Dampier Peninsula Greater Bilby (*Macrotis lagotis*) Main Roads offset project: Final report

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In partnership with:

Final Report

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A - Yawuru Country Managers, B - Bardi Jawi Oorany Rangers, C - Nyul Nyul Rangers, D Nykina Mangala Rangers

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Summary

Over the last two centuries, the geographic range of the greater bilby (*Macrotis lagotis*) has contracted substantially, and the species is now restricted to a northern subset of its former distribution, part of which includes the Dampier Peninsula in the Kimberley region of Western Australia. In 2016, Main Roads WA provided funding to offset impacts to bilbies on the Dampier Peninsula as a result of the Cape Leveque Road upgrade (EPBC 2013/6984, CPS 6078/4). This project, coordinated by the Department of Biodiversity, Conservation and Attractions (DBCA), in partnership with traditional owner groups, aimed to survey, monitor, and commence adaptive management of bilbies on the Dampier Peninsula, to improve our understanding of their occurrence, as well as what is required to ensure their persistence into the future.

Analysis of 2-ha plot data collected across the Dampier Peninsula revealed that fire frequency and the extent of long unburnt habitat are important factors in predicting the presence of both bilbies and feral cats. Bilbies were more frequently detected in areas where there was a greater proportion of long unburnt habitat, while feral cats were least detected in these areas. Frequent fires tended to deter bilbies but not feral cats. These results support global studies suggesting that increasing fire frequency and spatial extent contribute to declines in multiple taxa due to increased predation and decreased resource availability. These findings provide valuable context for fire practitioners seeking to implement fire regimes that promote suitable habitats for bilby conservation within fire-prone areas of their range.

Bilby abundance estimates from scat searches and SECR analysis suggest that the Coconut Wells population has potentially declined to near extinction since 2020, while the Pio's Paddock population has increased and remained relatively stable. Both populations were relatively small, similar to other sites in Western Australia. The persistence of the Pio's Paddock population may be partially attributed to fire management practices limiting the impact of late dry season wildfires. The Coconut Wells population, not subject to strategic burning, experienced two late dry season fires, leading to significant vegetation changes and bilby disappearance from the site. In contrast, the Pio's Paddock population experienced only one cool early dry season fire. These findings emphasise the importance of reducing fire frequency to protect bilbies and support the ongoing burning practices of

the DPFWG, aiming to increase long-unburnt vegetation on the Dampier Peninsula and decrease fire frequency.

Camera trap data from 2020-2022 revealed relatively high feral cat occupancy at Pio's Paddock and Coconut Wells bilby populations, with comparatively lower dingo occupancy. No significant differences in dingo or feral cat occupancy were observed between treatment and control sites, suggesting strategic burning may not have influenced predator occupancy. However, limitations in sample size, statistical power, scale and unaccounted factors like prey availability could have influenced these results. Further research with larger sample sizes and more comprehensive spatial and temporal coverage is needed to better understand the relationship between strategic burning and predator occupancy to inform more effective fire management strategies for bilbies.

Between 2019 and 2022, fire management efforts at Pio's Paddock focused on controlled burns and firebreaks to mitigate the impact of late dry season wildfires on the bilby colony, fuelled by strong easterly winds. The Coconut Wells colony served as a control population. The 2019 strategic cool burns near Pio's Paddock effectively protected the area from wildfires that later impacted the Dampier Peninsula. In 2020, a prescribed fire burn created a fire scar at Pio's Paddock's eastern boundary, preventing damaging wildfires from entering the area. In 2021, early dry season aerial burning was conducted at Pio's Paddock's northern boundary, complementing previous fire management work. The 2022 burn plan involved strategic aerial ignition lines, diagonal burn lines, firebreak grading tracks, and fine-scale ground burning. The plan's successful implementation, due to collaboration between the Department of Biodiversity, Conservation and Attractions (DBCA) and Yawuru country managers, highlights the importance of partnerships in conservation and serves as a model for future fire management initiatives to protect vulnerable species like the bilby.

Introduction

The greater bilby (*Macrotis lagotis*), a medium-sized burrowing marsupial, has seen a large-scale decline in distribution since European colonization of Australia (Southgate 1990; Bradley *et al.* 2015) and is now listed as vulnerable to extinction by the IUCN (Burbidge and Woinarski 2016) and under the *Environment Protection and Biodiversity Conservation Act 1999* (DCCEEW 2023). The cause of this decline has been attributed to several factors, including predation by introduced feral cats (*Felis catus*) and foxes (*Vulpes vulpes*) (Paltridge 2002a; Bradley *et al.* 2015), altered fire regimes (Southgate *et al.* 2006; Southgate and Carthew 2007; Bradley *et al.* 2015), and habitat degradation through pastoralism, introduced herbivores, and clearing (Southgate 1990; Pavey 2006; Bradley et al. 2015). Bilbies now occupy only a northern subset of their former range, including the Tanami Desert in the Northern Territory, Great Sandy and Gibson Deserts, parts of the Pilbara and Kimberley in Western Australia, and a population in south-west Queensland (Gibson 2001).

The Dampier Peninsula in the southern Kimberley is home to the most north-western existing population of bilbies. Although previously considered a safe haven for the species, bilbies in this area remain threatened by feral cats, dingoes, and increasingly severe and frequent wildfires. The majority of the Dampier Peninsula and its bilby populations are managed by Traditional Owner groups under Native Title Claims, including the Nyul Nyul, Bardi Jawi Oorany, Nyikina Mangala, and Yawuru people (Figure 1), who consider bilbies to hold high cultural value. Several large pastoral stations also operate in the area, including Country Downs, Kilto, Roebuck Plains, and Yeeda.

To offset the impact of the Cape Leveque Road upgrade project (EPBC 2013/6984, CPS 6078/4) on local bilby populations, in 2016 Main Roads WA funded a project coordinated by the Department of Biodiversity, Conservation and Attractions (DBCA). This project, which partners with Nyul Nyul, Bardi Jawi Oorany, Nyikina Mangala, and Yawuru Country Managers on a fee-for-service basis, builds upon previous DBCA-coordinated bilby projects in the region and partners with the Kimberley Land Council, World Wildlife Fund, Environs Kimberley, and Rangelands Natural Resource Management to contribute to the broader Kimberley Bilby program.

The project's goal was to improve our understanding of bilby distribution, habitat preferences, and threats on the Dampier Peninsula and to implement appropriate management to enhance the persistence of local populations. The project aimed to:

1. Define the area of bilby occupancy through an array 2 ha sign plots across the Dampier Peninsula.
2. Monitor selected bilby populations annually by genotyping individuals from scats collected along transects to measure abundance.
3. Monitor predators, and other animals such as large herbivores, from remote cameras at selected bilby monitoring sites.
4. Manage threats at selected bilby monitoring sites by implementing primarily fire-related management activities.

This report presents the outcomes achieved across each of these components over the life of the project.

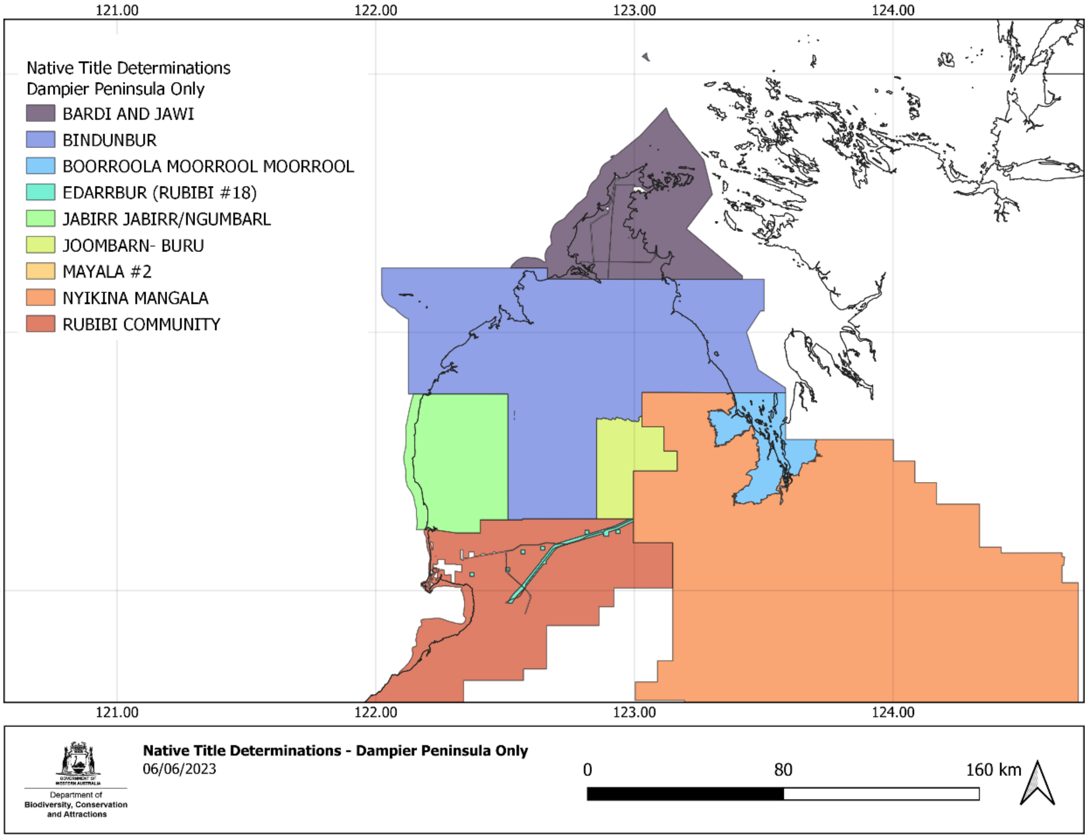

Figure 1 – Native Title determinations on the Dampier Peninsula.

1 Defining the area of occupancy

1.1 Background

The occupancy survey was designed to better understand the distribution of the bilby on the Dampier Peninsula. However, it also provided an opportunity to investigate the multiscale impacts of varying fire attributes on bilbies across this area, which is the most fire-prone section of their range in north-western Western Australia. In addition to examining the effects of fire on bilby occupancy, we also explored how these fire attributes influenced the occurrence of feral cats, a key predator of the bilby. We aimed to address two important questions: 1) How does fire influence the distribution of bilbies on the Dampier Peninsula and, 2) Is the impact of fire on bilbies mediated by the occurrence of feral cats, and if so, at what spatial scale?

1.2 Methods

1.2.1 Plot surveys

Bilby occupancy on the Dampier Peninsula was sampled across 69 x 2-ha sign plots (Figure 2). Collaborative planning sessions for sign plot locations was completed with Nyul Nyul, Bardi Jawi Oorany, Nyikina Mangala Rangers and Yawuru Country Managers. Sites were stratified according to fire frequency and the majority of plots sampled four times each (with a small number of plots three times). At the time of field surveys, some areas of the Dampier Peninsula remained as undetermined Native Title Claim and were not sampled. As a result, full spatial coverage of the Dampier Peninsula was not possible.

The standardised 2-ha sign plot technique provides systematically quantified and comparable data and is currently applied broadly in parts of arid and semi-arid Australia (Moseby et al. 2009; Southgate et al. 2018). At each 2-ha plot, trained observers recorded animal sign as well as plot covariates in a 2 ha area and within 100 m of a nearby vehicle track (Figure 3). Plot covariates included values such as landform, vegetation type, time since burnt, percentage of area suitable for tracking, substrate etc (Table S1). Animal sign (bilbies, feral cats, cattle, donkeys) and plot covariate data was collected electronically using Mobile Data Studio (Creativity Corp Pty Ltd).

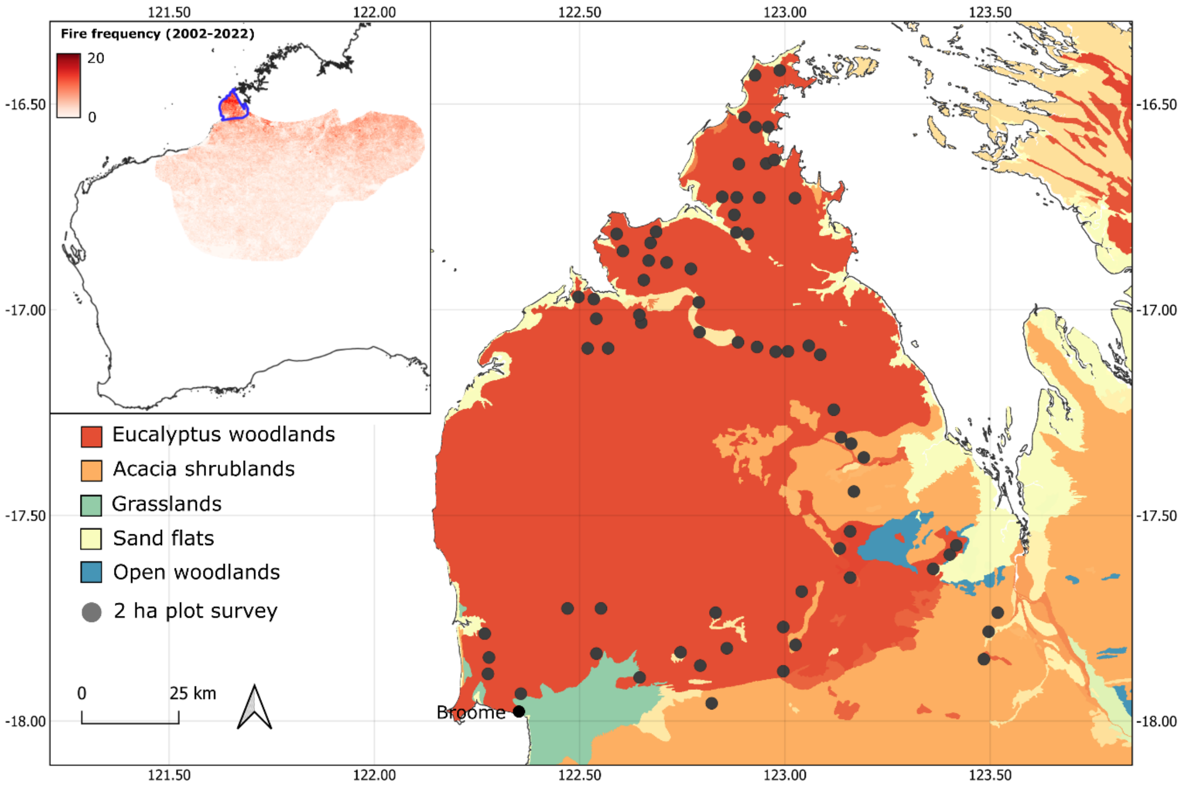

Figure 2 – Location of 2-ha sign plots located on the Dampier Peninsula in north-west Australia. Inset shows fire frequency across the greater bilby's (*Macrotis lagotis*) contemporary range (excluding the isolated Queensland population), with the study area outlined in blue.


Figure 3 – Nykina Mangala Rangers collecting 2 ha plot data.

1.2.2 Environmental data

The fire data used in this study comprised MODIS (Moderate Resolution Imaging Spectroradiometer) vector data, which had a resolution of 250-m and was available from the North Australia Fire Information service (http://firenorth.org.au). The status of data pixels (burnt or unburnt) was measured on a monthly basis.

Four fire history attributes were recorded for every visit at each site. These attributes included pyrodiversity, fire frequency, as well as the proportion of sites that were recently burnt (<1 year post-fire) and long unburnt (>3 years post-fire), as defined by Wysong *et al.* (2021) (Table 1).

Research has shown that fire attributes can have varying impacts on species depending on the scale at which they are measured (Nimmo *et al.* 2019; Wan *et al.* 2020). To account for this, we measured fire attributes at multiple scales for every animal presence record. We did this by creating buffers of different sizes for each presence record and then clipping fire data to those buffers, following Radford *et al.* (2021). The buffer sizes were 1 km (A = 3.14 km^2), 3 km (28.26 km^2), 5 km (78.5 km^2), and 10 km (314 km^2) from the presence records (Figure 4).

