EPBC Act Compliance Report

Broome-Cape Leveque Road Upgrade, Western Australia (EPBC 2013/6984)

Reporting period: 2 August 2022 to 1 August 2023

D23#860285#
October 2023

Report Compilation & Review	Name and Position	Date	Document Revision
Author	Environmental Officer	18/10/23	Draft v1
Reviewer	Senior Environmental Officer	25/10/23	Rev 0

Contents

1 INTRODUCTION

The Broome-Cape Leveque Road is located in the Shire of Broome and runs from Broome Highway, east of Broome townsite, to the northern Dampier Peninsula for a length of approximately 200 kilometres (km) to the Ardyaloon (One Arm Point) Aboriginal community. The road is a main transport link, providing access for Aboriginal communities including Beagle Bay, Lombadina/Djarindjin, and numerous Aboriginal outstations. Other stakeholders include Country Downs pastoral station, pearling industries and several tourist destinations such as Kooljaman Resort and Cygnet Bay.

Various sections of the Cape Leveque Road have been upgraded to a sealed standard over the last ten years. Main Roads Western Australia (Main Roads) proposed to upgrade 77.6 km (Straight Line Kilometre (SLK) 25 to 102.6) of the unsealed section of the Cape Leveque Road (see Figure 1). The proposed upgrade involved construction of a new road generally parallel to the existing unsealed road. Road user safety and reduced maintenance are two of the key reasons for the proposed upgrade.

1.1 Approval under the *Environment Protection and Biodiversity Conservation Act 1999*

On 3 September 2013, the Department of Climate Change, Energy, the Environment and Water (DCCEEW) (then Department of Sustainability, Environment, Water, Population and Communities) received a referral under the EPBC Act from Main Roads (Main Roads Western Australia, 2013) to upgrade the road between SLK 25 and 102.6.

On the 27 September 2013, Main Roads received formal advice from DAWE that the proposed upgrade was considered to be a 'controlled action' requiring assessment and approval under the EPBC Act. The proposed action was assessed at the Preliminary Documentation level of assessment.

Main Roads received approval from DCCEEW on the 6 July 2015 subject to a number of Conditions (EPBC 2013/6984).

1.3 Status of the Project

The Broome-Cape Leveque Road Upgrade Project (the Project) aims to both minimise the environmental footprint of works and maximise Aboriginal employment and local businesses for the communities of the Dampier Peninsula. Local engagement, participation and ownership is paramount to ensure social, environmental and economic opportunities are fully utilised.

The Broome-Cape Leveque Road was opened to the public in December 2020. On 1 February 2022 Country Downs Station received 652 mm of rain within a 24 hour period, resulting in significant and extensive damage to a large section of the Broome-Cape Leveque Road. The most severe damage occurred between SLK 35 – 80, with extensive damage to the drainage network and across the project site. Repairs to the road were completed by December 2022, with drainage improvements currently being undertaken, and planned to be complete by December 2023. The flooding also caused considerable damage to rehabilitation area, with further revegetation works planned to be undertaken at the completion of the 2023 improvements.

Based in Beagle Bay, the Nyul Nyul Rangers continue to provide specialised Greater Bilby Management, which delivers key components of the Project's Greater Bilby Management Plan. Pre-clearing Greater Bilby surveys by Traditional Owner Rangers are undertaken in accordance with the Project's Greater Bilby Management Plan. No active burrows requiring the relocation of Greater Bilbies were recorded on site this reporting period, nor were any individuals trapped nor sighted. Ecological expertise and specialised Greater Bilby services were provided by Dr Rick Southgate (Envisage Environmental Services).

Seven drainage culverts that also act as fauna underpasses were installed during previous reporting periods (Figure 2). The report by Dr Rick Southgate on fauna using these underpasses/culverts is attached (Appendix 1).

1.2 Purpose of this Report

This compliance report has been produced as required by Condition 3 of EPBC 2013/6984. Table 1 of this report outlines compliance with each approval condition over the 12 month period between 2 August 2022 and 1 August 2023 (the reporting period).

