Natural Resources
Kangaroo Island

Density estimates of feral cats on the Dudley Peninsula

A report for the Felixer versus Felis Project

Government of South Australia

Australian Government

National Landcare Program

PROGRAM

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PROJECT OFFICER CONTACT DETAILS

Kangaroo Island Feral Cat Eradication Project
Natural Resources Kangaroo Island
37 Dauncey Street
Kingscote SA 5223

Phone: (08) 8553 4444
Email: kinrc@sa.gov.au

NATURAL RESOURCES KANGAROO ISLAND CONTACT DETAILS

Damian Miley
Regional Director
37 Dauncey Street
Kingscote SA 5223

Phone: (08) 8553 4444
Email: kinrc@sa.gov.au

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FRONT COVER IMAGES:

Left photo: a feral cat caught in a cage trap at the Willson River Focus Site. *Photo by Karleah Berris.*

Right photo: an image of a feral cat caught on a remote Reconyx camera used to estimate density of feral cats at the Willson River Focus Site. *Photo by Natural Resources Kangaroo Island.*

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Introduction

The Felixer versus Felis project aimed to engage landholders in feral cat control activities on Kangaroo Island and investigate the effectiveness of the Felixer™ grooming traps through field tests. One deliverable of the project was to determine feral cat density at locations on the Dudley Peninsula, in preparation for control activities which would be occurring through the Felixer versus Felis project and the subsequent feral cat eradication project on the Dudley Peninsula.

Two previous studies have estimated density on Kangaroo Island (Bengsen *et al.* 2011; Pat Hodgens unpublished data), however neither of these studies estimated density in continuous native vegetation. As a precursor to the planned eradication of feral cats from the Dudley Peninsula, Kangaroo Island between 2019 and 2023, this project aimed to update the density estimate for agricultural land on the Dudley Peninsula and ascertain the density in areas of continuous native vegetation which comprise much of the landscape of the southern Dudley Peninsula.

The aim of this study was to estimate feral cat density at four sites, two largely cleared sites and two continuous native vegetation sites. This report comprises the results of this density study.

Methodology

Camera Trapping Array

In order to determine the density of feral cats in continuous native vegetation and mixed land use landscapes, camera trap arrays were established at two sites within conservation parks and two largely cleared private landholder sites (Figure 1).

Cameras were set in the following way:

- Willson River Focus Site - 36 Reconyx HC600 cameras set approximately 500 metres apart in a grid array measuring 2 km by 3 km. This site is mostly cleared with some remnant mallee vegetation and supports a sheep grazing enterprise.
- Sandhurst Focus Site - 12 Reconyx HC600 cameras set approximately 500 metres apart in a grid array measuring approximately 1 km by 1.5 km. This site is mostly cleared with some remnant and regenerating coastal vegetation, and has no stock present.
- Simpson Conservation Park - 16 Reconyx HC600 cameras set 1 km apart in a grid array measuring 2 km by 3 km. This site contains continuous mallee vegetation.
- Dudley Conservation Park - 21 Reconyx HC600 cameras set approximately 1km apart in a grid array measuring 2 km by 4 km. This site contains thick continuous vegetation.

Cameras were set approximately 30cm off the ground on a sturdy tree trunk or a stake, and located on wildlife movement paths or along farm vehicle tracks. All cameras were set to take 3 pictures in “Rapidfire” mode whenever motion sensors were triggered with no quiet period between pictures.