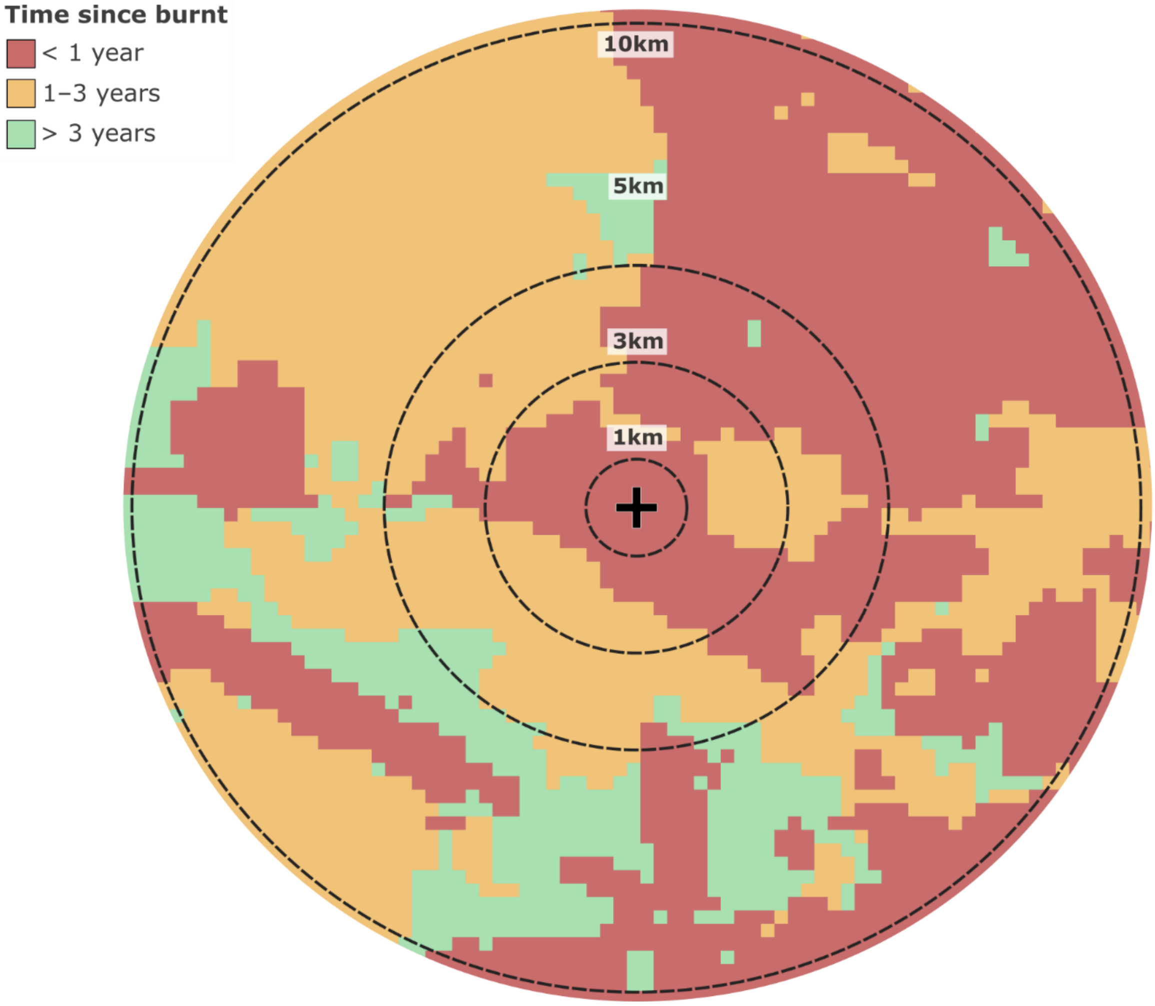

Figure 4 – Burn data used to measure fire attributes on the Dampier Peninsula in Northern Australia. The black cross represents the centre of a 2-ha plot site.

Table 1 - Fire attributes used to predict the presence of greater bilbies (*Macrotis lagotis*) and feral cats (*Felis catus*) on the Dampier Peninsula, north-west Australia.

Attribute	**Method**
Pyrodiversity	Sum of post successional vegetation ages within a defined area (site, patch, landscape).
Fire frequency	Sum of separate fires to have occurred within a defined area (site, patch, landscape) between the year 2000 and time of a 2-ha plot survey.
Proportion recently burnt (<1 year post fire)	The proportion of a defined area (site, patch, landscape) burnt 1 year prior to a 2-ha plot survey.
Proportion long unburnt (>3 years post fire)	The proportion of a defined area (site, patch, landscape) last burnt greater than 3 years prior to a 2 ha plot survey, following (Wysong *et al.* 2021).

Other environmental factors likely to influence the occurrence of bilbies and feral cats, including dominant vegetation type and annual rainfall, were also recorded for each site, at each scale. Vegetation data was sourced from the National Vegetation Information System (NDVI 2020) at 100*100 m resolution. The majority of sites (n= 65) were dominated by either eucalyptus woodland or acacia shrublands (Figure 2). The four sites that did not fall into either of these two categories were removed due to inadequate sampling replication. While substrate is known to be an important predictor of bilby occurrence, it was not included in models here given almost all sites were located on calcareous and siliceous sands (Rudosols).

1.2.3 Data analysis

To measure the effect of fire attributes on species occurrence, we fit binomial generalized linear mixed-effects models using the package lme4 (Bates *et al.* 2015) in r version 4.1.2 (R Core Team 2021). The use of occupancy models was considered, however it was decided against this approach due to the likelihood that the time period between repeat surveys would violate assumptions related to closure.

To test whether the presence of cattle, donkeys, dingoes, or feral cats had a direct effect on bilby presence, we first fit a series of models with these species as fixed effects and bilby presence as the response variable. Site ID was included in the models as a random factor to account for sampling replication within sites.

Next, to examine the effect of fire, we fit separate models for each fire attribute, at each scale, for both bilbies and feral cats (n total models = 24), with species presence or absence at each site on each visit set as the response variable. All models included dominant vegetation type, annual rainfall and one of the four fire attributes as fixed effects. In addition, site ID was included in models as a random factor to account for sampling replication within sites. Fixed effects were deemed to have a significant effect on species occurrence when estimated confidence intervals did not overlap zero.

1.1 Results

The most detected species across all plots were cattle (92.8%), followed by feral cats (62.3%), dingoes (55.1%) and donkeys (30.4%) (Figure 6). Bilbies were detected at 18.8% of plots. Bilby detections was made primarily from diggings, burrows, tracks and presence of scats (Figure 5).

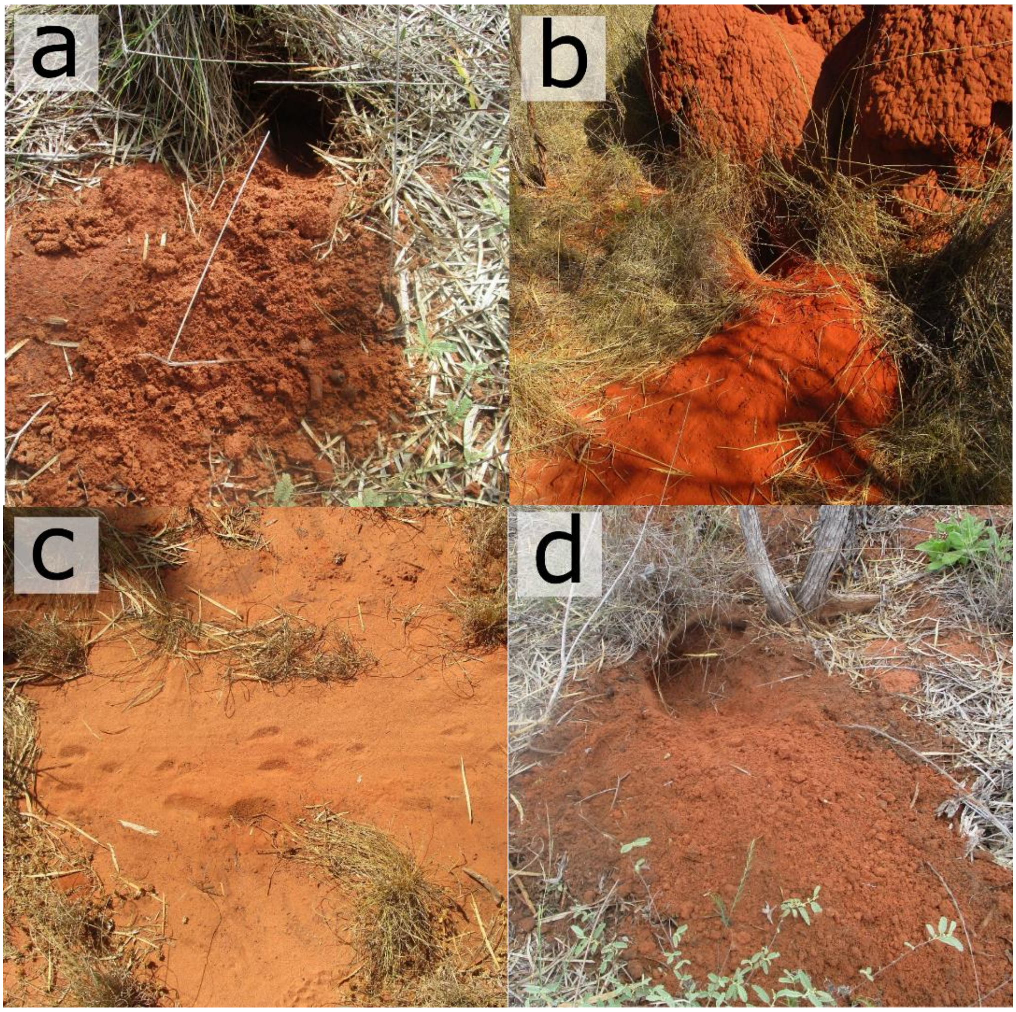

Figure 5 – Active bilby signs encountered to confirm presence during occupancy surveys, active burrow, diggings (note digging at base of *Acacia eriopoda* extracting root dwelling larvae), digging and scat and tracks.

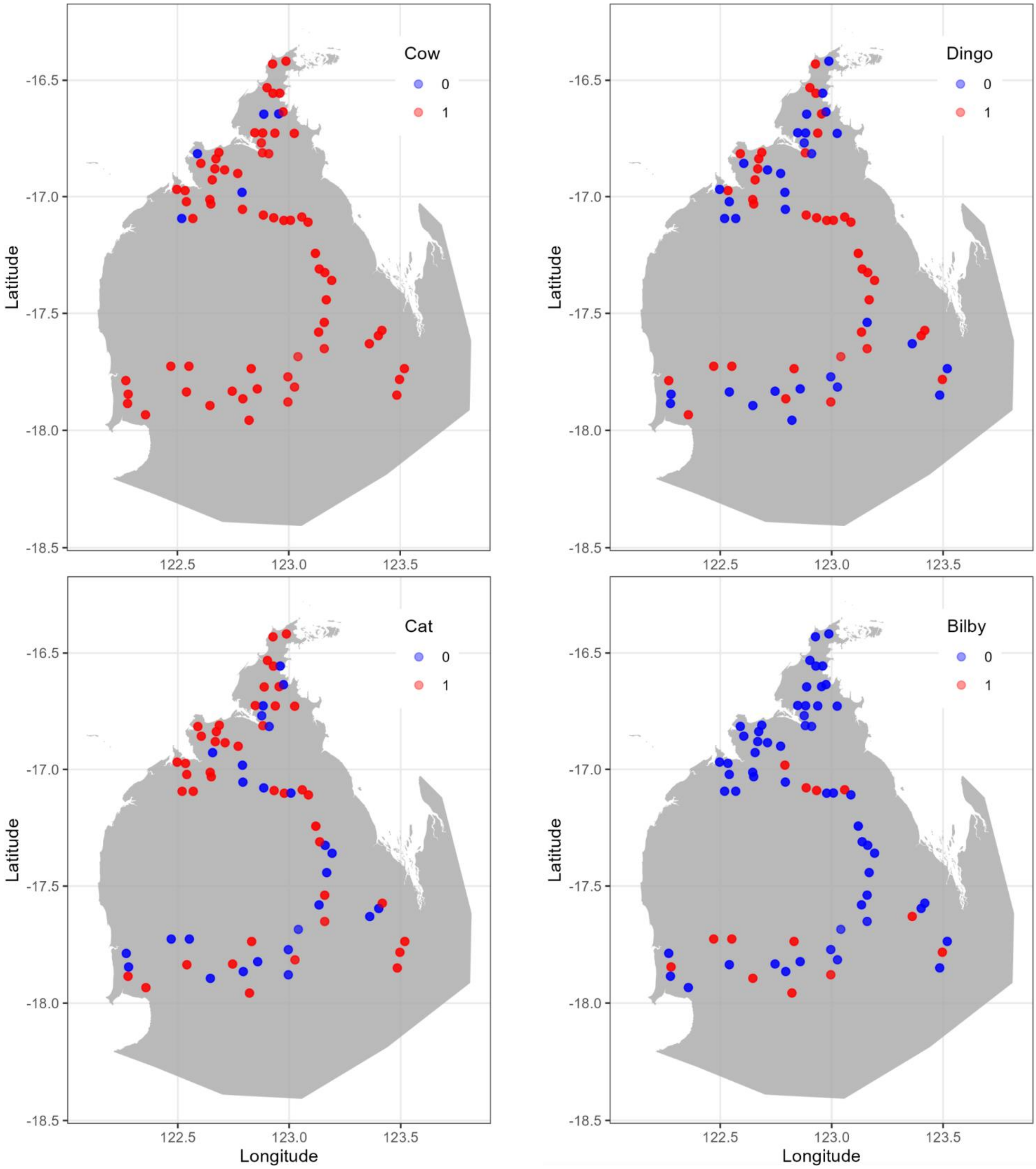

Figure 6 – Species occurrence data collected using 2-ha plot surveys on the Dampier Peninsula.

Generalised Linear Mixed-Effects Models indicated the presence of feral cats, dingoes, donkeys or cattle did not have a significant effect of the presence of bilbies at plots, as none of these predictors were included in the top model (Table 2). However, it's important to note that the second ranked model with delta AICc<2 did include feral cat presence as negative predictor of bilby occurrence, suggesting its possible there is an association there.

Table 2 – Generalised Linear Mixed-Effects Model selection table used to elucidate the impact of feral cats, cattle, dingoes and donkeys on bilbies occurrence on the Dampier Peninsula.

(Intercept)	Cat	Cow	Dingo	Donkey	df	AICc	Delta AICc
-14.1					2.0	46.2	0.0
-13.3	-1.4				3.0	48.1	1.9
-14.0				-0.5	3.0	48.2	2.0
-14.3			0.3		3.0	48.3	2.0
-14.1		0.0			3.0	48.3	2.0
-13.1	-1.4			-0.6	4.0	50.2	3.9

Bilby presence was influenced by the proportion of unburnt habitat, with the largest effect observed at the largest scale (10 km) (Figure 7). Here, the likelihood of bilby presence increased from absent (0%) when there was no unburnt habitat to 24.2% when the entire site was unburnt (Figure 8). Fire interval also influenced bilby presence at the 3 km and 5 km scales, with presence decreasing from 34.8% at sites that had been burnt 7 times in the previous 20 years to 0% at sites that had been burnt 20 times in the same period (Figure 8). Bilby occurrence predictions were associated with wide confidence intervals, likely due to the limited sample size.

Feral cat presence was also related to the proportion of unburnt habitat, but the effect was in the opposite direction when compared to bilbies (Figure 7). For example, the likelihood of feral cat presence decreased by ~30% between sites that were 100% long unburnt and 0% long unburnt, and this was consistent across scales (Figure 7). The likelihood of feral cat presence also increased with increasing fire frequency at the 3 km and 5 km scales and decreased with increasing proportion of habitat long unburnt at the 5 km scale.

Pyrodiversity, annual rainfall and dominant vegetation type had no significant influence on the presence of bilbies or feral cats at any scale (Tables S1-S4).

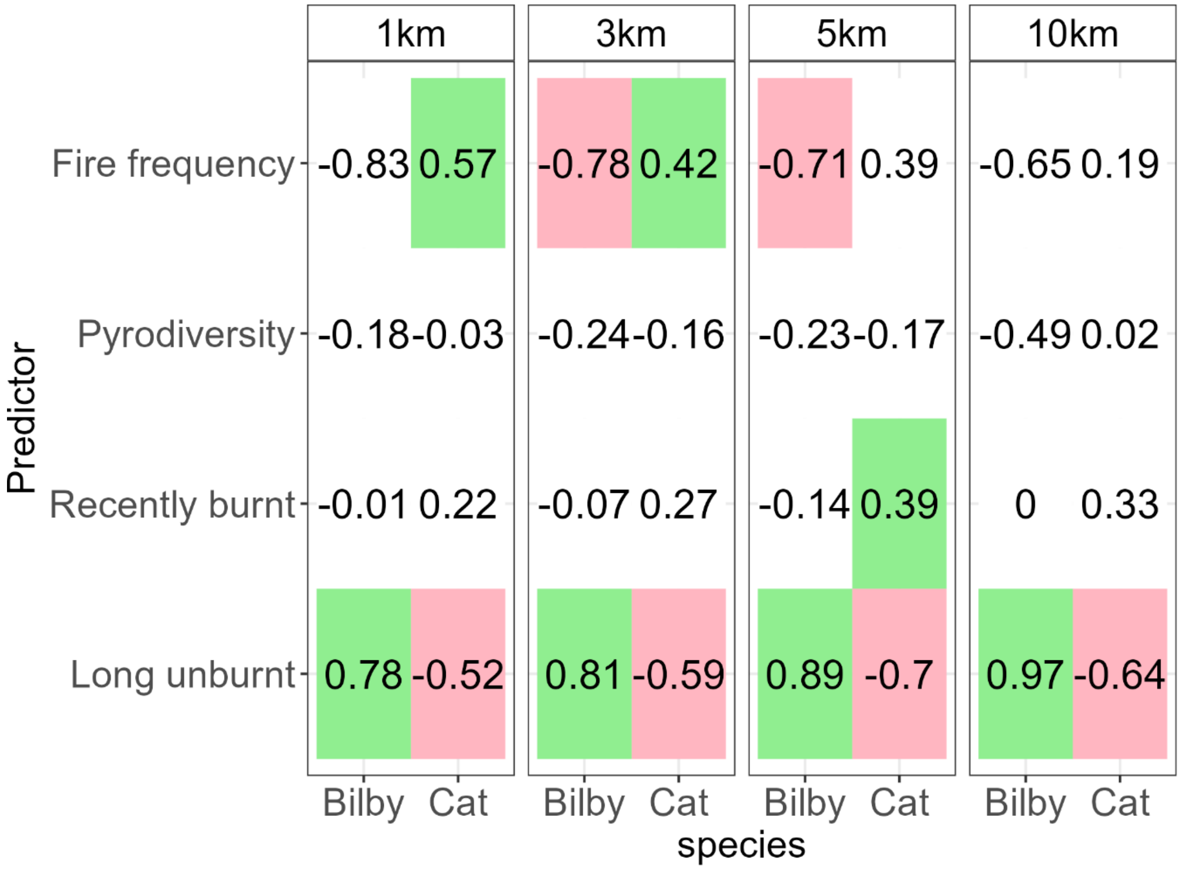

Figure 7 – Model estimates from generalized linear mixed-effects models testing the influence of fire attributes on the presence of greater bilbies and feral cats on the Dampier Peninsula in north-west Australia. Coloured cells show estimates where the effect was significant ($p < 0.05$). Red cells indicate a negative effect, and green cells indicated a positive effect.

