Feral cat management on Indigenous lands | Final report

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Acknowledgements

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Australian Wildlife Conservancy, particularly Hugh McGregor and his cat detecting canine companions Sally and Brangle.

Cover photos

Front cover - Feral cat eating a phasogale, by Fredy Mercay.

Back cover - Warddeken Rangers have been working with Northern Territory Government scientists to research the best way to use motion detection cameras to survey wildlife.

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Contents

Summary

A collaborative project between scientists, Indigenous rangers and Traditional Owners from the Djelk and Warddeken Indigenous Protected Areas (IPAs) in Arnhem Land, Northern Territory sought to gain a better understanding of the role of feral cats in mammal declines across north Australia and trialled methods for their control.

Methods for studying feral cats in a cross-cultural setting generated a greater understanding of the ecology of cats in Northern Australia. Valuable information on cat distribution and behaviour was acquired in a remote region of north Australia. However, attempts to suppress feral cat populations in this region were unsuccessful.

The highly collaborative nature of this project resulted in substantial gains in Indigenous awareness and engagement with biodiversity and the threat posed by cats. The acquired knowledge is informing plans of management for these IPAs. This project demonstrated the importance of working collaboratively in research with Indigenous landowners and rangers on Aboriginal lands, and the value of their contribution to project development and implementation. However, it also highlighted areas of capacity that require further development before Indigenous groups can manage these kinds of projects fully autonomously.

1 Background

Cats have been implicated in the decline of a suite of small mammal species across northern Australia (Burbidge 2014; Woinarski, Armstrong *et al.* 2010). The Traditional Owners and land-managers of Warddeken and Djelk IPAs have been concerned about mammal declines and the role of predation by feral cats. Many native mammals are culturally important as totemic species and for utilitarian purposes. Community elders consider it important that younger generations know and see these species. Consequently they wanted to understand the role of cats in mammal declines, and explore the feasibility of undertaking cat control on their lands.

Research on cats in northern Australia is limited (McGregor *et al.* in review), and little was known about cats in Arnhem Land. Discussions with Traditional Owners/Indigenous Rangers suggested cats have been present, common and widespread on the Arnhem Land plateau for the last 50 years. Formerly cats were hunted for food but this was uncommon.

This project aimed to gain a better understanding of the distribution and ecology of cats, particularly in the stone country of Arnhem Land. It emerged that Traditional Owners and rangers from Manmoyi and Kamarrkawarn Homelands within the Warddeken IPA were particularly interested in working with scientists to develop and share skills and knowledge in researching cat ecology, impacts on mammals, and control measures.

Objectives were to:

1. Trial and develop methods for surveying and monitoring feral cat distribution and occurrence that could be undertaken by Indigenous rangers, including motion-sensing cameras, sand pad, and tracking techniques with the use of Cybertracker.
2. Improve understanding of cat ecology, through satellite/radio-tracking, diet analyses, and documenting Indigenous ecological knowledge of cats.
3. Trial techniques to manage cats, including hunting, trapping, and use of cat-detection dogs.

A key requirement was that methodologies could be applied by Indigenous people, and that flexibility in approach within an action-learning context was required. Significant community engagement and education were undertaken in order to foster awareness about cats in local communities and their significance in management of country.

2 Methods

2.1 Geographical context

The project was undertaken within the Arnhem Land plateau of Warddeken and Djelk Indigenous IPAs (Fig. 1), within the Arnhem Land Aboriginal Land Trust, adjacent to Kakadu National Park. The region is remote and rugged, characterised by extensive areas of deeply dissected sandstone massif with deep gorges and towering outcrops (Fig. 2). Interspersing these outcrops are alluvial valleys, sand-sheets, and lateritic plains supporting eucalypt open forests (Needham 1988). In most years vehicle access in the area is severely limited by wet season rains.

The focal study area was centred around the homelands of Manmoyi and Kamarrkawarn in the Warddeken IPA (Fig. 1). The adjacent Djelk IPA was also involved in some project aspects.

