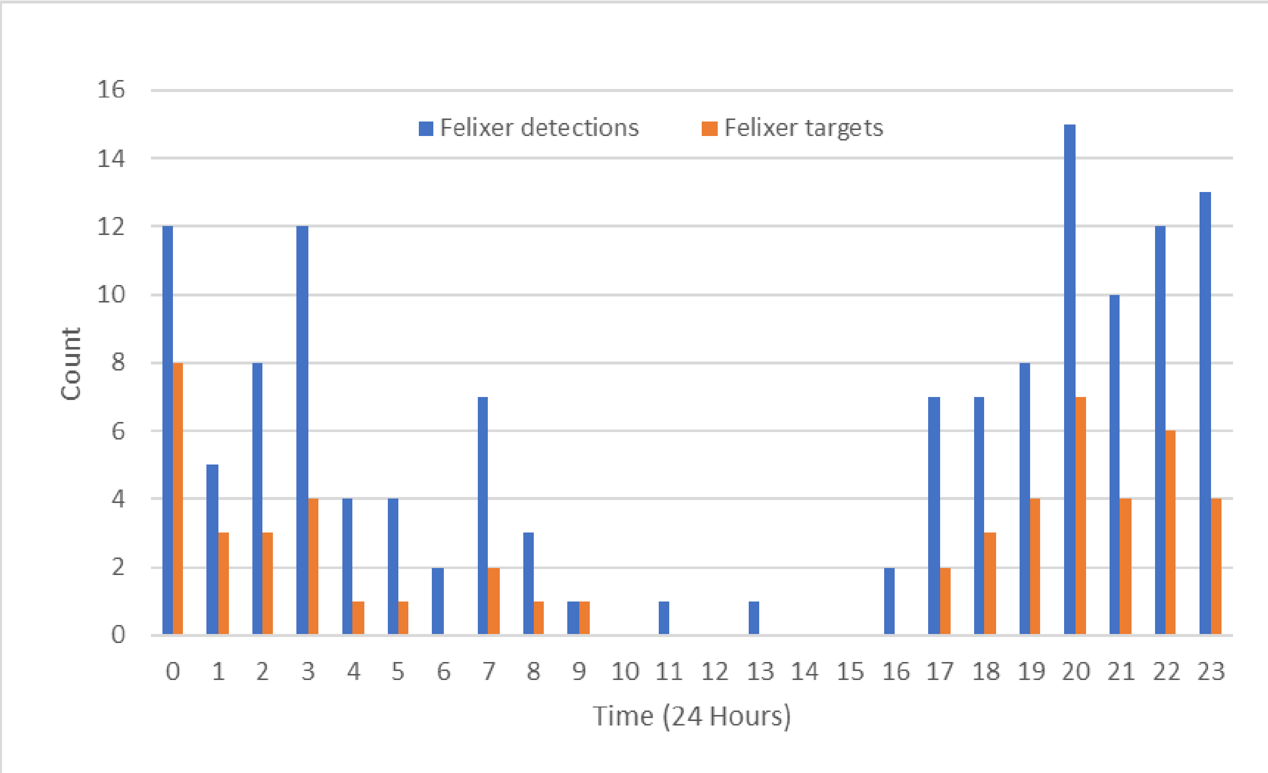


Figure 14. The circadian pattern of feral cat detections (n=134) and target events (n=54) by Felixers across all four experimental field trials of Felixers at Perup and Lake Muir, Western Australia. Note this includes all Felixer data, not accounting for temporal differences in survey effort due to some Felixers periodically being in hybernation.

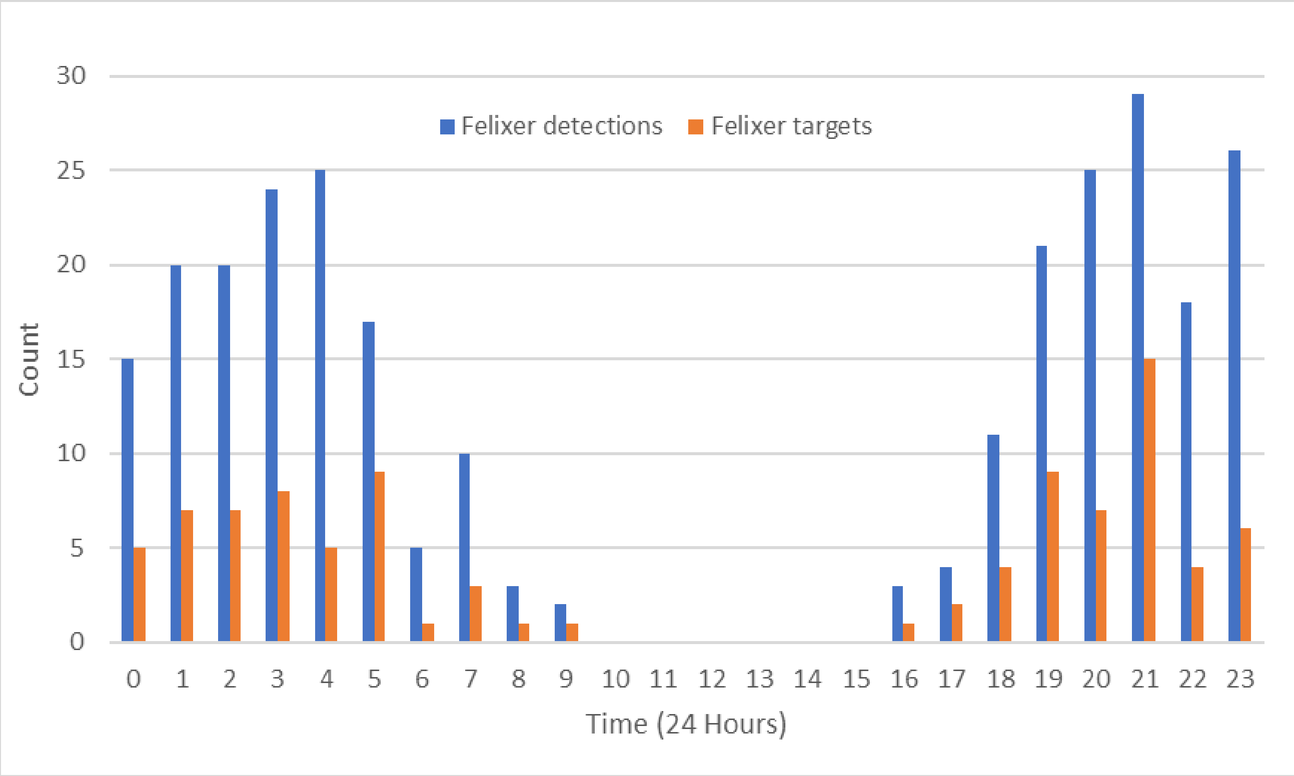


Figure 15. The circadian pattern of fox detections and target events by Felixers across all four experimental field trials of Felixers at Perup and Lake Muir, Western Australia. Note this includes all Felixer data, not accounting for temporal differences in survey effor effort due to some Felixers periodically being in hybernation.

3.8.2 Circadian patterns from the camera arrays

In general, feral cats and foxes showed similar circadian patterns of detection with feral cat detection rates peaking between 1900 hrs and 0159 hrs before gradually reducing over the rest of the night. Fox activity had a much less pronounced peak between 2000 hrs and 2259 hrs and then slowly reduced over the rest of the night. Relatively few feral cat and fox detections were between the daylight hours of 0800 hrs and 1700 hrs (7.6% and 3.8%, respectively; *Figure 16*).