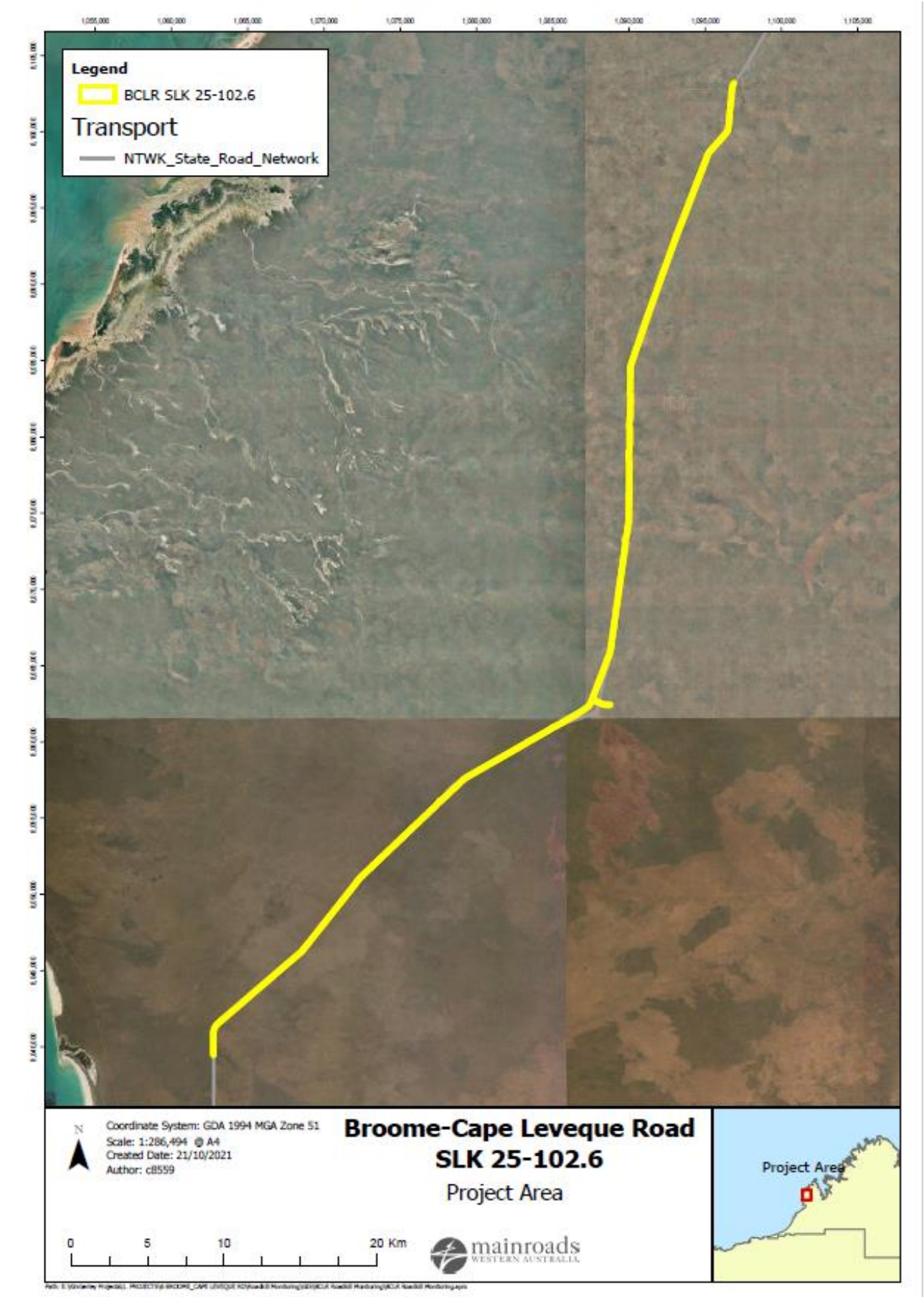

Figure 1. Project Area

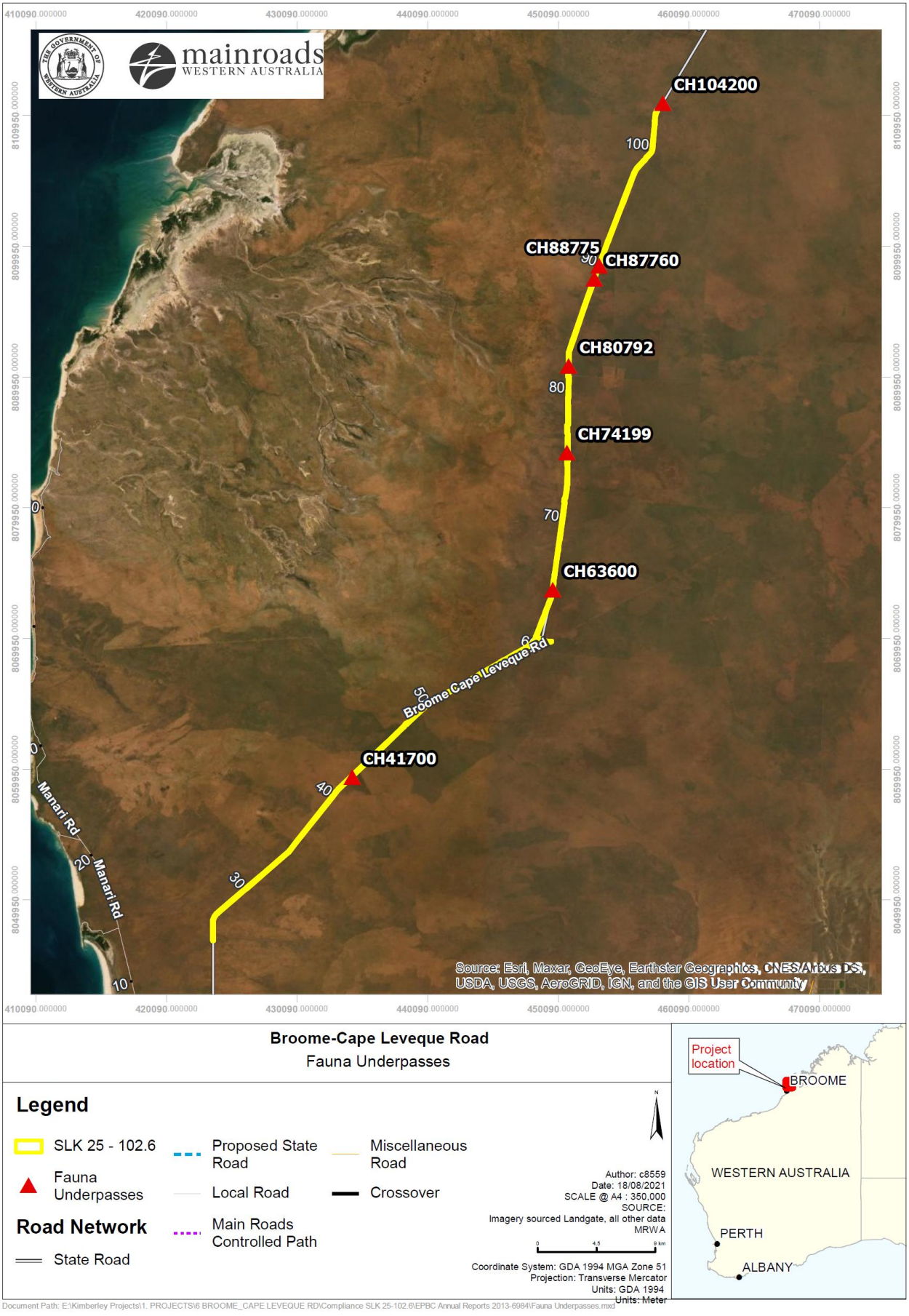

Figure 2: Fauna Underpasses

2 COMPLIANCE

Table 1: Compliance with Conditions of EPBC Approval 2016/7665

Condition Number	Condition	Status	Evidence/Comments
1	Within 10 days after the commencement of the action, the person taking the action must advise the Department in writing of the actual date of commencement.	Complete	As per the definition of 'Commencement of Action' in EPBC 2013/6984, the Project commenced on 2 August 2017, with the clearing of small amounts of native vegetation for geotechnical investigations. The Department was advised of the Commencement of Action via a letter dated 9 August 2017.
2	The person taking the action must maintain accurate records substantiating all activities associated with or relevant to the conditions of approval, including measures taken to implement the management plan required by this approval, and make them available upon request to the Department. Such records may be subject to audit by the Department or an independent auditor in accordance with section 458 of the EPBC Act, or used to verify compliance with the conditions of approval. Summaries of audits will be posted on the Department's website. The results of audits may also be publicised through the general media.	Compliant	Main Roads WA has maintained all records in accordance with this condition and legal obligations, under the State *Records Act 2000* (Western Australia).