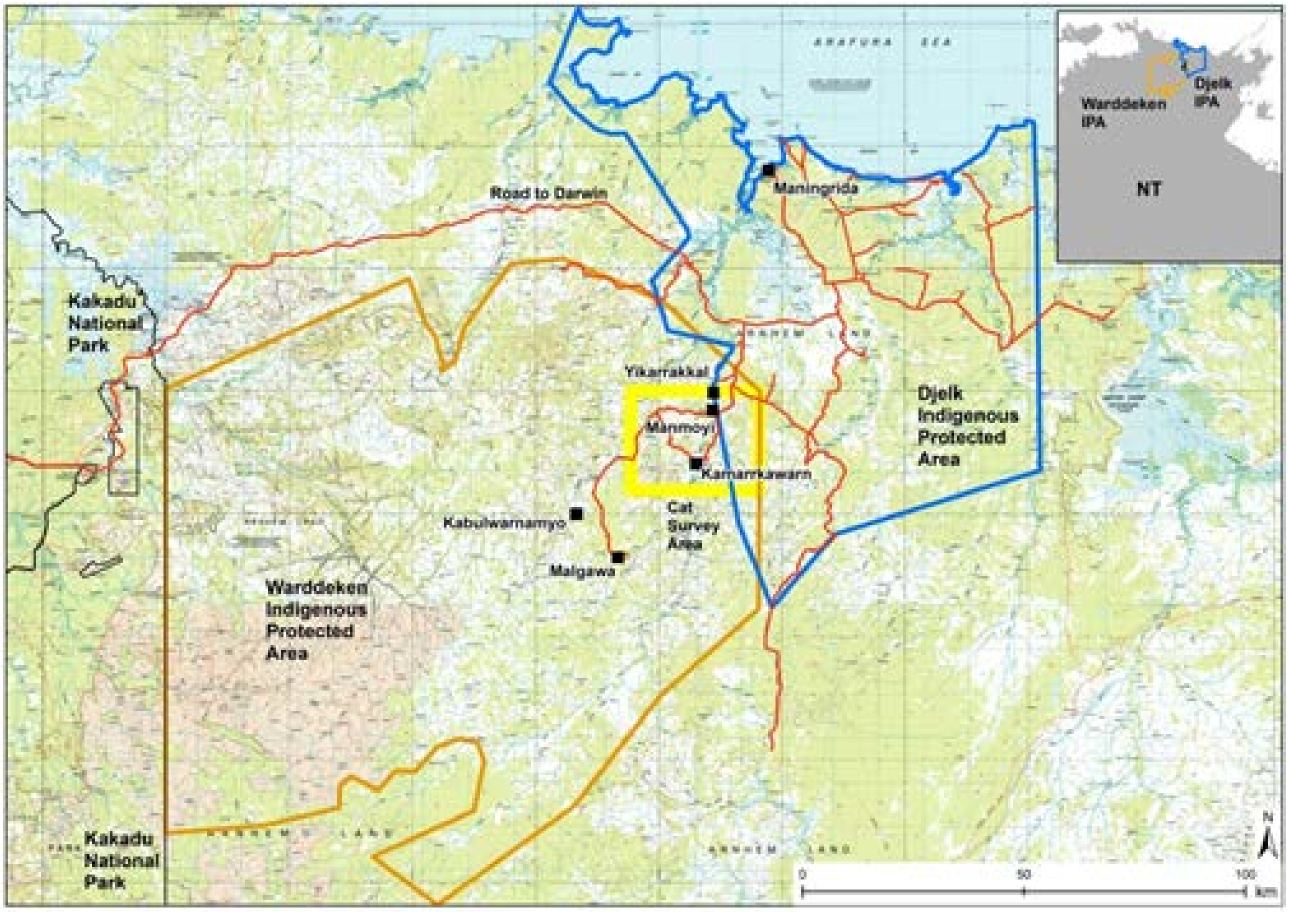


Figure 1: Location of study area in the NT. Orange line - Warddeken IPA; blue line - Djelk IPA; yellow square – primary study area.

Figure 2: Typical Arnhem Land plateau dissected sandstone massif.

2.1.1 Planning and consultation

Comprehensive planning and consultation with Indigenous partners was essential. As the project operated on Aboriginal land, in order to respect cultural interests, Traditional Owners had full control over what was done, when and where.

A "two-tool box" approach to research was adopted, recognising that both western and Aboriginal groups have particular skills and knowledge to contribute toward the project. Indigenous Rangers/Traditional Owners have intimate knowledge of the country, plants and animals, and exceptional observation and tracking skills. Scientists have technical knowledge of project design and methodology, and research, and responsibility for reporting on outcomes of the project. All aspects of the project were planned and agreed to through regular consultation with Traditional Owners/Indigenous rangers including:

- Locations of all field work, ensuring sites of cultural significance were avoided;
- Timing of activities, taking consideration of cultural priorities;
- Who would/could be involved ensuring consideration of cultural relationship and that all non-Indigenous workers had appropriate approvals;
- Design and methodology of research;
- Development and production of project products including video, reports, posters, media and conference presentations and ensuring that culturally appropriate people were speaking on particular issues.

Planning and consultations involved IPA management staff, ensuring their awareness and that adequate capacity existed to support all proposed activities.

There were a number of cross-cultural issues to which we needed to be sensitive. Responsibilities and rules regarding land ownership are complex and dictate who can make decisions and who can perform work. Particular clan/family groups have responsibility for certain parts of country; there are both "owner" and "manager" responsibilities. Owners make decisions, in consultation with their managers, about what can/cannot be done in an area. Managers ensure decisions are carried out and must be present when working in that area. Additionally, the land is imbued with spiritual meanings and sensitivity; different places have varying levels of cultural significance which dictate who can/cannot go there. Complex avoidance relationships also govern with whom one can associate, talk, or work. Consequently, we needed to be sensitive to the makeup of work teams and defer to Traditional Owners/Indigenous Rangers for those decisions. Throughout the project we endeavoured to be guided by Traditional Owners/Indigenous Rangers in relation to cultural matters to ensure we maintained healthy and respectful working relationships.

2.2 Development of cat sampling techniques

2.2.1 Camera traps

Prior to this study the development of suitable methodologies for sampling feral cats in north Australia was limited. In order to refine methods to detect cats for the region we conducted a series of camera-trap trials.