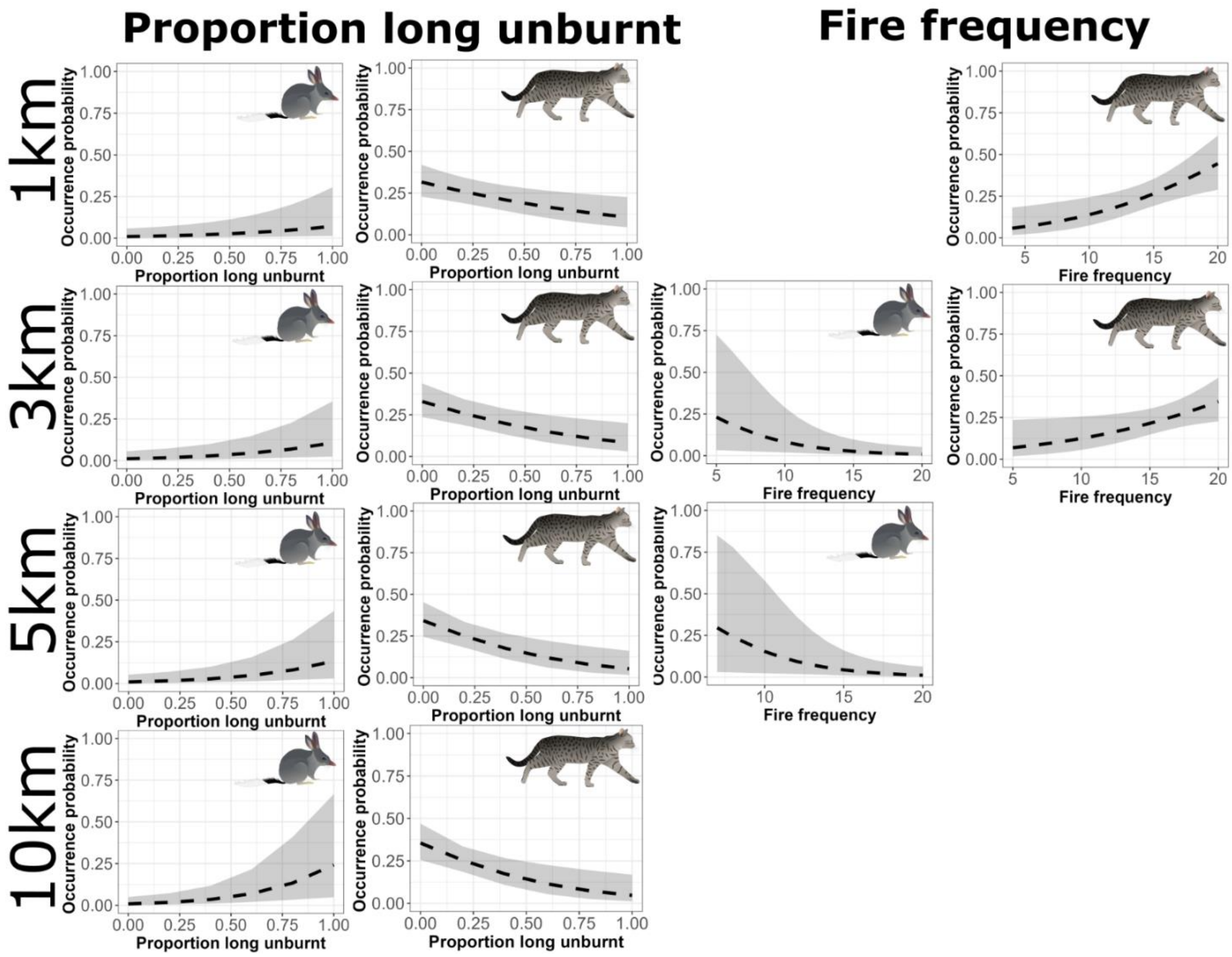

Figure 8 – Model predictions from generalized linear mixed-effects models testing the influence of fire attributes on the presence of greater bilbies and feral cats on the Dampier Peninsula in north-west Australia. Grey shading indicates 95% confidence intervals. Each row shows predictions from models using data collected at varying distance from 2-ha plot (site, patch, landscape).

1.2 Discussion

Our findings indicate that fire frequency and the extent of long unburnt habitat are potentially important factors in predicting the presence of both bilbies and feral cats across multiple spatial scales in the highly fire prone landscape of the Dampier Peninsula. Bilbies were more frequently detected in habitat that had not been burnt for at least three years, while feral cats were least detected in these areas. Similarly, frequent fires tended to be a deterrent for bilbies, but not for feral cats. These results support findings from global studies which suggest trends of increasing fire frequency and spatial extent have contributed to declines observed across multiple taxa, presumably due to an increase in predation and decrease in resource availability (Engstrom 2010; Kelly *et al.* 2020). These results provide important context for fire practitioners seeking to implement fire regimes which promote habitat suitable for the conservation of bilbies within fire-prone areas of their range.

Do cattle, donkeys, feral cats or dingoes influence the distribution of bilbies on the Dampier Peninsula?

Grazing by cattle and other feral herbivores, such as donkeys, has been identified as a potential threat to the greater bilby across their range (Southgate 1990; Lavery and Kirkpatrick 1997; McDonald *et al.* 2015; Cramer *et al.* 2016; DCCEEW 2023). The grazing activity of these species results in physical damage to the friable soils, an impact that is exacerbated by the provision of water-points that increase the grazing range of livestock (McKenzie *et al.* 2007). Interestingly, our study found limited evidence to suggest that cattle or donkey presence influenced the occurrence of bilbies on the Dampier Peninsula. However, this may be due to the lack of discrimination between sites, as for example, cattle were present at almost every site. We suggest future research incorporate a range of sites with varying levels of cattle and donkey presence or abundance, including control sites free from these herbivores. This approach would help to better understand their influence on bilby populations and help inform more effective conservation strategies.

Predation is another major factor associated with the decline of bilbies (DCCEEW 2023). Both feral cats and dingoes are known to prey on bilbies and can potentially threaten their populations (Paltridge 2002b; Moseby *et al.* 2011; Woinarski *et al.* 2014). In this study, we found no significant correlation between the presence of these predators and bilbies. Similar to introduced herbivores, the influence of predators on bilbies is likely to be density-dependent, rather than whether they are just present or absent at a site. Plus interactions between predator/herbivore density and other factors such as habitat condition/fire age may prove to have an even greater influence on bilby distribution (Moseby *et al.* 2019). This is supported by the fact that bilbies have managed to coexist with feral cats in many parts of Australia for over 200 years and with dingoes for approximately 4,000 years, suggesting that bilbies can persist in the presence of a low density of predators, but the value of that threshold is not clear (Southgate 1990; Moseby *et al.* 2019; Blumstein *et al.* 2019; Berris *et al.* 2020).

How does fire influence the distribution of bilbies on the Dampier Peninsula?

Previous studies that examine the interaction between bilbies and fire have mostly occurred in areas that experience less rain and less fire than the current study area, such as in the Tanami Desert. In these more arid locations, there is evidence to suggest bilbies are associated with areas of recently burnt habitat , probably because they are able to take advantage of post-fire ephemeral grasses (Southgate and Carthew 2007), which can make up a substantial proportion of their diet in arid areas (Southgate *et al.* 2006).

In contrast to arid environments, the presence of bilbies on the Dampier Peninsula was found to be highest in areas with higher proportions of habitat that had not burnt for at least three years. The observed disparity in fire-age of suitable habitat between these two areas may be attributed to several factors, with one of the most salient being the differences in the post-fire composition and structure of the vegetation in the higher rainfall Dampier Peninsula woodlands compared to arid grasslands. For example, in arid landscapes, the post-fire spinifex grassland is usually characterised by a low level of vegetation cover that lasts for 1-3 years, thereby creating an open environment where bilbies can forage for fire-promoted annuals like *Yakirra* sp. (Southgate *et al.* 2006). In more tropical environments like the Dampier Peninsula, burnt landscapes are often rapidly colonised by fast growing annual grasses such as *Sorghum stipoidium* (Radford *et al.* 2015, Radford and Fairman 2015). By dominating the understory, these annual grasses are likely to reduce the availability of other important annuals like *Yakirra* and impede the movement of bilbies.

In our study, bilbies favoured habitat which had been less frequently burnt. This result is supported by previous research in northern Australia, where in general, mammal declines have been linked to high fire frequencies (Woinarski *et al.* 2010; von Takach *et al.* 2020). High fire frequencies alter vegetation communities by promoting species with high fire tolerance, and displacing species that are fire sensitive (Russell-Smith et al. 2003; Rossiter *et al.* 2003; Miller *et al.* 2010). In addition to killing invertebrate prey and outcompeting native grasses and herbs, which may be important food sources for bilbies (Gibson 2001), these changes can substantially increase the flammability of landscapes, further increasing fire frequency, intensity and scale (Russell-Smith et al. 2003). Similar effects have been observed within the study area (Wysong *et al.* 2021) with major increases in highly flammable annual *Sorghum*, and this is thought to be at least partly responsible for the disappearance of a long-term local bilby population. In this example, an intense late dry season fire replaced stands of *Acacia tumida* — a plant species important for harbouring cossid larvae which are preyed on by bilbies — with annual Sorghum grasslands. These changes in the vegetation led to a repeat late dry season fire event two years following the fire, after which bilbies were no longer present at the site (See Section 3).

Is the impact of predation reduced in areas that are not recently or frequently burnt?

In contrast to bilbies, we found that the likelihood of feral cat presence increased as the extent of long unburnt habitat decreased, and fire frequency increased. While the literature suggests that the response of feral cats to fire is variable and dependent on habitat type (Doherty *et al.* 2015; Doherty *et al.* 2022), there is evidence that cats do target areas that are frequently impacted by disturbance (Davies *et al.* 2020). The most widely accepted explanation for this behaviour is related to prey access, as feral cats are able to locate and pursue prey more easily in structurally simple habitat (Geary *et al.* 2020). For example, previous studies conducted in the savannas of the Kimberley and Cape York Peninsula regions by McGregor *et al.* (2015, 2016) demonstrated that feral cats exhibit improved hunting efficiency in grassland and recently burnt habitats. Similarly, Trewella (2023) found habitat use by feral cats was most frequent in areas with high fire frequencies and low tree basal area. It is plausible, therefore, that mature acacia shrubland and eucalypt woodland (> 3 years post fire) limits the hunting efficiency of feral cats by providing a complexity of vegetation cover for bilbies. In addition to the immediate reduction in vegetation cover caused by fire, long-term reductions in shrubland/woodland structural complexity caused by repeated fires at short intervals are also likely to benefit feral cats, and likely to the detriment of bilbies (Davies et al., 2020; Stobo-Wilson et al., 2020b).

Management implications

Our findings highlight the potential importance of fire frequency and long unburnt habitat (> 3 years) in determining habitat suitability for bilbies, and mitigating ecological damage inflicted by feral cats on the Dampier Peninsula. For example, based on model predictions at the 3 km scale, increasing the proportion of long unburnt habitat in the landscape from 20% to 60% tripled the likelihood of bilby occurrence, while almost halving the likelihood of feral cat occurrence. Similarly, reducing fire frequency from once every year to once every ~4 years more than doubles the likelihood of bilby occurrence, and halves the likelihood of feral cat occurrence. These targets align directly with objectives established by the Dampier Peninsula Fire Working Group (DPFWG) — a coordinated fire planning group which brings together Traditional Owners, Indigenous ranger groups, government agencies, regional conservation groups, non-profit organisations, the pastoral and natural resources industries, and scientific experts to work collaboratively to improve fire management on the Dampier Peninsula (Wysong *et al.* 2021). A recent review of the project's performance in relation to these objectives demonstrated that fire management efforts in the region increased the extent of vegetation unburnt from 18 % in 2015 to 65 % in 2020 (Wysong *et al.* 2021). In addition, the proportion of habitat burnt 3 or more times was halved over the same period. Our study supports the ongoing burning practises being implemented by DPFWG that aims to increase the extent of long unburnt vegetation on the Dampier Peninsula and reduce fire frequency.

2 Bilby population abundance monitoring

2.1 Background

The original intention for the project was that four core bilby populations would be selected for annual abundance monitoring (two where prescribed fire would be applied and two as controls). However, despite an extensive search, only two bilby populations could be located that met the requirements for the project. These were Pio's Paddock (treatment site), and Coconut Wells (control site), both of which are located less than 20 km from Broome.

2.2 Methods

Abundance surveys were conducted at Coconut Wells from 2019 to 2022, and at Pio's Paddock from 2020 to 2022. All surveys were conducted using procedures described in Dziminski *et al.* (2021).

Sample collection

Scat collection at each colony was structured into two stages. Stage one involved delineating the boundary of bilby activity at a site, so as to determine the size of the area bilbies are using. The second stage involved establishing transects within the bilby activity area, and using those transects to locate scat material.

Clearly decomposed or broken up scats were not collected. Most scats were found on top of, or within, the sand-spoil of a digging. If the digging was very eroded and weathered, indicating it was created probably >2 weeks prior, then the associated scats were not collected because the scats were less likely to yield DNA (Carpenter and Dziminski 2017). Collected scats were placed in labeled 30-ml plastic tubes, with approximately 33% filled with silica gel beads and a cotton wool ball, until DNA extraction. The silica gel ensured pellets remained dry because moisture degrades DNA. The cotton ball reduced rubbing of beads against pellets, which may remove bilby epithelial cells from the surface of the pellet, reducing available cells for DNA extraction. Vials with samples were transported in a cooler bag, kept out of the sun, and stored at room temperature until DNA extraction.

DNA extraction, PCR amplification and genotyping

Bilby scat samples were initially soaked and gently agitated in ~400 ul of SLP buffer to obtain sloughed cells from the surface of the scat. Supernatant from this mixture was transferred to tubes and genomic DNA extractions were completed using the Omega Bio-tek MagBind® Stool DNA 96 Kit (Omega Bio-tek, Norcross, GA, USA) as per the manufacturer's standard protocol. We eluted DNA in a final volume of 100 ul using a 50% dilution of the final elution buffer to reduce EDTA interference with MassArray typing. Samples were concentrated (60 ul DNA reduced to 30 ul) via vacuum centrifuge prior to analysis to improve genotyping results. DNA samples were genotyped using a custom-designed multiplexed panel of single nucleotide polymorphism (SNP) markers (n = 35 SNP loci) on the MassARRAY System (Agena BioScience) at the Australian Genome Research Facility, Brisbane (AGRF).

Molecular sexing of scat samples was carried out using four custom-designed bilby sex-linked primers (Brandies, 2021) included on the MassArray panel. To account for discrepancies in sex identification across scat samples, we followed guidelines established by Sun *et al.* (2021) for classification. Samples were classified as male if they exhibited successful amplification for at least two Y-linked markers and consistently showed the same sex identification across multiple scats. We defined likely sex as a set of scats with minimal variation between markers and/or scats. Predicted sex referred to a cluster of scats with significant discordance, and the selected sex represented the majority of results. Scats that demonstrated low to no amplification signal from sexing markers or were indistinguishable due to equal probabilities were classified as undetermined.

To improve the stringency of genotype matching, we removed samples and loci with amplification rates below 70% and 30% respectively. MassARRAY SNP results were processed in a custom R package 'ScatMatch' (Huntley 2021) designed to group scats based on genotype similarity i.e. by the number of allelic mismatches between samples.

