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RESEARCH ARTICLE

Abundance and detection of feral cats decreases after severe fire on Kangaroo Island, Australia

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Abstract

Predation by feral cats (*Felis catus*) has caused the extinction of many native species in Australia and globally. There is growing evidence that the impacts of feral cats can be amplified in post-fire environments, as cats are drawn to hunt in or around recently burnt areas and are also more effective hunters in open habitats. In 2018–2019, we established arrays of camera traps to estimate the abundance of feral cats on Kangaroo Island, South Australia. Much of the island (including five of our seven survey sites) was subsequently burnt in a severe wildfire (December 2019–February 2020). We re-sampled the sites 3–8 months post-fire (seven sites) and 11–12 months post-fire (three sites). At two unburnt sites sampled post-fire, it was possible to produce density estimates of cats using a spatially explicit capture–recapture approach. Where estimating density was not possible (due to low detections or individual cats not being distinguishable), the number of individuals and percentage of trap nights with detections was compared between the sampling periods. Some low-level cat control occurred within 2 km of three of the seven arrays (all within the burn scar) within 3 months of the fire. Across the five burnt sites, there was a decline in cat detections post-fire (including those without post-fire cat control). At 3–8 months post-fire, there was, on average, a 57% reduction in the number of individual cats, and a 65% reduction in the number of nights with cat detections, relative to pre-fire levels. Although cat detections declined following the fire, reduced population sizes of prey species and reduced cover as a result of the fire might still mean that cat predation is a threat to some surviving prey species. Management that reduces feral cat predation pressure on wildlife following wildfire should enhance the likelihood of post-fire wildlife persistence and recovery.

KEYWORDS
abundance, camera trapping, *Felis catus*, fire impacts, habitat use, invasive species, spatially explicit capture–recapture, threatened species

INTRODUCTION

Fire shapes the composition and distribution of faunal communities across much of the world's land area (Bowman et al., 2009). Fire can affect wildlife directly, via short-term mortality due to the effects of heat and smoke (Garvey et al., 2010), and indirectly via short to long-term changes in the structure and composition of the vegetation, as it is initially consumed or damaged, and then regrows following the fire (Fox, 1982; Monamy & Fox, 2000). Such changes to habitats following fire alter the availability of food and shelter resources upon which many animal species rely (Andersen et al., 2012). For example, by removing ground cover, fire may increase the vulnerability of some species to both native and invasive predators (Leahy et al., 2016; Letnic et al., 2004).

Cats (*Felis catus*) pose a considerable ongoing threat to wildlife in Australia (Woinarski et al., 2015, 2019) and globally (Doherty et al., 2016) through predation, competition and disease transmission (Medway, 2004; Nishimura et al., 1999; Phillips et al., 2007). Across Australia, the predation impacts of feral cats are thought to be greatest in areas with sparse ground-layer vegetation cover (Lawes et al., 2015). This may be in part because (1) cats are more abundant in these areas (Legge et al., 2017) and/or (2) cats potentially hunt most effectively in open habitats as there may be less cover for prey, making them easier to detect and capture (McGregor, Legge, Jones, & Johnson, 2015). Therefore, the removal of vegetative cover by fire may advantage feral cats, even if some cats are killed by fire, and even if there is a lower abundance of prey species post-fire. Indeed, in tropical northern Australia, cats preferentially use fire scars, sometimes travelling long distances to visit them (McGregor et al., 2014, 2016). Likewise, small mammals are likely more vulnerable to feral cat predation in burnt habitats with little vegetative cover (Leahy et al., 2016).

Much research into the response of cats to fire has occurred in tropical northern Australia (Davies et al., 2020; McGregor et al., 2014; McGregor, Legge, Jones, & Johnson, 2015; Stobo-Wilson et al., 2020), with far fewer studies in temperate southern Australia (Arthur et al., 2012; Hradsky et al., 2017), where fires are less frequent but typically of much higher severity (Murphy et al., 2013). Hradsky et al. (2017) reported a five-fold increase in the occurrence of invasive predators (cats and red foxes *Vulpes vulpes*) within 3 months of fire in temperate south-eastern Australia. In contrast, following extensive high-severity fire in a forest and heathland mosaic in south-eastern New South Wales, the abundance of feral cats decreased and remained relatively low for almost 10 years (Arthur et al., 2012; Catling et al., 2001). Across Australia, however, there is increasing evidence that large-scale fires may negatively affect native species at a landscape scale, through compounding impacts of predation (including by feral cats) in burnt landscapes (Doherty et al., 2022; Doherty, Bengsen, & Davis, 2015; Hradsky, 2020; Ziembicki et al., 2014).

Kangaroo Island, in South Australia, has high densities of feral cats (Hohnen et al., 2020; Taggart et al., 2019). A feral cat eradication program has begun on the island, with cat control activities underway in 2019 on the Dudley Peninsula on the island's eastern end. The island is also home to threatened animals (including the endemic Kangaroo Island dunnart *Sminthopsis fuliginosus aitkeni* and Kangaroo Island echidna *Tachyglossus aculeatus multiaculeatus*) which are vulnerable to the direct and indirect impacts of fire, including through increased risk of predation by feral cats.