Firstly we assessed the influence of different lures and camera placements on detection. This trial was conducted at 84 sites across five widespread locations in the Top End, covering a range of biomes and land tenures: Warddeken and Djelk IPAs, Kakadu National Park, Fish River Station (Indigenous Land Corporation) and Wongalara Station (AWC). Cameras and lures were deployed for 20 nights. Sites were selected in open areas and along discrete pathways, such as dry creek lines, to assess the influence of camera placement on cat detection. Lures tested included chicken soaked in fish oil, a Feline Attractant Phonic audio device (FAP), and cat scent (Cat-astrophicTM). Each was accompanied by a visual lure made of a feathers and a CD. A logistic regression model incorporating binomial errors, with detection/non-detection of cats at each camera, and camera placement and lure type as covariates was run in R version 3.1.0 (R Core Team 2014).

In the second trial we examined relationships between sampling effort and cat detection probabilities. Five cameras and bait stations were deployed at each of 59 sites across four areas of the Top End: Warddeken and Djelk IPAs, Kakadu National Park and the greater Darwin area. At each site cameras were deployed no more than 100m from a central camera and no less than 30m apart. Standard small mammal bait was used in order to test the efficacy of this method for improving native mammal detection concurrently. Cameras were deployments for up to 11 weeks. Data were analysed by multi-method occupancy modelling, which permits modelling of presence-absence data at two spatial scales, accounts for non-independence of detections between spatial scales, and for situations when a species is temporarily unavailable due to movement (Nichols *et al.* 2008).

At Warddeken and Djelk IPAs the Indigenous Rangers directed the site selection for deploying camera-traps following discussions regarding the habitat types that needed to be surveyed. Indigenous Rangers worked together with scientists to deploy and recover the cameras. As well as providing training in camera-trap use, this allowed discussion and assessment in the appropriateness of the techniques for use by Indigenous rangers. A CyberTracker sequence was developed to provide Indigenous Rangers with an accessible, paperless means of accurately recording camera deployment and recovery metadata. The sequence was developed in conjunction with the NAILSMA I-tracker Land Patrol Application, which is freely available from their website (http://www.nailsma.org.au/i-tracker/download-i-tracker-land-patrol-application).

2.2.2 Bokno Manborhl - Estimating feral cat occupancy using 'track transects'

Recording cat tracks using sand-pads as a survey and monitoring method was initially trialled in Warddeken in 2010, when two 50m sand-pads were established and monitored over a 4 day period. In 2012, two 5m^2 sand-pads were established at 18 sites, and monitored for 2-3 weeks. However, no cat tracks were recorded in either trial. From these findings, combined with the time and resources necessary to establish sand-pads at numerous locations over a wide area, it was concluded that constructing sand pads was not a viable option for broader surveys of cats in the region. This, along with several other factors, led to the development and trialling of track transects referred to as 'Bokno Manbolh':

- Poor results from camera-trap and sand-pad trials to detect feral cats despite regular sighting of cats and their tracks by Indigenous rangers;
- Previous experience with other activities demonstrated that single purpose activities utilising traditional knowledge and observation skills of Warddeken and Djelk Indigenous Rangers had a high rate of uptake and success;
- An extensive network of creek lines and sand-sheets throughout the landscape provided natural 'sand-pads';
- Traditional Owners/Indigenous Rangers had intimate and extensive knowledge of access through the country, and the skills required to detect cat tracks; and
- Occupancy modelling of sign along transects has previously been used successfully for assessing predators (Karanth *et al.* 2011, Thorn *et al.* 2011).

The main requirements from a conventional scientific perspective were to get wide coverage across the study area with representation across a range of habitat types and landforms. With this in mind Traditional Owners/Indigenous Rangers drew on their knowledge of land accessibility and cultural significance to map out a 330km network of pathways across the study area.

Transect routes, ranging from 6 to18 km in length were walked between October 2012 and August 2013. A total of 330 km of transects were walked. Four to twelve Traditional Owners/Indigenous Rangers and at least one non-Indigenous project scientist participated in each route, recording observed cat tracks. Identification of cat tracks relied on the highly developed observational skills of the rangers. Tracks were not recorded unless there was a high level of certainty and consensus amongst rangers. Indigenous Rangers recorded data on a CyberTracker sequence, including participants, date, cat-track coordinates, transect coordinates and other fauna observations. GIS was used to collect environmental data including area burnt prior to survey, habitat ruggedness, and presence of a mapped watercourse as a surrogate for sandy substrate. Sandy substrate was considered to be easier to track.

Data were analysed using an occupancy model that accounts for spatial auto-correlation in detection probability, and tested the influence of environmental covariates on occurrence of cat tracks. The effect of the number of rangers/observers on detection probability was also tested. The unit of occupancy was selected as a 1 km^2 cell. For a particular cell to be included in the analysis at least a 100 m segment of walked transect had to occur within the cell. In total 280 cells were included in the analysis.

2.2.3 Spotlighting

Rangers indicated they often observed cats while driving at night, and had a desire to use spotlighting to survey cats, as it was an activity they were highly experienced with, enjoyed and utilised their observation skills. Indigenous Rangers recorded their observations using CyberTracker. Between 2011 and 2013, 580km and 565 hours of spotlight surveying along roads were undertaken.