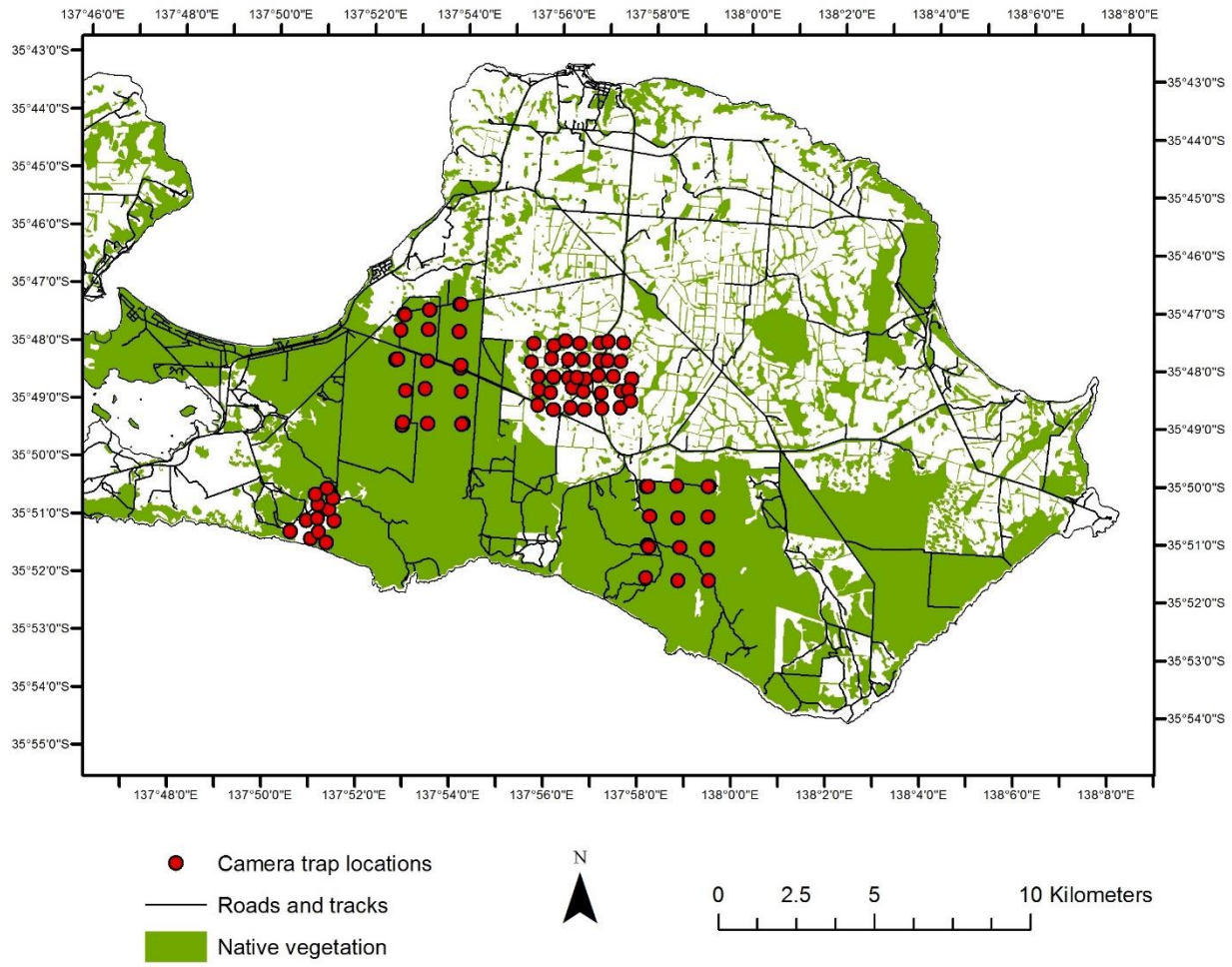

Figure 1. Locations of camera traps on the Dudley Peninsula on Kangaroo Island. Two arrays occurred in continuous native vegetation, and two more in mostly cleared areas.

Data Analysis

Camera images were downloaded, and a date range was selected for analysis when all cameras at a site were operational. The date range analysed was as follows:

- Willson River Focus Site – 12 December 2018 to 11 February 2019, 61 camera trap nights. Seven cameras which had issues with functionality or went flat early in the study were excluded from the analysis.
- Sandhurst Focus Site – 9 August 2018 to 13 October 2018, 65 camera trap nights.
- Simpson Conservation Park – 7 November 2018 to 22 January 2019, 76 camera trap nights.
- Dudley Conservation Park – 18 October 2018 to 18 December 2018, 61 camera trap nights, seven cameras that went flat early on in the study or had functionality issues were excluded from analysis.

As cats were more active at night than during the day at our sites, one sampling day was from midday to the following midday. All images within the specified date range were viewed and images of feral cats were recorded. Images were compared to one another carefully in order to identify individual feral cats and determine how many times and at how many different locations each individual was observed. For tabby cats, stripe patterns on the front and rear legs and the tail were the most

commonly used feature to identify individuals. Each individual cat was given a unique identification number for the purposes of the analysis.