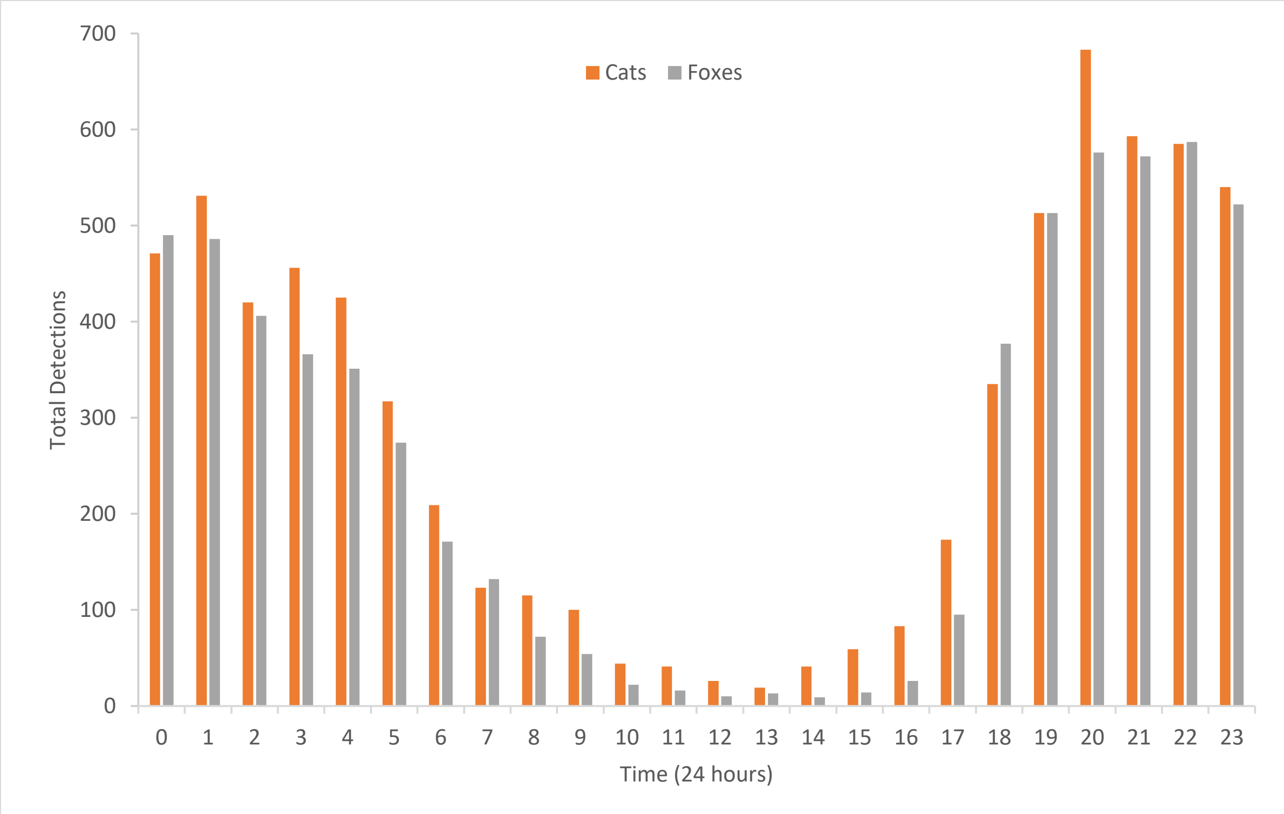


Figure 16. The circadian pattern of detections of feral cats and foxes from the camera arrays associated with the four experimental field trials combined.

The circadian pattern of feral cat activity showed some variation between sites, with North Perup and Central Perup showing different patterns to each other and the other two sites. The feral cats at North Perup had an earlier increase in activity between 1900 hrs and 2000 hrs which was not observed at the other sites. The feral cats at Central Perup also had a second peak of activity each night between 0200 hrs and 0500 hrs which was not present at the other sites (*Figure 17*).

The temporal pattern of fox detections was much more consistent across the four study sites with all four sites showing the same pattern of a peak of activity between 1900h and 2200h before reducing across the rest of the night (*Figure 18*).

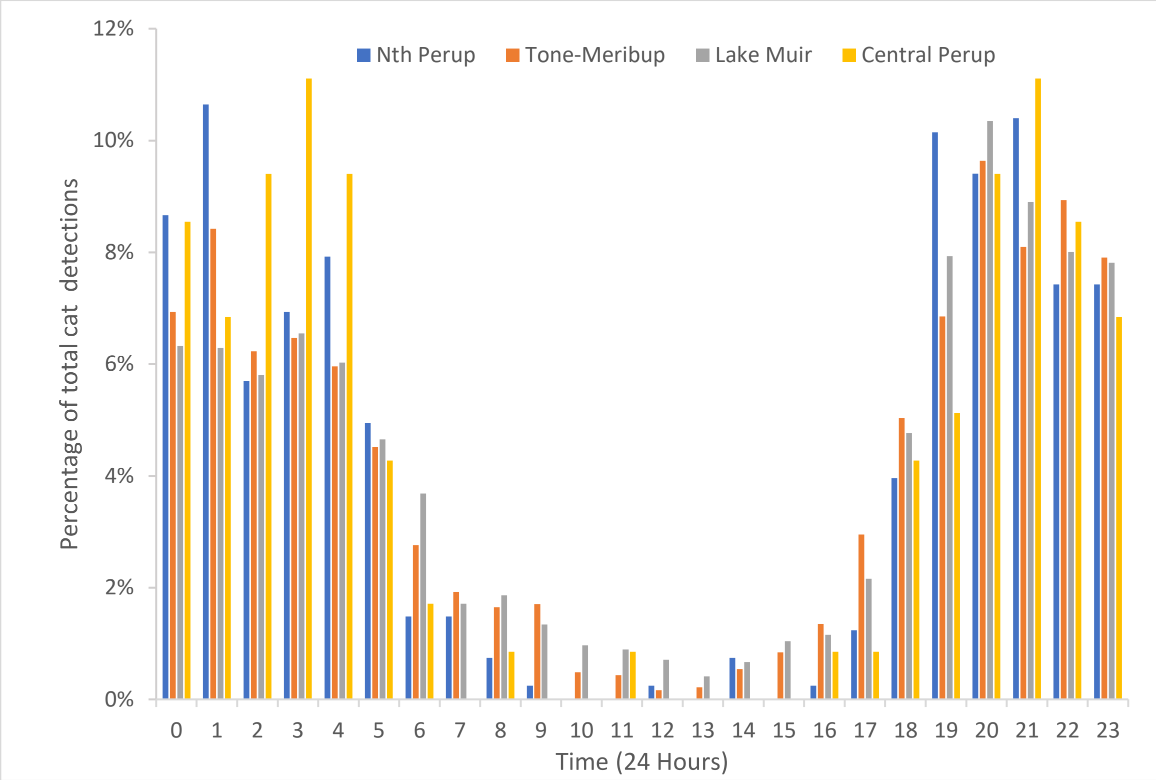


Figure 17. Circadian patterns of feral cat detections from the camera arrays associated with the four experimental field trials.

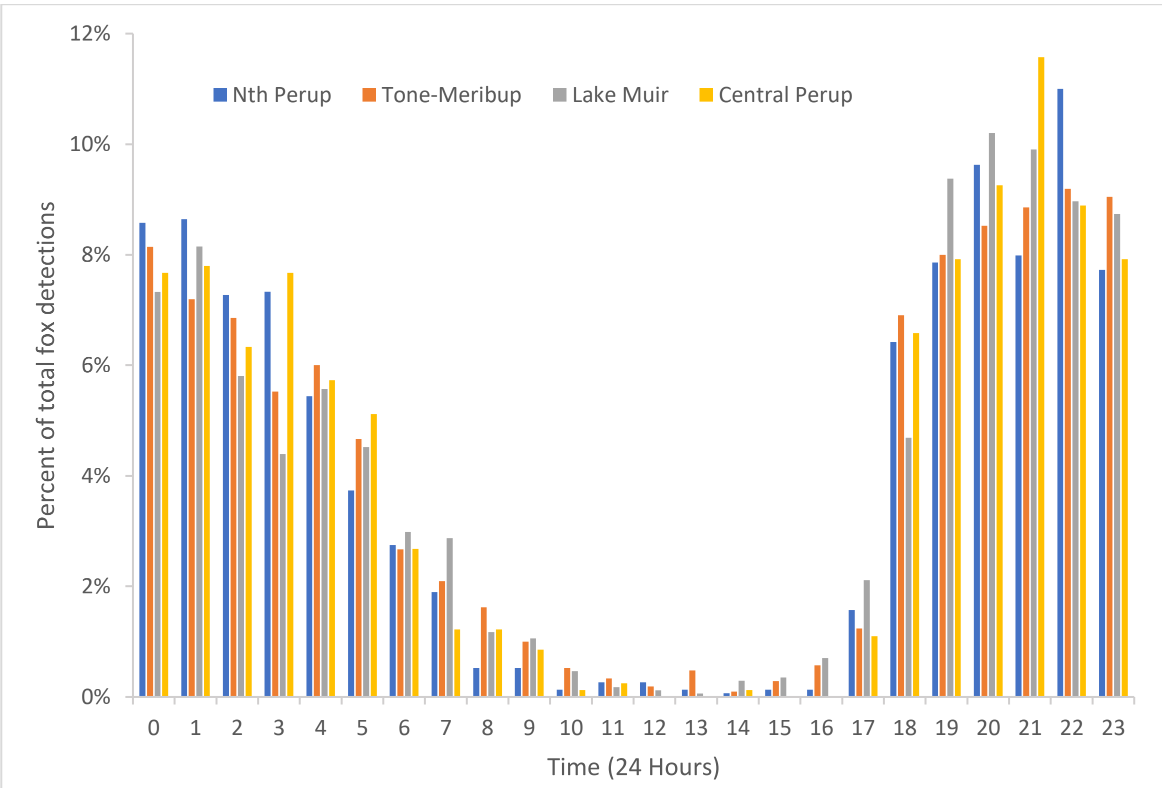


Figure 18. Circadian patterns of fox detections from the camera arrays associated with the four experimental field trials.