2.3 Feral cat ecology

Prior to this project, no information on cat ecology in Arnhem Land was available. To gain baseline data on cat ecology in the stone country we radio-tracked cats in Warddeken IPA. Over a two-week period in September 2013 spotlight surveys were undertaken to detect and capture cats with the assistance from AWC staff and their two cat-detecting dogs (http://www.australianwildlife.org). A total distance of 430 km was searched over 65 hours. Only two cats were captured and released with GPS collars attached (Telemetry Solutions, Model Quantum 4000 Enhanced Ext Memory LS14500 Sirf III), configured to provide a repeated signal every 30 minutes for two days, followed by one reading per day for four days, over the life of the collar. Collars were left on for 12 weeks, with data downloaded remotely every 3-4 weeks via helicopter.

Throughout the project, whenever cats were culled their stomach contents were analysed to identify prey items. Mammal fur, if present was collected for future identification. These data were pooled with similar sample data collected from cats across the Top End in order to gain an insight into feral cat diet compared to other parts of Australia.

Figure 3: Warddeken Ranger fitting a GPS collar to a feral cat.

2.4 Trial of management techniques

Spotlighting and shooting trials were undertaken in September-October 2013 when grass and foliage cover were at a minimum, increasing likelihood of cat detection. Indigenous Rangers used spotlights over 400km of road network over 4 weeks and approximately 85 hours. Access was limited to a relatively small proportion of the study area due to limited road network and rugged landscape. Dissected sandstone massif blocked access to much of the area, and tracks are restricted to the more open valleys and plains.

Trapping of cats was trialled with cage traps and bag traps. Bag traps (Fabric Animal Traps, fabricanimaltraps.com.au) are a hinged jaw-type trap with synthetic 'wool bale' material stretched around the jaws and opening into a bag behind, a trip mechanism is hidden under the floor of the trap (see Fig. 4). Success in trapping feral cats had previously been achieved in Tasmania.

During consultations various cat trapping methods were discussed, including leg-hold traps, which have been used successfully elsewhere in Australia. However, leg-hold traps were not trialled, due to Traditional Owner/ Indigenous Ranger concerns about potential injury and stress in cats and other wildlife.

Information gathered from the track transect and the GPS-collared cats was used to identify habitats used by cats; along the base of rocky escarpments and creek banks. Two transects with 12 traps were set up in each habitat. Along each transect, two bag traps followed by two cage traps in an alternating pattern were placed 100m apart. Traps were covered with vegetation in an attempt to make them look less alien to cats (Fig. 4).

Tinned pilchard and dry chicken-flavoured cat food/dry liver mix were used for bait. Both bait types were deployed in each trap in separate bowls, and were changed daily. Soiled cat litter collected from a local Darwin cattery was placed next to traps as a potential attractant to lure males. This was enhanced every few days with fresh urine collected from a de-sexed pet cat in Manmoyi. Two weeks of free baiting commenced in early July 2014, followed by 10 days of trapping, generating 528 trap-nights.

Figure 4: Baited bag-trap camouflaged with vegetation in an attempt to make them more attractive to feral cats.

3 Results

3.1 Development of cat sampling techniques

3.1.1 Camera Trap trials

In the lure and camera placement camera-trap trial, cats were detected at 17% of sites over 3200 trap-nights. There was no significant difference in detections between the three lure types ($P > 0.38$) (Fig. 5). Additionally there was no significant difference between cameras deployed in open habitat or pathways ($P = 0.87$).

In the five camera deployment trials, cats were detected at 37% of sites with a total of 52 detections (Stokeld *et al.* in review). The probability of detecting a cat on one camera in one week was very low ($p = 0.15$ +/- 0.04). However, our ability to detect a cat, given a site was occupied, increased significantly when additional cameras were incorporated for longer survey periods. For instance, the probability of detecting a cat, given a site was occupied, was 79% when an array of five cameras was deployed for five weeks. However, detection probability diminished markedly with less cameras or shorter deployment periods (Fig. 6).