Density was estimated using spatially explicit capture-recapture methods (secr) (Borchers and Efford 2008; Efford *et al.* 2009) using R version 3.3.1 (R Core Team 2018). Buffer width should be wide enough so that animals at the edge have effectively no chance of appearing in the sample. Therefore buffer width was determined by calculating a trap-based measure of the scale movement, and then checking the detection probability at different distances. Buffer width using this method was then compared to distances determined from radio-tracking data. A buffer width was chosen for each site that was sufficiently wide so that increasing the buffer width further had negligible effect on the density estimates. A buffer width of 2000 metres was used for the estimates in this instance. At the Sandhurst site, due to its proximity to the coastline, a polygon feature was imported in to R to clip the buffered area so that the ocean was excluded from analysis and recognised as non-habitat. Three different detection functions were modelled; the half-normal (HN), negative exponential (EX) and hazard rate (HR) functions. These three functions differ in the probability they assign to very distant detections, with the half-normal having a very low probability of distant detections. Models that incorporated each of the three detection functions were compared using Akaike's Information Criterion (AIC) (Akaike 1973). Models were then ranked in order of AIC differences and Akaike weights, and if no one model had a weighting of > 90 % then estimates were derived by calculating model-averaged estimates from the model set. At the Willson River Focus Site density estimates were also derived from different periods of camera trapping data to compare the effect of short camera trapping surveys (ie one week) to longer surveys (the full 61 days). Datasets were compiled for one week through to eight weeks and the density estimates from these shorter datasets were compared to the density estimate for full 61 days of camera trapping.

In order to predict changes in estimated density over the site, inhomogeneous Poisson models were fitted to describe the spatial variation in feral cat density estimate and compared to a null model, where density did not vary spatially. Models were run using the predicted best detection function from previous modelling. These models were also compared using Akaike's Information Criterion (AIC) (Akaike 1973) and ranked in order of AIC differences and Akaike weights. If density was found to be influenced by spatial location, plots were produced showing the potential variation in density across the site. If AICc values were close between models, a further plot was produced of the density average at each raster by determining the average density at each point based on model weights. This approximates a model-averaged estimate plot for the HR detection function models.

Results

Density estimates at Dudley Peninsula sites

Four camera arrays were deployed on the Dudley Peninsula between August 2018 and February 2019. Data from 4680 camera trap nights was used, resulting in 219 detections of feral cats, with 50 individual cats able to be identified in 164 of those detections (Table 1).

Feral cat density at sites on the Dudley Peninsula varied from 0.53 feral cats per km^2 (SE = 0.23, 95% CI 0.24 – 1.18) in Simpson Conservation Park to 2.98 feral cats per km^2 (SE = 0.62, 95% CI 1.99 – 4.45) at the Willson River focus site (Table 2). Feral cat density was highest at the Willson River focus site, a working sheep farm, and was lowest in continuous native vegetation. A density estimate was unable to be calculated for Dudley Conservation Park due to the very low number of recaptures at the site.

Table 1. Number of cat detections, detection in which cats were able to be individually identified, number of individual cats and camera trap nights at each of the four sites.

	Cat detections	Identifiable cat passes	Individuals	Trap nights
Willson River Focus Site	157	113	30	1891
Sandhurst Focus Site	22	17	7	780
Simpson Conservation Park	31	26	7	1216
Dudley Conservation Park	9	8	6	793

Table 2. Feral cat density per km^2, with standard error and 95 % confidence intervals, at three sites on the Dudley Peninsula calculate using spatially explicit capture recapture methodology. Dudley Conservation Park was excluded as there were too few re-sightings of individuals to run a mark-recapture model.

Site	Habitat	Land Use	Feral cat density per km^2	SE	lcl	ucl
Willson River Focus Site	Working sheep farm, cleared paddocks with some remnant woodland native vegetation	Sheep farming	2.98	0.62	1.99	4.45
Sandhurst Focus Site	Cleared areas with remnant coastal vegetation, no stock	Lifestyle/ conservation	1.43	0.70	0.58	3.55
Simpson Conservation Park	Continuous native vegetation, mallee woodland, some areas recently burnt	Conservation	0.53	0.23	0.24	1.18

Spatial variation in density across sites

The most parsimonious model indicated there was an influence of space on density at the Willson River Focus Site, a site which predominantly comprised farmland. The HR detection function inhomogeneous Poisson model predicted that there was a gradient in density that increased from north to south across the property (Figure 2). A map was compiled from the results of the HR model, using the density averages for each raster to create a map that approximated model average estimates (Figure 3). This density average plot shows the models predict an increase in density at the more southern parts of the site, with the increased density curved further north to incorporate the farm dump, house and sheep yards and lower reaches of the Willson River. The density in all inhomogeneous models was predicted to be lowest in the north-west corner of the property.

The most parsimonious model for the Sandhurst Focus Site and Simpson Conservation Park site indicated density did not vary spatially at these sites.

