CSIRO PUBLISHING

RESEARCH PAPER
https://doi.org/10.1071/WR23128

WILDLIFE RESEARCH

Trialling a new method to attract feral cats (*Felis catus*) *in situ* – the Mata Hari Judas queen

Abby L. Dennien[A,B], Megan C. Edwards[A,*], Julia M. Hoy[B,C], Vere Nicolson[B], Megan J. Brady[B] and Peter J. Murray[A]

For full list of author affiliations and declarations see end of paper

***Correspondence to:**
Megan C. Edwards
School of Agriculture and Environmental Science, University of Southern Queensland, 487-535 West Street, Darling Heights, Qld 4350, Australia
Email: meg.edwards@unisq.edu.au

Handling Editor:
Penny Fisher

Received: 4 October 2023
Accepted: 30 March 2024
Published: 16 April 2024

Cite this: Dennien AL *et al.* (2024) Trialling a new method to attract feral cats (*Felis catus*) *in situ* – the Mata Hari Judas queen. *Wildlife Research* **51**, WR23128. doi:10.1071/WR23128

ABSTRACT

Context. Feral cats are a significant threat to wildlife in Australia and globally. Current feral cat management techniques have limitations that can result in wary, remnant individuals persisting in the landscape and reducing overall pest control efficacy, thus there is a need for additional innovative management techniques. **Aims.** This research aimed to identify whether the Mata Hari Judas technique could be applied to female cats (queens) *in situ* as a means of attracting and assisting the capture of feral cats. **Methods.** Three queens were induced into prolonged oestrus and contained in enclosures (vennels) *in situ* with traps attached to capture attracted feral cats. Two vennel treatments were trialled, one housing a Mata Hari Judas queen (queen vennel) and another using auditory and olfactory lures from a Mata Hari Judas queen (faux queen vennel) to compare the attractiveness of the two treatments at three study sites. Camera traps and soil plots were used to monitor and compare cat activity surrounding the vennels prior to, during and after the presence of a Mata Hari Judas queen or her lures. **Key results.** Both vennel treatments attracted multiple feral cats of both sexes, and each trapped one male cat, demonstrating proof of concept for this technique. The queen vennel was significantly more attractive than the faux queen vennel, as demonstrated by higher frequency of cat detections and the duration of time feral cats spent at this vennel. Comparisons between monitoring periods and when the vennels were active showed significant differences in the frequency of cats attracted to the area, further supporting that both the queen and her lures were attractive to cats. **Conclusions.** This research is the first instance where Mata Hari Judas queens have been successfully used *in situ* to attract and capture feral cats. Future studies should aim to assess this technique in a controlled area with a known cat population to allow for a direct comparison of efficacy with more traditional feral cat management methods. **Implications.** With further refinement, the use of Mata Hari Judas queens *in situ* could provide an efficient technique for removing remnant cats.

Keywords: animal behaviour, animal reproduction, *Felis catus*, feral cat management, invasive species, Mata Hari Judas queen, Pest management, predator control, wildlife conservation.

Introduction

Feral cats (*Felis catus*) are one of the most significant threats facing wildlife on a global scale (Nogales *et al.* 2004; Medina *et al.* 2011; Medina *et al.* 2014; Dickman *et al.* 2019; Legge *et al.* 2020). Their impact is widespread, not only geographically, but also in the mechanisms in which they affect native species, including through predation, competition for resources, transmission of diseases and interaction with other environmental pressures (Doherty *et al.* 2015, 2017; Woinarski *et al.* 2017, 2018; Dickman *et al.* 2019; Murphy *et al.* 2019; Legge *et al.* 2020). In Australia, cats have been implicated as one of the primary causal factors in the extinction of more than 25 mammal species and the continued decline of many others (Woinarski *et al.* 2015; Legge *et al.* 2020). As such, the control of feral cats and the reduction of their impact on native species is a necessity and priority for government agencies and conservation organisations globally (Nogales *et al.* 2004; Denny and Dickman 2010; Legge *et al.* 2020; Department of Climate Change Energy the Environment and Water 2022).

Cat management programs in Australia are generally focused on the removal of cats from fenced reserves or islands, problem individuals or the general reduction of cat abundance to ease the pressure on native species in key areas, with varying success (Nogales *et al.* 2004; Doherty *et al.* 2017; Legge *et al.* 2020). Current feral cat management teams often employ a combination of traditional management techniques, including shooting, live trapping and baiting (Short *et al.* 2002; Nogales *et al.* 2004; Doherty *et al.* 2017; Dickman *et al.* 2019; Legge *et al.* 2020).

Shooting of feral cats is a widely used technique, often in conjunction with other methods (Doherty *et al.* 2017). In particular, shooting by individual citizens contributes greatly to feral cat control (Garrard *et al.* 2020). Live trapping typically uses either cage or leg hold traps (McGregor *et al.* 2016) and offers a targeted approach with discrimination between feral and owned cats possible. Baiting is often done on a larger scale to reduce populations, but is not always a viable strategy for managing cats given their preference for live prey (Doherty *et al.* 2017; Dickman *et al.* 2019). Typical baits include using sausages laced with 1080 (sodium fluoroacetate) and hard shells encapsulating PAPP (para-amino propiophenone) (Doherty *et al.* 2017; Dickman *et al.* 2019; Legge *et al.* 2020).

Although these techniques can be successful, they are not without limitations, including intensive labour and associated costs, their indiscriminate nature, welfare concerns (such as the humaneness of poison baiting (Johnston *et al.* 2020)) and wariness of remnant individuals (Doherty *et al.* 2017; Legge *et al.* 2017). Cat eradication programs can take years to complete, with remnant individuals often proving difficult to remove, thus the need for new additional efficient management techniques (Nogales *et al.* 2004; Ratcliffe *et al.* 2010; Algar *et al.* 2011; Robinson and Copson 2014; Dickman *et al.* 2019; Algar *et al.* 2020).

The Mata Hari Judas technique has been used to successfully manage introduced vertebrate pests (Campbell *et al.* 2004; Campbell and Donlan 2005; Cruz *et al.* 2009; Carrion *et al.* 2011; Masters *et al.* 2018). The technique was first developed with goats (*Capra hircus*) and has since been applied to red deer (*Cervus elaphus*), another gregarious species (Campbell 2002; Campbell *et al.* 2007; Crouchley *et al.* 2011). It uses an animal's reproductive instinct against itself and targets remnant individuals that are otherwise difficult to locate or capture (Campbell 2002; Campbell *et al.* 2007). Traditionally, the technique involves inducing females into oestrus with a hormonal implant, fitting them with a tracking device, and releasing them into an area with remnant conspecifics (Taylor and Katahira 1988; Campbell 2002; Campbell *et al.* 2007). The Mata Hari Judas female then attracts or locates conspecifics of both sexes and at a later date is located with all associated conspecifics removed, typically through ground or aerial hunting (Taylor and Katahira 1988; Campbell 2002; Campbell *et al.* 2007).

The use of Mata Hari Judas goats has become a useful tool in goat eradication programs (Campbell and Donlan 2005; Campbell *et al.* 2007; Cruz *et al.* 2009). Mata Hari Judas goats performed better than any other control technique in removing the last 1000 goats on Santiago Island in the Galapagos, reducing the time and associated costs of the control program (Cruz *et al.* 2009). The application of this technique with other species has been proposed, including as a tool for feral cat management (Murray *et al.* 2020). Because the Mata Hari Judas technique relies upon the instinct of an animal to locate a mate, cats' sexual promiscuity (Dickman *et al.* 2019) has the potential to assist in the use of the technique (Campbell *et al.* 2007; Murray *et al.* 2020). Previous studies have determined that sexually mature female cats (queens) can be induced into prolonged oestrus using a number of mechanisms (Hyndman *et al.* 2020; Murray *et al.* 2020). Furthermore, queens induced into prolonged oestrus are attractive to male cats (toms), a critical first step in applying this technique to cats (Murray *et al.* 2020). Therefore, the next step is to investigate the potential of using the Mata Hari Judas technique *in situ* to attract feral cats. However, there are several challenges, considering the Mata Hari Judas technique has previously been applied to species with considerably different behaviour, diet and ecology (Campbell *et al.* 2007; Murray *et al.* 2020).