In the summer of 2019–2020, a large fire – the largest in the island's recorded history – burnt 46% of Kangaroo Island (Keelty et al., 2020), including most of the west and centre of the island, and most of the island's conservation reserve network. The fire occurred during the so-called 'Black Summer' bushfire season, in which almost 10.5 million hectares of forest in the temperate and sub-tropical bioregions of southern and eastern Australia burned, an area unprecedented in recorded history (Boer et al., 2020; Wintle et al., 2020). Given that very few studies have examined the responses of cats to fire in temperate habitats, the response of the feral cat population to the Kangaroo Island fire was uncertain. The fire may have caused a decline in the island's total cat population through direct mortality (i.e. due to the effects of heat or smoke) or indirectly through starvation post-fire in a burnt landscape that supported lower densities of prey species. However, studies in other parts of Australia indicate that feral cat visitation rates to fire scars (from outside the burnt area) can be high (Hradsky et al., 2017; McGregor et al., 2016); if this was the case on Kangaroo Island, such dispersal may have led to localized increases in the density of feral cats in burnt areas.

To understand the potential impacts of feral cats on native wildlife in temperate environments following large-scale fires, we assessed how cat activity and abundance changed from pre-fire levels, at sites burnt and unburnt in these fires, within three habitat types on Kangaroo Island: farmland, forest and forest–farmland boundaries (as outlined in Hohnen et al. (2020)). We assessed feral cat activity 3–8 and 11–12 months after the fire. This information was expected to provide insight into the impacts of large-scale fires on feral cat populations, and therefore what management actions may be required post-fire to support wildlife population recovery.

METHODS

Study area

This study was conducted on Kangaroo Island (4405 km^2; Figure 1), in farmland, conservation reserves (Flinders Chase National Park, Ravine des Casoars Wilderness Protected Area, Kelly Hill Conservation Park, Simpson's Conservation Area) and crown land. The island's climate is temperate with warm dry summers and cool wet winters, and there is a rainfall gradient from the island's west (700 mm mean annual rainfall) to east (500 mm mean annual rainfall) (Bureau of Meteorology, 2020). The vegetation of western Kangaroo Island is dominated by an overstorey

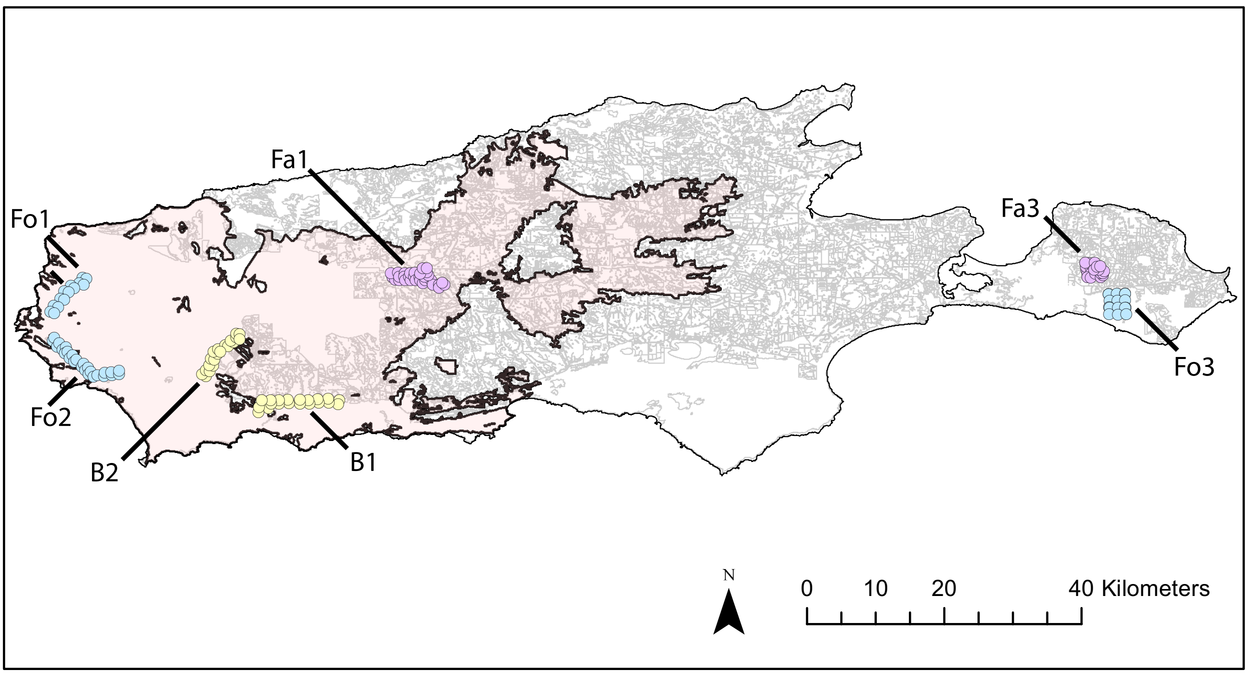

FIGURE 1 Map of Kangaroo Island showing camera locations (circles) and camera sampling arrays. Blue circles indicate arrays sited primarily in forest (including Forest 1 [Fo1], Forest 2 [Fo2] and Forest 3 [Fo3]), yellow circles indicate arrays on forest–farmland boundaries including Boundary 1 (B1) and Boundary 2 (B2), and purple circles indicate arrays on farmland including Farm 1 (Fa1) and Farm 3 (Fa3). Cleared farmland is shaded grey and the location of the fire scar is shaded pink.