Condition Number	Condition	Status	Evidence/Comments
3	Within three months of every 12 month anniversary of the commencement of the action, the person taking the action must publish a report on their website addressing compliance with the conditions of this approval over the previous 12 months, including implementation of any management plans as specified in the conditions. The compliance reports must remain on their website for a minimum of 12 months (beginning on the date of publication). Non-compliance with any of the conditions of this approval must be reported to the Department at the same time as the compliance report is published. The person taking the action must continue to annually publish the report on their website addressing compliance with each of the conditions of this approval until such time as agreed to in writing by the Minister.	Compliant	This Report has been prepared pursuant to this condition and will be published on the Main Roads website. All previous reports remain available on the Main Roads website at: https://www.mainroads.wa.gov.au/community-environment/environment/construction-project-compliance-reports/ or Construction Project Reports | Main Roads Western Australia[1] .
4	The person taking the action must notify any non-compliance with this approval to the Department in writing within two business days of the person taking the action becoming aware of non-compliance.	Not Applicable	No non-compliances were recorded within the reporting period.
5	Upon the direction of the Minister, the person taking the action must ensure that an independent audit of compliance with the conditions of approval is conducted and a report submitted to the Minister. The independent auditor must be approved by the Minister prior to the commencement of the audit. Audit criteria must be agreed to by the Minister and the audit report must address the criteria to the satisfaction of the Minister.	Not Applicable	The Minister has not requested an independent audit of the Project.

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Condition Number	Condition	Status	Evidence/Comments
6	If the person taking the action wishes to carry out any activity otherwise than in accordance with the management plan as specified in the conditions, the person taking the action must submit to the Department for the Minister's written approval a revised version of that management plan. The varied activity shall not commence until the Minister has approved the varied management plan in writing. The Minister will not approve a varied management plan unless the revised management plan would result in an equivalent or improved environmental outcome over time. If the Minister approves the revised management plan, that management plan must be implemented in place of the management plan originally approved.	Not Applicable	No variations to the Management Plans specified in EPBC 2013/6984 have been implemented during the reporting period.
7	If the Minister believes that it is necessary or convenient for the better protection of listed threatened species and communities to do so, the Minister may request that the person taking the action make specified revisions to the management plan specified in the conditions and submit the revised management plan for the Minister's written approval. The person taking the action must comply with any such request. The revised approved management plan must be implemented. Unless the Minister has approved the revised management plan, then the person taking the action must continue to implement the management plan originally approved, as specified in the conditions.	Not Applicable	The Minister has not requested specific revisions to the Management Plans.
8	If, at any time after five years from the date of this approval, the person taking the action has not substantially commenced the action, then the person taking the action must not substantially commence the action without the written agreement of the Minister.	Complete	The Commencement of Action date was 2 August 2018, which is within 5 years of the date of approval (6 July 2015).

Condition Number	Condition	Status	Evidence/Comments
9	Unless otherwise agreed to in writing by the Minister, the person taking the action must publish the management plan referred to in these conditions of approval on their website. The management plan must be published on the website within one month of being approved. The person taking the action must notify the Department within five business days of publishing the management plan on their website, and the management plan must remain on their website for the period this approval has effect.	Compliant	All Management Plans referred to in EPBC 2013/6984 were published on Main Roads WA's website prior to the reporting period of this report and available at: https://www.mainroads.wa.gov.au/projects-initiatives/all-projects/regional/broome-cape-leveque-road
10	To ensure there is no decline in the local Greater Bilby population as a result of roadkill on the sealed Cape Leveque Road, the person taking the action must submit a Roadkill Monitoring and Adaptive Management Plan (RMAMP) for the Minister's approval. The RMAMP must provide sufficient detail (timing, effort and methodology) to detect the level of impact of roadkill on the local Greater Bilby population during the construction phase and operational phase. Commencement of the action must not occur unless the Minister has approved the RMAMP. The approved RMAMP must be implemented. The RMAMP must:	Compliant	The RMAMP was submitted for the Minister's approval prior to the reporting period. The Minister's approval was obtained on the 6 July 2015. The RMAMP has been implemented as per the 2021/2022 progress report (Appendix 2). Approval of the RMAMP by the Minister confirms compliance with the subsections of Condition 10. As per the approved RMAMP, the Roadkill Monitoring Report for 2021 was submitted to DCCEEW in March 2022 and is appended to this report (Appendix 2).
	a. be developed and endorsed by a suitably qualified ecologist and a linear infrastructure ecologist		
	b. include survey methodology and effort to be implemented that are sufficient to determine the baseline local Greater Bilby population and the location of high density Greater Bilby areas		
	c. include sufficient monitoring methodology and effort to determine baseline Greater Bilby roadkill rates on the unsealed Cape Leveque Road prior to commencement of the action		

Condition Number	Condition	Status	Evidence/Comments
	d. include sufficient monitoring methodology to determine Greater Bilby roadkill rates on the sealed Cape Leveque Road during the construction phase and operational phase		
	e. include appropriate Greater Bilby roadkill trigger values and adaptive management measures to be implemented should Greater Bilby roadkill trigger values be reached during the construction phase and operational phase		
	f. include the requirement for ongoing monitoring and adaptive management measures until such time as it can be demonstrated that there is no decline in the local Greater Bilby population as a result of roadkill for three successive years		
	g. include the requirement to provide a report on survey findings and effectiveness of adaptive management to the Department annually by 30 June each year following commencement of the action, until such time as it can be demonstrated that there is no decline in the local Greater Bilby population as a result of roadkill for three successive years.		
11	To minimise impacts to the Greater Bilby during the construction phase, the person taking the action must develop a Greater Bilby Induction Training and Awareness Program (GBITAP). The GBITAP must:	Compliant	A GBITAP has been developed in collaboration with the Nyul Nyul Ranger Group. Nyul Nyul Rangers are actively involved in the project and are key to management of the Greater Bilby.
	a. be delivered to all employees and contractors prior to the commencement of the action and to any new employees and contractors arriving during the construction phase	Compliant	The GBITAP is delivered at the commencement of each swing on site to ensure all new starters on the Project are compliant with the project specific environmental induction requirements.