The release of a Mata Hari Judas queen *in situ* would not be efficient because cats are generally solitary and cryptic, and can be possessive of specific resources (Fisher *et al.* 2015; Dickman *et al.* 2019; Murray *et al.* 2020). Efforts to remove associates would also likely be unsuccessful given their small size (in comparison to other Mata Hari Judas species such as goats), cryptic behaviour and the potential welfare issues associated with the queen being attacked by conspecifics if released into unfamiliar territory (Fisher *et al.* 2015). Rather, Mata Hari Judas queens could be safely confined *in situ* while allowing attracted conspecifics to locate the queens, and be captured when trying to access them. A similar technique was used when a sow in induced oestrus was used to attract conspecifics while housed in a pen (Choquenot *et al.* 1993; McIlroy and Gifford 2005).

Furthermore, there is the potential to explore whether a live Mata Hari Judas queen is required or whether the auditory and olfactory cues of a Mata Hari Judas queen would be sufficient as lures. Cats use both scent and vocalisations as a means of communication (Dickman *et al.* 2019). The use of auditory and olfactory lures has been investigated and utilised when trapping cats with varying success (Clapperton *et al.* 1994; Edwards *et al.* 1997; Moseby *et al.* 2004; Read *et al.* 2015). Although there are commercially available auditory and olfactory lures for cats (Moseby *et al.* 2004), the use of the lures from a Mata Hari Judas queen could be more effective because the source would be confirmed to be in oestrus. Furthermore, the use of Mata Hari Judas queen lures instead of a live queen could eliminate some of the logistics and any perceived ethical or welfare issues associated with containing a live queen.

Therefore, this trial aimed to assess: (1) whether the Mata Hari Judas technique could be applied to attract and assist in the capture of cats *in situ*; (2) if using a combination of olfactory and auditory lures, could the Mata Hari Judas queen attract and assist in the capture of cats *in situ*; and (3) whether the lures are as attractive as the live Mata Hari Judas queen. We hypothesised that the Mata Hari Judas technique would be successful in attracting and capturing cats *in situ* when using either a live Mata Hari Judas queen or the olfactory and auditory lures from the Mata Hari Judas queen. In addition, we hypothesised that the live Mata Hari Judas queen would be a stronger attractant to cats *in situ* in comparison to the olfactory and auditory lures from the Mata Hari Judas queen.

Materials and methods

Study area

The trial was conducted on three study sites, all private properties in south-east Queensland (Fig. 1). The primary uses for the properties were conservation, ecotourism and cattle grazing. All three study sites contained similar habitats, comprising Eucalypt woodlands to open forests. Two locations were selected on each property, allowing for two different treatments, and ranged from 1.8 to 4.8 km apart. The locations were selected to allow for the greatest distance between treatments within the constraints of the property, while also factoring in accessibility. Historical cat detections from surveys (soil plots and camera traps) conducted by land managers and ecologists in the 4 years preceding the study were also considered when choosing locations. The general area around the site was cleared of long grass to allow for better visibility of camera traps.

Cat containment systems

A custom enclosure (designed and constructed prior to this trial), hereafter referred to as a 'vennel', was utilised to safely house the queens while *in situ* (Fig. 2). It measured 1.5 m wide, 1.8 m long and 1.5 m high. The vennel walls were primarily made of aluminium sheets, with four round cut outs fitted with wire mesh for attachment of pipe traps, and a section of wire mesh at the top of the walls for ventilation,

Fig. 1. Map of the study sites and locations of vennel treatments in south-east Queensland.

Fig. 2. A vennel used to house the Mata Hari Judas queen or her lures deployed in the field with pipe traps fitted and set, and soil plot surrounding the vennel. Also shown are camera traps used to record animal visitation around the vennel.

The roof was an insulated panel to ensure the vennel was an appropriate temperature and overhangs reduced sun and rain exposure inside the vennel.

A nest box was provided for shelter and sat on top of shelves, which lined two sides inside of the vennel and sat at a height of 70 cm above the floor (Fig. 3). The nest box could be closed from outside the enclosure to contain the cat and allow for easy access to the vennel for feeding or cleaning. A sand pit was provided as a litter tray. Auto waterers inside the vennel provided the queen access to fresh water. All cats were provided with enrichment items (e.g. scratching post, puzzle feeders, hanging toys) in the vennel to promote mental and physical wellbeing.

To trap any cats attracted, four custom pipe traps were connected to the vennel (pipe and door elements were derived from Tasmanian devil (*Sarcophilus harrisii*) traps and constructed prior to this trial). The PVC pipe traps were 1.2 m long and 30 cm in diameter and were connected to the vennel at the four circular cut outs in the walls. There were doors at either end of the pipes to allow the auditory and olfactory lures of the queen to disperse through the pipe trap and to create the illusion that they were the only way for feral cats to access the queen. The trap doors were activated by a treadle mechanism inside the trap. Due to the height of the vennel, the traps were 30 cm above ground level and used wooden supports to stabilise the traps (Fig. 2). This was also done in an attempt to reduce non-target captures (e.g. Short *et al.* 2002).

The traps were set late in the afternoon and checked early in the morning. Additional lures were added to the traps at study site 2 and three because observations showed cats were visiting the vennel and investigating traps but without capture. Additional lures were used in an attempt to encourage attracted cats to move further into the traps and thus activate the treadle mechanism inside the trap. The queens' faeces were used as a visual and scent lure in two traps at each vennel treatment at study site 2 on trapping nights 11–14. Dry cat kibble was used as a lure at study site 3 in two pipe traps at each vennel treatment on trapping nights 6–14.

Fig. 3. The inside of the vennel for both treatments, including a nest box, shelves, sand pit for litter, auto waterer, food bowl and enrichment items. Also shown is an attached pipe trap (closed), with mesh covering the circular hole in the vennel wall to prevent cats entering or exiting the vennel when the traps are active.

Any cats captured in the pipe traps during the experiment were removed from the traps into a custom-made handling bag. The bags were constructed of cotton drill fabric with enforced seams and had a 15 × 18 cm flap close to the bottom corner, fastened with sewn-on heavy duty Velcro to allow for access to a cat's neck. The cats were first checked for a microchip, to determine if they were an owned cat. If the cat had no microchip and was determined to be feral, they were fitted with a GPS collar to monitor their movements as part of a wider project outside of the scope of this study.

Monitoring cat activity

The vennel and surrounding area was monitored throughout the trial using camera traps and soil plots. A pre-monitoring baseline (inactive vennel) period occurred for a minimum of 5 days (range 5–10 days) to determine animal activity prior to the Mata Hari Judas queens or their lures being placed in the vennels (active vennel period). Monitoring continued during the active vennel period (range 7–15 days) and then afterwards for a post-monitoring period of a minimum of 5 days (range 5–10 days). Both camera traps and soil/sand plots were used to ensure all activity was captured, because each of these monitoring methods has strengths and weaknesses (Lyra-Jorge *et al*. 2008; Rovero and Zimmermann 2016).

Camera traps (Swift Enduro, Outdoor Cameras Australia, Toowoomba, Queensland, Australia) were used at all vennel sites throughout the trials (Fig. 4). Initially, 12 cameras were placed around each vennel site. Four were placed above each trap on the vennel wall at a height of 150 cm. Eight cameras were positioned on stakes at a 45° angle and 4 m (moved in from 6 m at study site 1) from each corner of the vennel, with four facing towards the vennel at 80 cm high and four facing away from the vennel at 100 cm high. An additional four cameras were added to the stakes at the height of 40 cm after 9 days at study site 1 because the initial cameras were failing to detect the activity of smaller animals on the soil plots. The four additional camera traps were relocated for study sites 2 and 3 to the wooden supports of a trap at 30 cm high to further improve the detection of soil plot and trap activity (Fig. 4). A further five cameras were deployed in the area surrounding each vennel at study sites 2 and 3 to confirm cat activity in the general area, referred to as cameras 'further out'. The unbaited cameras ranged from 30–500 m in distance from the vennels and were placed at points of interest to maximise cat detections i.e. along road edges, game trails, fence ends and near water sources, at approximately 60 cm high.