of Kangaroo Island mallee-ash (*Eucalyptus remota*), brown stringybark (*Eucalyptus baxteri*) or coastal white mallee (*Eucalyptus diversifolia*) (Ball & Carruthers, 1998). In contrast, much of the east of the island is cleared farmland and much of the on-farm remnant vegetation is dominated by an overstorey of Kangaroo Island narrow-leaved mallee (*Eucalyptus cneorifolia*) (Ball & Carruthers, 1998). Unlike the southern Australian mainland, the feral cat is the only introduced predator on Kangaroo Island as there are no foxes or dingoes (Hohnen et al., 2020).

The fire that is the focus of this study burnt for over 6 weeks, between 20 December 2019 and 6 February 2020. It burnt 211 474 ha, including almost all of Flinders Chase National Park and Ravine des Casoars Wilderness Protected Area, the island's two largest conservation reserves and also large tracts of privately owned bushland and farms (Figure 2) (Keelty et al., 2020). The area has had a recent history of frequent fires, with 2008–2009, the most severe season preceding 2019–2020 (Bonney et al., 2020).

Pre-fire camera trapping

This study utilizes data on feral cat activity from Hohnen et al. (2020), collected prior to the 2019–2020 wildfire. Nine arrays of between 14 and 44 motion sensor cameras were deployed between September 2017 and December 2018 (between 26 and 10 months pre-fire) across the study area (Table 1), and this study utilized data from seven of those arrays. This includes three arrays deployed in the forest, two in farmland and two on the forest–farmland border. The camera arrays varied in their design (Table 1), but all consisted of two to three parallel transects of cameras (forming a narrow rectangular grid), sometimes constricted by landscape features such as a narrow coastal isthmus, or farmland boundary. Most cameras were spaced approximately 700 m apart, but where the terrain constrained camera placement (e.g. a steep ravine, or a change in habitat type), they were placed slightly closer or further away (0.5–1 km). The spacing was chosen based on GPS tracking of 33 feral cats on the Dudley Peninsula

FIGURE 2 Photograph of the landscape following the 2019–2020 fire on Kangaroo Island.

TABLE 1 Number of cameras deployed 24–12 months pre-fire and both 3–8 and 11–12 months post-fire for each of the seven arrays, including information on which arrays were burnt.

	24–12 months pre fire 2017–2019						3–8 months post-fire 2020				11–12 months post-fire 2020			
Array	Months	Number of cameras	Months pre-fire	Trap nights	Burnt/unburnt	Number of cats removed within 2 km	Months	Number of cameras	Months post-fire	Trap nights	Months	Number of cameras deployed	Months post-fire	Trap nights
Border 1	Oct–Dec 2017	20	26–24	900	Burnt	0	Aug–Sep 2020	20	7–8	700	Dec–Jan 2020/21	20	11–12	960
Border 2	Oct–Dec 2017	20	26–24	900	Burnt	8[a]	Aug–Sep 2020	20	7–8	720				
Forest 1	Dec–Feb 2017	14	24–22	1246	Burnt	5[a]	July–Aug 2020	40	6–7	1246	–	–	–	–
Forest 2	Dec–Feb 2017	26	24–22	2314	Burnt	4[a]	July–Aug 2020	40	6–7	2314	–	–	–	–
Forest 3	Nov–Jan 2018/19	16	13–11	1168	Unburnt	0	May–Jun 2020	63	3–4	1860	–	–	–	–
Farm 1	Sep–Nov 2018	31	15–13	1612	Burnt	0	July–Aug 2020	24	6–7	1117	Dec–Jan 2020/21	24	11–12	1008
Farm 3	Dec–Feb 2018/19	36	12–10	2196	Unburnt	13[b]	Aug–Sep 2020	23	7–8	2093	Dec–Jan 2020/21	22	11–12	924

[a]Indicates cats removed between the fire and the 3–8 months post-fire resampling period.

[b]Removal of cats occurred after the initial sampling period, 7 months prior to the fire.

[c]Indicates arrays where cameras were lured.

which suggested that cats have an average home range of 3.72 km^2 (P. Hodgens, unpublished data, 2018). The diameter of a 3.72 km^2 circle is 2.2 km; therefore, with a camera spacing of about 700 m, a typical cat would have access to multiple cameras within its home range (see Hohnen et al., 2020 for further details).