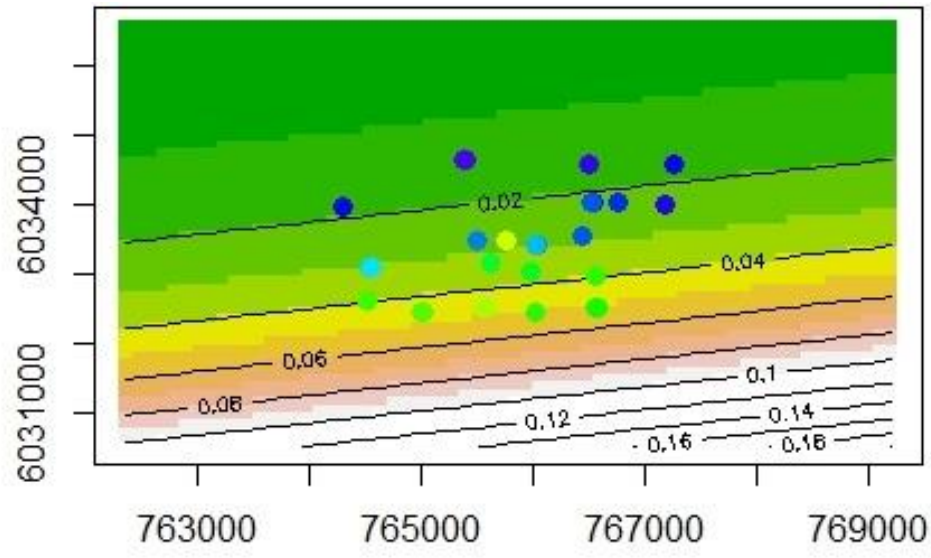

Figure 2. Estimated feral cat density at the Willson River focus site, using the most parsimonious model which predicted a linear trend in density. Contour lines represent cats per hectare (times by 100 for cats per square kilometre). The dots represent cameras where feral cats were observed, with colours representing different individuals. Note some individuals are masked as dots are overlaid on one another. Caution must be taken with interpreting results from outside the study zone (areas without dots).

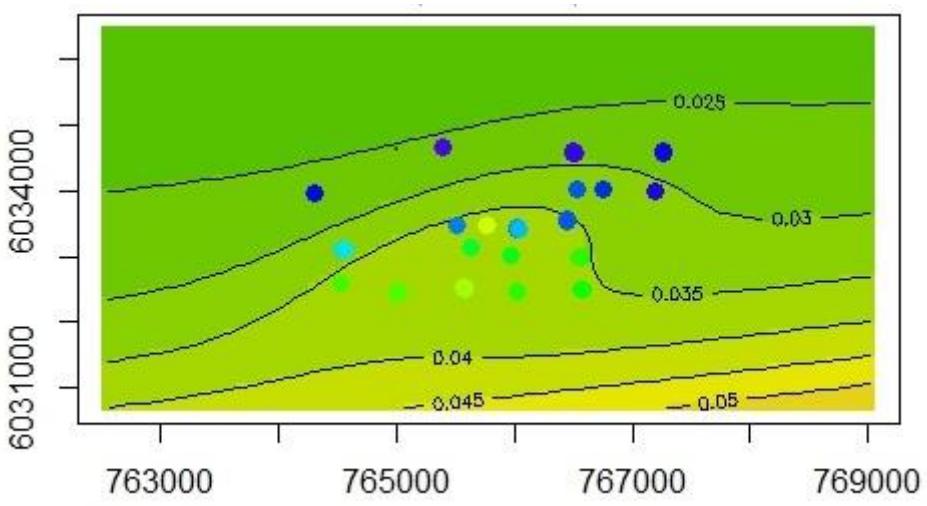

Figure 3. Estimated feral cat density at the Willson River focus site, from model averaged estimates of density per raster using the hazard rate detection function with contour lines representing the number of cats per hectare (times by 100 for number of cats per square kilometre). The dots represent cameras where feral cats were observed, with colours representing different individuals. Note some individuals are masked as dots are overlaid on one another. Caution must be taken with interpreting results from outside the study zone (areas without dots).

Detection rates of feral cats

The number of detections of feral cats was plotted for both the Willson River focus site and Simpson Conservation Park. A contour map produced from the number of detections at each camera roughly matched the density estimates produced for sites, with a clear cluster of detections around the farm dump site and higher detections in the south of the Willson River property (Figure 4).