4 Discussion

This project has assessed the safety of Felixers in the presence of wildlife found within the southern jarrah forests of the Upper Warren region and Lake Muir-Byenup areas. A series of trials across the region have demonstrated the effectiveness of Felixers to target feral cats at a meso-spatial scale (~14,000 ha) and helped identify ways to improve the efficiency and effectiveness of Felixers. The results of these trials also provide some direction as to how to sustain a reduction in feral cat densities to allow for the recovery of native prey species. These findings are based on 9,521 detection events of animals from 4,160 nights of Felixer deployment over three years. A total of 6,099 feral cat and 5,949 fox detections from 90,147 nights from camera arrays before, during and after these Felixer deployments across treatment and reference sites combined, were also used to assess spatio-temporal changes by the feral cat and fox populations. This study constitutes the most comprehensive assessment of Felixers in Western Australia to date.

4.1 Safety assessment

The results of this project demonstrate that the risks to non-target native fauna is very low. We are confident that there is a very low risk to the eight native fauna taxa that were identified with a 1080 LD_{50} less than the amount of 1080 in a single Felixer gel cartridge (8mg). Furthermore, we are confident that other sympatric small fauna species for which there is no information on their tolerance to 1080 are similarly at low risk from being mis-identified as a target. This is because no birds or mammals smaller than a woylie or koomal have yet been reported from programs using Felixers as being mis-identified as a target. This is expected given the algorithms used to identify targets are dependent on size, shape, and movement of the subject (John Read pers comm.).

The chuditch and European rabbit were identified from the desktop assessment as being at low and moderate risk, respectively, from a lethal interaction with a Felixer armed with 1080. Chuditch were shortlisted because of their morphology and quadrupedal movement and relatively low tolerance to 1080. However, none of the 503 chuditch detected by Felixers in our trials (conservative and standard targeting mode and photo-only and toxic arming status) were mis-identified as a target. Nonetheless, even if a chuditch was targeted, a single dose of gel is not considered lethal to an average-sized adult, even if it were to consume all the toxin from a gel dose discharged from a Felixer. While no rabbits were mis-identified as a target in this project, there have been two occasions from 1,891 detections across other projects where this has been the case (John Read pers. comm.). On the rare occasions that a rabbit has been targeted, if the individual was to consume a significant portion of the gel, it is expected to be sufficient to be lethal.

During the deployment of Felixers in toxic arming status using standard targeting mode, there was a 0.06% non-exempt false positive target rate (1 tammar /1645 non-target animal detections). This is well below the acceptable threshold of <0.5% specified by the APVMA (2023), see Appendix 1, which states that the false positive rate, "…must not exceed 0.5% for all non-target species (i.e., total false firings on all non-targets / total non-target images x 100)…". While there were also some false positive target incidents with woylies (4) and yongka (western grey kangaroos, 2), these species are considered exempt by the APVMA (2023), because of their high tolerances to 1080, and are therefore not included as false positives in their acceptable threshold calculations. The relatively high 1.5% non-target false positive target rate based on APVMA (2023) criteria observed during photo-only deployment in standard targeting mode at Yackelup was due to deliberately selecting sites with high tammar activity (i.e., tammar runs/pads in and adjacent to well-known tammar thickets that have relatively low activity for other terrestrial medium-sized mammals) and being a short one-week trial (i.e., small sample size). These results demonstrate that careful site selection can make a difference in non-target detection rates and that deploying Felixers in standard targeting mode in or near thickets used by tammar wallabies may result in higher false positive targeting of non-targets.

The target efficiency for feral cats and foxes, and non-target bycatch rates and welfare risks associated with Felixers, compare favourably to two other popular feral cat control methods previously used in the same region; leghold traps and Eradicat baits (*Table 31*). Leghold traps were deployed by the most experienced feral cat control experts in DBCA, on elevated platforms, planter boxes and drums designed to reduce non-target captures. It resulted in 0.6% trap success rate of feral cats and 4.8% non-target native capture rate (DBCA unpublished data). A total of 45% of the non-target animals captured sustained injury and 12% of the non-target captures resulted in death. The 33 native non-target captures included 21 chuditch, 6 koomal, 3 woylie, 1 kookaburra, 1 numbat, and 1 wambenger. A total of 52% (11/21) chuditch captures resulted in injury, including two (9.5%) that needed to be euthanised. The one wambenger captured also needed to be euthanised due to its injuries. The koomal was killed by a leghold trap (DBCA unpublished data). These rates of injury are comparable with those pooled across six sites in Western Australia: 38% birds, 29% mammals, and 33% reptiles captured in leghold traps were injured, of which 33%, 12%, and 21%, respectively were severely injured (i.e., often resulting in death) (Surtees *et al.* 2019).

An Eradicat baiting trial targeting feral cats in the southern jarrah forest resulted in 0.1% of baits being taken by a feral cat and 67–88% of baits were taken by non-target fauna (*Table 31*). Of the whole baits removed, 28% of baits were taken by woylie, 24% by koomal, 10% by mootit, 9% by chuditch, 6% by goanna, 5% by raven, 3% by currawong, 2% each by mardo, black rat, quenda and quokka and less than 1% each by, bobtail, emu, wambenger, kwara, feral pig, king skink, kookaburra, dunnart, southwestern crevice skink, tammar, and Australian magpie (Wayne *et al.* in prep).

Table 31. Comparison of target efficiency and non-target 'bycatch' for feral cat control methods in the southern jarrah forest.

Control method	Effort	Cat target rate	Fox target rate	Non-target rate	Study timing
Felixer trap - conservative	1,723 trap nights	1.5%	2.4%	0.0%	2021–22
Felixer trap - standard	645 trap nights	0.8%	2.2%	0.1%	2023
Leghold trap (elevated)	1,013 trap nights	0.6%	0.2%	4.8%	2018
Eradicat bait - clusters	998 baits	0.1%	0.1%	67.4%	2016–17
Eradicat bait - transects	4,660 baits	0.1%	0.4%	87.5%	2016–17

Note that target rates are relative to control effort (trap nights or number of baits), whereas target rate is otherwise related to number of detections elsewhere in this report.
Sources: Felixers (this study), Leghold traps (DBCA unpublished data), Eradicat bait (Wayne et al. in prep).

None of the false positive targeting of non-target native species (woylie, yongka, tammar or kwara) by the Felixers are considered to have any potential for being lethal. Individuals from these species would need to consume the entire 1080 toxin dose of multiple gels within a short period to receive a lethal dose: more than 7 to 238 doses for an average-sized adult within about 24 hours; *Table 10*). This is extremely unlikely given the safety provisions in the use of the Felixers (e.g., 120-second cooling-off period between live firing, limitations of the gel to accurately hit smaller woylie-sized animals, limitations in the number of gels deployed in a Felixer at any time, and the minimum distances between Felixers) and the behaviour of the individuals involved (e.g., the propensity to groom and the unlikelihood of an individual having been startled and hit by one gel, then staying in front of the Felixer long enough to be targeted again). While there were no expected lethal interactions by non-target fauna with Felixers, elevated leghold traps resulted in a 0.4% mortality rate per trap night (DBCA unpublished data) and up to 10% of the 78 chuditch individuals that removed Eradicat baits may have been lethal (A. Wayne unpublished data). The risks of a potential lethal event from Eradicat bait consumption by chuditch were much greater when the baits were deployed resembling clusters of 50 during aerial bait deployment than when deployed along transects (A. Wayne unpublished data).

Our results demonstrate that Felixer traps are safe for non-target species present in the southern jarrah forest IBRA region and are comparatively much safer than other conventional feral cat control methods currently being used. Felixers are also considered safe to use in Tasmania and New South Wales in the presence of eastern quoll (*Dasyurus viverrinus*), spotted tail quoll (*Dasyurus maculatus*), bettongs and potoroos (Rickards *et al.* 2023). However, greater care and consideration is needed when using Felixers in the presence of Tasmanian Devils (*Sarcophilus harrishii*; Rickards *et al.* 2023).

4.2 Felixer performance

For feral cats, Felixers had an overall mean detection rate of 4% (SD=1.4), an overall mean target rate of 41% (SD=17.5), which over the course of the trials in conservative targeting mode (an average 12.6 weeks per trial) resulted in an average of between 44% (SD=9.6) and 58% (SD = 15.8) of the feral cat individuals detected by the Felixers being targeted. While the target rate in standard targeting mode was higher than conservative mode, the increase was not large (122% and 132% for feral cats and foxes, respectively). However, accumulated over extended deployments, this difference could result in a substantially greater proportion of the individuals detected by the Felixers being ultimately targeted. While our results are consistent with this, having observed 100% of the feral cat individuals detected in standard targeting mode (n=5) being targeted during a 12.9-week deployment, the small sample size is insufficient to draw strong conclusions.

Note that the overall feral cat detection rate from the camera arrays (8%) was larger than the detection rate at the Felixer locations (4%). This difference is likely due to spatiotemporal differences (i.e., different sampling periods and the arrays sampled areas not covered by the Felixers). Also, the detection rate at the Felixer locations would be expected to reduce due to the successful targeting of feral cats during the toxic trials more so than across the camera arrays at the treatment sites that are still encountering feral cats not going to the Felixer locations. Furthermore, the data from the camera arrays include the reference sites that were being surveyed while feral cats were being targeted in the Felixer treatment sites.