Spatially explicit mark-recapture

To estimate bilby density for each population, we fit spatially explicit mark-recapture (SECR) models using the package 'SECR' in R version (Efford and Fewster 2013) . SECR models estimate the abundance and density of animal populations by combining capture-recapture data with spatial information using a maximum likelihood approach. SECR models have previously be used to estimate bilby densities in the Pilbara and the Kimberley with high success (Dziminski *et al.* 2021b).

All samples at each colony in each year were grouped into a single sampling session and occasion. The models used transect detectors with a hazard exponential (HEX) detection function and NelderMead maximisation method following Dziminski *et al.* (2021c). The position of each sample was collapsed onto the nearest point on the transect line. Activity areas were used as habitat masks in models. Abundance estimates were generated by multiplying densities estimates (bilbies per ha) by the size of activity areas.

2.3 Results

Across all populations and years, a total of 243 scats (successfully genotyped) were collected across 74.2 km of transects (Table 3). Abundance estimates ranged between 2 and 16 (mean = 7). While surveys in 2019 and 2020 indicated that abundance was highest at the Coconut Wells populations, a decline was recorded in 2021, and the population could not be located in 2022 (Figure 9). By contrast, the Pio's Paddock population increased between 2020 and 2021, and remained stable in 2022.

Table 3 – Results of bilby abundance monitoring on the Dampier Peninsula from 2019 to 2022.

Population	Year	Area (ha)	Transect (km)	Scats	Individuals	Density	Abundance
Coconut Wells	2019	517	17.4	62	4	0.008	4
Coconut Wells	2020	790	10.3	69	5	0.009	7
Pio's Paddock	2020	169	10.3	24	2	0.013	2
Coconut Wells	2021	53	12.3	9	3	0.063	4
Pio's Paddock	2021	73	8.4	41	7	0.100	8
Pio's Paddock	2022	94	15.5	38	6	0.064	6

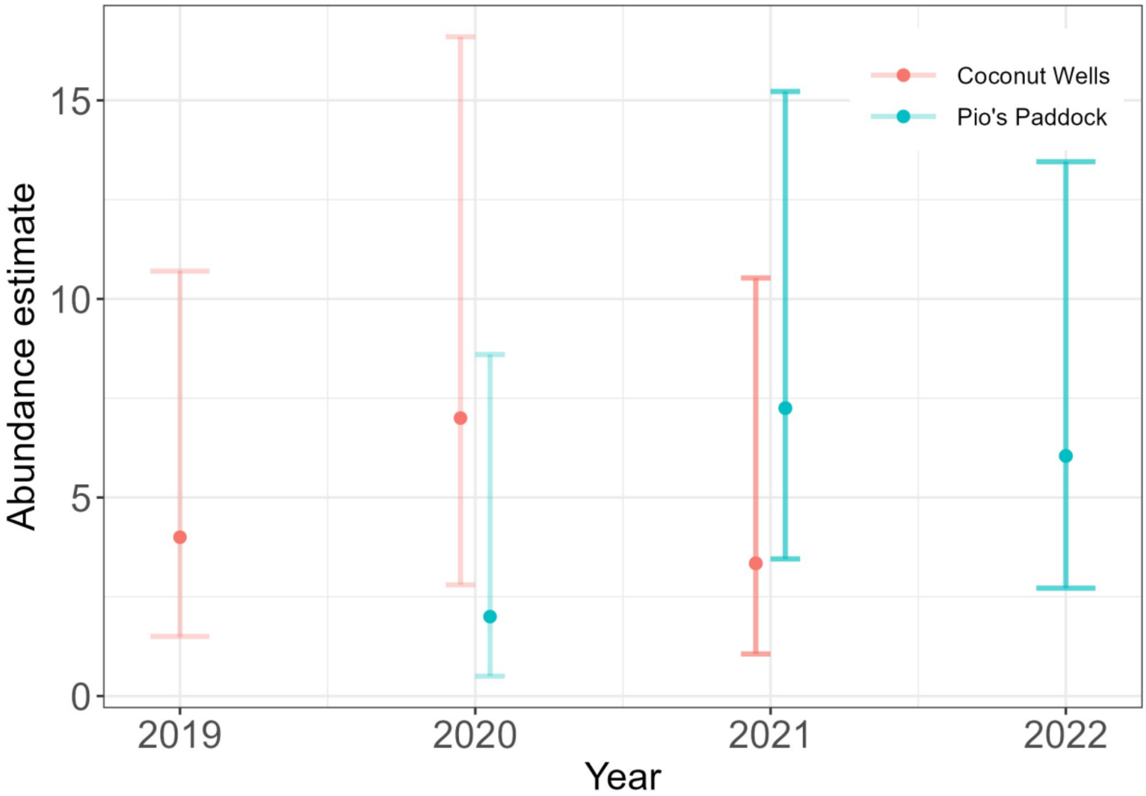

Figure 9 – Abundance estimates from Coconut Wells and Pio's Paddock populations between 2019 and 2022.

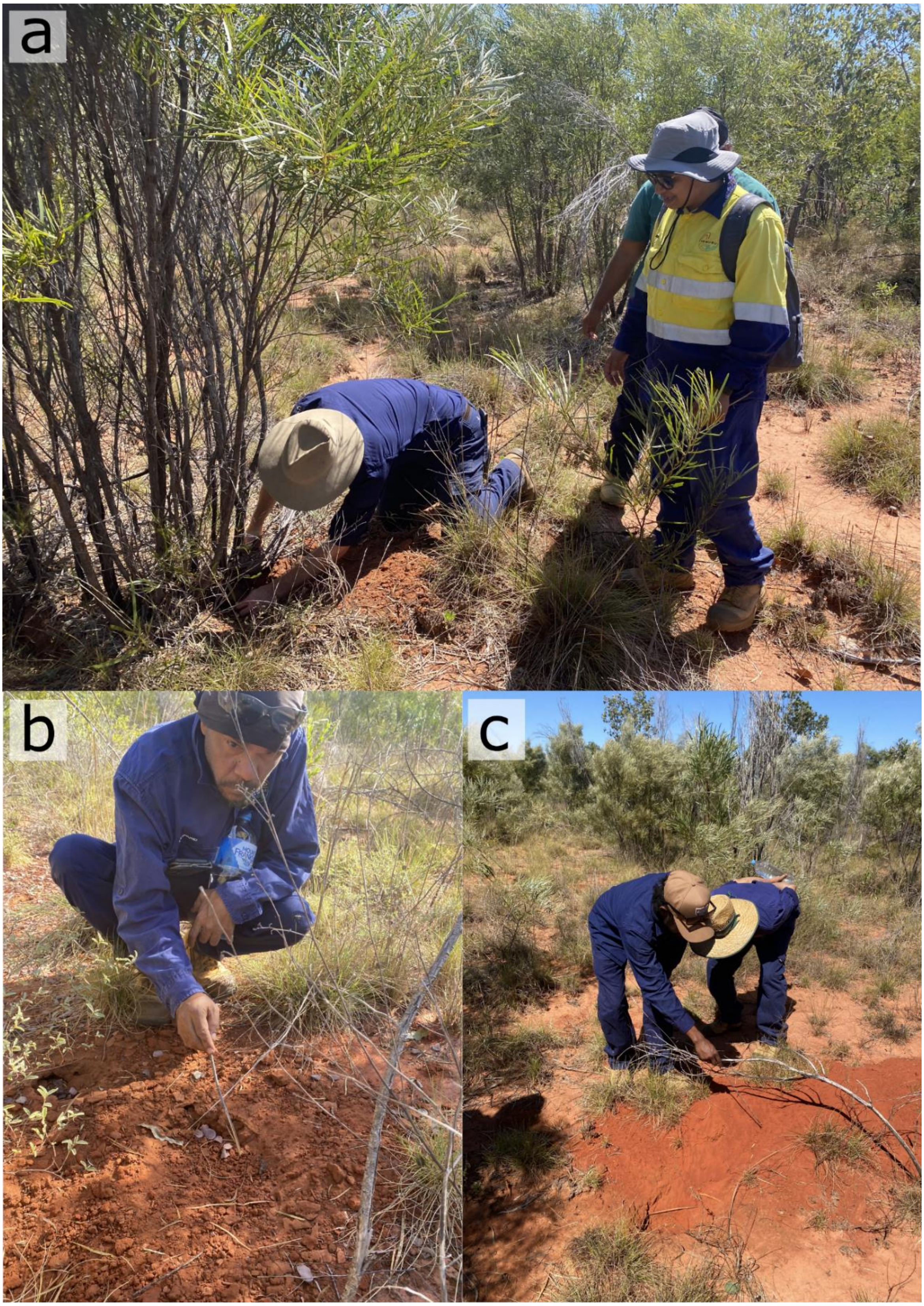

Figure 10 – Yawuru country managers and DBCA staff search for bilby scat material at Pio's Paddock

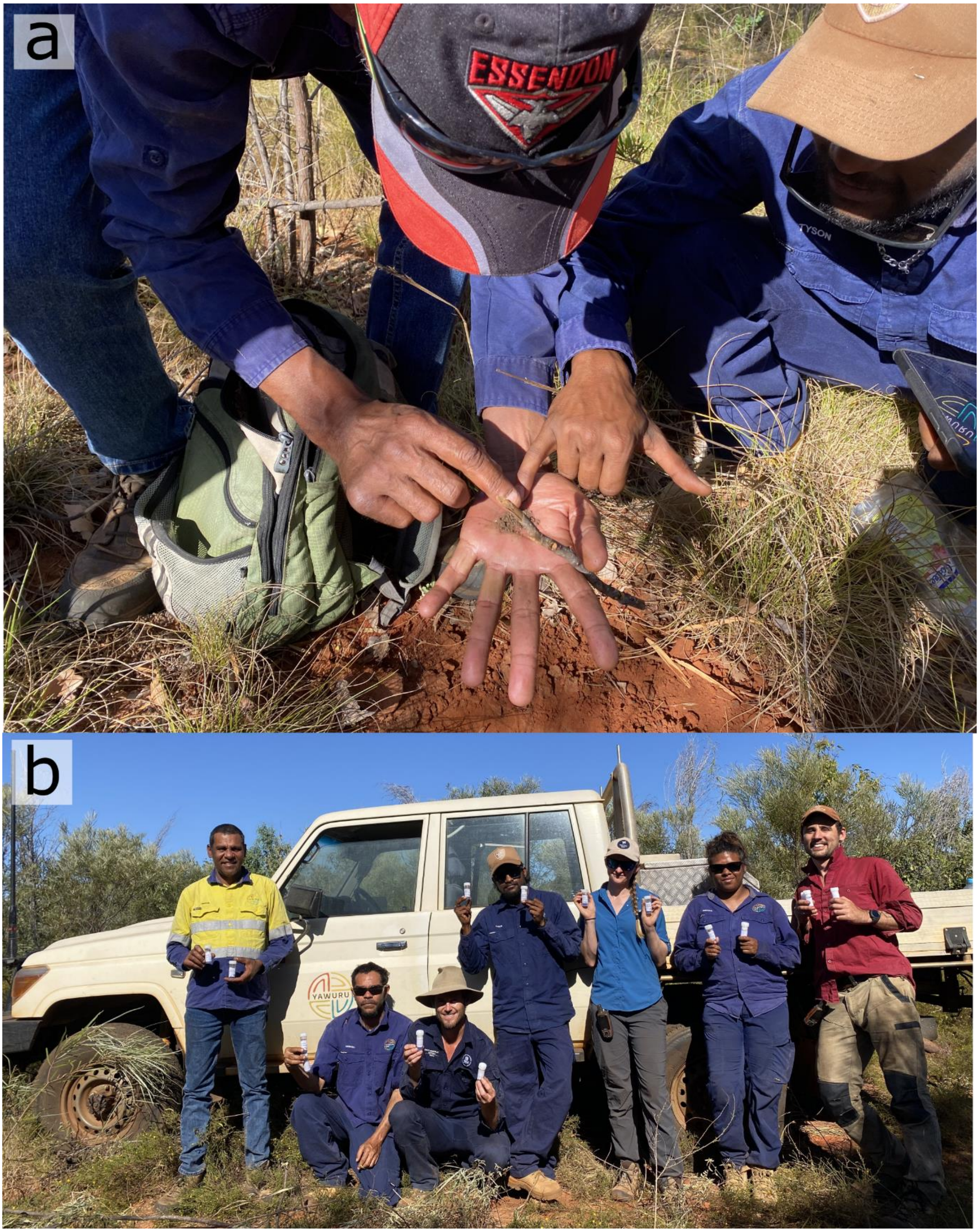

Figure 11 – Yawuru country managers and DBCA staff search for bilby scat material at Pio's Paddock.

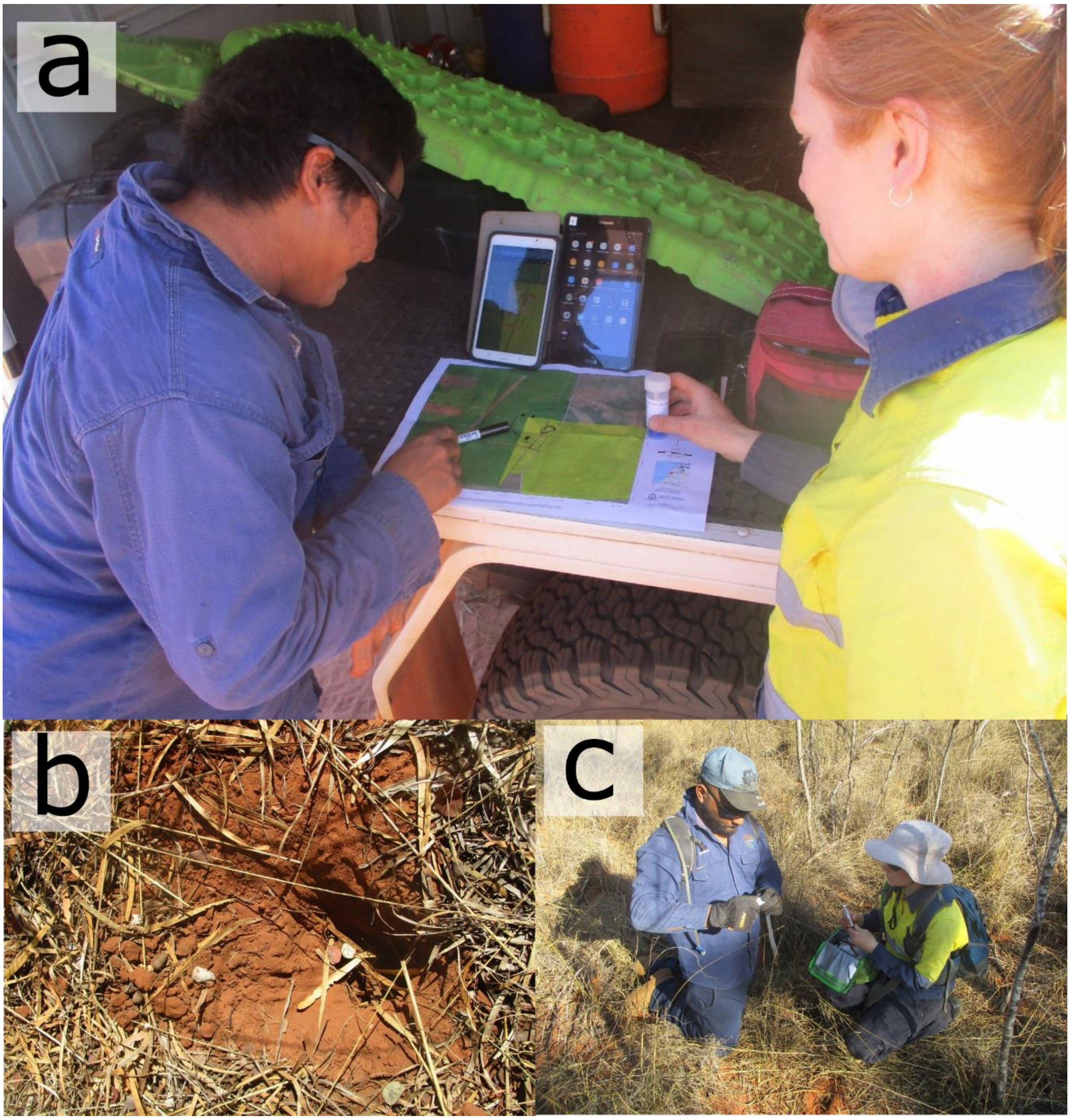

Figure 12 – Yawuru country managers and DBCA staff entering scat data.

2.4 Discussion

Estimates of bilby abundance from scat searches and SECR analysis indicates that since 2020, the Coconut Wells population has potentially declined to the point of local extinction, while the Pio's Paddock population has increased and remained relatively stable. It is worth noting that in most years, both populations were relatively small, but comparable to some other areas in Western Australia (Dziminski *et al.* 2021b).