We used Reconyx® Hyperfire HC600 and PC800 cameras, which have an infrared flash only (i.e. they produce greyscale night-time images and colour day-time images). Cameras were programmed to take three images per trigger, 1 s apart, with no minimum time delay between triggers. During the pre-fire period, cameras were attached to trees or stakes 30–40 cm from the ground and all obstructions 1.5 m in front of the camera were removed. Lures were not used, but the cameras were placed in open areas or along animal trails, as studies elsewhere in Australia indicate that cats will move along trails if they are encountered (Geyle et al., 2020; McGregor, Legge, Potts, et al., 2015; Read et al., 2015). Cameras were deployed for 6–12 weeks (Table 1).

Post-fire camera trapping

Of the nine arrays sampled pre-fire in 2017 and 2018, seven arrays were resampled 3–8 months post-fire in 2020 (five burnt, two unburnt), and three were sampled again 11–12 months post-fire (two burnt, one unburnt) (Table 1). One forest-farmland border array in the initial 2017–2018 survey did not have enough cat detections to produce a density estimate, so this array was not resurveyed post-fire, and one farmland array was not resurveyed post-fire due to logistical constraints. The 3–8 months post-fire resurvey period included two farmland arrays (one unburnt and one burnt), two forest arrays (one unburnt and one burnt) and three forest-farmland border arrays (all burnt) (Table 1). The 11–12 months post-fire resurvey period included two farmland arrays (one burnt and one unburnt) and one forest farmland border array (burnt). Only three arrays were resurveyed in the 11–12 months resurvey period due to extensive cat management occurring over this period around four of the original seven arrays (described in detail in the 'post-fire cat management' section below).

We used Reconyx® Hyperfire HC600 and PC800 cameras, as well as Swift Enduros and Little Acorn LTL_5610 cameras, which all have an infrared flash. Logistical constraints meant that some arrays differed slightly in the number of cameras deployed pre- and post-fire (Table 1). The same camera locations were used pre- and post-fire with the exception of the arrays at Forest 1 and Forest 2. Logistical constraints meant that these arrays were deployed as part of a separate trial, and therefore did not follow the pre-fire design (Figure S1). These two camera arrays were also baited with a scent lure consisting of blood, tuna oil and meat-based sauce.

Image analysis

Each image containing a cat was examined and the pelage markings, particularly on the lower legs and tail, were noted. Individual identification of cats based on pelage markings was carried out using the methods outlined in McGregor, Legge, Potts, et al. (2015), where markings of each animal are used to identify individuals in subsequent images. Once all cats from an array had been identified, the set of images was re-examined twice for any inconsistencies in identification. Some cats were unidentifiable from the camera images because they had no unique pelage or body markings (such as black cats) and these were included in models as 'unmarked' individuals. Other cats could not be identified individually if their bodies were oriented towards the camera at an angle where critical identifying features such as the shoulder and rump were not visible. These individuals were included in the models as 'uncertain'. In some instances, certain arrays had too few cat detections to calculate a density estimate. Therefore, as a comparison pre- and post-fire, the percentage of trap nights (24-h periods) with cat detection was compared.

Statistical analyses

The time series of cat encounters on cameras was divided across each 6–12 weeks period into nights, and cats were recorded if present by a given camera during a given 24-h period. A comparison of the percentage of nights with cat detections pre-fire and 3–8 months post-fire was made with a paired t-test in the 'stats' package in R (R Core Team, 2013). Comparison of the same metric pre-fire and 11–12 months post-fire did not occur due to the low sample size. Where possible, density was estimated using a spatially explicit capture–recapture approach in the package 'secr' v 3.2.1 in the program R (Efford, 2020). This approach requires the estimation of a buffer, which is the maximum distance from the home range centre of a given animal to the point where the probability of detection approaches zero. For all arrays, we used the buffer width produced by the 'suggest.buffer' function in the 'secr' package. In all models, we used the half-normal detection function (HN). We then created a set of models with variables that influence g0 (estimated probability of detecting an individual at the centre of its activity range) including: '*b*', a learned response to cameras; '*t*', variation in detection with time and 'v1', variation in detection between cameras on roads or cameras on trackways. We also modelled a set of variables that might affect σ (the shoulder of the detection function) including: '*t*', variation in home range through time and 'h2', variation in home range size between individuals. All models were compared using Akaike Information Criterion (AIC) scores; the model with the lowest AIC value was used to predict cat density.