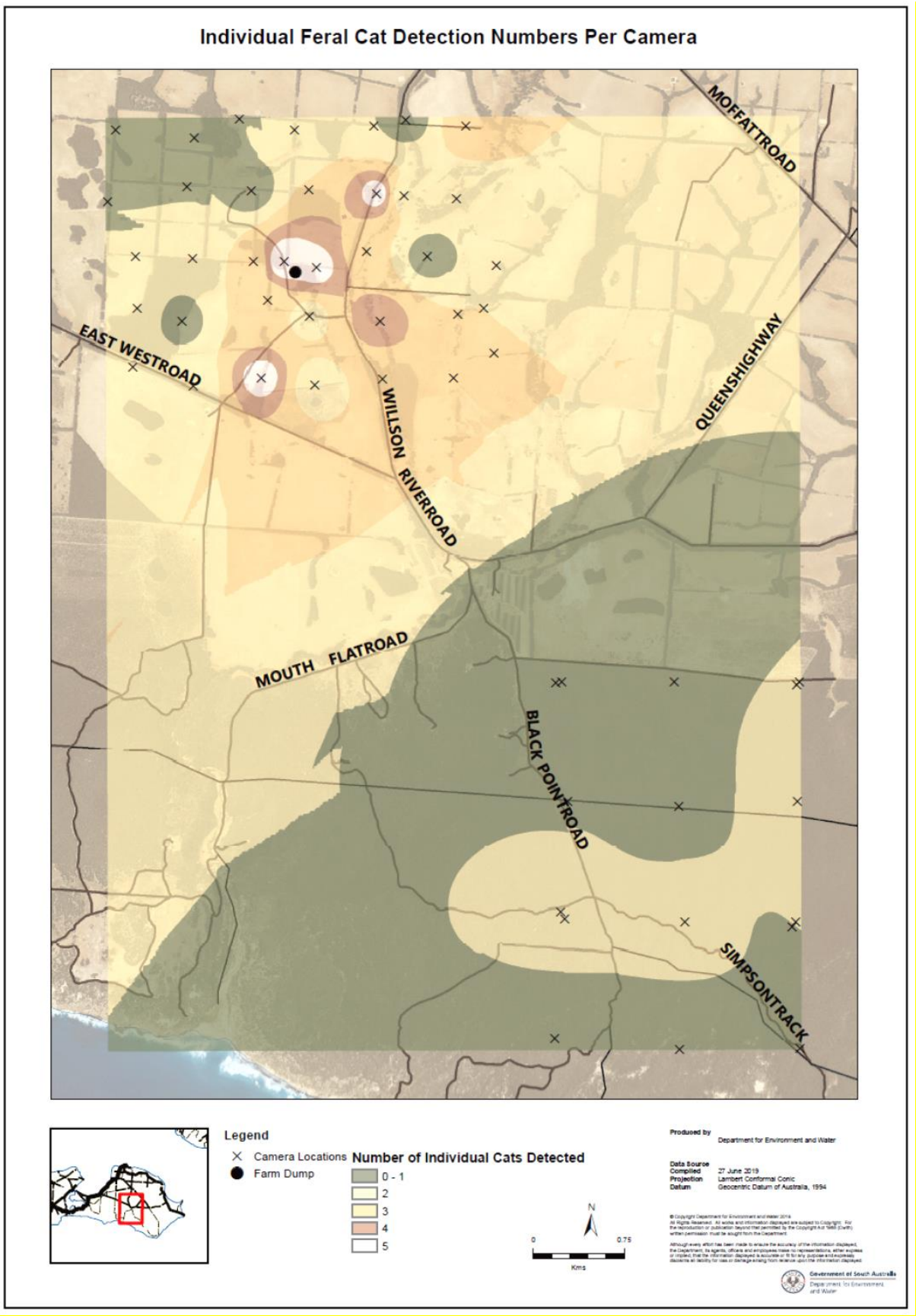

Figure 4. Contour map produced from the number of individual cats detected at cameras located at the Willson River focus site and Simpson Conservation Park.

Density estimates and length of survey period

The number of individual feral cats detected and the total number of detections increased over time (Figure 5).