Condition Number	Condition	Status	Evidence/Comments
	b. provide education on the appearance, characteristics and behaviour of the Greater Bilby sufficient to allow employees and contractors to accurately identify the species	Compliant	The GBITAP includes material on how to identify Greater Bilbies, as well as their behavioural characteristics.
	c. include maps of high density Greater Bilby areas	Compliant	The GBITAP and associated Environmental Induction provide details on the Project's Construction EMP which contains maps of high density areas.
	d. institute a signposted speed limit of no greater than 60 km/h, along with educational signage to increase awareness of Greater Bilby presence, at high density Greater Bilby areas and 200m either side of high density Greater Bilby areas to be observed by all employees and contractors	Compliant	Speed limit at all construction areas are limited to a maximum speed of 60km per hour. Speed limits are signposted with traffic control signage.
	e. include instructions on threats to the Greater Bilby and how to avoid or reduce impacts to the Greater Bilby through measures including, but not limited to, road awareness and waste management.	Compliant	The GBITAP and associated Environmental Induction provide details on the Project's Construction EMP which contains management measures that are communicated to personnel working on the road. Measures include waste management, roadkill and sighting reporting system.
12	To minimise impacts to the Greater Bilby as a result of onsite works during the construction phase, the person taking the action must ensure that a suitably qualified ecologist implements the *Cape Leveque Road Greater Bilby Relocation Protocol, October 2014* in conducting pre-clearance surveys and relocation of Greater Bilby individuals, if present. All Greater Bilby deaths must be recorded.	Compliant	Main Roads engaged the services of suitably qualified ecologists to manage the trapping and relocation program during the construction phase - Dr Malcolm Lindsay (Environs Kimberley).

Condition Number	Condition	Status	Evidence/Comments
13	To minimise impacts to the Greater Bilby of the sealed Cape Leveque Road during the operational phase, the person taking the action must ensure that the Cape Leveque Road upgrade is designed, constructed and maintained in a manner that minimises the potential for Greater Bilby roadkill from public use of the sealed road through avoidance, deterrence and increased visibility, including in particular:	Compliant	While it was initially thought proposed mitigation measures may be appropriate in minimising threats posed to Greater Bilby, further investigation and design analysis confirmed these measures were not an appropriate management strategy and would have no beneficial impact on reducing the risk of bilby mortality. The highest threat assessed for bilby populations on the Dampier Peninsular is the interaction of fire and introduced predators, particularly feral cats. Based on the findings, there is little support to justify the inclusion of road engineering works as a means to reduce the risk of mortality for species like the bilby. A road maintenance zone of 16 m from the centreline has significantly increase visibility. No bilby signs were detected using the underpass sites in 2021 or 2022 and there was no reports of bilbies by the Nyul Nyul Rangers in the study area. Accordingly, no high density Greater Bilby areas were identified within the vicinity of the project area.
	a. installation of signage educating the public of Greater Bilby presence at high density Greater Bilby areas and 200m either side of high density Greater Bilby Areas	Not Applicable	No high density Greater Bilby areas have been identified within the vicinity of the project area that require signage.
	b. the use of coloured pavement at high density Greater Bilby areas and 200m either side of high density Greater Bilby areas	Not Applicable	No high density Greater Bilby areas have been identified within the vicinity of the project area that require different coloured pavement.
	c. the use of audible rumble strips at high density Greater Bilby areas and 50m either side of high density Greater Bilby areas.	Not Applicable	No high density Greater Bilby areas have been identified within the vicinity of the project area that require the use of rumble strips.

Condition Number	Condition	Status	Evidence/Comments
14	In order to minimise the potential of the proposed action to facilitate the increased spread of feral cats, foxes and weeds, the person taking the action must:	Compliant	Effective management of feral cats, foxes and weeds have been implemented.
	a. fence all standing pools of water resulting from the action	Compliant	All dams constructed have been fenced, and regular site inspections are undertaken to identify any unfenced standing pools of water that could attract feral animals.
	b. remove or fence all rubbish generated as a result of the action at the end of each working day	Compliant	All rubbish is appropriately contained in closed bins and removed off-site. All food waste is bagged for disposal. No feral animals have been recorded at rubbish disposal points.
	c. weeds must be managed and controlled in accordance with the Cape Leveque Road Upgrade Revegetation Management Plan, October 2014.	Compliant	No weeds have been recorded in the clearing area as of the reporting period.
15	To offset the residual significant impact to the Greater Bilby, the person taking the action must ensure that the offsets program is undertaken by a suitably qualified ecologist, including:	Compliant	The offset program is being undertaken and managed by the DBCA. A report of the program's progress is attached at Appendix 3.
	a. a baseline survey to determine the area of occupancy of the Greater Bilby and its threats on the Dampier Peninsula must be developed and undertaken in conjunction with DPaW and Traditional Owner Rangers. The survey must use established techniques and record signs of Greater Bilby, signs of introduced predators, habitat characteristics, fire history and grazing pressure. This baseline survey must be undertaken on SLK 90-102.6 prior to the commencement of the action. The baseline survey must be undertaken on SLK 25-90 prior construction occurring in SLK 25-90.	Complete	Baseline surveys have been undertaken. The DBCA, in collaboration with local Ranger groups and NGOs are currently undertaking occupancy surveys across the Dampier Peninsula which commenced in early 2017. Survey techniques were developed by the DBCA. Main Roads commissioned GHD Pty Ltd to undertake a baseline Greater Bilby Survey on the SLK 25 – 102.6 section between October and December 2015.