The persistence of the Pio's Paddock bilby population may be partially attributed to our fire management that aimed to mitigate the effects of late dry season wildfires. Between 2019 and 2022, the Coconut Wells population, which was not exposed to strategic burning, experienced two late dry season fires (December 2019 and 2021; see Section 4), which significantly impacted the vegetation at the site. For instance, after the 2019 fire, *Acacia tumida* stands, that harbour cossid larvae favoured by bilbies, were supplanted by annual Sorghum grass. This not only likely reduced the availability of important food sources, but also potentially hindered bilby movement and foraging efficiency as discussed in Section 1. Furthermore, this shift in vegetation fueled another late dry season fire two years later, after which bilbies could no longer be located at the site. In contrast, the Pio's Paddock population only experienced one cool early dry season fire (May 2019) and no late dry season fires during the same timeframe.

These findings, along with those from Section 1, emphasise the importance of reducing fire frequency to conserve bilbies. They also support the ongoing burning practices by the DPFWG, which aim to expand the extent of long-unburnt vegetation on the Dampier Peninsula and decrease fire frequency. However, it's essential to acknowledge the inherent limitations of these conclusions due to the relatively small sample size, encompassing only two populations. Additional comprehensive studies involving a larger number of populations across varied contexts are necessary to substantiate these preliminary insights.

3 Predator monitoring

3.1 Background

Predation is recognised as a major threat to bilby populations across their range (Pavey 2016), particularly from feral cats (Moseby *et al.* 2011; Lollback *et al.* 2015), foxes (Johnson and Isaac 2009) and dingoes (Paltridge 2002b). While the management of predators was outside the scope of this project, it was of interest to better understand this likely threat by monitoring their occurrence in the vicinity of bilby populations studied as part of this project. Hence, a camera-trap monitoring program was established at the two bilby abundance monitoring sites discussed in Section 2. This also allowed a comparison of predator occupancy between a site where fire was managed and an unmanaged control site.

3.2 Methods

Camera traps

Predator occupancy was monitored via a network of remote sensing cameras deployed at Coconut Wells and Pio's Paddock bilby populations between 2020 and 2022 (Figure 13. Figure 14). A minimum of five cameras were deployed at each site in each year. Cameras were deployed for a minimum of 6 weeks. Cameras were positioned to observe vehicle tracks or face the entry of bilby burrows. Vehicle tracks provide movement corridors for introduced predators and their activity on tracks is often higher than off tracks (Raiter *et al.* 2018). Bilby burrows can also act as natural lures in the landscape, with many other prey species as well as bilbies inhabiting them, attracting predators that regularly visit these features in an often barren landscape (Hofstede and Dziminski 2017; Dawson *et al.* 2019).


Figure 13– Predator camera traps are deployed by Yawuru rangers on a bilby burrow.

Occupancy analysis

Data was first structured into one-week sampling occasions. Detection histories for each site were then assembled by pooling detections for each site into a single measure of detection/non-detection for each sampling occasion. Occupancy models were then formulated in terms of parameters ψ, (occupancy) and p (detectability), where ψ is the probability that site i is occupied by the species, and p is the probability of the species being detected at site i on night j, conditional upon its presence. The models assume detection of the species at sites is independent of species detections at other sites, that there are no false detections, and that occupancy remains constant over the sampling period.

To test whether feral cat or dingo occupancy varied between the two bilby populations (Pio's Paddock, Coconut Wells), the variable 'population' was included as a predictor for occupancy. Similarly, the variable 'year' was also included to test if there was a difference in feral cat or dingo occupancy between years. The probability of detecting feral cats and dingoes was expected to vary depending on whether a camera was located on a track, or on a bilby burrow. As such, the variable 'location' (track or burrow) was included as a predictor for feral cat and dingo detectability.

Occupancy models were fit using the unmarked package (Fiske and Chandler 2011) in R version 3.6.2 (R Core Team 2019). Model selection was conducted by first running a global model including all predictors, and then using the *dredge* function in statistical package *MuMIn* to determine which subset of predictors produce a model with the most parsimonious fit — model with lowest AIC value. This model was used to estimate feral cat and dingo occupancy and detectability across the two bilby populations.

3.3 Results

Sampling effort between 2020 and 2022 totalled 233 one-week sampling occasions (Figure 15, Figure 16). Feral cats and dingoes were detected in 20% (46/233) and 13% (31/233) of all sampling occasions, respectively (Figure 15). No foxes were detected.

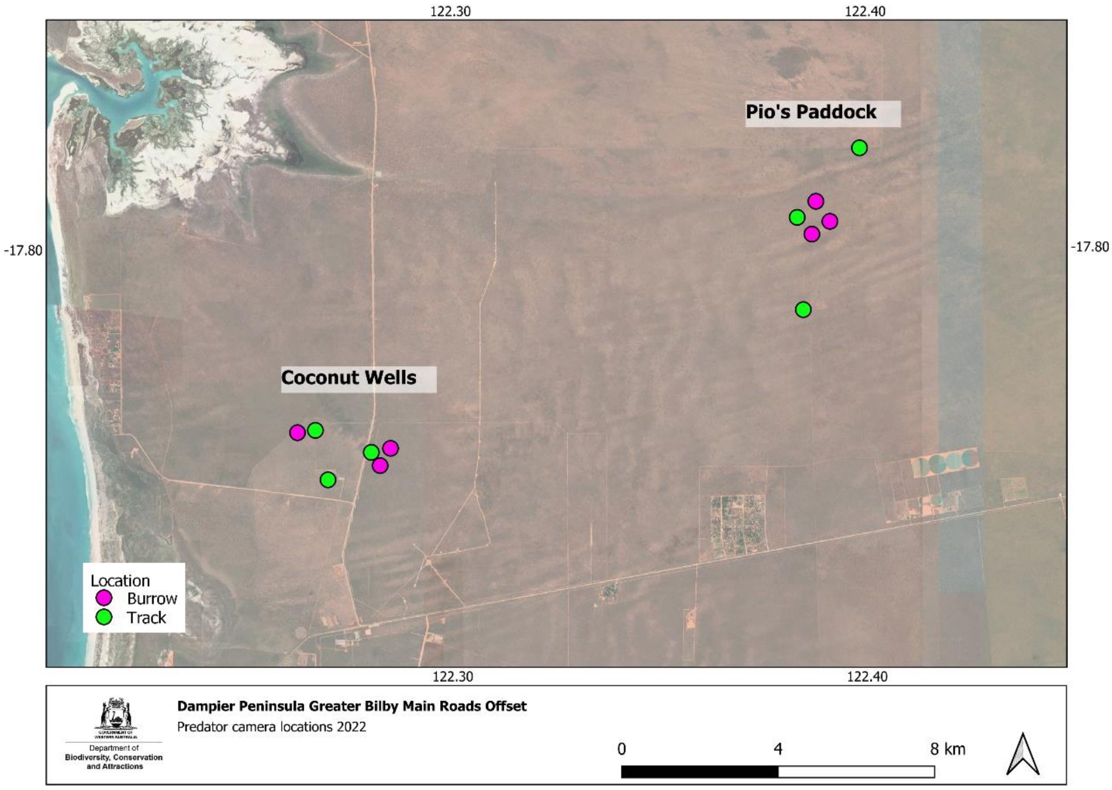

Figure 14– Predator camera locations at Coconut Wells and Pio's Paddock in 2022

The most parsimonious model for feral cats included location (track, burrow) as a predictor for detectability, but included no predictors for occupancy (Table 3), indicating no difference in feral cat occupancy either between sampling years, or between populations (Pio's Paddock, Coconut Wells). Predicted feral cat occupancy across all sites and years for feral cats was over 99.4%. Results from the top model indicated cameras located on tracks were more than twice as likely to detect feral cats than cameras located on burrows, similar to modelling from 2021 (Figure 17) (Moore *et al.* 2022).

The most parsimonious model for dingoes also included location (track, burrow) as a predictor for detectability, but included no predictors for occupancy (Table 4), indicating no difference in dingo occupancy either between sampling years, or between populations (Pio's Paddock, Coconut Wells). Predicted dingo occupancy across all sites and years for feral cats was over 67.9%. Results from the top model indicated cameras located on tracks were more than three times more likely to detect dingoes than cameras located on burrows.

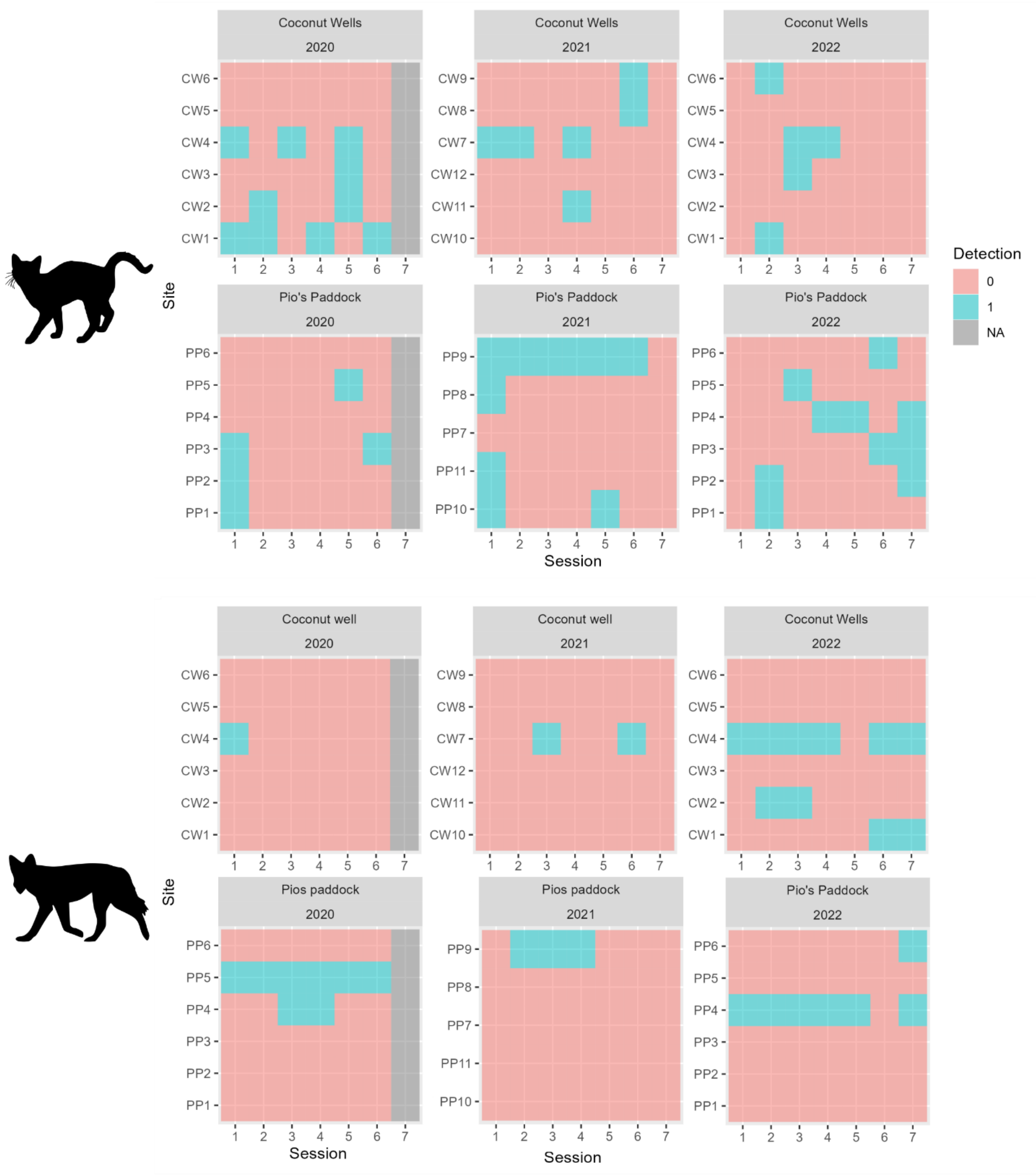

Figure 15– Feral cat and dingo detection histories at Coconut Wells and Pio’s Paddock between 2020 and 2022.

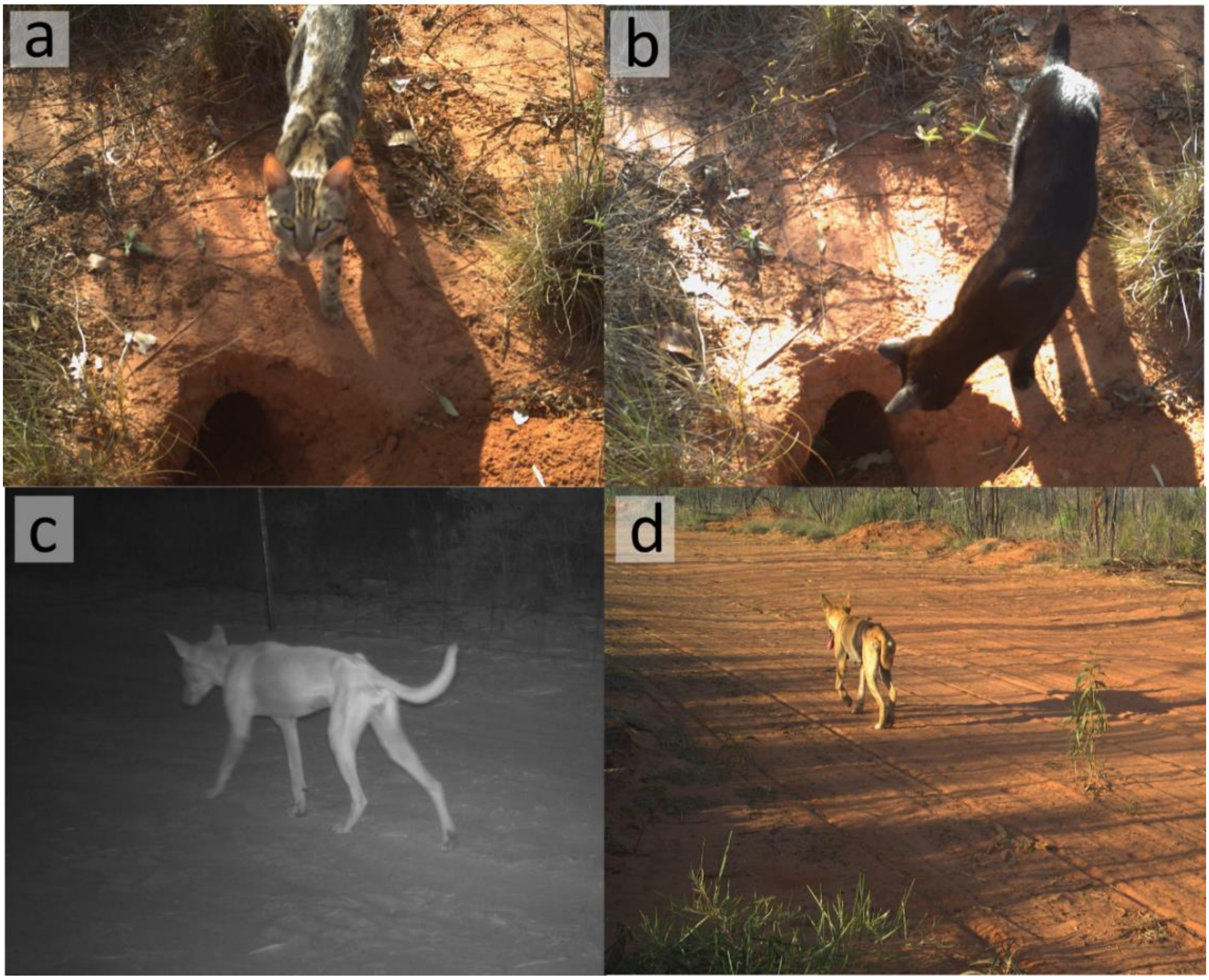

Figure 16 – Feral cat and dingoes detected on camera trap and Pio's Paddock and Coconut Wells in 2022.