Post-fire cat management

Some cat management by the Kangaroo Island Landscape Board occurred in Flinders Chase National Park and Ravine des Casoars Wilderness Protected Area around three camera sampling arrays within the first post-fire sampling period (3–8 months post-fire). In this first period, five cats were removed (by trapping) within 2 km of the Forest 1 array, four cats within 2 km of Forest 2 and eight within 2 km of the Border 2 array; no such management occurred near the other four arrays. Between the 3–8 months resample period and prior to the 11–12 months resample period, cats were not removed from within 2 km of the three sampled arrays (Border 1, Farm 1 and Farm 3). Other arrays (including Border 2 Forest 1 Forest 2 and Forest 3) all underwent cat baiting between 3 and 8 months post-fire and 11–12 months post-fire and were therefore not resampled. Cat management also occurred at the unburnt farmland site (Farm 3) from February to May 2019 when 13 cats were removed. This was after the pre-fire sampling was undertaken, 7 months prior to the fire and 10–15 months prior to the resampling that occurred 3–8 months post-fire.

RESULTS

Summary information

Prior to the fire, there were 558 detections of 95 individual cats across the seven arrays from 10 336 camera trap nights (Table 2). In the post-fire sampling (3–8 and 11–12 months), there were 246 detections of 55 individual cats from 9703 camera trap nights (Table 2). While density estimates of cats could be made for all seven arrays pre-fire, only two of those seven arrays deployed after the fire had sufficient cat detections to produce cat density estimates, and these were both in unburnt sites, one in forest and one in farmland. No arrays in the burnt areas (two on the forest–farmland border, two in forest, and one in farmland) had enough post-fire cat detections to produce density estimates.

Feral cat density

As mentioned, cat detections post-fire were sufficient to calculate density estimates at only two unburnt sites 3–8 months post-fire and at unburnt sites 11–12 months post-fire (Table 3). Prior to the fire, cat densities at the unburnt forest array (Forest 3 Table 3) were 0.53 ± 0.22 (SE) cats km^{-2} (see Hohnen et al. (2020) for further details on model selection). This site was not burned, but 3–8 months after the fire occurred elsewhere on the island, the best model estimated the density of cats at this site to be higher than pre-fire levels: 1.18 ± 0.51 (SE) cats km^{-2} (Table S1). Estimates of detection probability (g0) at this unburnt site were higher before the fire than after (0.09 and 0.04, respectively).

In contrast, the density of cats in the unburnt farmland array (Farm 3 Table 3) prior to the fire was 3.27 ± 0.13 cats km^{-2} (see Hohnen et al. (2020) for further details on model selection). Three to 8 months after the fire, the best-fitting model included the σ variable 'H2', which described variation in home range size between individuals. In this model, the estimated cat density was lower than pre-fire levels at 1.22 ± 0.53 cats km^{-2}. The next best-fitting model for that array was the null model, but it was not competitive with the top model (ΔAIC ≤ 2). Estimates of detection probability did not vary considerably pre- and post-fire (0.02 and 0.03 respectively). This array was the only one of the three sites resampled 11–12 months post-fire that had enough cat detections for a density estimate to be computed. The best-fitting model for this time period was the null model, where both σ and g0 were held constant (Table S1), which estimated the density at 1.81 ± 0.43 cats km^{-2}. No other models were competitive with the top model.

Feral cat activity and number of individuals

Changes in feral cat activity pre- and post-fire were expressed in terms of detection rate (i.e. the percentage of camera trap nights with cat detections) (Figure 3, Table 2). Across all burnt sites, there was a significant decrease in cat detection rate from pre-fire to 3–8 months after fire ($t(4) = 5.54$, $p = 0.005$). The number of individual cats detected also decreased across all burnt sites from the pre-fire values to 3–8 months after fire ($t(4) = 3.54$, $p = 0.023$). Across the five burnt sites, there was on average a 57% reduction in the number of individual cats, and a 65% reduction in the number of nights with cat detections, 3–8 months post-fire relative to pre-fire levels. This compares to the two unburnt sites where there was on average a 19% reduction in the number of individual cats, and with more

TABLE 2 The number of feral cat detections and trap nights detected 24–12 months pre-fire and both 5–8 and 11–12 months post-fire for each of the seven arrays.

	24–12 months pre-fire 2017–2019				3–8 months post-fire 2020					11–12 months post-fire 2020			
Array	Cat passes	Identifiable cat passes	Individuals	% Traps nights with cat passes	Number of cats removed within 2 km	Cat passes	Identifiable cat passes	Individuals	% Trap nights with cat passes	Cat passes	Identifiable cat passes	Individuals	% Trap nights with cat passes
Border 1[a]	41	31	7	4.22	0	10	8	5	0.71	9	7	4	0.83
Border 2[a]	50	36	10	6.11	8[b]	5	5	3	1.39	–	–	–	–
Forest 1[a]	127	95	11	4.98	5[b]	28	16	7	1.67	–	–	–	–
Forest 2[a]	92	76	18	3.15	4[b]	27	17	5	1.81	–	–	–	–
Forest 3	29	24	7	2.05	0	86	77	16	5.11	–	–	–	–
Farm 1[a]	70	51	12	3.91	0	15	10	5	1.34	19	16	5	1.78
Farm 3	149	105	30	4.46	13[c]	75	67	14	2.05	63	49	15	6.06

[a]Indicates sites that were burnt.

[b]Indicates cats removed between the fire and the 3–8 months post-fire resampling period.