Soil/sand plots were constructed around the vennel and pipe traps to monitor activity close to each vennel (Fig. 2). Vegetation was cleared down to bare soil for approximately 1 m continuously around the vennel and pipe traps. At study site 1, the soil on location was sifted to create a fine layer of soil for reading tracks easily. At study sites 2 and 3, washed play sand was brought in and placed over the bare soil. This refinement was as a result of the difference in readability of tracks between soil types and to standardise the remaining plots. Soil/sand plots were read each morning of the trial and all tracks were measured, identified and recorded to species level where possible. The plots were re-set each evening and a shoe print was placed in the soil plot. If this print was not present the following morning, the soil/sand plot was deemed invalid.

Three cameras were also located inside the vennel to monitor the Mata Hari Judas queen (Fig. 4). The queens were observed twice daily (morning and afternoon) for approximately 10 minutes while housed in the vennel to monitor their health and wellbeing. The quantity of food

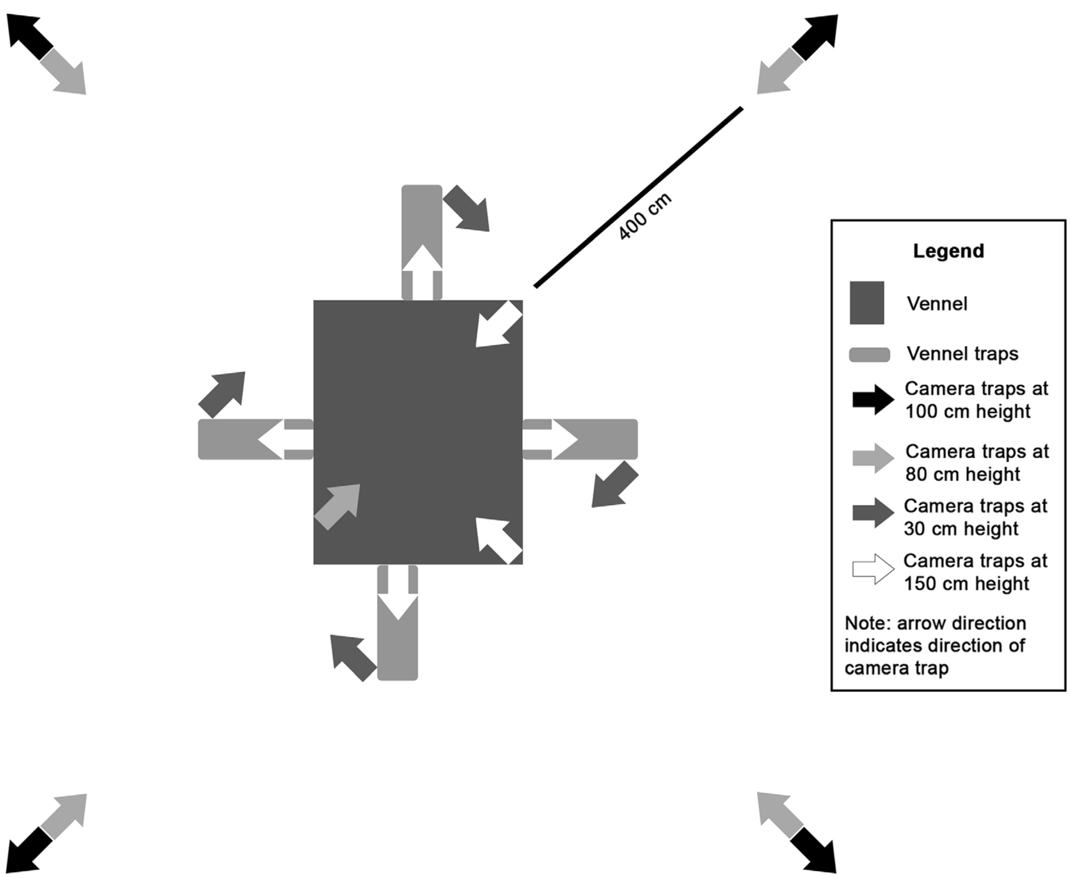

Fig. 4. Camera trap lay out surrounding the vennels at study site 2 and three.

provided and food residue was recorded each day to establish and monitor food intake of the queen.

Vennel treatments

Two treatment types were used, the queen vennel and faux queen vennel. At each study site a queen vennel and faux queen vennel were deployed in two separate locations, totalling six vennels deployed over the three study sites. Treatment 1 (queen vennel) housed the Mata Hari Judas queen. Three queens (one per study site) were obtained from the Toowoomba Animal Management Centre between January 2022 and March 2022, after attempts to capture feral cats were unsuccessful. These animals had no microchips and were deemed (by the RSPCA) unable to be rehomed. The queens weighed between 2.2 and 3.0 kg.

On acquiring the queens, they were anaesthetised and their general health and wellbeing assessed by a veterinarian to ensure they were suitable to be included in the trial (i.e. no obvious illnesses or wounds, appropriate body condition score, not pregnant). In order to induce oestrus, a Compudose™ 100 implant was cut to produce a quarter of the original implant, containing approximately 5.25 mg of oestradiol-17ß, and inserted subcutaneously in the periscapular region as per methods outlined in Murray *et al.* (2020).

The Mata Hari Judas queen was housed in the queen vennel for a minimum period of 7 days and a maximum of 15 days (active vennel period). After 7 days, if cats had not been detected by the camera traps or soil/sand plots for 3 days consecutively, the trial was deemed to be finished. The queen was then removed from the vennel and euthanised by a veterinarian via intravenous pentobarbitone while under anaesthetic. A post mortem was then conducted by a veterinarian. The queens were weighed and general body condition recorded. The implant site was dissected to investigate the location and state of the Compudose implant and surrounding tissue. The reproductive tract was examined for abnormalities, particularly the uterine wall, which revealed thickening in a previous study (Murray *et al.* 2020). Faeces and urine from the queen remained in the vennel until the end of the post monitoring period when the vennel was removed from the site.

Treatment 2 (faux queen vennel) had no live animal, instead utilising the queens' olfactory (urine and faeces) and auditory (vocalisation recordings) cues as lures. The faux queen vennel was furnished in the same manner as the queen vennel. Urine and faeces were transferred daily during the active vennel period from the queen vennel to the faux queen vennel. The first queen's vocalisations were recorded using an acoustic monitoring device (AudioMoth, Open Acoustic Devices) and replayed on a speaker (Megaboom 3, Ultimate Ears, Irvine, California, USA; maximum sound level 90 dBc) at the faux queen vennel for all sites. The audio was played from approximately 5 pm to 6 am during the active vennel period. It consisted of a continuous cycle of the queen's vocalisations for 10 minutes followed by a 10-minute break. At all study sites, the faux queen vennel was inactive (no traps set or vocalisations playing) for one less day than the queen vennel, either to allow time for the collection of urine, faeces and vocalisations or due to weather conditions resulting in limited access to the study site. At the conclusion of the active vennel period, vocalisations ceased, but faeces and urine remained in the vennel until the end of the post-monitoring period.

Data analyses

In order to determine if it is possible to attract cats using a combination of olfactory and auditory lures from the Mata Hari Judas queen, and whether this is as attractive as the live Mata Hari Judas queen, the number of cat visits and the duration of time spent by cats at the vennels treatments were compared. The number of 'cat visits' were quantified using camera trap data. Cats were first individually identified by their unique markings and sexed when possible, using the camera trap images. Because there were multiple cameras in close vicinity and directed at a similar area, cat visits incorporated data from multiple cameras as one visit. A visit was classed as separate if 60 minutes or more had elapsed between camera trap images of the same individual cat. If there were two separate cats in the images, it was classed as two visits.