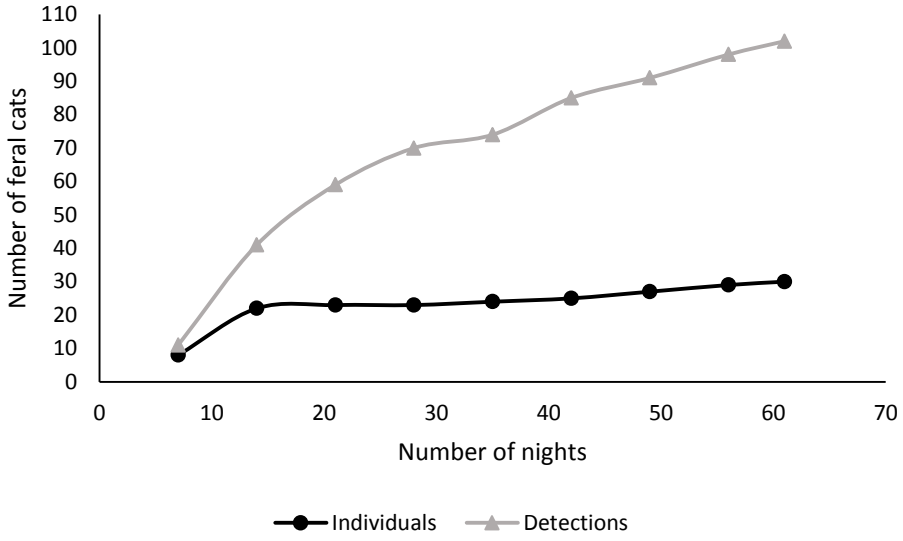

Figure 5. The number of individual feral cats detected and the total number of feral cat detections over time with varying survey lengths.

Estimates were also calculated for different survey periods using the same dataset, with the shortest survey being seven days and longest being 61 days in length. Density estimates had high standard errors and wide confidence intervals for the first fourteen days (Figure 6). Once a survey period reached 28 days both the density estimate and standard error remained similar even when longer datasets were added (Figure 6). The density estimate for 61 days of data was slightly increased compared to for 28 days data due to more individual cats being detected over the longer time period.

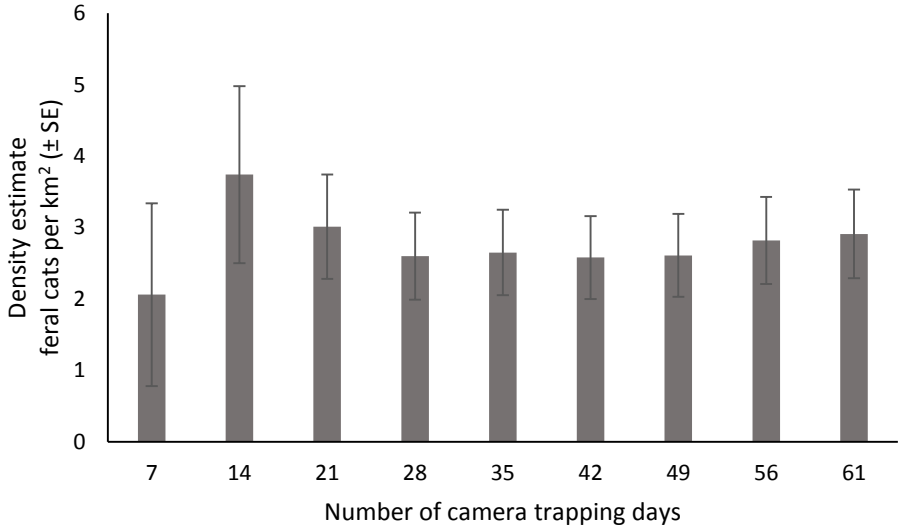

Figure 6. Density estimates calculated with varying survey lengths using the same dataset.

Population estimate for the Dudley Peninsula

With density estimates only obtained from three sites and each site being a different habitat type, there is some uncertainty in how representative these density estimates are for other areas of bushland and farmland on the Dudley Peninsula. However, using the single density estimates

obtained in this study for each habitat type and multiplying them by the area of each property type (Appendix B) on the Dudley Peninsula gives a population estimate of 645 feral cats on Dudley Peninsula (Table 3). As our estimate of feral cat density of rural production land was very high (2.98 feral cats per km^2), we also then calculated a population estimate substituting the rural production density with the result obtained by Bengsen *et al.* 2011 of 0.70 feral cats per km^2. This resulted in a population estimate of 237 feral cats on the Dudley Peninsula (Table 3). Both of these estimates exclude the number of cats in areas classified as "urban/other" as we currently have no density estimate for urban areas of Kangaroo Island.

Table 3. Population estimates for the Dudley Peninsula using the density estimates calculated in this study, and the density estimate for rural production land calculated by Bengsen *et al.* 2011.