[c]Removal of cats occurred after the initial sampling period, 7 months prior to the fire.

TABLE 3 Density of feral cats pre-fire, 3–8 months post-fire and 11–12 months post-fire at selected sites across Kangaroo Island.

Location	Period	Cats/km^2	Density standard error	Lower confidence interval	Upper confidence interval	g0[a]	Value g0	Standard error	Sigma[b]	Value sigma	Standard error
Border 1	Pre-fire	0.06	0.03	0.02	0.17	N	0.05	0.02	N	1548.39	338.61
Border 2	Pre-fire	0.27	0.10	0.13	0.56	V1	0.05	0.01	N	845.88	129.76
Forest 1	Pre-fire	0.30	0.11	0.15	0.59	N	0.02	0.00	H2	558.66	82.63
Forest 2	Pre-fire	0.87	0.36	0.40	1.91	N	0.01	0.00	H2	366.33	88.51
Forest 3	Pre-fire	0.53	0.22	0.24	1.15	N	0.05	0.02	N	328.87	54.98
Farm 1	Pre-fire	0.19	0.06	0.10	0.35	V1	0.02	0.01	N	1442.81	139.80
Farm 3	Pre-fire	3.27	0.13	3.02	3.54	T	0.09	0.02	N	237.45	14.97
Forest 3	3–8 months post-fire	1.18	0.51	0.67	1.69	N	0.03	0.01	h2	184.19	47.01
Farm 3	3–8 months post-fire	1.22	0.53	0.54	2.77	N	0.04	0.01	h2	1369.98	186.95
Farm 3	11–12 months post-fire	1.81	0.49	1.07	3.06	N	0.03	0.01	N	376.86	43.75

Note: The only sites with sufficient cat detections in both post-fire periods to compute a density estimate were unburnt. All sites in this table were either sampled before the fire or were sampled after the fire but were not burnt.

[a]Variables that influence g0 include '*b*', a learned response to cameras; '*t*', variation in detection with time; 'v1', variation in detection between cameras on roads or cameras on trackways.

[b]Variables that influence sigma include '*t*', variation in home range though time; 'h2', variation in home range size between individuals.

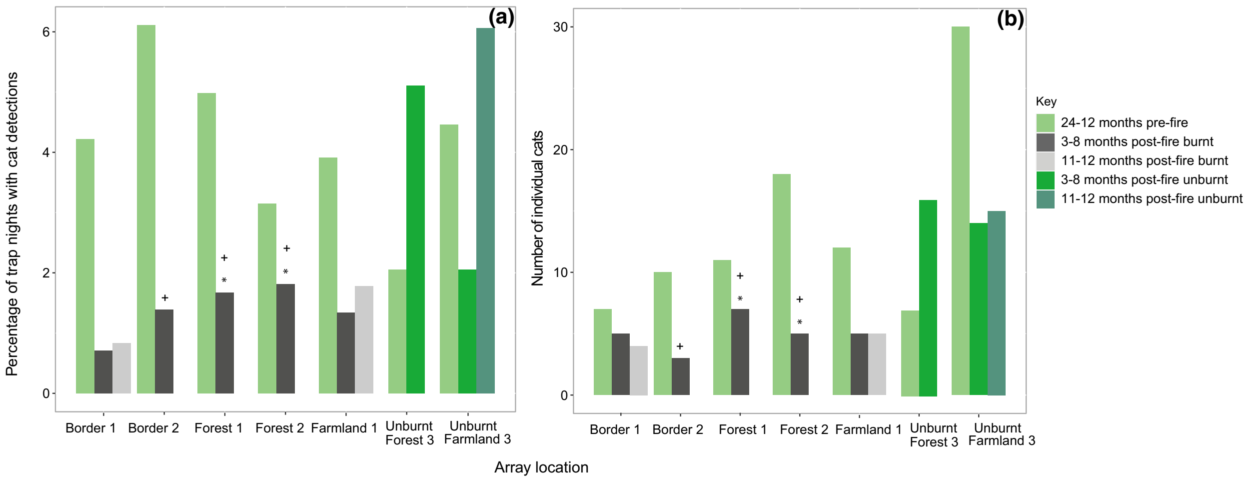

FIGURE 3 The (a) percentage of trap nights with feral cat detections and (b) the number of individuals, across both pre-fire and the two post-fire sampling periods. The symbol * indicates arrays where cameras were lured, in post-fire sampling. The symbol + indicates arrays, where feral cat control took place prior to the post-fire resampling.

variable cat detection responses (Table 2), 3–8 months post-fire relative to pre-fire levels. Both arrays on the forest–farmland border (Borders 1 and 2) burnt during the fire, and the percentage of trap nights with cat detections 3–8 months post-fire, decreased from 4.2% and 6.1% pre-fire to 0.7% and 1.3%, respectively. For both burnt forests (Forest 1 and 2) arrays, the detection rate dropped from 4.9% and 3.1% pre-fire to 1.6% and 1.8% post-fire, respectively. Likewise, a drop from 3.9% pre-fire to 1.3% 3–8 months post-fire occurred at the one burnt farmland array (Farm 1, Table 2). At the two burnt sites resampled 11–12 months post-fire, detection rates were still less than half those of pre-fire levels (Table 2).