To identify if there were any differences in the number of cat visits to the vennel treatments during the pre-monitoring, active vennel and the post-monitoring periods, we used a generalised linear mixed effects model with a Poisson distribution in the package lme4 (Bates *et al.* 2015). Study site was included in the model as a random effect. One-sided Wilcoxon signed rank tests were used to identify any differences between the cat visits at each vennel treatment and the surrounding area for study site 2.

The duration of time spent at the vennels by feral cats was also quantified in order to gauge the attractiveness of the vennel treatments. Due to low (1 detection) or no activity at some sites, only study site 2 was included in this analysis. The duration of each visit was calculated using camera trap data and was based on the time the cat first appeared at the vennel to when it was last seen. This incorporated data from multiple cameras around the vennels and was combined into a nightly total over the Mata Hari Judas trial period. The cumulative total of time spent by feral cats at each vennel was then calculated. Furthermore, a one-sided Wilcoxon signed rank test was used to determine if there were any significant differences between the duration of cat visits spent at the vennel treatments at study site 2. All analyses were conducted using R Studio (R Core Team 2021).

Results

General overview

In total, six individual cats were detected at two of the three study sites (Table 1) and half of the six vennels. There was a

Table 1. Summary of the monitoring and results for both the queen and faux queen vennel at all three study sites, including cameras further out.

	Study site 1	Study site 2	Study site 3
Experiment length	21 days (5 days pre, 11 days active, 5 days post)	28 days (7 days pre, 14 days active, 7 days post)	34 days (10 days pre, 14 days active, 10 days post)
Camera trap nights	639	1217	1526
No. of individual cats identified on camera	0	5	1
No. of camera trap events for cats (cat visits)	0	56	2
No. of species detected on camera	17	22	39
No. of trap nights	84	108	108
No. of cats trapped	0	1	1

For details of other species captured on camera, please see Table S2.

total of 26 visits to the vennels by four male and two female cats throughout the trial (Table 2).

Attractiveness of vennel treatments

Both the queen and faux queen vennel attracted multiple feral cats overall (Table 2), and each trapped one tom cat. During the active vennel period, 16 visits were recorded at the queen vennel and five visits at the faux queen vennels. Four out of the six cats made multiple visits to the vennels. Cat 2 (located at study site 2) was the only individual that visited both vennels treatments.

The study period (i.e. pre-monitoring, active vennel, post-monitoring periods) significantly influenced the number of cat visits to the vennels ($R^2 = 0.60$; Table S1; Fig. 5). Cat visits significantly increased during the active vennel period when compared with the pre-monitoring period ($P = 0.024$) and the post-monitoring period ($P = 0.049$). Furthermore, a one-sided Wilcoxon signed rank test revealed that there was a statistically higher probability that feral cats would visit the queen vennel in comparison with the faux queen vennel during the active vennel period at study site 2 (V (test statistic) = 3.5, $P = 0.011$).

Table 2. The total number of visits by individual feral cats to each vennel treatment at all study sites.

Cat ID	Sex	Study site	Queen vennel visits	Faux queen vennel visits
1	M	2	10	0
2	M	2	6	2
3	F	2	3	0
4	M	2	0	3
5	U	2	0	1
6	M	3	0	1
Total			19	**7**

Cats were sexed using images from the camera traps, either through visual confirmation of genitals or observations of mating occurring on camera. Excludes data from camera traps 'further out'. U = unknown sex.

Of the cameras placed further out from the vennels, monitoring the surrounding area at study sites 2 and 3, there was a total of 34 cat detections. During the active vennel periods, cat detections further out from the vennels totalled 18 for the queen vennel and eight for the faux queen vennel. A one-sided Wilcoxon signed rank test revealed there was no statistical difference between the number of feral cat visits at the cameras further out from each vennel treatment during the active vennel period at study site 2 (V (test statistic) = 13, $P = 0.140$).

Feral cats spent a cumulative total of 9 hours and 40 minutes at the queen vennel and 46 minutes at the faux queen vennel over the entire study period at study sites 2 and 3 (Fig. 6). The mean time spent per visit at the queen vennel was 31 minutes, compared with 2 minutes at the faux queen vennel. A one-sided Wilcoxon signed rank test confirmed feral cats spent significantly more time at the queen vennel compared with the faux queen vennel during the active vennel period at study site 2 (V (test statistic) = 1, $P = 0.004$) (Fig. 6). The longest visit lasted 1 hour and 58 minutes at the queen vennel, with both male and female attracted cats regularly seen rolling on their backs, grooming and resting for extended periods of time. Furthermore, at the queen vennel, the feral cats would often locate themselves on the side of the vennel where the nest box was located and Queen 2 would regularly sit atop the nest box where she was visible to attracted cats. The longest visit at the faux queen vennel was nearly 18 minutes, during the only detection at the vennels at study site 3. There were no detections at site 1.

No non-target species were caught in the pipe traps, although 45 species were identified at the vennel or surrounds over all three study sites from camera traps and the soil plots (Table S2). Soil plot data were not included in statistical analyses because the soil plots were only valid for 40% of the trial due to poor weather conditions. Additionally, on the nights the soil plots were valid, they failed to detect cat activity 41% of the time when compared with camera traps.

Mata Hari Judas queens

Mata Hari Judas queens were confined in their vennel for a range of 11 to 14 nights. All three queens consumed food every night they were in their vennels and regularly defecated. The enrichment items provided were engaged by all of the queens. At no point during the twice-daily observations did any of the queens display behaviours or ill health requiring further action.

At study site 2, Queen 2 unexpectedly escaped from the vennel on day 2 of the active vennel period due to her size and minor differences between the vennels (i.e. a gap in the

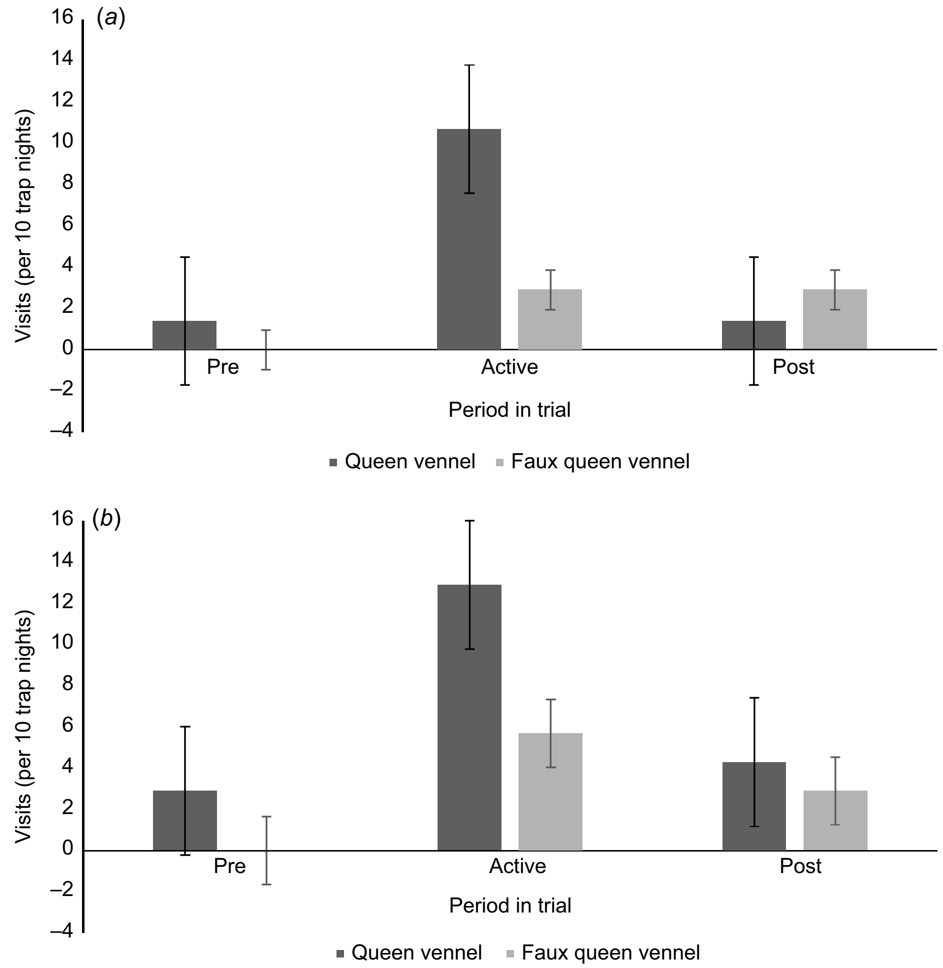

Fig. 5. Number of cat visits to (*a*) the vennels and (*b*) the cameras further out over the different trial periods (adjusted to 10 trap nights) at study site 2. Bars indicate standard errors.