Property type	Area (km^2)	Cat density (current study)	Population estimate (current study)	Cat density (Bengsen *et al.* 2011 farmland density)	Population estimate (Bengsen *et al.* 2011 farmland density)
Rural production	179	2.98	533	0.70	125
Native vegetation	166	0.53	88	0.53	88
Rural residential	17	1.43	24	1.43	24
Urban/Other	15	N/A	?	N/A	?
TOTAL	**384**		**645**		**237**

Discussion

This study indicates the density of feral cats varies markedly across the Dudley Peninsula between different habitat and land use types, and the small number of study sites in this study mean estimating the total population size of feral cats is problematic. Estimated feral cat density was highest at the Willson River focus site, which comprised of a mostly cleared agricultural landscape supporting a sheep farming enterprise. Density at this site was found to vary spatially, with the highest density predicted to be around the farm carcass dump area, the southern part of the Willson River and the southern boundary of the property. Carcass availability at the dump and in the southern areas of the farm (where a kangaroo cull was carried out during the study) are likely to have contributed to the clustering of feral cats around the southern part of the farm. Radio-tracking data also supports the hypothesis that feral cats were highly active in the paddocks with culled kangaroos. The Willson River had permanent pools of water throughout the summer survey period, which may also attract native wildlife and feral cats during dry times. It could be that the combination of the presence of carcasses, vegetation quality in the surrounding area and the reliable water availability make this southern part of the property high quality feral cat habitat. This study suggests that areas of high carcass availability may lead to high densities of feral cats.

The lowest estimated feral cat density was in Simpson Conservation Park, which consisted of continuous remnant mallee woodland vegetation. There was little evidence that density varied spatially in this environment. Density was also not found to vary spatially at the Sandhurst site, which consisted of mainly cleared land with some remnant coastal and mallee vegetation. This provides further evidence that lure points in the agricultural landscape, such as areas of carcass disposal on farms or areas where culls have been carried out, may lead to increased and clustered feral cat density at these sites.

The feral cat densities recorded in this study are significantly higher than the average density of feral cats on mainland Australia (0.27 cats per km^2, Legge *et al.* 2017). The densities recorded in this study are consistent with densities recorded on other islands, with offshore Australian islands generally recording higher densities than mainland Australia (Legge *et al.* 2017). The significant variation in density recorded in this study between the sites, despite two of these sites being only 3-4 km away from one another, indicates feral cat density can vary significantly on Kangaroo Island even over small distances. This study also shows how problematic calculating a population size is when density varies so much across the landscape. The population estimate calculated using our density estimates (634 feral cats) is around 2.7 times the population estimate calculated using a feral cat density on rural production properties reported by Bengsen *et al.* 2011. Further replicate sites in farmland could help us to understand the magnitude of variation in density on rural properties and help us to understand how to predict where feral cat "hot spots" will be. Long-term studies of feral cat density would be required to determine whether density varies seasonally or annually in response to environmental conditions.

This study did not have any sites in the urban areas of the Dudley Peninsula. Modified environments such as towns have been recorded elsewhere in Australia to have extremely high feral cat densities (mean of 8.2 cats per km^2, Legge *et al.* 2017) therefore further research on the feral cat density in Kangaroo Island townships needs to be undertaken to accurately determine density and hence the amount of control required in these parts of the landscape.

High feral cat density in open and agricultural landscapes has both benefits for control but negative impacts for farmers. High feral cat density is a likely cause of the high incidence of sarcocystosis in sheep on Kangaroo Island (Taggart *et al.* 2019a, Taggart *et al.* 2019b), which leads to direct economic losses for sheep producers. However there is evidence to suggest that feral cats in agricultural landscapes on Kangaroo Island regularly scavenge carcasses on-farm and from wildlife roadkill from direct observations of feral cats on farms and roadsides. The willingness of cats on Kangaroo Island to take non-live prey may account for the higher bait uptake by feral cats reported in the Phase 1 trials on Kangaroo Island (NRKI, unpublished data) and the higher cage trap success recorded at the Willson River focus site (14.2 %). Therefore cats used to scavenging in the agricultural landscape may be abundant, however they may also be more easily controlled through cage trapping, shooting and baiting which can prove difficult in other areas of Australia.

The ideal length of time a camera trapping survey should be conducted for an accurate density estimate needs to take in to account several considerations. One assumption of the density models used in this analysis is that the population sampled is a closed population. This assumption may be violated if the sampling period extends over long time periods and animals are recruited in to the population or lost due to mortality. Only one feral cat was identified as a kitten from the current breeding season at the Willson River focus site, and all others feral cats were adults. Therefore is it expected that recruitment made little difference to the estimate. We cannot rule out that some animals may have immigrated to or emigrated from the site during the sampling period, however radio-tracking data from 16 feral cats at the Willson River focus site indicated home ranges were relatively stable over the study. Loss of individuals through mortality or emigration however may have occurred. One cat out of the 16 that were radio-collared died of natural causes during the camera trapping survey period. This indicates that although mortality did occur it was unlikely to be significant among the population during the period of time used for the density estimate. As the standard error of density estimates did not change significantly once a survey was 28 days in length or longer, there is some merit in using a sampling period of this length in order to reduce the chances of violating the closed population assumption. However the probability of detection must also be factored in as short survey lengths are likely to reduce the probability of detection.