Condition Number	Condition	Status	Evidence/Comments
	b. an annual and ongoing survey must be developed and implemented in conjunction with DPaW and Traditional Owner Rangers. This survey must commence within six months of completion of the baseline survey and continue for at least two years, and monitor: i. at least four locations of the Greater Bilby population using DNA fingerprinting techniques ii. the population of introduced predators through the use of camera traps iii. grazing pressure, food resources and fire history.	Compliant	The offset program is being undertaken and managed by the DBCA, who are implementing this with local Ranger groups (Appendix 3).
	c. a threat management program must be submitted to the Minister for approval prior to implementation. The threat management program must be developed and implemented in conjunction with DPaW and Traditional Owner Rangers and must address either introduced predators, fire regimes or grazing pressure or a combination of these threats at high priority sites for the Greater Bilby. The threat management program must include an adaptive management component. Threat management must commence within one year of commencement of the action and continue for at least one year. At least $120,000 is to be spent on direct threat abatement action per year of the threat management program	Compliant	The Threat Management Plan was submitted to the Department prior to construction.
	d. at a minimum, $600,000 is to be provided to DPaW to enable development and implementation of the offsets program. Evidence of expenditure must be provided to the Minister within three months of the final payment	Complete	As previously reported, Main Roads provided DBCA with the stated funds in two instalments. The final instalment was paid to the State Offset Fund on 10 May 2016 for release to DBCA once specific milestones are completed.

Condition Number	Condition	Status	Evidence/Comments
	e. provision of information to the annual compliance report required by the conditions attached to this approval reporting on the survey findings, ongoing monitoring and effectiveness of adaptive management measures to address threats to the Greater Bilby, for the duration that the offsets program is implemented.	Compliant	Results for the annual surveys and progress of the Dampier Peninsula Bilby Project offsets program is included in Appendix 3.

3 APPENDICES

Appendix 1	Report on Bilby and Fauna Underpass use on the Broome-Cape Leveque Road Upgrade October, 2022 – Dr Rick Southgate
Appendix 2	2022/23 Roadkill Monitoring Report (Final)
Appendix 3	DBCA Offsets Report: Dampier Peninsula Greater Bilby (Macrotis lagotis) Main Roads offset project: Final report.

Appendix 1: Report on Bilby and Fauna Underpass use on the Broome-Cape Leveque Road Upgrade October, 2022 – Dr Rick Southgate

REPORT ON BILBY AND FAUNA UNDERPASS USE ALONG THE BROOME-CAPE LEVEQUE ROAD UPRADE IN OCTOBER 2022

Dr Richard Southgate
Envisage Environmental Services
October 2023

Summary

A survey to determine the bilby activity and the use of fauna underpasses installed along the Broome-Cape Leveque Road (BCLR) upgrade was undertaken in October 2022 as part of the approval conditions required to be undertaken by Main Roads (Western Australia).

During the first year of survey in 2021, no sign bilby was detected at culvert sites or other sites sampled along the BCLR upgrade. No bilby sign was detected using the culvert sites in 2022 and there have been no reports of bilbies by the Nyul Nyul Rangers in the study area.

Seven culverts were monitored using remote cameras along the BCLR. Three cameras were deployed in the vicinity of each culvert for a period of 56 days. One camera was attached to the roof of the culvert, one placed facing the entrance of the culvert and the other within 150 m facing along a track or wildlife pad likely to be traversed by medium-sized animals.

A range of species were recorded by the cameras including feral cats, dingoes and agile wallabies and several bird and reptile species. Feral cats were the most common medium-size animals to be detected at the culverts and the only species that travelled through a culvert under the road. The high cat activity around the culverts may pose an elevated threat to prey species. Based on the survey findings, there is little support to justify the inclusion of fauna underpasses within road engineering works as a means to reduce the risk of mortality for species like the bilby .

Introduction

An upgrade and bituminisation of the Broome-Cape Leveque Road has been conducted by Main Roads Western Australia (Main Roads). As part of the Project approval conditions, the development was assessed under both Federal and State Legislation and the Greater Bilby was identified as a threatened species occurring within the Project area. This species in considered vulnerable to extinction both nationally and in Western Australia. The species has declined by 70% nationally and wild populations are is now restricted to the more northern and less productive parts of its former range (Fig. 1). The highest threat assessed for wild bilby populations on the Dampier Peninsula was the interaction of fire and introduced predators (Dziminski and van Leeuwen 2019).

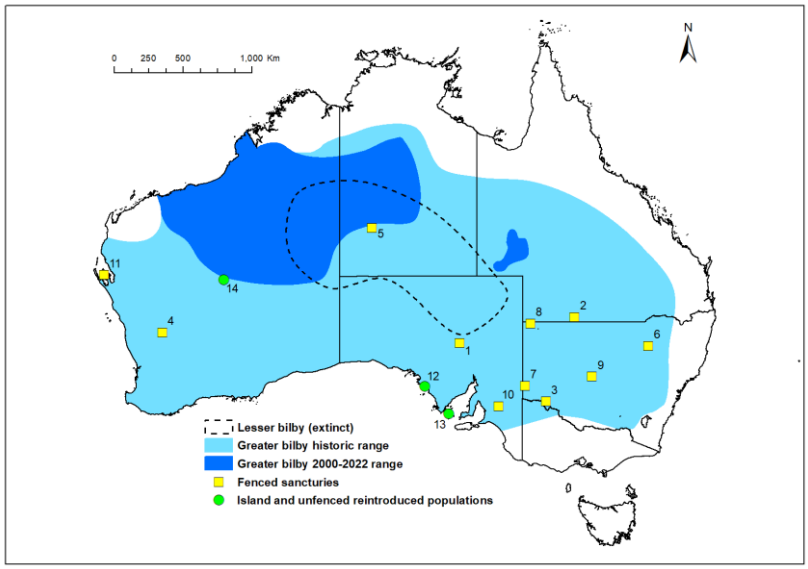


Fig. 1 Current and former Greater and Lesser Bilby ditribution Reintroduced or introduced populations of the Greater Bilby: 1 Arid Recovery, 2 Currawinya, 3 Mallee Cliffs, 4 Mt Gibson, 5 Newhaven, 6 Pilliga, 7 Scotia, 8 Sturt, 9 Yathong, 10 Yookamurra, 11 Peron, 12 Venus Bay, 13 Thistle Is, 14 Matuwa.

The Cape Leveque Road Greater Bilby Management Plan was developed in response to Project approval conditions and this outlined the activities that should be undertaken during and following completion of the upgrade. This included ongoing monitoring of the population for five years after a series of fauna underpasses where installed. The Management Plan also indicated that a series of fauna underpasses be inserted to reduce the risk of mortality to the Greater Bilby and other native fauna caused by vehicle traffic along the road.