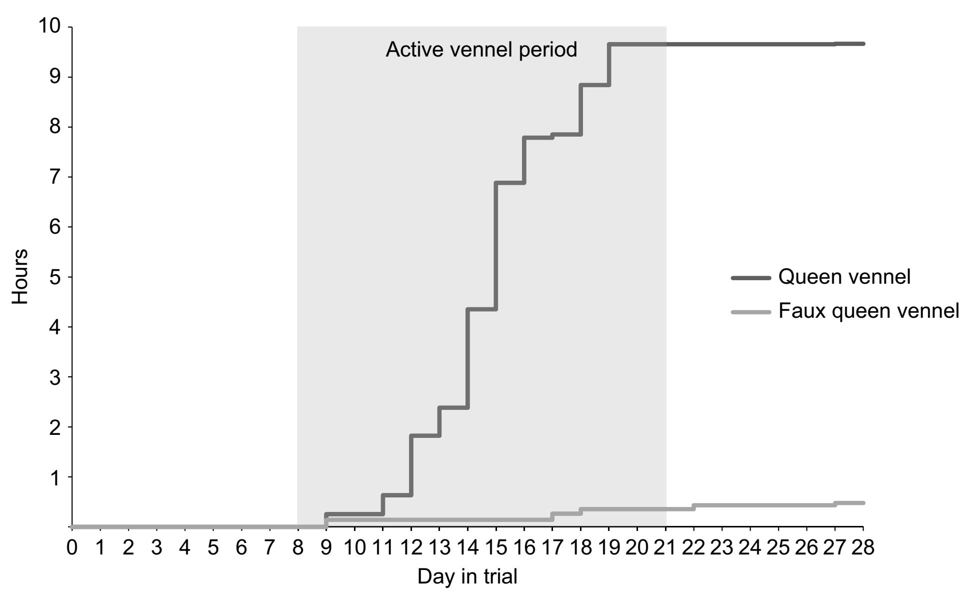

Fig. 6. Cumulative duration of hours spent by feral cats at the queen and faux queen vennel at study site 2.

mesh that allowed for the attachment of adjacent walls). The pipe traps were set and baited with her faeces and cat kibble and the vennel door left open that night in an effort to recapture the queen. Queen 2 was captured overnight in a vennel pipe trap at the queen vennel that she escaped from. On this same night a tom (Cat 1) was attracted to and later trapped in a pipe trap attached to the queen vennel. Cat 1 was first detected on camera at the vennel before the queen had been trapped and while the queen was not in the vicinity, based on camera trap images. Cat 1 returned later after the queen had been captured, and was also trapped. Queen 1 was examined by a veterinarian and placed into the vennel, for which the differences in build had been addressed, on day 3.

There were variations in behaviour and temperaments of the queens. Queen 1, after a couple of days acclimatising to the vennel, had a temperament characteristic of a stray cat who had some previous human interaction, such as seeking human positive interactions and a lack of aggression towards humans. Queen 1 also showed various characteristic oestrus behaviours during daily observations including vocalising, head/neck rubbing, lordosis, tail deflection and rolling. Queen 2 and 3's temperaments were characteristic of feral cats. No oestrus behaviours were witnessed during in-person observations as they remained in the nest box, but these behaviours were observed on the camera trap from inside the vennel.

All three queens were considered to be in good body condition by the veterinarian on post-mortem examination. Queen 1's post-mortem examination revealed a thickening of the uterine wall and mild inflammation around the incision area. Queens 2 and 3 had recently had offspring prior to the study so it was difficult to determine whether the uterus or uterine wall showed any abnormalities because these fluctuate during pregnancy and the postpartum period (Blanco *et al.* 2015; Gatel *et al.* 2020).

Discussion

Attractiveness of vennel treatments

This trial was the first instance where the Mata Hari Judas queen technique was successfully used *in situ* to attract and assist in the capture of feral cats, representing proof of concept. The significant increase in the number and duration of cat visits to vennels during the active vennel period, when the Mata Hari Judas queen or her lures were present, indicates that the presence of the Mata Hari Judas queen or her lures can attract cats to the area. This is further supported by the lack of difference in feral cat visits at the cameras further out from each vennel treatment during the active vennel period, indicating the feral cats were attracted to the vennels, as opposed to just moving through the area.

The study also revealed that the queen vennel was significantly more attractive to feral cats than the faux queen vennel, as hypothesised. Feral cats visited more, and spent significantly more time at, the queen vennel at site 2. The queen vennel provided the opportunity for visual and auditory interactions between the queen and attracted cats. The queen vennel also had dynamic authentic and real time vocalisations, as opposed to recordings that may have had less variation, and the pheromones from the queen herself and her fresh urine and faeces. Of particular note, Cat 1, who despite being captured, sedated and fitted with a GPS collar (as part of a wider project), continued after release to visit the queen vennel on a regular basis for extended periods of time. The capture of one cat at each vennel treatment supports the suggestion that both vennel treatments types are attractive. However, given the small sample size of cats physically captured, further cat capture data would be needed to confirm this.

Both male and female feral cats were attracted to the vennel treatments. If employed in future cat control programs, the ability of this technique to attract both sexes is an important factor to increase the impact of the program and ensure that all remnant individuals are eliminated regardless of sex. Multiple males were attracted to both vennels, sometimes in the same night, suggesting narrow temporal and spatial overlap of males on occasion surrounding the vennels. Although there are examples of male feral cat home ranges overlapping with one another (Molsher *et al.* 2005; Bengsen *et al.* 2012; McGregor *et al.* 2015; Leo *et al.* 2016; Roshier and Carter 2021), they are generally considered a solitary species (Dickman *et al.* 2019). These results suggest that the Mata Hari Judas technique may be effective in not only attracting cats in the immediate area, but also drawing in cats from surrounding areas to investigate. This is valuable when dealing with islands or fenced areas, because few vennels may be needed, and cats may be attracted to a central or convenient location to then be removed. Further studies should investigate how the vennels and Mata Hari Judas queens affect the movement of cats in the surrounding area to indicate the effective distance of the technique to attract cats.

No cats were detected on cameras or soil plots at either vennel location at study site 1 or at the queen vennel at study site 3. Only one individual cat (the captured tom) was detected at the faux queen vennel on one occasion at study site 3. Past surveys on the study properties confirmed presence of cats, so it was expected that they would be detected at all vennels. There are a multitude of factors potentially impacting the abundance of cats in the general area and the lack of cat activity at some of the vennels, such as landscape complexity, prey abundance, predator management and disturbance regimes (Christensen and Burrows 1995; Brook *et al.* 2012; Hohnen *et al.* 2016; Molsher *et al.* 2017; Davies *et al.* 2020; Stobo-Wilson *et al.* 2020). Additionally, it is possible that any cats in the area could have perceived the structure of the vennel and any minor clearing done as too risky to investigate, so were present but not detected.