For foxes, Felixers had an overall mean detection rate of 13% (SD=8.7), and an overall mean target rate of 35% (SD=17.1). The target rates were higher in photo-only than in toxic arming status and higher in standard target mode than in conservative target mode for both species. While the latter was expected, the difference between photo-only and toxic arming status was not. The higher target rate in photo-only arming status is likely because of more repeat detections of the same individuals, which are more likely to be identified as a target due to normalised behaviour of familiarised individuals walking past the Felixer, meaning they may present themselves better more often (side on) for target recognition. While in toxic arming status, once a feral cat or fox has presented itself in a suitable way to be recognised as a target (and having been fired upon), it is unlikely to ever return, either because it has died having consumed the gel, or because the interaction with the Felixer is likely to deter the same individual from coming back again (more likely to be the case for red foxes).

The effect of the audio lure on the detection and target rates for feral cats and foxes from our small trials is not clear. While there were no significant differences in the detection rates of feral cats and foxes in our study, larger sample sizes for these species are needed to test the effects of audio-lures more thoroughly. With more thorough testing it is expected that the detection rate of at least owls and possibly feral cats and foxes will be demonstrated to be significantly greater when at least some audio lures are used.

4.3 Effects of Felixers targeting feral cats and foxes

More feral cats are expected to have been present in the treatment areas than were detected and targeted in front of the Felixers. Evidence from the cameras located in close proximity to the Felixers indicate that at least some feral cats may avoid the Felixers. It is also expected that there were other feral cats within the treatment areas (~14,000 ha) that may not have come within the vicinity of the Felixers given the density of the Felixers (approximately 1 for every 1,750 ha) and the highly variable size of individual feral cat home ranges (e.g., home ranges of 4,578–11,370 hectares by 1 female and 3 males in the Upper Warren region (A. Wayne, unpublished data) and 0.27–2,300 hectares for females and generally somewhat larger for males elsewhere in Australia; Woinarski *et al.* 2019).

It was not possible to confidently determine how many individual feral cats were within the treatment areas and what proportion were successfully targeted by Felixers, due to the high proportion of detections that could not distinguish the individuals involved (i.e., more than half of the feral cat detections were of generally indistinguishable black cats; consequently, distinguishing residents from transients and recent immigrants was also not possible). For the same reason it was also not possible to quantify the changes in feral cat densities using SECR modelling associated with the Felixer trials. Therefore, it is not possible at this stage to determine whether culling rates achieved in these trials meet the minimum annual target rates of between 0.35 and 0.6 described by Venning *et al.* (2021), needed to reduce an island feral cat population (i.e., no immigration) to less than 0.1 its pretreatment size within 10 years. Similarly, it is not possible to determine with any confidence whether we achieved our goal of reducing the feral cat population within the ~14,000 hectares treatment areas by more than 60% by deploying 8 Felixers for about 8 weeks. While the project target of culling >60% of the feral cats was certainly not achieved at Lake Muir (33–40% of individuals detected in front of the Felixers in 9.6 weeks and <31% of the individuals detected within the treatment area prior to the toxic deployment of the Felixers),and probably not at North Perup (50–67% of individuals detected in front of the Felixers over 14 weeks in conservative mode and <57% of the individuals detected within the treatment area prior to the toxic deployment of the Felixers), it might have been achieved at Tone Meribup (50–68% of individuals detected in front of the Felixers over 15 weeks in conservative targeting mode and <89% of the individuals detected within the treatment area prior to the toxic deployment of the Felixers), and Central Perup (<80% over 10 weeks in standard targeting mode based on both the number of individuals detected in front of the Felixers and within the treatment area prior to the toxic deployment of the Felixers and noting that the targeting of 1/5 cats was not lethal). However, more information and repeat trials are required to confirm whether minimum target cull rates can be demonstrably and consistently achieved.

Nonetheless, the targeting of feral cats by the Felixers resulted in a significant reduction in feral cat activity in experimental trial 3 only, where it was estimated that between 50% and 68% of individual feral cats present at the Felixers were targeted by the Felixers. This change however was matched by a similar reduction in feral cat activity at the reference site, so no significant interaction was found between site treatment and period (before and after Felixer deployment). In experimental trial 1 feral cat detection rates at the Felixer treatment site did not change significantly after four feral cats were targeted, however at the same time feral cat activity at the reference site increased significantly suggesting that the removal of feral cats by the Felixers resulted in a significant comparative difference on the rate of feral cat detections. In experimental trials 2 and 4 the Felixer treatment sites did not show significant changes in feral cat detection rates due to the Felixer deployments. These results suggest that use of Felixers has the potential to reduce feral cat activity at the mesoscale, however a better understanding of the other factors affecting feral cat activity is also required to determine this conclusively.

Significant differences were observed between the trial sites both in terms of the effect of the targeting of feral cats on the rate of detections, but also in the factors related to feral cat detections at the camera site level. This suggests that decisions about the placement of Felixers in the landscape will need to be made on a site-specific basis and the most effective locations for Felixers may be affected by the amount of agricultural land nearby, site topography, climate and potentially other factors that are unique to each site.

The results of experimental trial 3, when the greatest number of resident feral cats were targeted by the Felixers, indicate that reinvasion of areas after feral cats are targeted can be rapid. After the Felixers were removed from the treatment site (Tone-Meribup), the rate of feral cat detections quickly increased and surpassed that at the reference site after approximately six weeks (*Figure 9*). This result would indicate that longer-term deployment of Felixers (i.e., > 4 months, perhaps continuous) is likely necessary for the suppression of feral cat activity, and removal of the Felixers, even for relatively short periods, may result in a rapid increase in feral cat activity. This also suggests that, as with most vertebrate predator control programs, a landscape scale approach is needed to reduce the rates of reinvasion where feral cats have been controlled.

There was no evidence from any of the four experimental trials to suggest that the targeting of foxes by the Felixers had a negative effect on fox detection rates. This may be a result of foxes not being killed after being targeted, rapid reinvasion of territories if foxes were killed or other factors influencing fox activity more so than the Felixer deployment. These results suggest that the use of Felixers to target foxes in this environment is at best ineffective, or at worse may be exposing foxes to sub-lethal doses of 1080 if they partially ingest gels without getting a lethal dose. The newer iteration of the Felixers (v3.2) have the capability to exclude foxes from being targeted and this may be a prudent option to use unless it is confirmed that a high proportion of foxes targeted by the Felixers are being killed.

4.4 Optimising Felixer use and sustaining reductions of feral cat and fox

4.4.1 Spatio-temporal targeting for peak feral cat activity

Targeting control efforts within a landscape in a way that will maximise the probability of encounter of feral cats and foxes is key to maximising the effectiveness of control efforts to reduce the threat to vulnerable and priority fauna. Based on the results of these trials and our experience, there are several ways that the effectiveness of the Felixers could be improved. These can be classified as 1) where and when the Felixers are deployed in the landscape (this is relevant to all lethal control methods), 2) specific aspects of the site and setup of the Felixer, and 3) technical aspects of the Felixer. We briefly provide examples of these factors here.

With respect to timing, seasonal power supply limitations (especially May–July; discussed further below) are likely to be a greater constraint to targeting feral cats than seasonal variation in cat detection rates. While there were some statistically significant differences in feral cat detection rates either in relation to season alone or as part of an interaction with distance from agriculture, all these models accounted for a very low amount of the variation (<10%). Based on this evidence, any time of year may be suitable for targeting cats in the southern jarrah forest. However, there may be a very slight general advantage to detecting feral cats in Bunuru (February–March), and at some sites there may also be a very slight detection advantage in Makaru (June–July) and Birak (December–January), particularly in areas close to agriculture.

Other spatial factors that related to feral cat detection rates also varied between sites and accounted for a very small amount of the variation in feral cat activity. Nonetheless, it included a positive association with topographic wetness, a negative association with elevation and a negative association with distance from hydrological features. These variables are likely to be related to local site productivity, which have more prey available and would therefore be attractive areas to feral cats.

Other landscape-scale factors that were not investigated here but may have higher levels of feral cat activity include,

- Areas with an abundance of food resources (e.g., rubbish tips, hay/grain storage areas with high rodent numbers, etc).
- Areas of recent disturbance (e.g., immediately after high severity large fires; McGregor *et al.*, 2016 & 2017; Doherty et. al., 2023).
- Locations where feral cats are more likely to move (e.g., tracks, ecotones, access points across/around/through physical barriers such as rivers/wetlands, breakaways, gullies, etc).

Contemporary intelligence on feral cat activity across the landscape can also help optimise lethal control by prioritising locations identified to have the greatest feral cat activity. Evidence of activity may be gained from sign (tracks and scats), sightings and cameras. In trials 3 and 4 in this study, this was achieved through using the information from the camera arrays and 'scouts' to select where Felixers would likely detect more feral cats. While the benefits of this approach are not clearly demonstrated by the feral cat detection rates on Felixers (which is also a function of feral cat densities in these areas), our experience is that this substantially improved the opportunities for lethal targeting of the feral cats during these trials. Information from sign and direct sightings of feral cats was of limited value at our sites given the nature of the substrates (predominantly gravel and loam, not sand) and vegetation (thick ground storey shrub layer limiting off-track visibility). Reconnaissance using these methods may be more effective elsewhere.