For the two unburnt arrays (Farm 3 and Forest 3), the results were less consistent. For Farm 3, an array approximately 42 km from the fire edge, the cat detection rate decreased from 4.4% to 2.0% 3–8 months post-fire. For Forest 3, an array approximately 45 km from the fire edge, the cat detection rate increased from 2.0% to 5.1% (Figure 3) 3–8 months post-fire. For Farm 3, the one unburnt site resampled 11–12 months post-fire, the detection rate of 6.0% increased substantially from the 2.0% value at 3–8 months post-fire and was slightly higher than pre-fire levels of 4.4% (Table 2).

DISCUSSION

Few studies have examined the impact of a high-severity uncontrolled fire on feral cat densities, as this requires an almost chance overlap between pre-fire sampling, and the subsequent occurrence of a wildfires. Therefore, this study provides valuable information on how cat populations respond to wildfire. Cat activity dropped considerably at all arrays that were burnt by high-severity fires in the summer of 2019–2020, compared to pre-fire levels. Across the five burnt sites resampled 3–8 months post-fire, there was a 57% reduction in the number of individual cats observed, and a 65% reduction in the number of nights with cat detections, relative to pre-fire levels. At the two burnt sites resampled 11–12 months post-fire, there was no evidence of feral cat population recovery, with activity still less than half that pre-fire. Given the extent, severity and speed of the fire, it is likely that some feral cats were killed directly, but post-fire mortality due to starvation may also have occurred.

It should be noted that these results may be somewhat influenced by the occurrence of low-level cat control within the national park after the fire. Cat control occurred within 2 km of three of the seven arrays (all within the burn scar) between the fire and the 3–8 months post-fire resampling period. The removal of some cats from within the fire scar suggests that natural densities post-fire may be higher than described here. However, the extent of pre- to post-fire decline in cat activity was even more substantial in the two burnt sites that had no cat control (Border 1 [reduction of 83%] and Farm 1 [65%]) than in the three burnt sites that had some cat control in the vicinity (Forest 1 [56%], Forest 2 [42%], Border 2 [77%]) (Figure 3), suggesting that reductions due to fire were at least as pronounced as any population loss due to control. There were also some differences in array design pre- and post-fire, particularly for the two forest arrays that were located in the burn scar (Forest 1 and 2). Logistical limitations meant that these were re-sampled (3–8 months post-fire) as part of a separate study, which necessitated a slightly different arrangement of cameras in a grid layout, and the addition of a scent lure. Although the lure may have increased cat detections at these two sites (Figure 3), comparable changes in cat density were also observed at site Border 2, an unlured site with otherwise similar conditions (burnt with low-level cat control). We acknowledge that these issues (some post-fire cat removals at some of our sampled sites, and the addition of lures at two of our post-fire sampled sites) introduce some imperfections in our study design, but we note (i) that the results are largely consistent for sites with and without these factors and (ii) rigidly perfect research designs are usually unattainable in wildfire settings. This is especially so as a conservation management imperative to protect surviving native species (in this case through attempts to reduce the compounding impacts of predation) may trump the desirability for, or achievability of, consistency in research protocols.

The substantial declines in cat activity and the number of individual cats detected at burnt sites in our study are consistent with the findings of the only other comparable study from mainland south-eastern Australia that compared cat abundance before and after a high-severity fire (Arthur et al., 2012; Catling et al., 2001). Doherty, Dickman, et al. (2015) and, more recently, Hradsky (2020) proposed a conceptual model with two distinct pathways by which predators (both exotic and native) interact with fire to suppress populations of small mammals. A 'functionally mediated pathway' (i.e. increased per-capita impact of a predator on a prey population) and 'numerically-mediated pathway' (i.e. increased local density of predators relative to prey through the attraction of predators to the recently burnt area and unburnt parches within it) were identified. In the case of the Kangaroo Island fire, the results of this study indicate the numerically-mediated pathway may not be important, at least so recently after fire (i.e. cat density did not increase in burnt areas), but the functionally mediated pathway may still influence wildlife populations on Kangaroo Island. The response of cats to the Kangaroo Island fires may also be influenced, in part, by fire-induced mortality and by the vast scale of these high-severity fires that mostly homogenized great swathes of the landscape (Figure 2). For example, research in south-east Queensland has shown that cat detection rates were highest on forest–farmland edges as they exploit ecotones or mosaics that provide a mix of cover for stealthy hunting and open areas where prey is exposed (Graham et al., 2013): the post-fire landscape of Kangaroo Island provided limited spatial heterogeneity – across vast areas, there were no fire edges or burnt patches within mostly unburnt settings. However, it should be noted that a temporary post-fire increase in the Kangaroo Island cat population may have occurred prior to the first 3–8 months post-fire sampling period (1–3 months post-fire) and therefore may have not been detected with the survey methods.