Mata Hari Judas queens

The confinement and induced oestrus of the Mata Hari Judas queens appeared to have no adverse impact on their welfare. All queens were eating consistently, defecating regularly and engaging with the enrichment items. Engagement with the provided enrichment items and feeders was, in particular, an indicator of good health and minimal stress (Ellis 2009; Dantas-Divers *et al.* 2011; Houser and Vitale 2022). The thickening in Queen 1's uterine wall was seen when developing the Mata Hari Judas queen technique (Murray *et al.* 2020), although Queen 1's uterine wall showed less thickening than the previous study. It is thought the abnormalities seen in the uterine wall of queens is a result of the exogenous hormones from the Compudose implant (Murray *et al.* 2020).

The difference in behaviour and temperament among queens may have affected the successfulness of the technique *in situ*. It is difficult to estimate the impact this may have had on the queens' ability to attract feral cats. However, it is possible that this individual queen variation contributed to the lack of cat activity at study sites 1 and 3. There is corroborating evidence in other species of some Judas individuals (the same process as Mata Hari Judas individuals but where oestrus is not induced) being unsuccessful in finding or attracting conspecifics (Taylor and Katahira 1988; Keegan *et al.* 1994; McIlroy and Gifford 1997; Kessler 2002). A couple of reasons were suggested for these unsuccessful Judas animals. Firstly, there were no conspecifics within the search area (Taylor and Katahira 1988), which as discussed previously could have been the case for study sites 1 and 3 in this trial, although it is unlikely. Secondly, Judas animals that are not sourced locally may affect their ability to find or attract conspecifics (McIlroy and Gifford 1997; Kessler 2002; Burt and Jokiel 2011). Due to time and the difficulties previously experienced with trapping feral cats, the queens were not captured locally. Lastly, although it is not explicitly discussed in the literature, it is possible that poor performance could be a result of the individual animal (and consequently a misalignment with the role of a Judas animal), but it is yet to be measured.

Ultimately, the behaviour and temperament differences in queens is a variable that is difficult to control and potentially affects the success of the technique. Future applications would benefit from either more extensive efforts to measure and assess variation in queens, or the removal of this variable altogether by not using a live animal and focusing on just using the queen's olfactory and auditory cues.

The unexpected escape and subsequent capture of Queen 2 did stimulate interesting considerations. It is possible that the queen's movements in the landscape led the tom back to the vennel on that night, biasing the results. However, the continued visits to the queen vennel by feral cats (including that tom several times) throughout the trial period suggests that she was attractive while in the vennel. Despite the tom cat that was captured that night not being able to see her, the auditory and olfactory attractants were still in effect. For the remainder of the active vennel period, attracted cats would regularly sit just outside of the sand plot, on the side of vennel with the nest box and look up to the queen sitting atop her nest box. No other cats were trapped again at this vennel and after a first initial investigation of the vennel, the attracted feral cats appeared to show very little interest in the traps. The only other cat that was trapped was in the faux queen vennel at study site 3, at which no live animal could be seen.

These observations, though only anecdotal and based on a few occasions with a small sample size, suggest that the ability to see the Mata Hari Judas queen at the top of the vennel may not be beneficial to the technique and in fact could deter attracted cats from entering a pipe trap. Therefore, it is suggested that future studies should investigate adjusting the vennels so that the queen cannot be seen from the outside and the only 'accessible' point to visually access her is through the pipe traps. The use of other types of traps (such as leg-hold traps) could also be investigated.

Future directions

As hypothesised, the Mata Hari Judas technique was successful at attracting feral cats *in situ*, and this research represents proof of concept. Future studies should now investigate larger sample sizes to allow for a more extensive investigation into *in situ* application. Additional study sites and extensive pre- and post-monitoring of feral cat populations are recommended to determine the efficacy of this technique for feral cat management on a broader scale, particularly in a fenced area with a known cat population to allow for comparisons with other cat management techniques.

Elements of this trial were not indicative of the real-world application of this technique. Captured feral cats would typically be euthanised but in the instance of this research, cats were collared as part of a wider project beyond the scope of this particular study. The removal of the cats captured as a part of this trial may have considerably altered the results that were achieved. For example, other feral cats may have moved into the previously occupied territory and potentially increased the number of cat visits or individuals identified surrounding the vennel (Lazenby *et al.* 2014). Future studies should investigate the effect of removing the attracted and captured cats on the local population.

There are several refinements that could be made to the vennel design to improve the successfulness of the technique. The wire mesh at the top of the vennel should be covered to restrict the visibility of the Mata Hari Judas queen to attracted cats. Additionally, there should be further consideration into the design of the traps and the connection to the vennel. Alterations such as partially insetting the traps into the vennel could be investigated to determine if there is a trap design more conducive to catching cats. This technique could also be used in collaboration with other feral cat management methods. For example, a Felixer (Thylation, Adelaide, South Australia, Australia) could be deployed with a vennel to eliminate the need for a cat to go into a pipe trap or in remote areas to reduce the frequency of access required to a faux queen vennel (if olfactory lures persisted effectively) and the labour associated with trapping. Alternatively, remotely monitored traps that alert when a trap has been triggered could be considered to reduce labour of checking traps in the instance of a faux queen vennel.

Finally, focus should be placed on increasing the attractiveness of the faux queen vennel. The faux queen vennel treatment showed promise, attracting multiple cats and trapping one individual. Moving away from having a live queen in the vennels has a number of positive benefits. It would eliminate the logistics of acquiring a queen, the variables of queen behaviour and the time associated with feeding and monitoring a live animal. Furthermore, given the complexities of opinions regarding cat management, it would eliminate any perceived ethical or welfare issues associated with containing a live queen.

This research is the first instance where Mata Hari Judas queens have been successfully used *in situ* to attract and capture feral cats. With further refinement, the use of Mata Hari Judas queens *in situ* could provide an efficient technique for removing remnant cats from the landscape. The technique would best be employed as a part of a feral cat management program, particularly in closed systems such as fenced conservation reserves and small islands, to reduce the time required to eradicate the wary remnant individuals. As a result, the implementation of this technique as a feral cat management tool could have a significant impact in the fight to conserve native species on a global scale.

Supplementary material

Supplementary material is available online.

References

Algar D, Angus GJ, Onus ML (2011) Eradication of feral cats on Rottnest Island, Western Australia. *Journal of the Royal Society of Western Australia* **94**, 439–443.

Algar D, Jonhston M, Tiller C, Onus M, Fletcher J, Desmond G, Hamilton N, Speldewinde P (2020) Feral cat eradication on Dirk Hartog Island, Western Australia. *Biological Invasions* **22**, 1037–1054. doi:10.1007/s10530-019-02154-y

Bates D, Mächler M, Bolker B, Walker S (2015) Fitting linear mixed-effects models using lme4. *Journal of Statistical Software* **67**, 1–48. doi:10.18637/jss.v067.i01

Bengsen AJ, Butler JA, Masters P (2012) Applying home-range and landscape-use data to design effective feral-cat control programs. *Wildlife Research* **39**, 258–265. doi:10.1071/WR11097

Blanco PG, Rodríguez R, Batista PR, Barrena JP, Arias DO, Gobello C (2015) Bidimensional and Doppler ultrasonographic evaluation of postpartum uterine involution in the queen. *Theriogenology* **84**, 82–85. doi:10.1016/j.theriogenology.2015.02.013

Brook LA, Johnson CN, Ritchie EG (2012) Effects of predator control on behaviour of an apex predator and indirect consequences for mesopredator suppression. *Journal of Applied Ecology* **49**, 1278–1286. doi:10.1111/j.1365-2664.2012.02207.x

Burt MD, Jokiel J (2011) Eradication of feral goats (*Capra hircus*) from Makua Military Reservation, Oahu, Hawaii. In 'Island Invasives: Eradication and Management'. (Eds CR Veitch, MN Clout, DR Towns) pp. 280–284. (IUCN: Auckland, New Zealand)

Campbell KJ (2002) Advances in Judas goat methodology in the Galápagos Islands: manipulating the animals. In 'Judas Workshop 2002'. (Eds J Gregory, B Kyle, M Simmons) pp. 70–77. (New Zealand Department of Conservation: Otago Conservancy, Dunedin, New Zealand)