Three individual cats were observed for the first time between day 49 and 61 of the survey. There is the possibility that these three cats were residents in the area and yet were not detected until that time, or they could have been new recruits or immigrants to the area. These three extra cats increase the density slightly (from 2.61 cats per km^2 to 2.91 cats per km^2). If shorter surveys are used there is the possibility that some cats who do not have cameras intersecting their regular paths of travel will be missed. Therefore there is a trade-off between violating the assumption of a closed population and ensuring surveys are long enough to detect most feral cats at the site. In this case it appears there are only small differences for surveys between 28 and 61 days in length, and density did not change significantly in response to the few individuals detected late in the survey.

Conclusions

- Feral cat density is highly variable across the Dudley Peninsula, with a very high density of 2.98 cats per km^2 recorded at a farmland site and 0.53 cats per km^2 recorded in bushland.
- The feral cat population size is estimated at **645** feral cats on the Dudley Peninsula using density estimates obtained in this study, and **237** feral cats using a more conservative density estimate for rural production properties as recorded by Bengsen *et al.* 2011. Further density estimates are needed to get a more accurate population estimate on the Dudley Peninsula.
- Carcasses in the landscape may attract feral cats and cause high feral cat densities. Farmers could consider changing their management of carcasses on farm to reduce their availability to feral cats which may help to reduce clustering of high numbers of feral cats on farms.
- The willingness of feral cats in the Kangaroo Island agricultural landscape to scavenge on non-live prey-items may mean cage trapping, baiting and shooting could be more successful in these landscapes on the island than they have been in other areas of Australia.

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References

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. In 'Proceeding of the Second International Symposium of Information Theory'. (Eds. B. N. Petrov, F. Caski) pp. 267-281. (Academiai Kiado: Budapest.)

Bengsen, A., Butler, J., and Masters, P. (2011). Estimating and indexing feral cat population abundances using camera traps. *Wildlife Research* **38**, 732-739.

Borchers, D. L., and Efford, M. G. (2008). Spatially explicit maximum likelihood methods for capture-recapture studies. *Biometrics* **64**, 377-385.

Efford, M. G., Dawson, D. K., and Borchers, D. L. (2009). Population density estimated from locations of individuals on a passive detector array. *Ecology* **90**, 2676-2682.

Legge, S., B. Murphy, H. McGregor, J. Woinarski, J. Augusteyn, G. Ballard, M. Baseler, T. Buckmaster, C. Dickman, and T. Doherty. (2017). Enumerating a continental-scale threat: How many feral cats are in Australia? *Biological Conservation* **206**, 293-303.

R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at http://www.R-project.org/

Taggart, P. L., Stevenson, M. A., Firestone, S., McAllister, M. A., and Caraguel, C. G. B. (2019a). Spatial analysis of a cat-borne disease reveals that soil pH and clay content are risk factors for sarcocystosis in sheep. *Frontiers in Veterinary Science*. DOI: 10.3389/fvets.2019.00127

Taggart, P. L., Fancourt, B. A., Bengsen, A. J., Peacock, D. E., Hodgens, P., Read, J. L., McAllister, M. M., and Caraguel, C. G. B. (2019b). Evidence of significantly higher island feral cat abundance compared to the adjacent mainland. *Wildlife Research*, online early.

Appendix A – density distribution model results

Model selection of density distribution models of Willson River Focus Site using the hazard rate (HR) detection function.

Model	Explanation	npar	AIC	ΔAIC	wt
Dxy	Linear trend in density	6	1062.82	0.00	0.56
Null	No spatial variation	4	1064.16	1.34	0.29
Dxy2	Quadratic trend in density	9	1065.49	2.67	0.15

Model selection of density distribution models for Sandhurst Focus Site using the negative exponential (EX) detection function.

Model	Explanation	npar	AIC	ΔAIC	wt
Null	No spatial variation	3	201.65	0.00	0.50
Dxy	Linear trend in density	5	202.30	0.65	0.37
Dxy2	Quadratic trend in density	8	204.34	2.68	0.13

Model selection of density distribution models for Simpson Conservation Park using the negative exponential (EX) detection function.

Model	Explanation	npar	AIC	ΔAIC	wt
Null	No spatial variation	3	266.27	0.00	0.73
Dxy	Linear trend in density	5	269.42	3.16	0.15
Dxy2	Quadratic trend in density	8	269.99	3.72	0.12

Appendix B – Land use areas of Dudley Peninsula used to calculate population estimates