Table 4 – Occupancy models used to predict feral cat occupancy and detectability at Pio's Paddock and Coconut Wells bilby populations.

p(Int)	psi(Int)	p(Location)	psi(Population)	psi(Year)	df	AICc	delta
-1.9	1.4	+			3	207.3	0.0
-1.9	2.3	+		+	5	207.9	0.6
-1.9	7.0	+	+	+	6	208.3	1.0
-1.8	0.8	+	+		4	209.0	1.7
-1.1	0.9				2	212.7	5.4
-1.1	0.4		+		3	213.5	6.2
-1.2	1.5		+	+	5	214.5	7.2
-1.1	1.5			+	4	214.8	7.5

Table 5 – Occupancy models used to predict dingo occupancy and detectability at Pio's Paddock and Coconut Wells bilby populations.

p(Int)	psi(Int)	p(Location)	psi(Population)	psi(Year)	df	AICc	delta
-12.4	0.8	+			3.0	118.0	0.0
-11.4	0.5	+		+	5.0	121.9	3.9
-12.3	0.0	+	+		6.0	123.4	5.3
-12.0	0.2	+	+	+	8.0	129.8	11.8
-0.2	-0.9				2.0	138.4	20.4
-0.2	-1.1			+	4.0	141.7	23.7
-0.2	-1.6		+		5.0	143.9	25.9
-0.2	-1.4		+	+	7.0	149.8	31.8

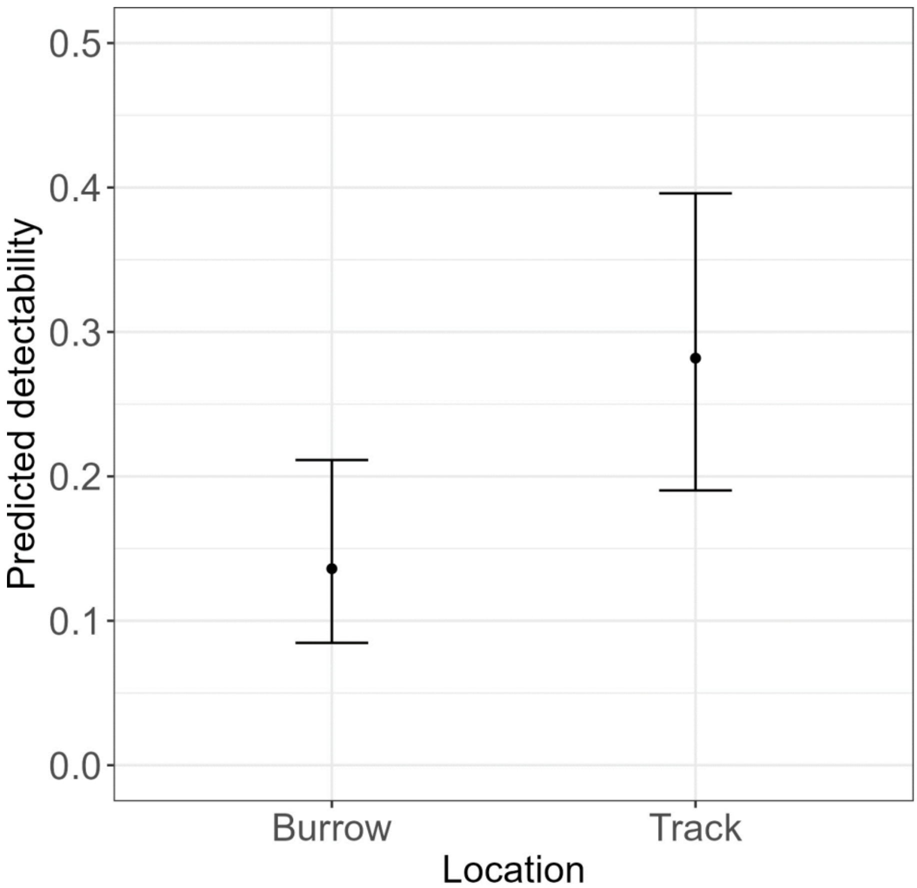

Figure 17 - A comparison of predicted feral cat detectability (per 2 week sampling period) between cameras located on burrows and tracks.

3.4 Discussion

Estimates based on camera traps across the 2020 – 2022 sampling period indicated feral cat occupancy was high across both Pio's Paddock and Coconut Wells bilby populations, while dingo occupancy was comparatively lower. These estimates line with broader occupancy monitoring conducted across the Dampier Peninsula, as detailed in section one. Studies elsewhere in the Kimberley have found similarity high occupancy rates for feral cats. For example, Hohnen et al (2016) found feral cat occupancy in topographical simple habitats in the Central Kimberley was >80%. Similarly, Doherty *et al.* (2021) found that feral cat occupancy in Charles Darwin Reserve was around 80% prior to the application of targeted baiting, while Johnston *et al.* (2012) estimated pre-bait feral cat occupancy was over 90%.

One potential explanation for high feral cat occupancy observed here could be the lack of topographic complexity in the study area. Hohnen *et al.* (2016) found feral cat occupancy declined with increasing ruggedness at a site in the Kimberley region, potentially due to reduced hunting success. Further, the close proximity of the study areas to residential areas should also be considered. The human dwellings may inadvertently or intentionally supply feral cats with resources, including both food and shelter, thereby supporting higher feral cat densities than would otherwise exist . Additionally, the housing estate may act as a source of stray cats, which, when not managed adequately, can supplement the existing feral population.

No significant differences in dingo or cat occupancy were observed between the treatment and control site. This observation contrasts with previous research suggesting that habitat modification could potentially affect predator distribution (Doherty *et al.* 2022). It is important to consider that several factors, such as the timing and intensity of burning, may influence the outcomes of fire management practices on predator occupancy (Legge *et al.* 2018). However, it is also possible that an effect was present but went undetected due to the limitations of our sample size and associated statistical power. Additionally, other interacting factors not included in our analysis such as prey availability, may have influenced predator occupancy patterns, making it more challenging to isolate the impact of strategic burning. Additional research incorporating larger sample sizes and more comprehensive spatial and temporal coverage with consideration of potential interactions is needed to better understand the relationship between strategic burning and predator occupancy. This would help inform the development of more effective fire management strategies aimed at reducing the impact of introduced predators on native species, such as bilbies.

4 Management of threats

4.1 Background

The Dampier Peninsula Bilby Offset Project Threat Management Plan determined the highest threat for bilby populations on the Dampier Peninsula was the interaction between fire and introduced predators (Dziminski and van Leeuwen 2019). However, given that the scope of the current project did not include the management of introduced predators, threat management focused on reducing the impacts of inappropriate fire regimes. Section 1 of this report addressed the influence of fire on bilbies at the landscape scale across the Dampier Peninsula area that was sampled during the initial occupancy survey, clearly indicating the importance of unburnt vegetation for the species, as well as infrequent fires. As discussed in Section 2, abundance monitoring was focused at two local bilby populations, one where strategic burns were applied (Pio's Paddock) and the other as an unmanaged control site (Coconut Wells). Section 2 discusses the likely benefits to bilbies resulting from managing fire to prevent large and intense late dry-season wildfires. In this section, we provide specific details in relation to fire management that took place at Pio's Paddock.

4.2 Fire management at Pio's Paddock

2019

In May 2019, DBCA executed strategic cool burns (not associated with this project) approximately 1 km north of the Pio's Paddock population, along with a larger burn spanning roughly 11 km in length, 10 km to the northeast (Figure 23). These measures effectively buffered the area from large-scale, late dry season wildfires fuelled by strong easterly winds that affected the Dampier Peninsula in November 2019, including the habitat occupied by the Coconut Wells bilby population (Figure 18, Figure 19).

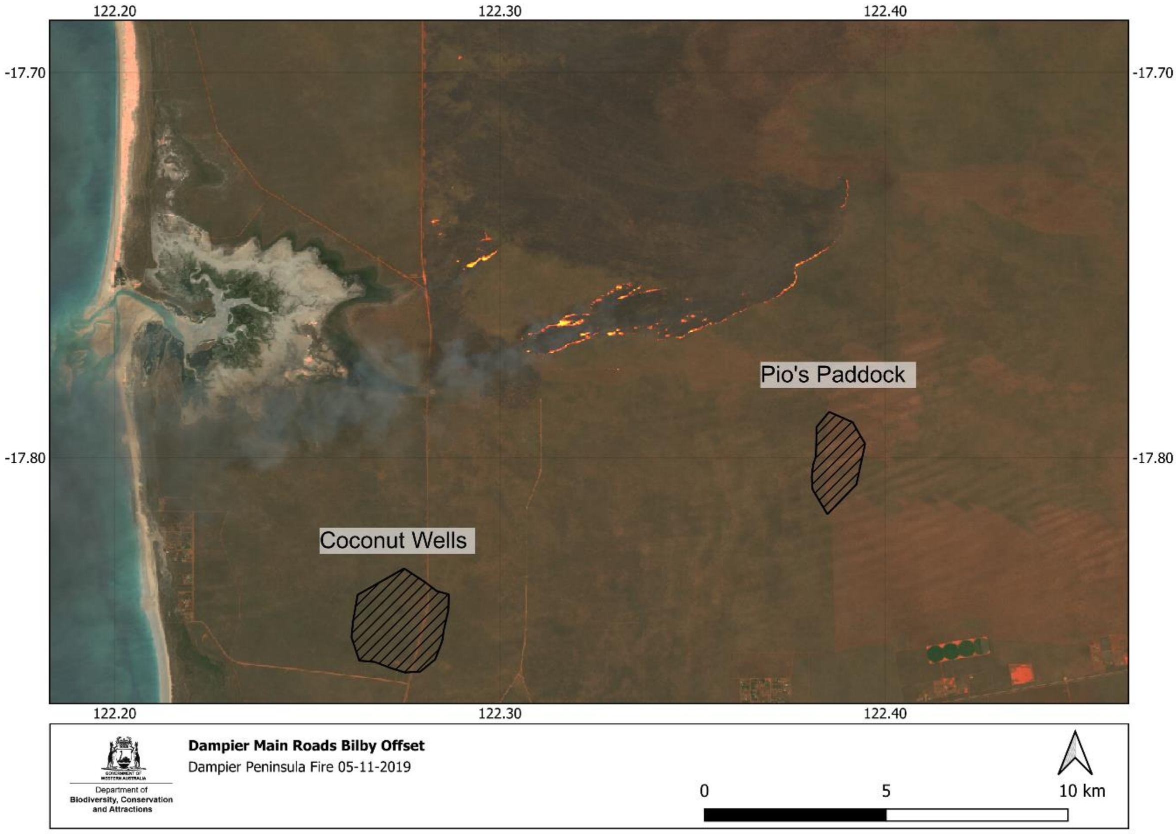

Figure 18 – Sentinel 2 satellite imagery showing the 2019 late dry season fire which impacted the Coconut Wells bilby population.

Figure 19 – Vegetation at Coconut Wells before and after the 2019 late dry season fire.

2020

A prescribed burn was conducted at the eastern boundary of Pio's Paddock to create an effective fire scar and prevent damaging late dry season wildfires from entering the area. Execution involved edging the western side of a north-south running track, spotting every 10-15 meters with a flame thrower. Country Managers rotated through flame thrower use for training, and drip torch work was carried out as required, followed by ongoing patrols along the fire line.

Fire-take and scarring effectiveness varied due to factors like vegetation, grass cover, and environmental conditions. In areas where fire take was achieved, the fire behaviour was optimal for prescribed fire conditions. About 62 hectares were burnt during ground burning operations, and 514 hectares during aerial burn operations. Although scarring was not as effective as desired, the burnt areas provided fire age and vegetation heterogeneity within the landscape, which is preferred by bilbies and could be used for future prescribed fire operations (Figure 23).

2021

In 2021, fire management efforts were concentrated on the northern boundary of Pio's Paddock, where DBCA conducted aerial burning during the early dry season (June 2021) (Figure 23). This strategy was designed to complement the fire management work carried out in 2020. The Broome region, including the monitoring site at Pio's Paddock, faced the threat of late dry season wildfires in November 2021. DBCA staff effectively communicated the area's environmental importance to Department of Fire and Emergency Services (DFES) staff during the emergency response, leading to successful protection of the Pio's Paddock monitoring site with the support of DBCA's on-ground wildfire suppression efforts. During the October 2021 wildfires, a section of the Coconut Wells monitoring site was impacted (Figure 20).

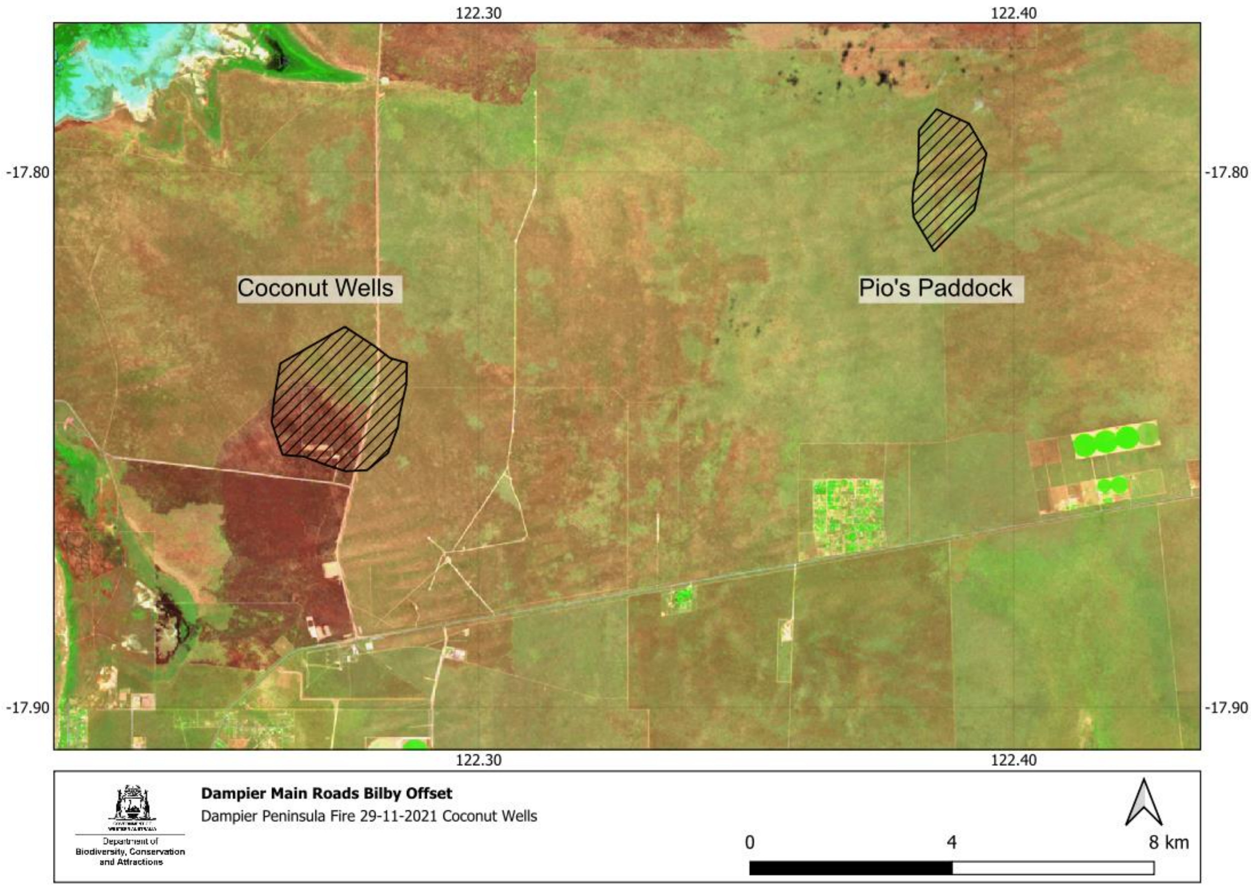

Figure 20 – Sentinel 2 imagery showing the 2021 late dry season fire which impacted the Coconut Wells bilby colony.

2022

The 2022 burn plan for Pio's Paddock involved strategic aerial ignition lines to prevent late dry season wildfires typically fuelled by strong south-easterly winds (Figure 21). Lines were proposed to run in a north-west/south-east direction for better effectiveness with dry season winds. Fine-scale ground burning around the bilby population was also proposed to achieve patchiness and promote desirable vegetation bilby food plants. This comprehensive approach to fire management at Pio's Paddock aimed to balance the protection of bilby populations with the reduction of fire risk. By incorporating both aerial and ground-based techniques, the burn plan was designed to maintain a mosaic of habitats that support bilby food plants and provide refuge from predators.

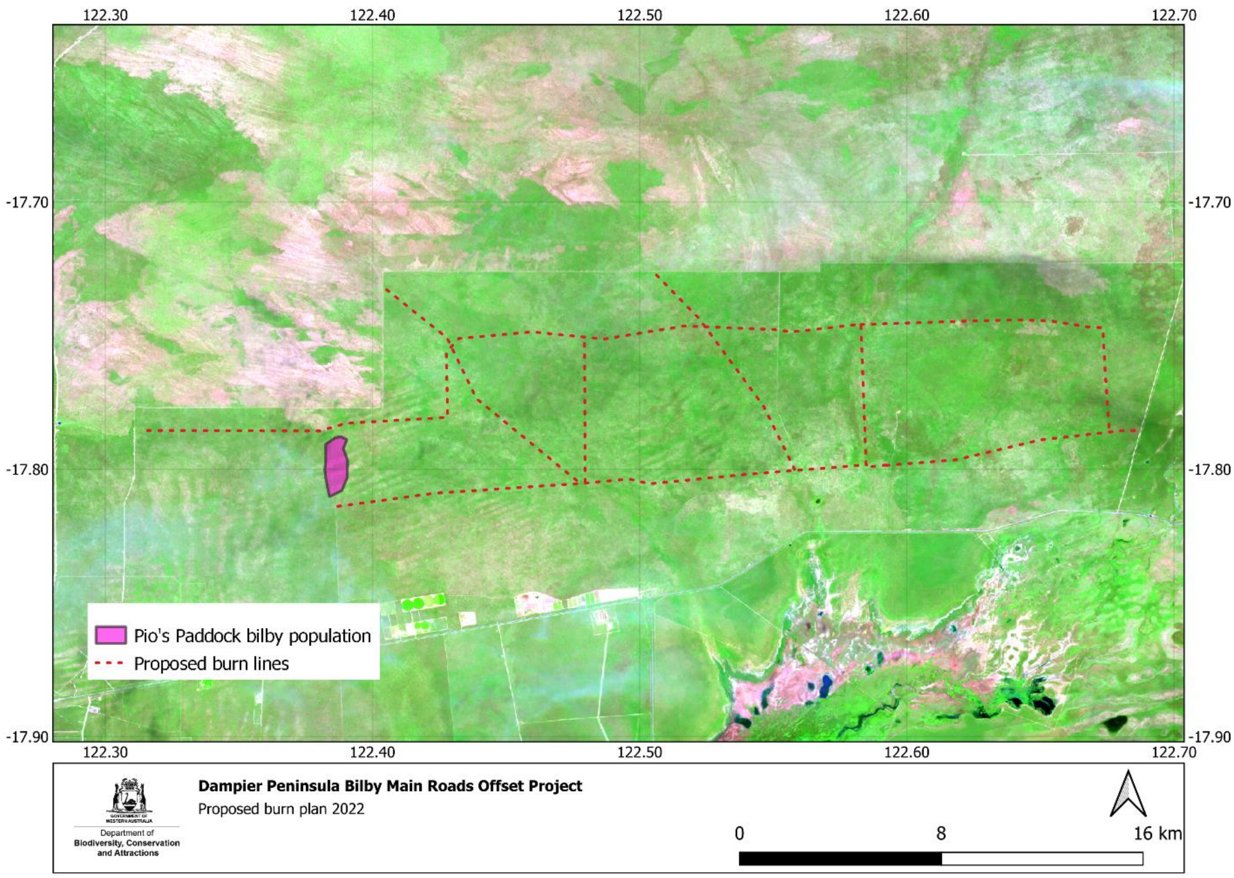

Figure 21 – 2022 proposed burn lines at Pio's Paddock on the Dampier peninsula.