Campbell KJ, Donlan CJ (2005) Feral goat eradications on Islands. *Conservation Biology* **19**, 1362–1374. doi:10.1111/j.1523-1739.2005.00228.x

Campbell K, Donlan CJ, Cruz F, Carrion V (2004) Eradication of feral goats Capra hircus from Pinta Island, Galápagos, Ecuador. *Oryx* **38**, 328–333. doi:10.1017/S0030605304000572

Campbell KJ, Baxter GS, Murray PJ, Coblentz BE, Donlan CJ (2007) Development of a prolonged estrus effect for use in Judas goats. *Applied Animal Behaviour Science* **102**, 12–23. doi:10.1016/j.applanim.2006.03.003

Carrion V, Donlan CJ, Campbell KJ, Lavoie C, Cruz F (2011) Archipelago-wide island restoration in the Galápagos Islands: reducing costs of invasive mammal eradication programs and reinvasion risk. *PLoS One* **6**, e18835. doi:10.1371/journal.pone.0018835

Choquenot D, Kilgour RJ, Lukins BS (1993) An evaluation of feral pig trapping. *Wildlife Research* **20**, 15–21. doi:10.1071/WR9930015

Christensen P, Burrowns N (1995) Project desert dreaming: experimental reintroduction of mammals to the Gibson Desert, Western Australia. In 'Reintroduction Biology of Australian and New Zealand Fauna'. (Ed. M Serena) pp. 199–208. (Surrey Beatty and Sons: Chipping Norton, NSW, Australia)

Clapperton BK, Eason CT, Weston RJ, Woolhouse AD, Morgan DR (1994) Development and testing of attractants for Feral Cats, *Felis catus* L.. *Wildlife Research* **21**, 389–399. doi:10.1071/WR9940389

Crouchley D, Nugent G, Edge K (2011) Removal of red deer (*Cervus elaphus*) from Anchor and Secretary Islands, Fiordland, New Zealand. In 'Island Invasives: Eradication and Management'. (Eds CR Veitch, MN Clout, DR Towns) pp. 422–425. (IUCN: Auckland, New Zealand)

Cruz F, Carrion V, Campbell KJ, Lavoie C, Donlan CJ (2009) Bio-economics of large-scale eradication of feral goats From Santiago Island, Galápagos. *Journal of Wildlife Management* **73**, 191–200. doi:10.2193/2007-551

Dantas-Divers LMS, Crowell-Davis SL, Alford K, Genaro G, D'Almeida JM, Paixao RL (2011) Agonistic behavior and environmental enrichment of cats communally housed in a shelter. *Journal of the American Veterinary Medical Association* **239**, 796–802. doi:10.2460/javma.239.6.796

Davies HF, Maier SW, Murphy BP (2020) Feral cats are more abundant under severe disturbance regimes in an Australian tropical savanna. *Wildlife Research* **47**, 624–632. doi:10.1071/WR19198

Denny EA, Dickman C (2010) Review of cat ecology and management strategies in Australia. (IACR Centre: Canberra, ACT, Australia)

Department of Climate Change Energy the Environment and Water (2022) Threatened Species Action Plan 2022-2032. (Commonwealth of Australia: Canberra, ACT, Australia)

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

Doherty TS, Dickman CR, Nimmo DG, Ritchie EG (2015) Multiple threats, or multiplying the threats? Interactions between invasive predators and other ecological disturbances. *Biological Conservation* **190**, 60–68. doi:10.1016/j.biocon.2015.05.013

Doherty TS, Dickman CR, Johnson CN, Legge SM, Ritchie EG, Woinarski JCZ (2017) Impacts and management of feral cats *Felis catus* in Australia. *Mammal Review* **47**, 83–97. doi:10.1111/mam.12080

Edwards GP, Piddington KC, Paltridge RM (1997) Field Evaluation of Olfactory Lures for Feral Cats (*Felis catus* L.) in Central Australia. *Wildlife Research* **24**, 173–183. doi:10.1071/WR96013

Ellis SLH (2009) Environmental enrichment: practical strategies for improving feline welfare. *Journal of Feline Medicine and Surgery* **11**, 901–912. doi:10.1016/j.jfms.2009.09.011

Fisher P, Algar D, Murphy E, Johnston M, Eason C (2015) How does cat behaviour influence the development and implementation of monitoring techniques and lethal control methods for feral cats?