The extent to which the location of the Felixers (or other lethal control methods) remain fixed or move throughout the control program may also improve control efficiency and effectiveness. There may be some advantages of responding to spatio-temporal changes in feral cat activity during the control period, particularly if there is substantial variability. From our limited exploration of responsively moving Felixers during the trial, this generally resulted in improved feral cat detection and targeting opportunities than would have been the case had the Felixers remained in their original location. However, further investigation is needed to determine how much benefit may come from this approach in longer term deployments.

Modelling can also be used to refine the design of the deployment of lethal control methods such as Felixers. This can inform aspects such as number and density of Felixers, duration of deployment and the extent to which the traps might be relocated within the treatment area. The data from these latest trials can improve the reliability of these models to improve the effectiveness of the next trials. Information on the movement patterns, home ranges, breeding biology and ecology of the cat population being targeted would also improve the modelling of the optimal use of Felixers as well as predicting their efficacy at reducing the population of feral cats like the approach used by Venning *et al.* (2021).

Consideration of the risk from and to humans in relation to the Felixers was also a major constraint as to where in the landscape the Felixers were located (e.g., Felixers were deployed on minor tracks that had relatively little or no recent traffic, that were also able to be closed to public access, specifically for the purposes of these trials). This resulted in compromises to the potential efficiency and efficacy of targeted feral cat control. It may be worth considering what solutions may be possible in deploying the Felixers in the best locations in the landscape that can also adequately address the human safety and Felixer security issues as well.

4.4.2 Felixer set up

There are several aspects of the way in which the Felixer is set up that can improve the detection and targeting of feral cats. From our experience these include,

- Adequate concealment of the Felixer to reduce the chances of a feral cat being aware of its presence and therefore potentially changing its behaviour in a way that reduces its potential to be detected (e.g., avoidance) or being targeted (e.g., not presenting and behaving in a way that the Felixer will be able to identify the feral cat as a target). This can involve obstructing the view of the Felixer from approaching animals and camouflage (preferably using natural, local materials). For the feral cat to be identified as a target ideally it should walk past at a steady walking pace without stopping or approaching the Felixer.
- Natural features such as logs and dense vegetation and forest debris can be used wherever possible to help ‘funnel’ the feral cat past the Felixer as much as possible. This includes limiting the opportunities for the feral cat to avoid walking in front of the Felixer by detouring around it.
- Selecting sites and orienting the Felixer in a way that improves the likelihood for feral cats to present themselves laterally (side-on). This is required by the Felixer v3.1 to discriminate true targets.

- A suitable backdrop less than four metres from the Felixer is required (Thylation Operations Pty Ltd, 2020). Using natural, preexisting features such as logs and large trees may help to not deter an approaching feral cat.
- The Felixer site should remain as natural and as undisturbed as possible to minimise opportunities for alerting or distracting an approaching feral cat. The aim is to have the feral cat walk perpendicularly through Felixer detection zone without pausing. Selecting sites that are naturally very flat should mean they will require less disturbance to set up as needed.
- Where disturbance is necessary, it may be beneficial to do so well before Felixers are deployed, to allow time for the site to settle (i.e., evidence of the disturbance to diminish) and the fauna to become familiar with the changes.
- Having cameras associated with the Felixers are important for helping to inform how to improve the effectiveness of Felixers. For example, they inform the species involved in detection and target events and quantify the number of feral cat individuals involved. However, they also may influence the effectiveness of the Felixers by potentially distracting or deterring feral cats. In the absence of having better cameras in the Felixer, associated cameras need to be well concealed and/or located further away, or not deployed at all. It is important to know how covert the cameras really are, rather than what they are reported to be, given that many emit visible light and sounds when activated (Meek *et al.*, 2014). The benefits and disadvantages of having cameras within the vicinity of the Felixers needs to be carefully considered.
- Avoid visiting the site as much as possible to reduce the cues that may distract or deter target animals. When visiting the sites, do so as early in the day as possible so that smells dissipate before cat activity increases in the evening.
- While it is possible that audio or other lures may increase the detection rates of some species, the results from these trials are insufficient to inform whether this is the case. Whether the use of lures increases the target rates of feral cats and foxes also needs to be determined. The extent to which target and non-target animals are attracted to lures may affect the rates by which they are identified as a target. For example, a feral cat that directly approaches a Felixer within the detection zone to investigate a lure, will not be presenting itself side-on, so may not be correctly identified as a target based on the current technology and algorithms. Conversely, macropods that may be attracted by a lure may also present themselves in a way that may increase the risk of them being identified as a target. More extensive trials are needed to determine if and how the true target rate can be improved with lures and whether this increases the risk to non-targets.
- Deployment in standard targeting mode is expected to be more efficient and effective than conservative targeting mode and can be regarded as a negligible risk for non-target species. Nonetheless, areas with high numbers of tammar should either be avoided in standard targeting mode or have the Felixers deployed in conservative targeting mode to reduce the disturbance to tammar wallaby individuals.

4.4.3 Technical aspects of the Felixer

There are several ways the capability and specifications of the Felixers could be improved to increase their effectiveness of detecting and targeting feral cats and foxes while not targeting non-targets. These include, improving the target rate without reducing the false positive target rate, reducing the lost time due to faults and human error, improving the power supply and storage capabilities, and improving the image quality from inbuilt cameras.

Refinements to the accuracy of identifying targets has the potential to result in substantial improvements to the efficiency and accuracy of the Felixers. The Felixer trials in the southern jarrah forest resulted in a 31% and 38% overall target rate of feral cats in conservative and standard targeting mode respectively and 31% and 41%, respectively for foxes. Therefore, there is scope for substantial gains provided they do not increase the risks to non-target fauna. Upgrades being made in the latest model that includes image recognition and artificial intelligence and the ability to upgrade older models (such as v3.1 used in this study) with the same technological advances may go some way to achieving these gains. For example, the AI upgrades have reportedly overcome the missed target opportunities resulting from the 'SLOW' movement detections (John Read pers comm.) that resulted in 10% and 5% of missed feral cat targets under conservative and standard targeting modes, respectively, in our study.

A reduction or elimination of technical faults and human error could result in significant improvements in Felixer efficacy. In our study there was a 13% and 14% loss of opportunities to target a feral cat or fox respectively that resulted from an 11% of Felixer nights having a total failure or partial compromise in Felixer performance due to faults, power issues and human error. Most of the faults occurred in the initial field trials of the Felixers and were resolved through software and mechanical repairs or replacements. So much of this improvement has already occurred. However, the opportunity remains for improvements to power supply and storage (discussed further below).

Power supply and storage limitations can be managed to some extent by avoiding using the current Felixer models in the southern jarrah forest May–July when power issues are greatest. Restricting the deployment of the Felixers to locations with little or no shading from the vegetation at these times of year (i.e., to maximise the power supply capabilities of the existing Felixers), may also be an option. Some power saving may also be possible by programming the Felixers to go into hibernation during the times of day when feral cat activity is least, so that there is a greater chance the Felixers will be fully functional when the probabilities of detection are greatest (i.e., Felixer activity informed by the seasonal and circadian detection patterns for the feral cat and fox). However, all of these 'workarounds' result in a reduced capacity for the Felixers to operate efficiently and effectively throughout the year and across the southern jarrah forest.

A better solution would be to resolve the power supply and storage limitations through improving the capabilities of the Felixers. Adding larger external power storage (batteries) was not considered cost efficient or practical in our situation given the expected need to replace the batteries at least weekly, given the limited capacity to recharge the batteries when deployed in the field. Being able to use larger and/or more efficient solar panels in conjunction with a higher capacity regulator would enable more power to be supplied to the Felixers. Installing the solar panels above ground to reduce shading might also be possible but would also be more costly. These same power issues may not apply elsewhere, such as at higher latitudes and in environments with less shade at ground level (e.g., open woodlands, and semiarid and arid areas).

Having better photographic images recorded by the Felixers has several advantages. The quality and resolution of the images needs to be sufficient to confidently identify the species (to satisfy animal welfare safety assessments and reporting), and individual feral cats involved (for assessing control effectiveness). Having this capacity inbuilt will reduce the need for users to deploy supplementary cameras within the vicinity of the Felixers to get this same information. From our observations, having these supplementary cameras close to the Felixers likely reduces the detection and target rate of feral cats.

4.5 Sustaining reductions of feral cat and fox populations

Longer deployments would be expected to continue to reduce feral cat numbers. And while the proportion of individuals detected by the Felixers that were successfully targeted ranged between 33% and 68% in conservative mode and 100% of the individuals in standard targeting mode, the number of feral cats within the treatment areas is expected to be larger. Our results also indicated that reinvasion of these areas by feral cats can occur rapidly when the Felixers are removed. Therefore, more trials are needed to determine to what extent more time and/or more Felixers may further reduce the feral cat numbers in meso-scale treatment areas (i.e., ~14,000 ha).