For development of the Project, the following approvals were granted:

- DotEE 2015, EPBC 2013/6984 Approval under the EPBC Act.
- DER 2014, CPS 6078 Clearing Permit (CPS 6078/4 – 9 June 2020).

The Clearing permit CPS 6078/4 contained the following condition:

> 9(f) During the term of the permit, the Permit Holder shall implement a Greater Bilby (*Macrotis lagotis*) monitoring program that includes:
>
> (ii) Annual monitoring for a period not less than five years commencing within 12 months of the completion of the fauna underpasses identified under conditions 9(c) and 9(d), to assess the persistence of Greater Bilby (*Macrotis lagotis*) populations within 500 metres of the upgrade Broome-Cape Leveque Road (BCLR), and the level of use and effectiveness of the fauna underpasses for Greater Bilby (*Macrotis lagotis*).

The aims of the monitoring program along the BCLR have been to:

- establish whether bilbies, if assessed to be active in the vicinity of a culvert, make use of the culverts to cross the roadway.
- determine the use of the concrete culverts by other fauna, particularly predators
- collect data on fauna use of different size culverts to enable a comparison with the findings of similar studies conducted in other regions
- assess if bilby activity remains evident at previously occupied locations along the BCLR

This report provides a description of a monitoring program conducted in 2022 with a comparison of the monitoring results from 2021.

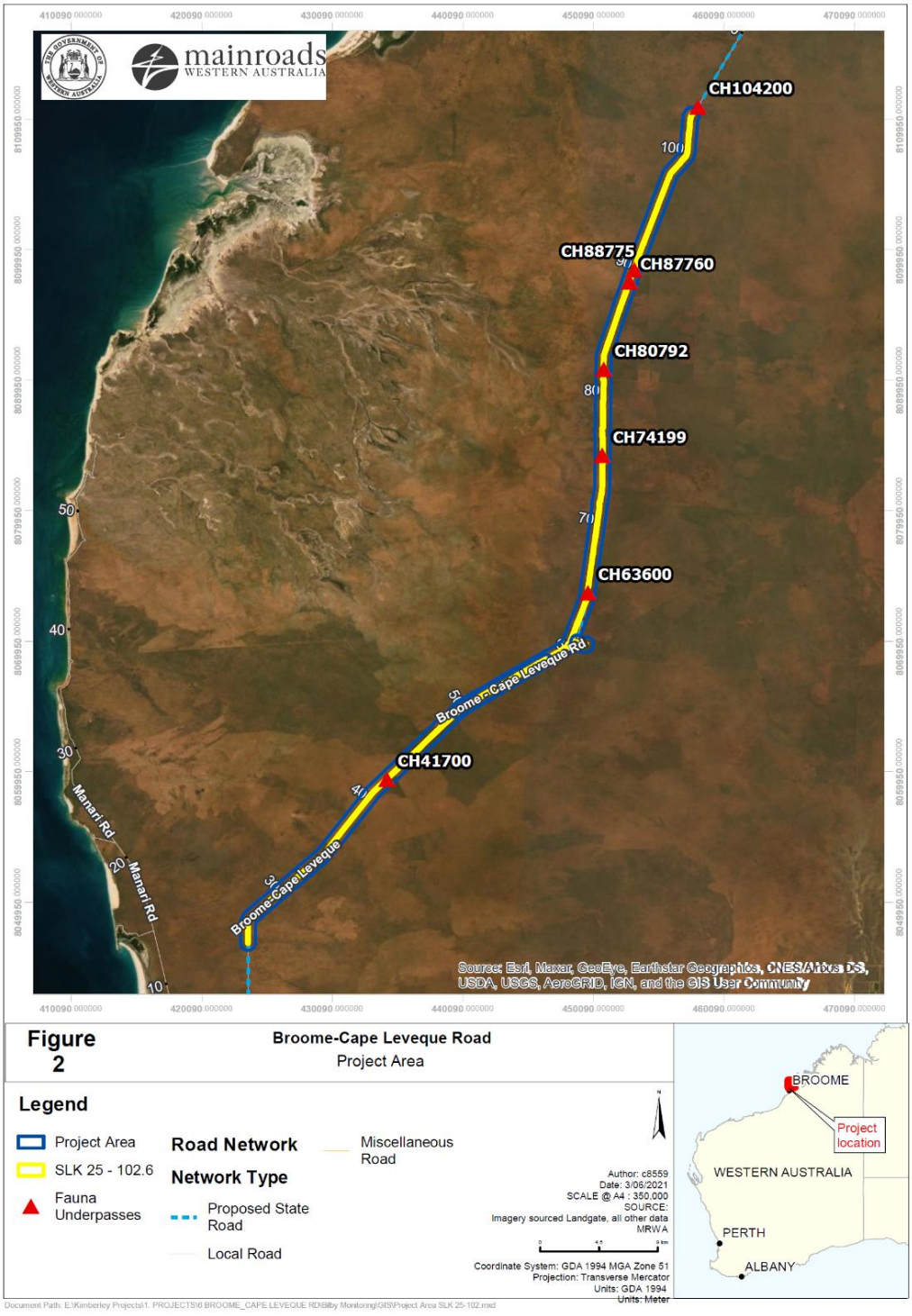
Methods

Project area

The Project area and underpass locations are shown in Fig. 2 and underpass coordinates are presented in Table 1. The Project area includes a 500 m corridor on either side of the upgraded BCLR (SLK 25-102.6) and seven fauna underpasses.

Table 1 Fauna underpass locations, culvert dimensions and condition

Underpass ID	Coordinates		Date Installed	Wide (m)	Height (m)
CH41700 (Cul61)	-17.550923°	122.380651°	19/09/2019	0.9	0.3 open clean
CH63600 (Cul62)	-17.421790°	122.525759°	05/09/2019	0.9	0.9 open clean
CH74199 (Cul63)	-17.327000°	122.536508°	22/08/2019	2 x 0.9	0.9 open clean
CH80792 (Cul64)	-17.267192°	122.537766°	28/07/2019	0.9	0.3 sand fill
CH87760 (Cul65)	-17.206832°	122.556499°	28/11/2018	0.9	0.3 sand fill
CH88775 (Cul66)	-17.198170°	122.559802°	19/11/2018	0.9	0.3 open clean
CH104200 (Cul67)	-17.085465°	122.605999°	18/11/2018	0.9	0.45 sand fill



The culvert monitoring project has built on previous monitoring along the BCLR and added value to monitoring conducted by the Department of Biodiversity, Conservation and Attractions (DCBA) and Kimberley Minerals Ltd (formerly Sheffield Resources Thunderbird Mineral Sands Project), Kimberley Land Council, Nyamba Buru Yawuru and Environs Kimberley and other organisations more broadly.