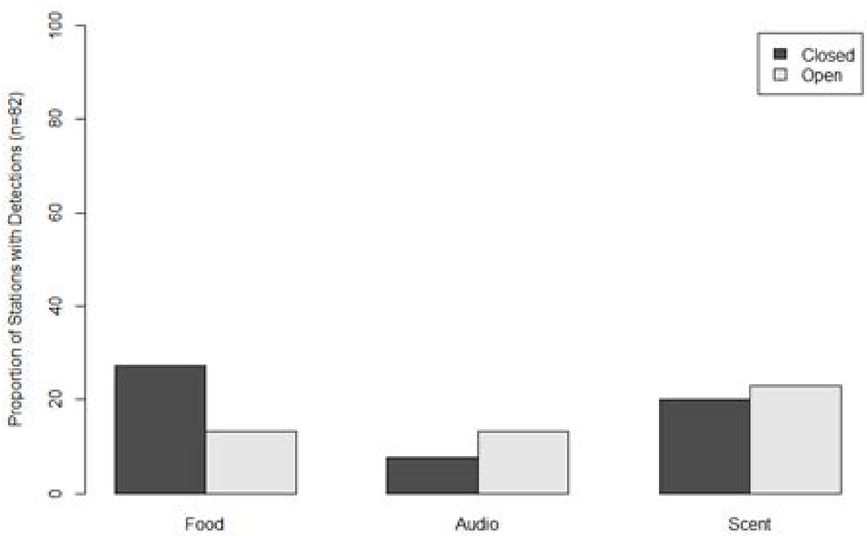
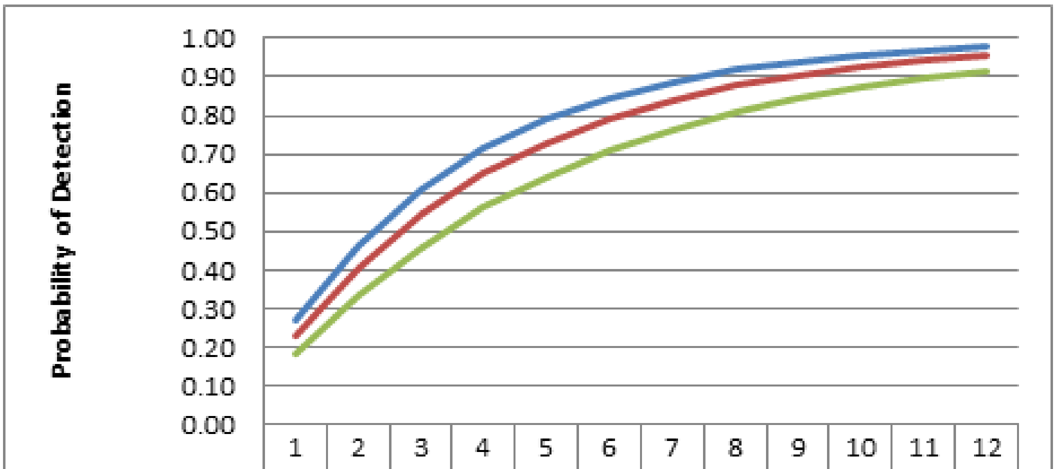


Figure 5: Proportion of stations that recorded cat detections displayed by lure type and camera placement.



	1	2	3	4	5	6	7	8	9	10	11	12
5 Cameras	0.27	0.46	0.61	0.71	0.79	0.85	0.89	0.92	0.94	0.96	0.97	0.98
4 Cameras	0.23	0.41	0.54	0.65	0.73	0.79	0.84	0.88	0.91	0.93	0.94	0.96
3 Cameras	0.19	0.34	0.46	0.56	0.64	0.71	0.76	0.81	0.84	0.87	0.90	0.92

Figure 6: Probability of detecting a cat using multiple camera-traps at a site for varying periods of time. Horizontal axis represents the number of weeks cameras are deployed. Values are the estimated detection probabilities.

Detection probabilities > 0.7 are required to obtain unbiased occupancy estimates (MacKenzie *et al.* 2002); consequently the deployment of five cameras for five weeks was adopted for further cat and mammal surveys across the Top End. An additional 40 sites were subsequently sampled in this way in Warddeken and Djelk, resulting in cat detections at 55% of these sites.

There was a high level of engagement by Indigenous Rangers with using camera-traps. After initial training the rangers were able to deploy camera-traps relatively independently, with scientists providing some minor quality control oversight. The uptake and use of CyberTracker sequences by the rangers to record deployment metadata also proved very successful.

3.1.2 Track Transects 'Bokno Manborlh'

A total of 234 cat tracks were recorded over 330 km of transects walked over 196 hours (Fig. 7). Non-Indigenous participants rarely detected cat tracks before they were identified by Indigenous Rangers. Furthermore non-Indigenous participants had difficulty distinguishing cat tracks from prints of other animals.

The key findings from an Occupancy Modelling analysis were:

- Feral cats were present and widespread in the region with a likelihood of occupancy within any 1 km x 1 km cell being 72%.
- Without accounting for the possibility that a cat was present but its track was not recorded, the naïve occupancy (simple presence and absence) was much lower at 34%.
- Our ability to detect feral cats was significantly improved when a watercourse (sand) was present on a segment; from 17 to 58%.
- Prior burning and habitat ruggedness did not appear to influence occupancy or detection.
- Changes in ranger group size and composition (range 4–12, different individuals) did not influence detection. This is a reflection on the high quality observational skills of Indigenous Rangers to be able to detect a cat track if it was present.

3.1.3 Spotlighting

Vehicle spotlight patrols resulted in detection of 29 cats over 980km and 165 hours of spotlighting, representing 0.18 cats per spotlight hour.

Comparison of the effectiveness of survey methods, as a function of time spent undertaking the work and number of cat detections returned, indicates that track transects were most time-efficient at detecting cats (Table 1). Spotlighting and trapping were the least effective of the methods trialled. These findings suggest that multi-camera trap arrays and track transects are the most appropriate methods for studying and monitoring feral cat distribution and occurrence in this region.