Control using the Felixers is likely needed throughout most, if not all, of the year to sustain a biologically meaningful reduction in the feral cat population (e.g., >35–60%, Venning *et al.* (2021)). This supposition is based on the results of this study (e.g., detection and target rates), and the potential for reinvasion due to the lack of barriers of movement by feral cats (e.g., predator proof fencing or large permanent water bodies), and the small spatial scale over which these trials were applied (11,500–16,000 ha). It would be expected that as the area of effective control increases and/or the barriers for reinvasion increased, that the rates of reinvasion should reduce such that periodic instead of continuous control may be sufficient in some cases.

5 Recommendations

These recommendations are focussed on the welfare and safety of non-target fauna and optimising the efficiency and efficacy of the Felixers to reduce the number of feral cats and the threats they pose to priority and vulnerable threatened native species in the southern jarrah forest. These recommendations are broadly categorised as i) safety and risks to non-target fauna, ii) technical aspects of Felixers, iii) deployment of Felixers, iv) comparison and integration with other control methods, v) integrated introduced predator management and threat mitigation, and vi) assessing and monitoring feral cat activity, abundance, and density. It should be noted that many of these recommendations are specific to the use of Felixers in the southern jarrah forest and may not be relevant to other regions.

5.1 Safety and risks to non-target fauna

- Felixers can be used safely in the presence of non-target native fauna in the southern jarrah forest. Felixers in conservative targeting mode are very safe, and while the standard targeting mode comes with an increased false positive rate on macropod species, it is still within acceptable tolerance ranges specified by the APVMA.
- Careful spatial and temporal selection for Felixer deployments can further reduce the risk to non-target wildlife and/or increase the detection and targeting of feral cats and foxes. For example, non-target risks can be reduced by locating Felixers away for high activity areas for non-target species (e.g., tammar thickets) and/or be deactivated at times when non-target

activity may be relatively high (e.g., crepuscular peaks of tammar activity in summer and autumn; Wayne *et al.* 2019).

- We recommend that the Western Australian subspecies of tammar (*Notamacropus eugenii derbianus*) and the kwara (*Notamacropus irma*) be listed as exempt species by the APVMA, considering their high tolerances to 1080. Other taxa such as koomal (*Trichosurus vulpecula hypoleucus*) and quokka (*Setonix brachyurus*) should also be considered for exemption based on their tolerances to 1080.

5.2 Technical aspects of Felixers

- Improved precision in identifying true targets without increasing the rates of false positive target identification of non-targets is likely to deliver the greatest improvements to the efficacy of these devices. The reported improvements to the latest model of Felixers (v3.2), which uses image recognition and AI, are likely to do this.
- Reasonable gains may be achieved through improvements in the dependability of the Felixers (i.e., reduce the lost time due to mechanical faults, software errors) and reducing human-related issues /operator error (e.g., through good operator manuals, training, use of quality parts less likely to be damaged by people, transportation, or the environmental conditions in the field). While substantial improvements were made during this project, maintaining a low rate of lost time due to faults and errors is clearly advantageous.
- Improve power supply and storage capabilities to allow for continual use in forest conditions throughout winter (lower light intensity, shorter periods of sunlight, more shadows).
- Higher quality images from a camera that is better quality, truly covertly operating and in-built is needed to more reliably identify the animals (species and feral cat individuals) that are detected by the Felixer. Having this ability will substantially reduce the need for additional external cameras that may compromise the effectiveness of the Felixer to encounter and target feral cats.

5.3 Deployment of Felixers

- One of the greatest improvements to the efficacy of the Felixers (and other lethal control methods alike) may be achieved by deploying the Felixers at locations that maximise the probability of encountering feral cats. This can be achieved through a reliable understanding of the habitat and movement preferences by feral cats in the environment in which the control is being undertaken. Results from this and other projects in the southern jarrah forest (Geary *et al.* 2022; A. Wayne unpublished data) suggest that while some common principles may apply to some extent (e.g., higher detection rates along forest tracks, see also Wysong *et al.* 2020), there may be substantial spatio-temporal variation even between sites and between individual feral cats. Adequate and contemporary field intelligence of feral cat activity and movement is therefore likely to be very important to maximising the success of Felixer deployments. The perspicacious use of remote sensor cameras can be a particularly effective method of identifying the best locations to deploy Felixers.
- We expect that there may be considerable variation between sites regarding the potential for new feral cat individuals to be detected once the resident animals are removed. Being able to better predict which sites may more readily encounter more and new individuals may also be particularly helpful in prioritising locations to deploy Felixers.

- More broadly, a greater understanding of the ecology, biology and behaviour of the feral cat population will help substantially to inform how best to go about controlling and managing the introduced predators and mitigating the threats they pose to the vulnerable threatened fauna.
- Covert deployment of the Felixer (i.e., concealment and camouflage, minimising disturbance, etc) may result in more detections and successful targeting of feral cats by reducing changes in feral cat behaviour (including avoidance, changing speed of movement through the detection zone, deviating from a line of travel perpendicular to the Felixer, etc).
- The deployment of cameras in association with the Felixers needs to be considered carefully, recognising that gaining more information on the taxa and/or individuals in the vicinity of the Felixers may come at the expense of reduced efficacy of the Felixers (or other control methods) to target more feral cats, because of the potential for cameras to affect feral cat behaviour and reduce the targeting opportunities for the Felixers.

5.4 Comparison and integration with other control methods

- Felixers are currently considered the most efficient and effective lethal control method for feral cats in the southern jarrah forest. Based on current available evidence the Felixers have lower animal welfare risks to non-target species than leghold traps in the southern jarrah forest. Felixers are also substantially more target specific than Eradicat baits. Furthermore, the target rate of feral cats and foxes is greater than for these other methods. While shooting may be suitable in adjacent agricultural areas it is not considered to be an effective method of lethal feral cat control in the forest areas due to poor visibility and limited access. The limited cage trapping efforts targeting feral cats in the southern jarrah forest have similarly been inefficient (unpublished data) but again may be more effective when used in adjacent areas (e.g., grain and hay storage areas on farms, rubbish tips, and around human settlements).
- Felixers may have a greater chance of successfully targeting feral cat individuals than other methods that rely on lures/attractants (traps, baits, etc), especially in areas with high prey abundance.
- Further work is needed to improve the efficacy of all available lethal control methods across the range of environmental conditions including major vegetation types (e.g., native forest and wetlands, livestock and pasture, timber plantations, vineyards, horticulture and annual cropping areas), disturbance histories (e.g., time since fire), relative abundance and types of food resources (which may affect the efficacy of food based lures and baits) and temporal factors (e.g., seasonal and interannual variation in the climate) in both the southern jarrah forest and adjacent agricultural areas.
- Comparisons of feral cat control methods should also investigate cost effectiveness.
- Opportunities for the complementary use of different methods within and across different environmental conditions (e.g., vegetation types) is also highly recommended. This may be particularly beneficial in being able to target different demographic parts of the feral cat population. For example, our experience is that the Felixers have been particularly effective in targeting large socially dominant male feral cats that are otherwise difficult to control using other methods reliant on social cues or food attractants. Whereas young, naïve, and curious feral cats may be more likely to take an Eradicat bait and may be less likely to be targeted by a Felixer because they are smaller size and/or tendency to approach the Felixers directly

rather than walking past and thereby presenting themselves laterally, which is needed for the Felixer v3.1 to be able to discriminate it as a target.
- Trial the new Felixer model v3.2 with AI and image recognition.

5.4.1 Integrated introduced predator management and threat mitigation

- Use lethal control methods as part of an integrated management system that co-ordinates the management of introduced predators, habitat, natural resources and human values, and the conservation and management of priority threatened species. This includes using lethal control methods in conjunction with other methods that reduce feral cat survivorship and recruitment, and integrate with other management activities to mitigate the threats to threatened fauna, e.g., habitat management to increase physical and chemical defences of the native fauna (Read *et al.*, 2015), reduce recruitment of feral cats through reduced immigration, reduced food resources (e.g., rabbits and introduced rodents, livestock and access to rubbish tips etc), integration with fox control and disturbance activities such as fire that may interact with introduced predator management and the susceptibility of threatened fauna.

5.5 Assessing and monitoring feral cats and priority fauna

- Assessing and monitoring the feral cat population and threatened fauna populations is fundamental to efficient and effective feral cat control. It quantifies the effectiveness of management actions and how this may vary over space, time, and context (e.g., associations with other management activities and environmental conditions). It informs managers whether current management regimes are meeting objectives or whether intervention or changes are required.
- The camera survey design for feral cats used in this study (50 cameras deployed ~2km apart on tracks within an average ~15,500 ha) provided good data on feral cat activity, however it was insufficient to derive a satisfactory density estimate using spatially explicit capture recapture models (SECR). This was due to the difficulties of being able to confidently distinguish feral cat individuals (given many detections were of similar-looking black feral cats). Developing methods that are better able to distinguish individual feral cats is therefore recommended. This may include capturing better image data of feral cat detections (e.g., higher quality images capturing multiple perspectives of the animal (e.g., both sides, front and dorsal), and perhaps across different parts of the light spectrum that may provide more detail of a feral cat that may otherwise appear plain black under some light conditions).
- The development and use of computer software that can discriminate feral cat individuals more accurately and efficiently would be highly beneficial to deriving better population estimates of feral cats.