Applied Animal Behaviour Science **173**, 88–96. doi:10.1016/j.applanim.2014.09.010
Garrard GE, Kusmanoff AM, Faulkner R, Samarasekara CL, Gordon A, Johnstone A, Peterson IR, Torabi N, Wang Y, Bekessy S (2020) Understanding Australia's national feral cat control effort. *Wildlife Research* **47**, 698–708. doi:10.1071/WR19216
Gatel L, Rault DN, Chalvet-Monfray K, De Rooster H, Levy X, Chiers K, Saunders JH (2020) Ultrasonography of the normal reproductive tract of the female domestic cat. *Theriogenology* **142**, 328–337. doi:10.1016/j.theriogenology.2019.10.015
Hohnen R, Tuft K, McGregor HW, Legge S, Radford IJ, Johnson CN (2016) Occupancy of the invasive feral cat varies with habitat complexity. *PLoS One* **11**, e0152520. doi:10.1371/journal.pone.0152520
Houser B, Vitale KR (2022) Increasing shelter cat welfare through enrichment: A review. *Applied Animal Behaviour Science* **248**, 105585. doi:10.1016/j.applanim.2022.105585
Hyndman TH, Algar KL, Woodward AP, Coiacetto F, Hampton JO, Nickels D, Hamilton N, Barnes A, Algar D (2020) Estradiol-17β pharmacokinetics and histological assessment of the ovaries and uterine horns following intramuscular administration of estradiol cypionate in feral cats. *Animals* **10**, 1708. doi:10.3390/ani10091708
Johnston M, Algar D, O'Donoghue M, Morris J, Buckmaster T, Quinn J (2020) Efficacy and welfare assessment of an encapsulated para-aminopropiophenone (PAPP) formulation as a bait-delivered toxicant for feral cats (*Felis catus*). *Wildlife Research* **47**, 686–697. doi:10.1071/WR19171
Keegan DR, Coblentz BE, Winchell CS (1994) Feral Goat Eradication on San Clemente Island, California. *Wildlife Society Bulletin* **22**, 56–61.
Kessler CC (2002) Eradication of feral goats and pigs and consequences for other biota on Sarigan Island, Commonwealth of the Northern Mariana Islands. In 'Turning the tide: the eradication of invasive species'. (Eds CR Veitch, MN Clout) pp. 132–140. (IUCN: Auckland, New Zealand)
Lazenby BT, Mooney NJ, Dickman CR (2014) Effects of low-level culling of feral cats in open populations: a case study from the forests of southern Tasmania. *Wildlife Research* **41**, 407–420. doi:10.1071/WR14030
Legge S, Murphy BP, McGregor H, Woinarski JCZ, Augusteyn J, Ballard G, Baseler M, Buckmaster T, Dickman CR, Doherty T, Edwards G, Eyre T, Fancourt BA, Ferguson D, Forsyth DM, Geary WL, Gentle M, Gillespie G, Greenwood L, Hohnen R, Hume S, Johnson CN, Maxwell M, McDonald PJ, 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 DR, Wayne AF, Woodford L, Zewe F (2017) Enumerating a continental-scale threat: How many feral cats are in Australia? *Biological Conservation* **206**, 293–303. doi:10.1016/j.biocon.2016.11.032
Legge S, Woinarski JCZ, Dickman CR, Doherty TS, McGregor H, Murphy BP (2020) Cat ecology, impacts and management in Australia. *Wildlife Research* **47**, i–vi. doi:10.1071/WRv47n8_ED
Leo BT, Anderson JJ, Phillips RB, Ha RR (2016) Home range estimates of Feral Cats (*Felis catus*) on Rota Island and determining asymptotic convergence. *Pacific Science* **70**, 323–331. doi:10.2984/70.3.4
Lyra-Jorge MC, Ciocheti G, Pivello VR, Meirelles ST (2008) Comparing methods for sampling large- and medium-sized mammals: camera traps and track plots. *European Journal of Wildlife Research* **54**, 739–744. doi:10.1007/s10344-008-0205-8
Masters P, Markopoulos N, Florance B, Southgate R (2018) The eradication of fallow deer (*Dama dama*) and feral goats (*Capra hircus*) from Kangaroo Island, South Australia. *Australasian Journal of Environmental Management* **25**, 86–98. doi:10.1080/14486563.2017.1417166
McGregor HW, Legge S, Potts J, Jones ME, Johnson CN (2015) Density and home range of feral cats in north-western Australia. *Wildlife Research* **42**, 223–231. doi:10.1071/WR14180
McGregor HW, Hampton JO, Lisle D, Legge S (2016) Live-capture of feral cats using tracking dogs and darting, with comparisons to leg-hold trapping. *Wildlife Research* **43**, 313–322. doi:10.1071/WR15134
McIlroy JC, Gifford EJ (1997) The 'Judas' Pig Technique: a Method that Could Enhance Control Programmes against Feral Pigs, Sus scrofa. *Wildlife Research* **24**, 483–491. doi:10.1071/WR96109
McIlroy JC, Gifford EJ (2005) Are oestrous feral pigs, Sus scrofa, useful as trapping lures? *Wildlife Research* **32**, 605–608. doi:10.1071/WR05006
Medina FM, Bonnaud E, Vidal E, Tershy BR, Zavaleta ES, Donlan CJ, Keitt BS, Le Corre M, Horwath SV, Nogales M (2011) A global review of the impacts of invasive cats on island endangered vertebrates. *Global Change Biology* **17**, 3503–3510. doi:10.1111/j.1365-2486.2011.02464.x
Medina FM, Bonnaud E, Vidal E, Nogales M (2014) Underlying impacts of invasive cats on islands: not only a question of predation. *Biodiversity and Conservation* **23**, 327–342. doi:10.1007/s10531-013-0603-4
Molsher R, Dickman C, Newsome A, Müller W (2005) Home ranges of feral cats (*Felis catus*) in central-western New South Wales, Australia. *Wildlife Research* **32**, 587–595. doi:10.1071/WR04093
Molsher R, Newsome AE, Newsome TM, Dickman CR (2017) Mesopredator management: effects of red fox control on the abundance, diet and use of space by Feral Cats. *PLos One* **12**, e0168460. doi:10.1371/journal.pone.0168460
Moseby KE, Selfe R, Freeman A (2004) Attraction of auditory and olfactory lures to Feral Cats, Red Foxes, European Rabbits and Burrowing Bettongs. *Ecological Management & Restoration* **5**, 228–231. doi:10.1111/j.1442-8903.2004.209-8.x
Murphy BP, Woolley L-A, Geyle HM, Legge SM, Palmer R, Dickman CR, Augusteyn J, Brown SC, Comer S, Doherty TS, Eager C, Edwards G, Fordham DA, Harley D, McDonald PJ, McGregor H, Moseby KE, Myers C, Read J, Riley J, Stokeld D, Trewella GJ, Turpin JM, Woinarski JCZ (2019) Introduced cats (*Felis catus*) eating a continental fauna: the number of mammals killed in Australia. *Biological Conservation* **237**, 28–40. doi:10.1016/j.biocon.2019.06.013
Murray PJ, Rogie M, Fraser N, Hoy J, Kempster S (2020) Development of the Mata Hari Judas Queen (*Felis catus*). *Animals* **10**, 1843. doi:10.3390/ani10101843
Nogales M, Martin A, Tershy BR, Donlan CJ, Veitch D, Puerta N, Wood B, Alonso J (2004) A review of feral cat eradication on Islands. *Conservation Biology* **18**, 310–319. doi:10.1111/j.1523-1739.2004.00442.x
R Core Team (2021) 'R: A language and environment for statisical computing.' (R Foundation for Statistical Computing)
Ratcliffe N, Bell M, Pelembe T, Boyle D, Benjamin R, White R, Godley B, Stevenson J, Sanders S (2010) The eradication of feral cats from Ascension Island and its subsequent recolonization by seabirds. *Oryx* **44**, 20–29. doi:10.1017/S003060530999069X
Read JL, Bengsen AJ, Meek PD, Moseby KE (2015) How to snap your cat: optimum lures and their placement for attracting mammalian predators in arid Australia. *Wildlife Research* **42**, 1–12. doi:10.1071/WR14193
Robinson SA, Copson GR (2014) Eradication of cats (*Felis catus*) from subantarctic Macquarie Island. *Ecological Management & Restoration* **15**, 34–40. doi:10.1111/emr.12073
Roshier DA, Carter A (2021) Space use and interactions of two introduced mesopredators, European red fox and feral cat, in an arid landscape. *Ecosphere* **12**, e03628. doi:10.1002/ecs2.3628
Rovero F, Zimmermann F (2016) 'Camera trapping for wildlife research.' (Pelagic Publishing: Exeter, UK)
Short J, Turner B, Risbey D (2002) Control of feral cats for nature conservation. III. Trapping. *Wildlife Research* **29**, 475–487. doi:10.1071/WR02015
Stobo-Wilson AM, Stokeld D, Einoder LD, Davies HF, Fisher A, Hill BM, Mahney T, Murphy BP, Stevens A, Woinarski JCZ, Rangers B, Warddeken R, Gillespie GR (2020) Habitat structural complexity explains patterns of feral cat and dingo occurrence in monsoonal Australia. *Diversity and Distributions* **26**, 832–842. doi:10.1111/ddi.13065
Taylor D, Katahira L (1988) Radio telemetry as an aid in eradicating remnant feral goats. *Wildlife Society Bulletin* **16**, 297–299.
Woinarski JCZ, Burbridge AA, Harrison PL (2015) Ongoing unraveling of a continental fauna: Decline and extinction of Australian mammals since European settlement. *Proceedings of the National Academy of Sciences* 112, 4531–4540. 10.1073/pnas.1417301112
Woinarski JCZ, Murphy BP, Legge SM, Garnett ST, Lawes MJ, Comer S, Dickman CR, Doherty TS, Edwards G, Nankivell A, Paton D, Palmer R, Woolley LA (2017) How many birds are killed by cats in Australia? *Biological Conservation* **214**, 76–87. doi:10.1016/j.biocon.2017.08.006
Woinarski JCZ, Murphy BP, Palmer R, Legge SM, Dickman CR, Doherty TS, Edwards G, Nankivell A, Read JL, Stokeld D (2018) How many reptiles are killed by cats in Australia? *Wildlife Research* **45**, 247–266. doi:10.1071/WR17160

Data availability. Data are available upon request by contacting the corresponding author.

Conflicts of interest. The authors declare no conflicts of interest.

Declaration of funding. The Lockyer Valley Regional Council provided funding for camera traps, the vennels and associated build costs, but had no involvement in the preparation of the data or manuscript. The Hidden Vale Project provided funding for a range of materials and services.

Acknowledgements. We acknowledge the Jagera, Yuggera, Ugarapul and Githabul peoples where we conducted our field research, as the keepers of ancient knowledge whose cultures and customs continue to nurture this land. We pay respect to past and present Elders. This research was conducted under the University of Southern Queensland Animal Ethics Approval 21REA003 and ratified through The University of Queensland Animal Ethics Approval 2021/AE000707 and Restricted Matter Permit (Scientific Research) PRID000776. Thank you to the property managers and volunteers who provided assistance on this project.

Author affiliations

[A]School of Agriculture and Environmental Science, University of Southern Queensland, 487-535 West Street, Darling Heights, Qld 4350, Australia.

[B]Hidden Vale Research Station, 617 Grandchester Mount Mort Road, Grandchester, Qld 4340, Australia.

[C]School of the Environment, The University of Queensland, St Lucia, Qld 4067, Australia.