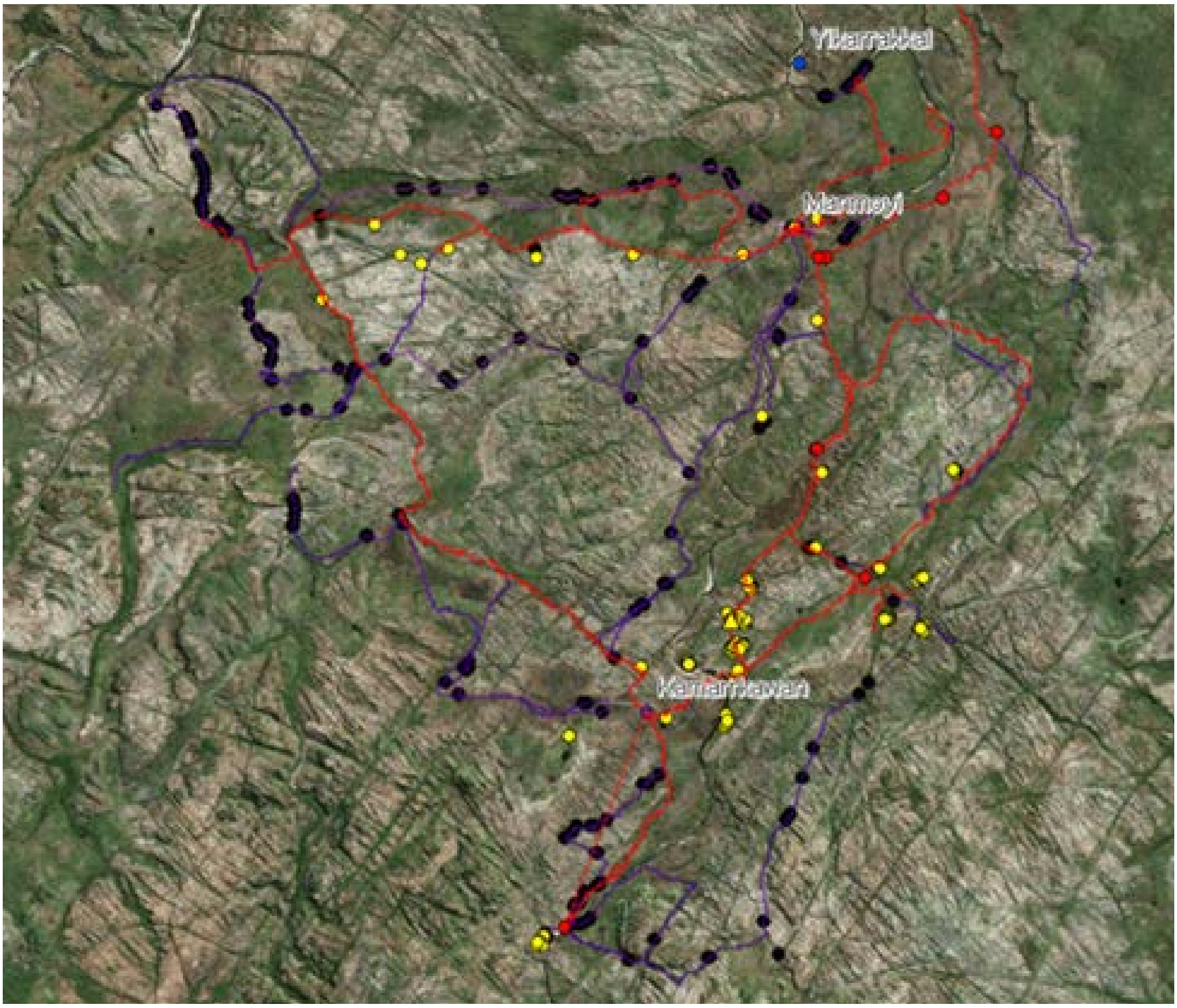


Figure 7: Cat observations from track transects and spotlight monitoring in Warddeken IPA. Purple lines - walking transects; purple points - cat tracks; Red lines - tracks patrolled at night mostly by vehicle; red points - cat sightings during patrols; yellow points - camera locations.

Table 1. Comparison of the effectiveness for each of the main techniques used for detecting cats in Warddeken IPA, based on detections compared with effort required for set up and conduct the method. Numbers of hours represents the amount of effort required for 4 people to set up or carry out the particular method

	Number of hours	Number of cat detections	Number of detections per hour
Camera-trap	80	27	0.34
Track transect	200	234	1.17
Spotlighting	165	29	0.18
Trapping	48	1	0.02

3.2 Feral cat ecology

3.2.1 GPS tracking

The cat collar data was subjected to a ninety-five percent minimum convex polygon analysis indicating home ranges of 1563 and 2326 ha for these two cats (Fig. 8). These are much larger than cat-home ranges measured simultaneously in the Kimberley (average 760 ha), and some of the largest home-range sizes ever found for cats in Australia (McGregor *et. al.* in press) and were comparable to sizes found in the desert during drought years (Edwards, De Preu *et al*. 2001). This is perhaps indicative of differences in prey availability as the Kimberley has a greater abundance, though facing similar threats of small mammal fauna compared to Arnhem Land (Carwardine, O'Connor *et al.* 2011)

For those days where fixes were recorded every 30 minutes, both cats travelled 4.9km per day on average. The maximum distance travelled was 12.1km. The actual distances are probably bigger than this, as the cat would have done a lot of weaving between each half hour fix.