Burns were implemented in two stages between the 23rd of May and the 2nd of July as part of a collaborative effort between the Department of Biodiversity, Conservation and Attractions (DBCA) and Yawuru country managers. Sentinel satellite imagery indicated that burns achieved reasonable take in the targeted locations, which provided good protection from late dry season fire, which typically spread in a south-easterly direction (Figure 23). On-ground assessments confirmed strategic fires burnt at low intensity, as indicated by the large proportion of mature *Acacia tumida* (an important food plant for bilbies) that remained intact (Figure 22).

The successful implementation of this plan is a testament to the collaborative efforts of the DBCA and Yawuru country managers, highlighting the importance of partnerships in achieving conservation outcomes. As a result, the burn plan for Pio's Paddock serves as a model for future efforts in managing fire-prone landscapes to protect vulnerable species like the bilby.

Figure 22 – Low intensity strategic burn conducted at Pio's Paddock on the Dampier Peninsula in 2022.

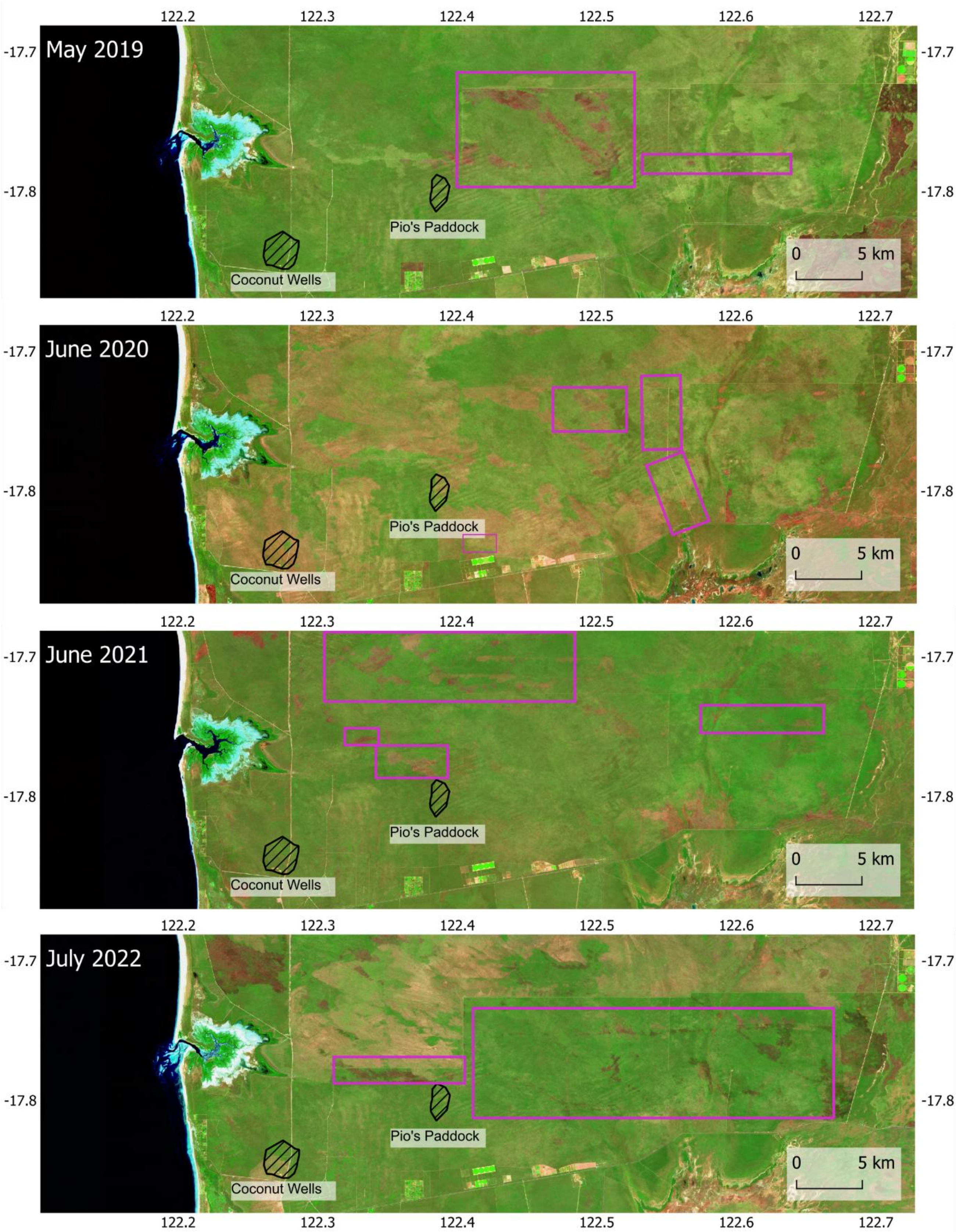

Figure 23 – Sentinel 2 imagery showing early dry season strategic burning implemented by DBCA between 2019 and 2022 near Pio's Paddock and Coconut Wells.

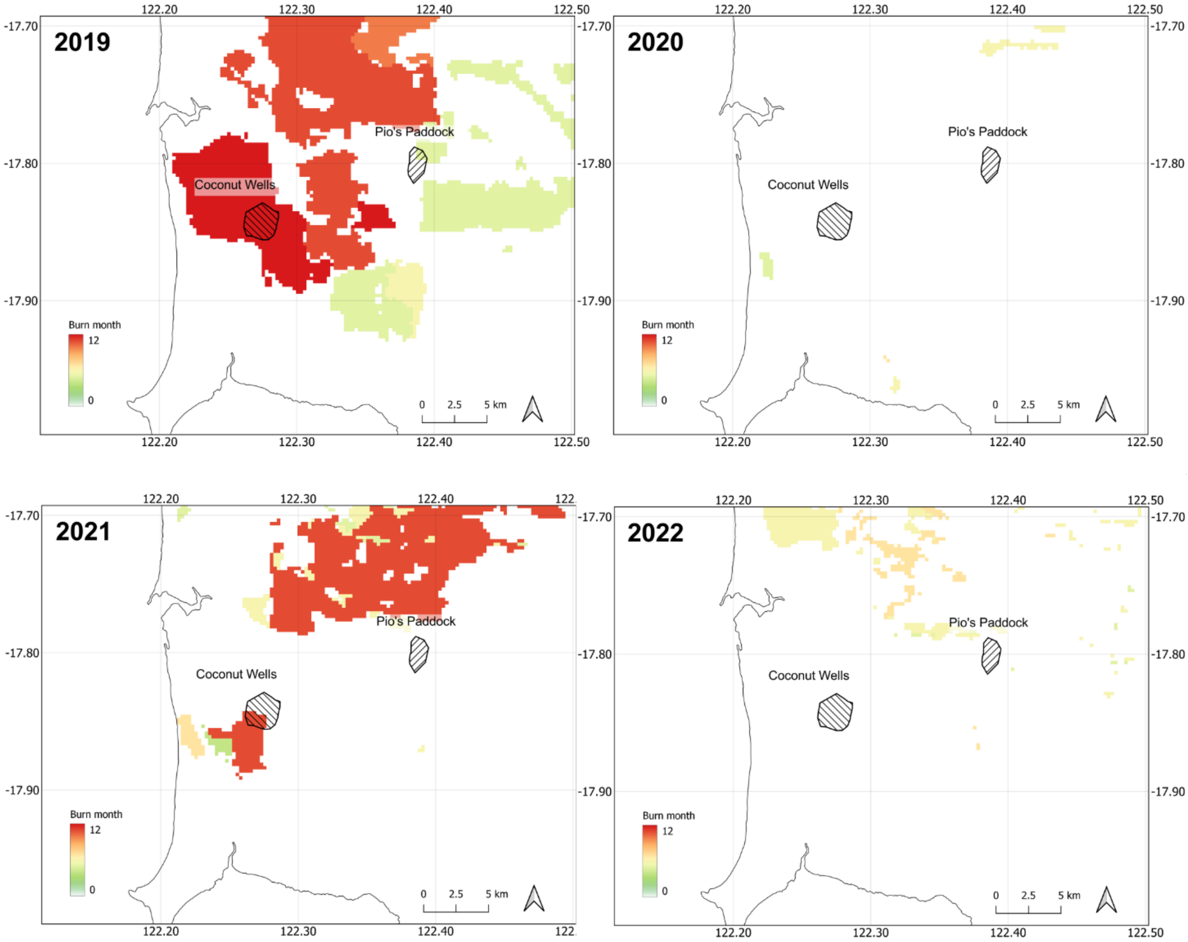

Figure 24 – Northern Australian Fire Information data showing fire histories at Pio's Paddock and Coconut Wells between 2019 and 2022.

Figure 25 – DBCA fire crew and Yawuru country managers preparing for strategic burns.

5 Conclusions

The survey and monitoring project on the Dampier Peninsula has provided important insight into the distribution and factors influencing the persistence of bilbies in the region. In light of the rapidly shrinking geographical range of bilbies, such research becomes critical in formulating effective conservation strategies. Results from occupancy analysis indicated that the landscape-scale influence of fire had a strong effect on bilby presence, as well as their notable predator, the feral cat. The frequency and spatial extent of fires, along with the presence of long unburnt habitats, appear to be important in predicting the presence of bilbies, as well as important predators, feral cats.

Local bilby abundance observations from the study suggest that strategic burning practices have the potential to improve likelihood of population persistence, although further investigation is needed to corroborate this hypothesis. The Coconut Wells population, which was not subjected to strategic burning, showed a considerable decline that may be attributed to substantial vegetation changes following two late dry season fires. In contrast, the Pio's Paddock population has shown relative stability during the same period. It's noteworthy that Pio's Paddock was subjected to strategic fire management practices, with only a single early dry season fire reported. However, given the limited number of populations studied, it's important to be cautious when attributing population stability to the fire management practices implemented at Pio's Paddock.

Camera trap data indicated that feral cat occupancy was high at both Pio's Paddock and Coconut Wells. However, based on the data available, no clear impact of strategic burning on predator occupancy was detected. It's important to note that due to the limited sample size and the potential influence of unaccounted factors, our understanding of the relationship between strategic burning and predator occupancy remains preliminary. Therefore, the findings should be interpreted with caution. Further research, encompassing a larger sample size and study scale, is needed to provide more definitive insights into the complex interplay between fire management practices and predator presence in these environments.

In conclusion, findings from this project highlight the importance of well-coordinated fire management practices and predator control in conserving bilby populations on the

Dampier Peninsula. Strategic burning to protect long unburnt vegetation has the potential to create more favourable habitat for bilbies while potentially mitigating the risk of predation. The integration of traditional owner knowledge and scientific research, as exemplified by the partnership between the DBCA and Nyul Nyul, Bardi Jawi Oorany, Nyikina Mangala, and Yawuru Country Managers, will be invaluable in refining these strategies and ensuring the persistence of bilbies in the Kimberley region.

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7 Supplementary material

Table S1 – 2ha plot survey habitat data template

Field	Value (example)
Date	30/07/2019
Created	13:58
Last Saved	14:00
Survey	Plot
Plot ID	BJ4
Latitude	-16.72
Longitude	122.88
Record type	Plot Data
Plot type	Targeted at habitat
Plot sequence	Second survey
Landform type	Plain (flat low ground)
Substrate	Sand
Vegetation structure	Open woodland
Time since rain that would clear animal tracks	3
Time since rain unit	Months
Time since strong wind that would clear animal tracks	2
Time since wind unit	Weeks
Time since burnt	<1 year
Shadow?	Slight
What percentage of the plot is suitable for tracking (eg sand or dirt)?	To 1/4 (0-25%)
Size of the majority of the sand patches?	<1m
Time spent on plot (approx minutes)	20
Organisation (eg Ranger Group)	Bardi Jawi

Table S2 – Model summary from generalised linear mixed-effects models testing the influence of fire attributes on the presence of greater bilbies and feral cats at the 1000 m scale on the Dampier Peninsula in north-west Australia.

	Bilby			Feral cat		
Variable	Estimate	p	SE	Estimate	p	SE
Intercept	-4.15	0.00	0.94	-1.20	0.00	0.22
Fire Frequency	-0.72	0.07	0.40	0.55	0.01	0.20
Annual rainfall	0.03	0.92	0.30	0.19	0.30	0.18
Acacia shrublands	0.76	0.48	1.07	-0.07	0.89	0.54
Intercept	-5.04	0.02	2.23	-1.17	0.00	0.23
Pyrodiversity	0.03	0.95	0.48	-0.10	0.60	0.18
Annual rainfall	-0.03	0.93	0.34	0.21	0.25	0.18
Acacia shrublands	0.73	0.59	1.37	-0.20	0.72	0.56
Intercept	-4.83	0.04	2.34	-1.16	0.00	0.22
Proportion recently burnt	-0.07	0.88	0.46	0.21	0.20	0.17
Annual rainfall	-0.02	0.94	0.34	0.23	0.20	0.18
Acacia shrublands	0.73	0.58	1.31	-0.14	0.80	0.55
Intercept	-4.09	0.00	0.84	-1.21	0.00	0.22
Proportion long unburnt	0.87	0.02	0.37	-0.57	0.00	0.20
Annual rainfall	0.07	0.81	0.29	0.20	0.26	0.18
Acacia shrublands	0.59	0.57	1.03	0.00	0.99	0.55

Table S3 – Model summary from generalised linear mixed-effects models testing the influence of fire attributes on the presence of greater bilbies and feral cats at the 3000 m scale on the Dampier Peninsula in north-west Australia.

	Bilby			Feral cat		
Variable	**Estimate**	**p**	**SE**	**Estimate**	**p**	**SE**
Intercept	-3.89	0.00	0.77	-1.24	0.00	0.22
Fire Frequency	-0.81	0.02	0.35	0.41	0.04	0.20
Annual rainfall	0.06	0.84	0.28	0.17	0.34	0.18
Acacia shrublands	0.70	0.48	0.99	-0.12	0.84	0.59
Intercept	-4.15	0.00	1.02	-1.21	0.00	0.22
Pyrodiversity	-0.48	0.30	0.46	-0.08	0.66	0.19
Annual rainfall	-0.06	0.84	0.30	0.20	0.27	0.18
Acacia shrublands	1.05	0.35	1.13	-0.27	0.65	0.59
Intercept	-4.10	0.00	1.09	-1.21	0.00	0.22
Proportion recently burnt	-0.17	0.66	0.38	0.29	0.08	0.17
Annual rainfall	-0.04	0.89	0.30	0.22	0.22	0.18
Acacia shrublands	0.83	0.45	1.11	-0.16	0.78	0.58
Intercept	-3.85	0.00	0.73	-1.27	0.00	0.22
Proportion long unburnt	0.85	0.01	0.34	-0.63	0.00	0.21
Annual rainfall	0.06	0.82	0.27	0.18	0.34	0.18
Acacia shrublands	0.57	0.56	0.98	0.02	0.97	0.58

Table S4 – Model summary from generalised linear mixed-effects models testing the influence of fire attributes on the presence of greater bilbies and feral cats at the 5000 m scale on the Dampier Peninsula in north-west Australia.