Research in northern Australia has shown that feral cats prefer to hunt in open habitats, such as recent fire scars, where they have significantly higher hunting success (McGregor, Legge, Jones, & Johnson, 2015). Further, feral cats sometimes travel long distances to visit fire scars and hunt along their edges (McGregor et al., 2014, 2016), presumably to take advantage of these open environments. This propensity of cats to move to sites where hunting efficiency is high is likely to be a more severe problem for prey species that do not move their home ranges as a result of fire and remain vulnerable not only to starvation but increased exposure to predation (Leahy et al., 2016). While the post-fire behaviour of small native mammals on Kangaroo Island is largely unknown if individuals survive the immediate effects of the fire (i.e. heat and smoke) they are likely to be exposed to predation by both native predators and feral cats. On Kangaroo Island, such prey species are likely to include the bush rat (*Rattus fuscipes*) and the threatened Kangaroo Island dunnart (Hodgens et al., 2022).

Interestingly, cat activity appeared to be more variable at unburnt than burnt arrays, with cat activity increasing at one unburnt array (in forest) and declining at the other (in farmland). Both unburnt arrays were located on the Dudley Peninsula, over 40 km from the fire scar itself, so the cat population there was unlikely to have been affected by the fire (and likewise it is unlikely that cats at our burnt sites may have been immigrants from unburnt areas >40 km distant). Some of the variability in pre- to post-fire changes in cat activity in unburnt sites may be in part due to feral cat control activities that occurred on the peninsula from 2019. Thirteen cats were removed from in and around the unburnt Farm 3 site between February and May 2019, which may explain the reduction in cat density at this site during the post-fire sampling. Short-term cat control has been found to cause little long-term (>12 months) changes in cat density elsewhere (Lazenby et al., 2015; Palmas et al., 2020), and therefore, cat activity at this farmland site may also be impacted by other factors such as the availability of carrion (wallabies which are sometimes shot on the property), which could have varied between the two survey periods.

Overall, the 2019–2020 fire on Kangaroo Island appeared to cause a marked decline in cat activity and density within the burnt area. However, cats were still present in these burnt habitats, indicating that some cats survived the event or may have immigrated in from unburnt areas. This study was opportunistic in that it was possible to assess changes in cat density or activity caused by a high-severity fire because we had established a baseline sample shortly before the fire that could be re-purposed as a monitoring program. For most Australian biodiversity, there is little or no long-term monitoring (Scheele et al., 2019), and as a consequence, it is difficult to assess the impacts of any unexpected event. High-severity fire is likely to be an increasingly frequent feature of the temperate Australian environment, and broad-scale development and implementation of monitoring programs would provide more scope for robust assessment of the impacts of such events. With the vegetative cover removed by fire, surviving prey species remain vulnerable to predation by feral cats until the vegetation has regrown sufficiently to provide adequate cover. Therefore, on Kangaroo Island and in other areas burnt by high-severity fires, feral cat control may be especially important to ensure that populations of vulnerable species recover after the fire. Such emergency interventions are likely to be required more frequently as the climate warms and fire frequency, severity, extent and impacts increase.

AUTHOR CONTRIBUTIONS

Rosemary Hohnen: Conceptualization (equal); data curation (equal); formal analysis (equal); funding acquisition (equal); investigation (equal); methodology (equal); project administration (equal); resources (equal); software (equal); validation (equal); visualization (equal); writing – original draft (lead); writing – review & editing (lead). **Alex I. James:** Conceptualization (equal); investigation (equal); methodology (equal); project administration (equal). **Paul Jennings:** Conceptualization (equal); data curation (equal); investigation (equal); methodology (equal); writing – original draft (equal); writing – review and editing (equal). **Brett P. Murphy:** Conceptualization (equal); formal analysis (equal); investigation (equal); methodology (equal); project administration (equal); software (equal); supervision (equal); writing – original draft (equal); writing – review and editing (equal). **Karleah Berris:** Conceptualization (equal); data curation (equal); formal analysis (equal); methodology (equal); project administration (equal); writing – original draft (equal); writing – review and editing (equal). **Sarah M. Legge:** Conceptualization (equal); data curation (equal); formal analysis (equal); funding acquisition (equal); investigation (equal); methodology (equal); project administration (equal); resources (equal); supervision (equal); validation (equal); writing – original draft (equal); writing – review and editing (equal). **Chris R. Dickman:** Conceptualization (equal); methodology (equal); project administration (equal); resources (equal); supervision (equal); validation (equal); writing – original draft (equal); writing – review and editing (equal). **John C. Z. Woinarski:** Conceptualization (equal); data curation (equal); formal analysis (equal); funding acquisition (equal); investigation (equal); methodology (equal); project administration (equal); resources (equal); software (equal); supervision (equal); validation (equal); visualization (equal); writing – original draft (equal); writing – review and editing (equal).

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data in this paper are available at: http://www.aekos.org.au/index.html#/home under the name of this paper.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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