Both the cats were nocturnal during the study period. After the sun rises around 6:00 am, cat activity drops right off and by 10:00 am each day; they are mostly still around 90% of the time. But around 19:00pm, they become active again. This is in line with what McGregor (2014) found in the Kimberley, where cats were nocturnal in hot weather (min temp > 30C), but more active in the day when temperatures are cooler.

A visual assessment of the habitat use by the two cats from the Arnhem Land plateau suggests they spent a lot of time in the ecotone between the stone country and the woodland plains country. They ventured up into the rocky areas at times but spent less time in the woodland plains away from the rocks. It is possible that the cats prefer this ecotone habitat alongside the stone country as it is provides the richest hunting grounds for them with suitable protection. Our trapping results show that the stone country supports the richest small mammal populations with very few small mammals found in the woodland plains. It may be difficult for cats to hunt in the more central areas of the stone country as it is difficult to access and provides much shelter for prey. However the margin of the stone provides less shelter for prey and is easy to navigate for the cats.

It should be noted that the results above are only relevant to the two cats collared during this project. From such a small sample size it is not possible to draw inferences for feral cats in general in the study area.

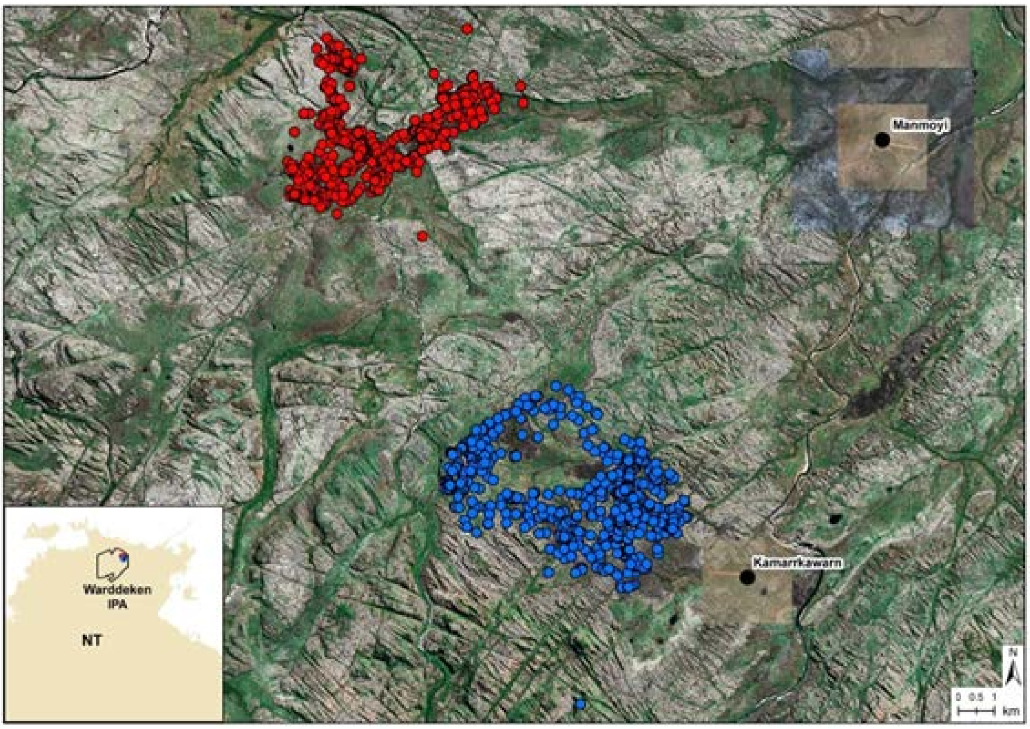


Figure 8: Locations of two GPS collared cats between 4th October and 17th December 2013. GPS fixes for "Blackie" (red dots) and "Nabudbulanj" (blue dots).

3.2.2 Analysis of stomach contents

Six feral cats were analysed for stomach contents from the study area. Cats had eaten at least 4 mammals (including 2 sugar gliders and 1 grassland melomys), 5 lizards, 3 birds and 11 insects. This data, pooled with data from across the Top End, will be used to examine Top End cat diet. Preliminary findings suggest, as with studies from elsewhere in Australia, a diversity of small vertebrates, dominated by mammals, make up the bulk of the diet.

3.3 Cat management trials

The Warddeken rangers observed nine cats during the culling patrol trial but were unsuccessful at culling any of them. The cryptic nature and likely low density of cats combined with limited vehicle access throughout the area likely contributed to the ineffectiveness of the attempted cull. Capturing attempts with the assistance of AWC dogs demonstrated the difficulties of locating cats in this remote and rugged landscape.

The live-trapping trial resulted in the capture of only one juvenile cat. Camera-traps set on 14 of the traps (7 cage traps, 7 bag traps) over four weeks detected no other cats. This suggests that cats are difficult to trap and low cat visitation rates indicate trapping may have limited effectiveness in this region.