	Bilby			Feral cat		
Variable	Estimate	p	SE	Estimate	p	SE
Intercept	-3.92	0.00	0.78	-1.23	0.00	0.22
Fire Frequency	-0.80	0.02	0.34	0.40	0.05	0.20
Annual rainfall	0.09	0.75	0.29	0.17	0.34	0.18
Acacia shrublands	0.72	0.48	1.00	-0.15	0.80	0.58
Intercept	-4.22	0.00	1.15	-1.23	0.00	0.22
Pyrodiversity	-0.19	0.67	0.45	-0.20	0.31	0.20
Annual rainfall	-0.05	0.86	0.30	0.18	0.31	0.18
Acacia shrublands	1.04	0.38	1.19	-0.13	0.83	0.61
Intercept	-4.11	0.00	1.13	-1.23	0.00	0.22
Proportion recently burnt	-0.14	0.71	0.38	0.38	0.02	0.17
Annual rainfall	-0.04	0.89	0.30	0.22	0.21	0.18
Acacia shrublands	0.84	0.45	1.12	-0.12	0.84	0.58
Intercept	-3.85	0.00	0.73	-1.30	0.00	0.23
Proportion long unburnt	0.88	0.01	0.34	-0.70	0.00	0.22
Annual rainfall	0.09	0.74	0.28	0.18	0.34	0.18
Acacia shrublands	0.54	0.58	0.98	0.10	0.86	0.59

Table S5 – Model summary from generalised linear mixed-effects models testing the influence of fire attributes on the presence of greater bilbies and feral cats at the 10000 m scale on the Dampier Peninsula in north-west Australia.

	Bilby			Feral cat		
Variable	**Estimate**	**p**	**SE**	**Estimate**	**p**	**SE**
Intercept	-4.16	0.00	1.00	-1.16	0.00	0.22
Fire Frequency	-0.65	0.09	0.39	0.19	0.33	0.19
Annual rainfall	0.10	0.75	0.31	0.20	0.26	0.18
Acacia shrublands	0.04	0.97	1.11	-0.42	0.41	0.52
Intercept	-4.47	0.00	1.33	-1.15	0.00	0.22
Pyrodiversity	-0.49	0.30	0.47	0.02	0.93	0.20
Annual rainfall	-0.08	0.79	0.31	0.24	0.19	0.18
Acacia shrublands	0.84	0.50	1.26	-0.54	0.34	0.56
Intercept	-4.61	0.11	2.89	-1.18	0.00	0.21
Proportion recently burnt	0.00	1.00	0.63	0.33	0.05	0.17
Annual rainfall	-0.07	0.85	0.33	0.24	0.17	0.18
Acacia shrublands	0.26	0.83	1.22	-0.28	0.59	0.51
Intercept	-3.79	0.00	0.72	-1.26	0.00	0.22
Proportion long unburnt	0.97	0.01	0.35	-0.64	0.00	0.22
Annual rainfall	0.17	0.56	0.28	0.18	0.32	0.18
Acacia shrublands	-0.28	0.77	0.96	0.04	0.94	0.53

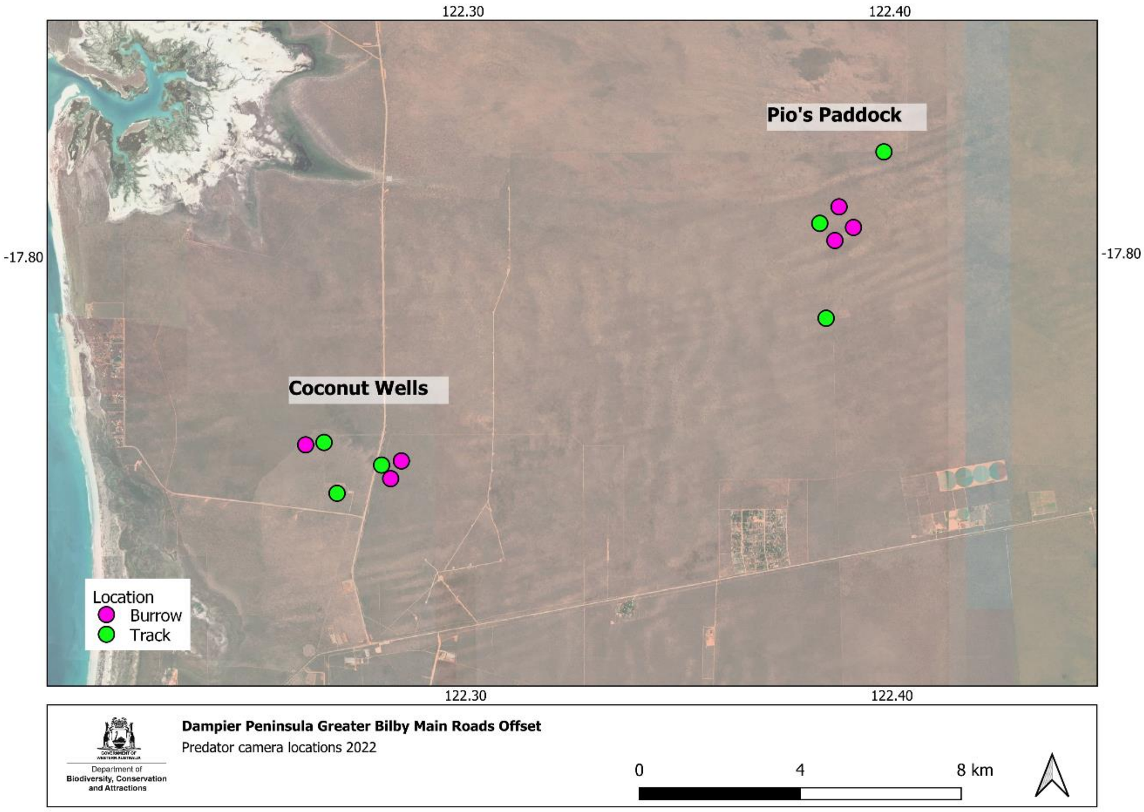


Figure S1 – Location of camera traps at Coconut Wells and Pio's Paddock bilby populations to monitor occurrence.

Dampier Peninsula Bilby Project 2016-2020

The Dampier Peninsula in northwest Western Australia is a stronghold of the greater bilby (*Macrotis lagotis*). This is despite the lesser bilby becoming extinct, and the greater bilby disappearing from at least 80 percent of its former range across Australia with an ongoing northward decline. The greater bilby is now listed as Vulnerable both in WA and under the *Commonwealth Environment Protection and Biodiversity Conservation Act* 1999. As part of the Cape Leveque Road upgrade, in 2016 Main Roads WA provided offset funding to undertake a three year project to survey, monitor and commence adaptive management of threats to bilby populations across the Peninsula.

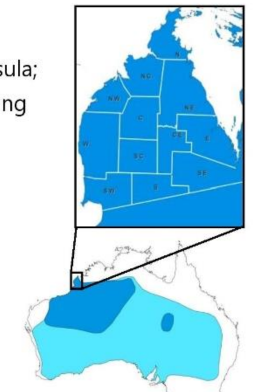
Coordinated by the Department of Biodiversity, Conservation and Attractions, this project will help fulfil a primary objective of the current interim bilby recovery plan (Bradley *et al.* 2015) and identified management priorities (Cramer *et al.* 2016). This is to retain/maintain the naturally-occurring distribution and genetic diversity of the bilby through understanding populations at the margin of the species' range on the Dampier Peninsula, gaining information on threats to populations and cost-effective strategies that can be implemented to manage threats.

Project objective

To monitor the occupancy and abundance of bilbies as well as key threatening processes on the Dampier Peninsula, while initiating on-ground actions to reduce the impacts from key threatening processes.

Aims and methods

- *Define the area of occupancy* through an array of 320 sign plot surveys and supplementary Remotely Piloted Aircraft (RPA) surveys across 12 sectors on the Peninsula;
- *Population monitoring* – four to six core populations monitored annually, involving genotyping individuals from scats collected along transects to measure abundance, occupancy from sign plots, predator occupancy from remote cameras, data on food resources, stock grazing pressure, introduced predators and fire regimes and
- *Management of threats* – priority management activities including managing fire and stock grazing implemented.



Past and present distribution of the greater bilby in Australia and survey sectors on the Dampier Peninsula

The project will employee Traditional Owners and Ranger Groups including Nyul Nyul, Yawuru, Bardi Jawi, Goolarabooloo, Jabirr Jabirr/Ngumbarl, Nimanburr and Nyikina Mangala on a fee-for-service basis. Best practice bilby survey and data collection methods will be used with Indigenous Biocultural Knowledge. The project will collaborate with WWF, Environs Kimberley and Rangelands NRM to contribute to the broader Kimberley Bilby Project.

Contacts

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GOVERNMENT OF WESTERN AUSTRALIA

Department of Biodiversity, Conservation and Attractions

PARKS AND WILDLIFE SERVICE

NYUL NYUL RANGERS · YIMARDOO WARRA RANGERS NYIKINA MANGALA · BARDI JAWI RANGERS · BARDI JAWI OORANY RANGERS · THE GOVERNMENT OF WESTERN AUSTRALIA · mainroads WESTERN AUSTRALIA

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Figure S2 – Dampier Peninsula Bilby Project flyer.

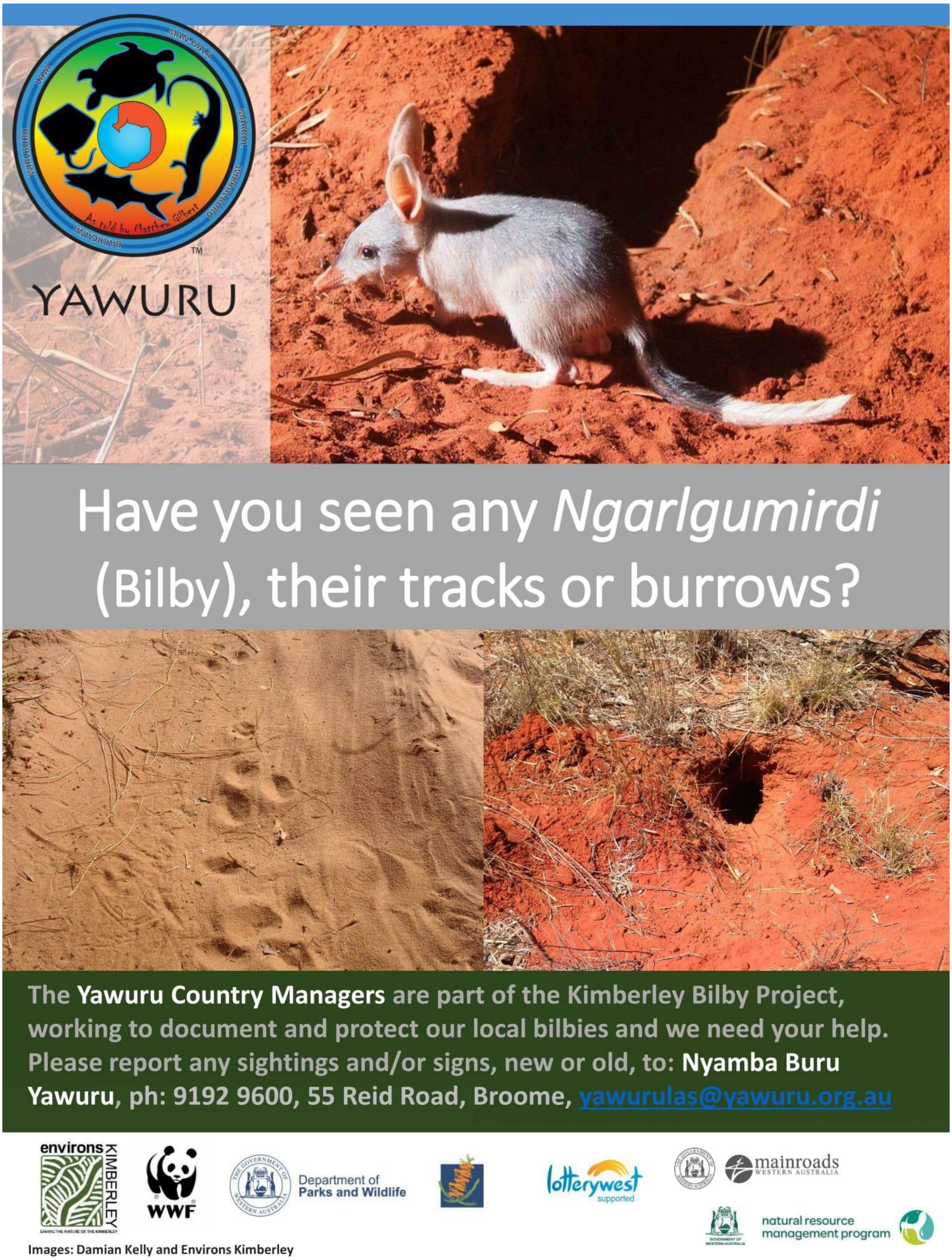

Figure S3 – Yawuru bilby information sheet.

Figure S4 – Nyul Nyul bilby information sheet.

Figure S5 – Nyikina Mangala bilby information sheet.

Figure S6 – Bardi Jawi bilby information sheet.

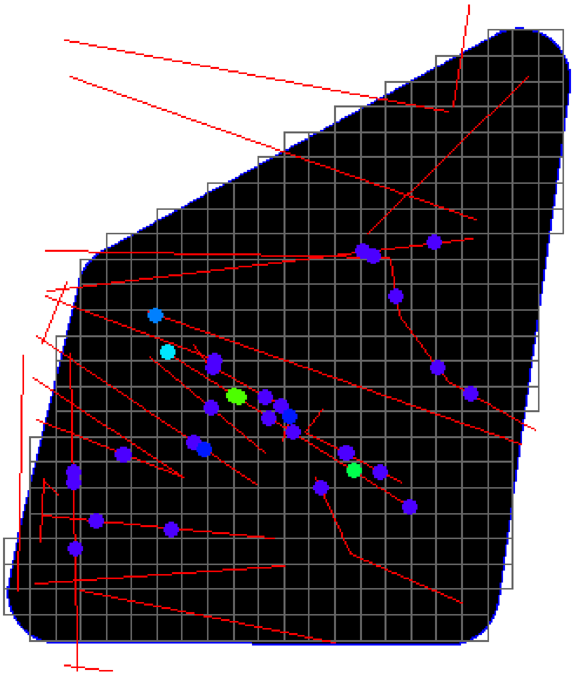

Figure S7 – Spatially Explicit Capture-Recapture (SECR) grid used to estimate bilby density at Pio's Paddock.

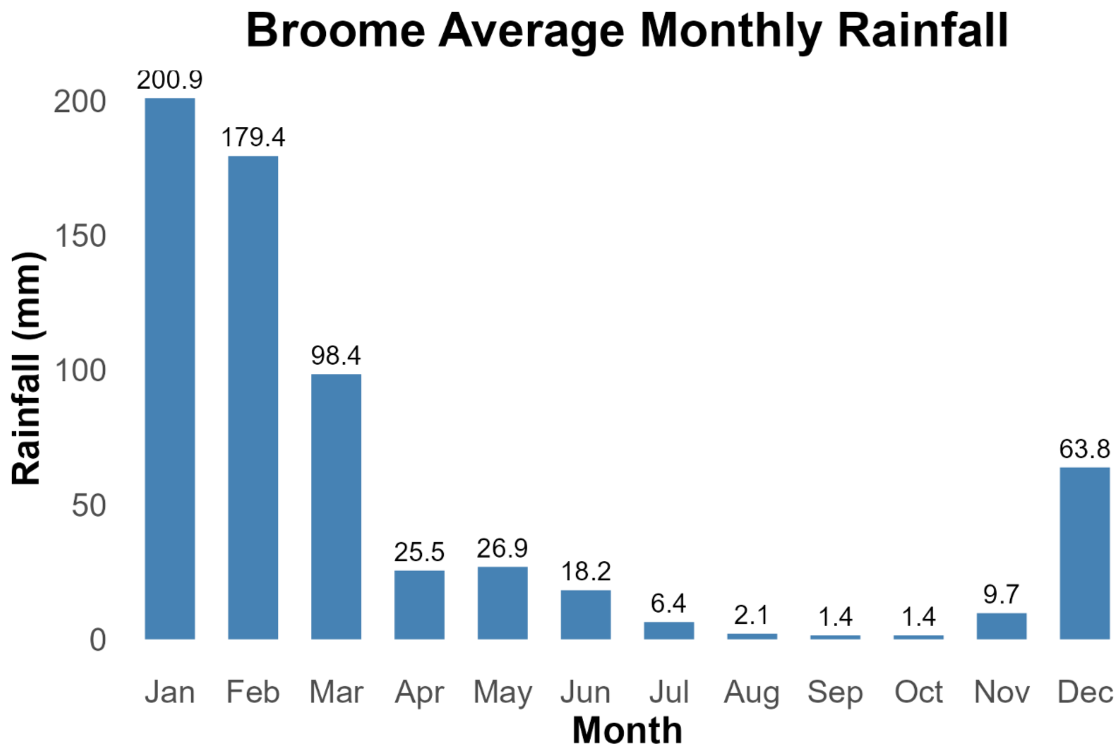

Figure S8 – Average monthly rainfall for the Coconut Wells and Pio's Paddock bilby populations.