6 References

Australian Pesticides and Veterinary Medicines Authority (APVMA) (2023). Thylation Felixer Leaflet 03.2023.P2.

Burrows, N. D., and P. E. S. Christensen (2002). "Long-term trends in native mammal capture rates in a jarrah forest in south-western Australia." *Australian Forestry* 65(4), 211–219.

Chambers, B., Dunlop, J., and Wayne, A. F. (2020). Felixer™ grooming trap non-target safety trial: Numbats. Report. South West Catchments Council, Department of Biodiversity and Attractions. (Perth, Western Australia).

Conservation and Land Management Regulations (2002). *Conservation and Land Management Act 1984*. Published on www.legislation.wa.gov.au.

Department of Agriculture, Department of Conservation and Land Management, Department of Health (2002). 1080 Summary information. Report. South Perth, Department of Agriculture.

Department of Parks and Wildlife (2017). Western Shield Plan 2017–2026. Department of Parks and Wildlife, Western Australia.

Doherty, T. S., Watchorn, D. J., Miritis, V., Pestell, A. J., and Geary, W. L. (2023). Cats, foxes, and fire: quantitative review reveals that invasive predator activity is most likely to increase shortly after fire. *Fire Ecology 19*(1), 22.

Dunlop, D.J., Birch, N., Moore, H., and Cowan, M., (2019a). Pilbara Northern Quoll Research Program. Report. Department of Biodiversity, Conservation and Attractions, Perth, Western Australia.

Dunlop, D.J., Birch, N., Davie, H., Nelson, J., and Read, R. (2019b). Felixer™ feral cat grooming trap trials in the presence of northern quolls. Report. Department of Biodiversity, Conservation and Attractions, Perth, Western Australia.

Ecological Horizons, (2020). Felixer™ Grooming Trap Trials - Ikara-Flinders Ranges National Park. Report.

Ecological Horizons, (2018). Olympic Dam Felixer™ Trial Report

Geary William L., Wayne Adrian F., Tulloch Ayesha I. T., Ritchie Euan G., Maxwell Marika A., Doherty Tim S. (2023) Fox and cat responses to fox baiting intensity, rainfall and prey abundance in the Upper Warren, Western Australia. *Wildlife Research* 50, 201–211.

Hodgens, P., (2019). Felixer™ vs Felis Report 30th June 2019. Terrain Ecology, Kangaroo Island.

Legge, S., Murphy, B. P., McGregor, H., Woinarski, J. C. Z., Augusteyn, J., Ballard, G., Baseler, M., Buckmaster, T., Dickman, C. R., Doherty, T., Edwards, G., Eyre, T., Fancourt, B. A., Ferguson, D., Forsyth, D. M., Geary, W. L., Gentle, M., Gillespie, G., Greenwood, L., Hohnen, R., Hume, S., Johnson, C. N., Maxwell, M., McDonald, P. J., Morris, K., Moseby, K., Newsome, T., Nimmo, D., Paltridge, R., Ramsey, D., Read, J., Rendall, A., Rich, M., Ritchie, E., Rowland, J., Short, J., Stokeld, D., Sutherland, D. R., Wayne, A. F., Woodford, L., and Zewe, F., (2017). Enumerating a continental-scale threat: How many feral cats are in Australia? *Biological Conservation* 206, 293–303. https://doi.org/10.1016/j.biocon.2016.11.032

McCaw, L., Hamilton, T., and Rumley, C. (2005). Application of fire history records to contemporary management issues in south-west Australian forests. 6th National Conference of the Australian Forest History Society Inc., Millpress Science Publishers, Rotterdam.

McGregor, H. W., Cliff, H. B., and Kanowski, J. (2017). Habitat preference for fire scars by feral cats in Cape York Peninsula, Australia. *Wildlife Research* 43(8), 623–633.

McGregor, H. W., Legge, S., Jones, M. E., & Johnson, C. N. (2016). Extraterritorial hunting expeditions to intense fire scars by feral cats. *Scientific reports*, *6*(1), 22559.

Meek, P. D., Ballard, G. A., Fleming, P. J., Schaefer, M., Williams, W., and Falzon, G. (2014). Camera traps can be heard and seen by animals. *PloS one* 9(10), e110832.

Moseby, K. E., McGregor, H., and Read, J. L., (2020). Effectiveness of the Felixer grooming trap for the control of feral cats: a field trial in arid South Australia. *Wildlife Research* 47(8), 599–609. https://doi.org/10.1071/WR19132

Read, J. L., Peacock, D., Wayne, A. F. and Moseby, K. E. (2015). Toxic Trojans: Can feral cat predation be mitigated by making their prey poisonous? *Wildlife Research* 42, 689–696.

Read, J. L., Bowden, T., Hodgens, P., Hess, M., McGregor, H., and Moseby, K., (2019). Target specificity of the Felixer grooming "trap." *Wildlife Society Bulletin* 43, 112–120. https://doi.org/10.1002/wsb.942

Rickards H, Read J. L., Johnson C. N., Jones M. E., Pauza M. D., Bentley J., Sculthorpe A., Humphrey M., and Hamer R. (2023). Is the Felixer cat control device safe for marsupial carnivores? *Wildlife Research* 50**,** 356–365.

Surtees C, Calver MC, and Mawson PR (2019). Measuring the welfare impact of soft-catch leg-hold trapping for feral cats on non-target by-catch. *Animals* 9, 217.

Thylation Operations Pty Ltd (2020). Felixer 3.1 Grooming Trap Standard Operating Procedure v. 10.08.20.

Venning KRW, Saltré F, and Bradshaw CJA (2021). Predicting feral cat reduction targets and costs on large islands using stochastic population models. *Conservation Science and Practice* 2021, e448. doi: 10.1111/csp2.448.

Wayne, A. F., Cowling, A., Lindenmayer, D. B., Ward, C. G., Vellios, C. V., Donnelly, C. F., and Calver, M. C. (2006). The abundance of a threatened arboreal marsupial in relation to anthropogenic disturbances at local and landscape scales in Mediterranean-type forests in south-western Australia. *Biological Conservation* 127(4), 463–476.

Wayne, A. F., Maxwell, M. A., Ward, C. G., Vellios, C. V., Williams, M. R., and Pollock, K. H. (2016). The responses of a critically endangered mycophagous marsupial (*Bettongia penicillata*) to timber harvesting in a native eucalypt forest. *Forest Ecology and Management* 363, 190–199.

Wayne, A. F., Maxwell, M. A., Ward, C. G., Vellios, C. V., Wilson, I., Wayne, J. C., and Williams, M. R. (2015). Sudden and rapid decline of the abundant marsupial *Bettongia penicillata* in Australia. *Oryx* 49(1), 175–185.

Wayne, Adrian F., Maxwell, M. A., Ward, C. G., Wayne, J. C., Vellios, C. V., and Wilson, I. J. (2017a). Recoveries and cascading declines of native mammals associated with control of an introduced predator. *Journal of Mammalogy* 98, 489–501. https://doi.org/10.1093/jmammal/gyw237

Wayne, A. F., Wilson, B. A., and Woinarski, J. C. Z., (2017b). Falling apart? Insights and lessons from three recent studies documenting rapid and severe decline in terrestrial mammal assemblages of northern, south-eastern, and south-western Australia. *Wildlife Research* 44, 114. https://doi.org/10.1071/WR16178

Wayne AF, Maxwell MA, Ward CG, and Chambers B (2021). Safety assessment of Felixer feral cat grooming traps in the southern jarrah forest, Western Australia. Report. Department of Biodiversity, Conservation and Attractions. (Manjimup, Western Australia)

Woinarski JCZ, Legge S, and Dickman CR (2019). 'Cats in Australia: Companion and killer.' (CSIRO Publishing: Clayton South, Victoria, Australia)

Wyre, G. (2004). Management of the Western Shield program: Western Shield Review—February 2003. *Conservation Science Western Australia* 5(2), 20–30.

Wysong, M. L., Iacona, G. D., Valentine, L. E., Morris, K., and Ritchie, E. G. (2020). On the right track: placement of camera traps on roads improves detection of predators and shows non-target impacts of feral cat baiting. *Wildlife Research* 47(8), 557–569.

7 Appendices

Appendix 1 Thylation Felixer Leaflet 03.2023. page 1 of 2. Australian Pesticides and Veterinary Medicines Authority

Thylation FELIXER

DANGEROUS POISON

KEEP OUT OF REACH OF CHILDREN

READ SAFETY DIRECTIONS BEFORE OPENING OR USING

Felixer Cartridge (1080)

ACTIVE CONSTITUENT:
2.67 g/L SODIUM FLUROACETATE (1080)
Each cartridge contains 8 mg SODIUM FLUROACETATE (1080)

For the control of feral cats when used with the Felixer as per the directions for use.