4 Outputs

The findings from this project have been disseminated widely in the following ways:

- Warddeken rangers produced an instructional video, to assist with training Indigenous Rangers and others in setting up camera-trap arrays.This was presented at the 2014 Territory Natural Resource Management (TNRM) Conference.
- Production of a technical booklet on camera trapping in the Top End.
- Workshop on camera-trap deployment methods in the Top End conducted at the TNRM Conference 2014, jointly demonstrated with Djelk Indigenous Rangers.
- Poster display on camera-trap methods for the 2014 TNRM Conference.
- Joint presentation at the 2014 TNRM Conference on 'Bokno Manborlh'.
- Presentations at the Ecological Society of Australia Conference 2014 on camera-trap methods for feral cats in the Top End, and 'Bokno Manborlh'.
- Presentations on 'Bokno Manborlh' to Djelk and Warddeken Boards.
- Community booklets prepared for Warddeken and Djelk IPAs explaining each project component, available through NERP for wider distribution.
- Warddeken Rangers produced a short video titled 'Feral Cats on Warddeken Country' presented at the Deckchair cinema, Darwin during science week 2014. The Territory Wildlife Park has included it in their Nocturnal House display.

5 Discussion – Key findings, lessons learnt, and future needs

5.1 Key findings

This project has been a successful collaboration between Traditional Owners, Indigenous rangers and scientists to develop techniques for surveying feral cats and investigating their ecology. We refined and adapted sampling methods for cats that proved suitable for implementation in the region. Furthermore these methods were highly amenable to Indigenous rangers who could implement them, under minimal supervision. The use of CyberTraker sequences greatly augmented these outcomes helping to ensure consistent data quality. The camera-trap methods are now being used across the Top End to gain greater insight into feral cat occurrence and relationships with mammal diversity. Track transects potentially provide a cost-effective means for Indigenous land managers to collect baseline data on cat occurrence, from which to monitor future changes.

Collectively, the data acquired on feral cats from the portfolio of methods deployed in this project has demonstrated that cats occur throughout the Arnhem Land Plateau, most likely at low density, although further research would be necessary to ascertain the latter. These findings generally align with Aboriginal Traditional Owner perspectives prior to the project.

Although limited in extent, we also demonstrated that hunting, trapping and shooting are not feasible methods for reducing feral cat numbers in this country, due to the cryptic nature of cats and the limitations on geographic access. As a result, Traditional Owners now have a greater and more pragmatic understanding of the challenges in addressing cats, which has influenced the development of plans of management for their lands.

5.2 Lessons learnt

This project demonstrated the effectiveness of the 'two toolbox' approach, whereby Indigenous traditional knowledge and skills, combined with contemporary scientific approaches, produced new information that was valuable and accessible to all project partners. This approach can be adopted elsewhere where traditional knowledge and attachment to land is still strong.

There was high engagement with, and uptake of, a range of ecological sampling techniques, such as camera trapping; these approaches will be useful for a wider range of Indigenous land managers. However, there were limitations in Indigenous capacity around project and sampling design, data management and analyses. Input on these project components from trained scientists remains essential.

Traditional Owners/Indigenous Rangers also derived significant cultural benefits from this project:

- Maintenance of traditional knowledge and skills.
- Opportunities to revisit and strengthen links to remote areas of country.
- Passing on traditional knowledge.

The project highlighted important considerations in developing successful research collaborations with Indigenous land managers on Aboriginal Lands:

- Projects must be developed collaboratively from the outset and must address issues of relevance and importance to Indigenous land managers. This ensures that Traditional Owners have ownership and responsibility, and a stake in the outcomes.
- Researchers require an understanding of and respect for Aboriginal culture when working with Indigenous people on Aboriginal Land. The success of research projects in this setting is contingent on their ability to accommodate a wide range of cultural considerations.
- Developing a 'two-tool box' approach augments Indigenous manager participation in projects, enhances engagement and support, and potentially increases the likelihood of project success.
- Commencing at the conceptual stages of projects, regular, iterative consultation and planning, and allowing joint decision making is essential. This provides opportunities for Traditional Owners/Indigenous Rangers to identify potential issues and address them, and a forum for regular feedback and raising awareness.

5.2.1 Constraints

Achieving some objectives was limited by the ruggedness and limited road network of the region, which meant access was mostly by foot or helicopter. This severely constrained efforts to trial cat control measures.

Carrying out research in a cross-cultural environment presented constraints, due to competing priorities. Balancing scientific rigour with thorough consultation, group decision making, working at a suitable pace for Indigenous Rangers, and using methodologies that were appropriate for rangers, was difficult. Flexibility was needed to accommodate cultural priorities including ceremonies and funerals. In some instances this resulted in methodological comprises, such as reduced sampling effort or consistency.

5.3 Future needs

Knowledge about the ecology of feral cats remains extremely limited across the Top End. Studies elsewhere may have limited inference to this region. Further research is desirable on patterns of occurrence and relative population densities of cats in different biomes and land management contexts.

There is a clear need to trial and develop cat control methods that are suitable to Northern Australia. Shooting and trapping may form part of the mix; however, such trials and development should be undertaken in more amenable locations.

As the number of IPAs expand and more Indigenous groups become engaged with sustainable land and biodiversity management, there is a need to help build capacity to undertake collaborative research that is realistic, mutually beneficial and informs management. Engagement with Indigenous management groups is also required to facilitate further development of management plans that are important and feasible to address ecological threats, and to develop suitable methods for evaluating outcomes.

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