The culvert monitoring project also aimed to adopt the procedures used by other projects to monitor culvert use by fauna along other linear infrastructure. This would potentially enable direct and broader comparison of the findings.

Furthermore, the project aimed to involve and engage the services of local Ranger Groups. The Nyul Nyul Rangers have worked consistently with Main Roads on Bilby Surveys during the construction phase of the Broome-Cape Leveque Road.

Previous monitoring of the Greater Bilby along the BCLR

The approach and amount of effort used to document bilby activity along the BCLR has been largely similar since inception with search on foot for sign of bilby tracks, diggings, scats and burrows. In recent times, the survey approach has largely been standardised with the application of the 2 ha sign based monitoring technique. That is, a search for track, scat and digging sign of target species within a 2 ha plot (200 x 100 m) for 25 minutes (Moseby et al. 2009). The technique is sometimes applied in addition to the deployment of remote cameras. The DCBA has been applying the 2 ha sign-based monitoring technique and cameras to monitor the Greater Bilby and other fauna on the Dampier Peninsula, Southern Kimberley and Pilbara.

Systematic monitoring of Bilby along the BCLR began in December 2012 when environmental consultants GHD monitored 14 locations. In October 2015, GHD sampled 101 plots using 2 ha plots spaced 1 km apart from SLK0-101. Sixteen of these plot locations were resampled in November and December by GHD. In September 2017, Environs Kimberley sampled eight locations. In May 2018, Biota environmental consultants conducted continuous sampling along the road from SLK0-25 and Nyul Nyul rangers searched along the roadway SLK7-104. In both instances the edge of the roadway and vegetated areas were searched for bilby sign by multiple observers with similar search effort conducted when sampling 2 ha plot. Data from these continuous transects were extracted to correspond with plot locations. Envisage Environmental Services conducted further resampling of plots in July (n=29) and September (n=39) 2018 and October (n=19) 2021. This survey history has resulted in some plots from SLK0-104 being sampled once and others up to eight times (**Appendix 1**).

At plots where bilby sign was detected, activity was not usually evident on a subsequent visit. That is, sign was infrequently detected when a site was resampled within a year or among different years. Consecutive bilby activity was recorded at only three of the 26 locations, resampled on more than three occasions.

Culvert monitoring on the BCLR

Culvert monitoring along the BCLR aimed to mirror a survey of fauna using underpasses in the Pilbara along the railway line to Port Hedland (Harriet Davie pers. com., Roy Hill). Here, a camera was mounted on the roof of a culvert to document actual movement of fauna through the passage. Another was placed at the culvert entrance to document fauna passing by but not necessarily using a culvert. A third camera was set along a wildlife pad or track in habitat adjacent to the culvert to document the background composition of fauna. Three culvert sizes were examined (600-900, 900-1500 and 1500-3200 mm), with three replicates of each. Cameras were deployed for a period of 20 weeks with two periods of monitoring (wet and dry) over a period of four years. The target species for monitoring were primarily northern quoll, bilby and cat, fox and dingo.

Along the BCLR, five of the seven culverts are 300-450 mm high x 900 mm wide and the remaining two are 900 mm high. In 2021, no cameras were set internally but cameras were set facing each culvert and set distally within 150 m of the culvert facing along a wildlife pad. In 2022, 21 cameras were set at the seven culvert sites, 11 Reconyx HP and 10 Reconyx HF. At each site, one camera was set facing the entrance of a culvert, one attached to the roof and facing along the internal length of the culvert and the other camera was set distally facing along a track or wildlife pad. The camera setup followed those used by in the Roy Hill study (see **Appendix 2**). The coordinates for the location of each camera deployed are listed in **Appendix 3**.

Results

Animal activity detected by the remote cameras in 2022

The cameras were deployed on the 21 September and retrieved on 15 November 2022 providing a potential operation period of 56 days. The cameras attached to the roof of each culvert were removed between 29/9-3/10 because heavy rainfall and flooding was predicted in the region. Two of the cameras placed facing a culvert malfunctioned two-three weeks at the end of the sampling period and one of the distally-placed cameras malfunctioned for the entire sample period, taking images only between 0900-1500.

No sign of bilby was evident on the images captured. Furthermore, no bilby activity was encountered opportunistically along the BCLR during the survey period. Little other native wildlife was detected entering or residing in the culverts except for geckos and bats. Some bird e.g. butcherbirds and goanna species were detected venturing a few metres but these detections were rare.

Feral Cats were the most frequently detected medium-sized mammal species recorded at sites and twice as likely to be detected at a culvert than on a wildlife pad (Table 1). The culverts were used for thoroughfare and for resting during the day often with multiple visits at the same time of day by the same individual (Fig. 3). All detections were of solitary individuals.

Table 1 Detection of cat, dog and agile wallaby from cameras set within a culvert, facing a culvert at an opening and set distally but within 150 m of a culvert. Weekly occurrence identifies whether a species was detected at least once at a camera site within a week during the sample period. Daily occurrence identifies the number of days a species was recorded at a camera site during the 56 day sample period.