WARNING: Small to medium sized canids may activate the Felixer, if fired upon the dose received may be fatal.

RESTRICTED CHEMICAL PRODUCT ONLY TO BE SUPPLIED TO OR USED BY AN AUTHORISED PERSON.

THIS PRODUCT MUST BE USED IN ACCORDANCE WITH THE LABEL INSTRUCTIONS AND ANY RELEVANT DOCUMENTATION ISSUED WITH STATE/TERRITORY AUTHORISATION TO USE FELIXER 1080 CARTRIDGES.

Important: Read the Label leaflet, Felixer Standard Operating Procedure, and complete the Felixer Accreditation https://thylation.com/training/ before use. Felixer data must be assessed at minimum frequency of once per month when in toxic mode, or the number of toxic doses loaded into the trap must be restricted to a maximum of 10 cartridges. Felixer data must be uploaded to the Felixer Management System at least every three months. Felixer cartridges must be removed from Felixer if greater than 0.5% of non-target species are fired on.

NET CONTENTS: 10 cartridges (3 mL/cartridge)

Cartridges are NOT for resale.

Thylation Operations Pty Ltd
Address: c/o Level 1, 100 Hutt St, Adelaide SA 5000, Australia
Telephone number: 1300 234 816

AUTHORISED PERSONS

Only authorised persons may possess, store, transport, handle or use Felixer 1080 Cartridges. Felixer 1080 Cartridges must be transported and stored in such a way that unauthorised personnel cannot have access to the Cartridges.

Only for use by persons authorised by the relevant State or Territory Government authority responsible for authorising people to possess and use products containing sodium fluoroacetate ("1080") Felixer 1080 Cartridges.

Refer to www.thylation.com and Thylation quote for reference to the relevant State or Territory Government Authority and related use documents.

DIRECTIONS FOR USE

RESTRAINTS

DO NOT load Felixer 1080 Cartridges into the Felixer until a minimum of two weeks in photo only mode has been observed and non-target species thresholds have not been exceeded.

DO NOT deploy Felixer in toxic mode until acceptable criterion of not more than 0.5% for non-target species has been achieved in photo-only trials.

In areas where vulnerable/endangered species or susceptible non target species are identified or may be present, seek expert advice in relation to the relative risks of deploying or not deploying Felixers from regional level conservation/ environment/ wildlife management departmental personnel before deploying in toxic mode.

DO NOT deploy Felixer in toxic mode in areas where dingoes are present during whelping season and dingo populations are protected.

DO NOT use except as instructed by this label or in accordance with directions of the relevant government authority.

Only for use by persons authorised by the relevant government authority.

DO NOT use Felixer 1080 cartridges unless loaded into the Felixer.

DO NOT store Felixer 1080 cartridges in the Felixer when the trap is not in deployed.

Usage restrictions

Information on non-target wildlife distribution, conservation status, habitat preference, diet, body weight, morphology and size of home range, can be used to reduce risks posed by toxic control programs.

Photo-only trials (without 1080) must be conducted for a minimum duration of 2 weeks prior to the deployment of 1080 cartridges at all new sites or when recommencing deployment at previous sites.

In photo-only trials, false-positive activation rates must not exceed 0.5% for all non-target species (i.e.,total false firings on all non-targets/ total non-target images x 100). Based on low risk of poisoning (adults only), the following non-target species may be excluded from the calculation: red kangaroo, western grey kangaroo, brush-tailed bettong, emu, malleefowl, Australian brush-turkey, and lace monitor. Individuals at young or juvenile life stages are NOT exempt from the calculation. Canines, except dingoes where protected, can be excluded from the calculation of the 0.5% non-target species criterion.

When in toxic mode, activation rates must be analysed at a minimum frequency of once per month to ensure the criterion of 0.5% false positive activations has not been exceeded. In locations where monthly site access is impractical, users must limit the number of toxic doses available to a maximum of 10 cartridges. Activation rates must be analysed prior to reloading 1080 cartridges into the Felixer. Toxic control programs must be suspended at sites where the Felixer has malfunctioned, or where non-targets (excluding exempt species) are fired on at a rate of greater than the criterion of 0.5%. When the 0.5% threshold has been exceeded, or the Felixer has been adjusted from a conservative mode to an aggressive mode, a minimum 2-week photo-only trial (non-toxic) MUST be undertaken prior to the deployment of 1080 cartridges.

To the extent possible, animal carcasses should be recovered during and for 14 days after a deployment and be destroyed by burning or burial according to the requirements of the State or Territory in which use has occurred.

Any incidents where it is suspected that > 0.5% non-target animals may have been poisoned must be reported the State or Territory authorities.

Record Keeping Requirements

A record of the non-target criterion assessment must be kept for all deployments of Felixer where the intention is to deploy the Felixer in toxic mode. Records MUST be kept for a minimum of 2 years and be made available to Regulatory Authorities on request.

A record of the number of cartridges loaded into each Felixer in each deployment must be kept.

Critical Use Comments:

- Place Felixer along the sides of trails, fence lines or underpasses and in other areas where feral cat activity is likely. Mark the location of the Felixers as appropriate (e.g.,using flagging tape, spray marker or a GPS coordinate) to ensure they can be relocated for checking. Care should be taken when marking Felixer sites so that detection by unauthorised persons is minimised.
- In order to maximise the likelihood of the trap activating when it detects a target animal all Felixer must be set up in accordance with the instructions in the Felixer SOP.
- Lures may be used in conjunction with Felixer to increase efficiency where appropriate.
- Note that the Felixer may be activated by small-medium dogs/ canids present in a control area. The dose received is likely to be fatal.
- Additional integrated control programs to reduce feral cat populations will improve cat control program success. Felixers take photographs of all detected animals whether they activate the Felixer or not. These data should be loaded to the Felixer Management System at least every three months to enable analyses of which species are activating the Felixers and to track the response of wildlife to feral cat control. Programs should be reviewed and modified regularly to maximise feral cat control efficiency.
- Ensure all safety precautions and directions (see below) are followed when loading Felixer 1080 Cartridges into the Felixer and when setting the trap.
- Loaded Felixer in toxic mode must be checked at a minimum frequency of once per month unless the trap is deployed with 10 or less cartridges loaded.
- Loaded Felixers should be checked more often where feral cat populations are high.
- Remove all Felixer 1080 Cartridges at the end of the control program, (there may be value in leaving unarmed traps in place to habituate cats between trapping programs). Felixer magazines must be cleaned by washing in soapy water and rinsing in clean water between control programs to remove 1080 product residue as per **Rehandling** instructions.
- Between control programs, traps should be maintained and serviced according to the device manufacturer's instructions to ensure they function properly.

Appendix 2: Number of mammal detection events on remote sensor cameras at the four experimental toxic field trial sites, excluding feral cat and foxes, in the southern jarrah forest (independent detection events based on 60min intervals)

Species name	**Common Name**	**North Perup**	**Lake Muir**	**Tone-Meribup**	**Central Perup**
Antechinus flavipes	Mardo	0	14	10	0
Bettongia penicillata	Woylie	6614	0	1427	4040
Capra hircus	Feral Goat	0	0	66	7
Cercartetus concinnus	Pygmy possum	0	1	0	0
Dasyurus geoffroii	Chuditch	705	870	235	1252
Equus caballus	Horse	0	21	0	0
Felis catus	Feral cat	404	3246	2331	118
Isoodon fusciventer	Quenda	478	64	819	591
Macropus fuliginosus	Yongka	2056	2850	2116	1008
Mus Musculus	House mouse	1	42	5	7
Myrmecobius fasciatus	Numbat	77	1	310	200
Notamacropus eugenii	Tammar	1053	178	480	329
Notamacropus irma	Kwara	117	920	459	60
Oryctolagus cuniculus	Rabbit	22	388	52	43
Phascogale tapoatafa	Wambenger	13	6	15	16
Pseudocheirus occidentalis	Ngwayir	77	1	5	95
Rattus fuscipes	Bush rat	0	3	2	0
Rattus rattus	Black rat	0	64	2	0
Setonix brachyurus	Quokka	0	4624	403	0
Sminthopsis species	Dunnart	7	61	6	16
Sus scrofa	Feral pig	0	368	79	0
Tachyglossus aculeatus	Nyingarn	59	44	99	48
Tarsipes rostratus	Honey Possum	0	1	0	0
Trichosurus vulpecula	Koomal	2844	2506	1690	2150
Vulpes vulpes	Red fox	1529	2164	1428	828
Various spp.	Feral deer	0	187	3	0
Various spp.	Rodent	0	1	0	0
Various spp.	Small mammals	0	39	4	5
Total trap effort	84,373	18,016 nights	37,240 nights	26,739 nights	8,152 nights
Survey period	12/1/2021 – 12/05/2023	12/1/2021 - 14/1/2022	6/4/2021 - 12/5/2023	14/1/2021 - 28/7/2022	14/11/2022 - 12/5/2023