Cat	Internally located		Culvert opening		Distally located	
	weekly occurrence	daily occurrence	weekly occurrence	daily occurrence	weekly occurrence	daily occurrence
CUL61	5	5	1	1	-	-
CUL62	1	1	2	2	0	0
CUL63	1	1	2	2	0	0
CUL64	1	1	2	2	1	1
CUL65	5	15	3	10	0	0
CUL66	5	11	2	3	4	4
CUL67	7	26	5	9	1	1
Sum	**25**	**60**	**17**	**29**	**6**	**6**

Dingo	Internally located		Culvert opening		Distally located	
	weekly occurrence	daily occurrence	weekly occurrence	daily occurrence	weekly occurrence	daily occurrence
CUL61	0	0	3	3	-	-
CUL62	0	0	1	1	0	0
CUL63	0	0	2	2	0	0
CUL64	0	0	0	0	0	0
CUL65	0	0	0	0	1	1
CUL66	0	0	0	0	0	0
CUL67	0	0	4	5	4	6
Sum	**0**	**0**	**10**	**11**	**5**	**7**

Agile wallaby	Internally located		Culvert opening		Distally located	
	weekly occurrence	daily occurrence	weekly occurrence	daily occurrence	weekly occurrence	daily occurrence
CUL61	0	0	0	0	-	-
CUL62	0	0	3	8	7	17
CUL63	0	0	0	0	5	7
CUL64	0	0	1	1	8	22
CUL65	0	0	1	1	6	10
CUL66	0	0	0	0	2	2
CUL67	0	0	0	0	0	0
Sum	**0**	**0**	**5**	**10**	**28**	**58**

At the three most-northern culverts, cat activity was frequent and visits occurred on 20-46% of the days monitored, sometimes by at least two different cat individuals. Cat activity was also detected on 9% of the days monitored at the most southern culvert. At the other three culverts, cat activity was detected only once and this included both the two taller culverts (0.9 x 0.9 m).

Cats were detected at cameras facing the culvert entrance but less frequently (maximum of 18% of the days monitored) than cameras placed internally. Only three of the six functional cameras set on a wildlife pad detected cat activity and only one recorded multiple detections (7% of the days monitored).

Dingoes were detected at the entrance of four culverts and at two of the six cameras placed at a distal location and overall, at six of the seven culvert sites. No dingoes were detected within a culvert or entering a culvert. A pair of dingoes and a mother and two pups were detected on separate occasions at one site. This site also had the highest multiple detections (11% of the days monitored).

Agile wallabies were most frequently detected by cameras set distally from a culvert and at the four most-southern sites (excluding the malfunctional camera). These sites had activity on 12-39% of the days monitored. Agile wallabies were also detected by three cameras facing culverts. No wallabies were detected entering or within the culverts.

Comparison with activity detected in 2021

The weekly and daily occurrence of cat detections from cameras placed distally and facing culvert openings were similar between sample years 2021 and 2022 (Table 2). No cameras were placed inside the culverts in 2021.

Overall, dingo daily detection occurrence was similar in 2021 and 2022 for the cameras placed distally from a culvert but weekly detection occurrence was greater in 2022 particularly for cameras placed facing the culvert.

Agile wallaby detection was similar between years but slightly greater in 2022 particularly for cameras facing the culvert opening.

Fig. 3 A feral cat relaxing in Culvert 65

Table 2 Proportional occurrence of cat, dog and agile wallaby detections from 2021 and 2022 for cameras set within a culvert, facing a culvert at an opening and set within 150 m (distal) of a culvert. Weekly occurrence indicates the sum of species' detections per week in relation to the sum of weeks sampled per camera location. The daily occurrence indicates the detections per day in relation to the sum of days sampled per camera location.

Cat	2021		2022	
	weekly occurrence	daily occurrence	weekly occurrence	daily occurrence
radius	0.113	0.019	0.125	0.018
opening	0.357	0.112	0.333	0.081
internal	-	-	0.446	0.153

Dingo	2021		2022	
	weekly occurrence	daily occurrence	weekly occurrence	daily occurrence
radius	0.094	0.024	0.114	0.021
opening	0.024	0.007	0.222	0.031
internal	-	-	0.0	0.0

Agile wallaby	2021		2022	
	weekly occurrence	daily occurrence	weekly occurrence	daily occurrence
radius	0.426	0.100	0.583	0.173
opening	0.048	0.010	0.111	0.032
internal	-	-	0.000	0.000

Discussion

The deployment of cameras was effective in identifying a variety of mammal, bird and reptile species associated with the culvert sites along the BCLR.
Key medium-sized target species such as feral cat, dingo and agile wallaby were commonly detected and with sufficient frequency to accurately reflect habitat use by each of these species. If bilbies were present and ventured near the culverts they would most likely have been detected.

No bilby activity was detected during the 2021 and 2022 camera survey or had been encountered opportunistically by Nyul Nyul rangers in the previously 36 months (N.

Hammagucci, pers comm.) suggesting bilby activity was very sparsely distributed or possibly absent in the study area.

None of the other target species except for feral cats were detected to enter or traverse through a culvert. Cameras placed internally or facing a culvert opening detected more than three times more cat activity that those placed along animal pads in the vicinity of a culvert. These results were consistent among years and indicate that cats were strongly attracted to culvert structures. Cats were observed to rest during the day within some of the culverts. The cameras placed internally detected more cat activity than those placed at an opening presumably because internal cameras captured some activity initiated from either end of the culvert. The distribution of cat activity was not uniform and overall, more cat activity was detected in the northern part of the study area.

The use of culverts by cats along the BCLR differs from data collected from the Pilbara. Preliminary analysis indicates cat activity was five times greater at a culvert mouth compared to traversing through the culvert and slightly less but roughly the same proportion were recorded in adjacent habitat as at the culvert mouth (Davie, pers comm.)

Along the BCLR the detection frequency of dingoes was similar at both culverts and cameras located at a distance from the entrance, and activity was evenly spread along the BLCR. Whereas agile wallabies were more than five times more frequently detected at cameras located distally from the culvert and more activity was evident in the southern part of the study area.

Management implications

A number of implications for management emerge from the BCLR culvert survey:

Cat activity was high and concentrated around culverts compared to the dingo. The culverts likely provide refuge and shelter for cats particularly the lower profile culverts (300-450 mm high). Therefore, it is plausible that culverts pose a greater threat to native species than a benefit and there is little support to justify the inclusion of fauna underpasses as a tool to reduce the risk of mortality for species like the bilby.

On the other hand, the frequent use of culverts by feral cats and absence of use by other terrestrial wildlife make these structures ideal locations to focus management activity to control feral cats with targeted hand baiting or with the deployment of Felixer traps. Further investigation is required to determine if the high use of culvert-like structures by feral cats is widespread though Dampier Peninsula and the Kimberley.

It would be beneficial to determine whether the pattern of culvert use by cats and native wildlife during the cooler, drier months was similar to the September-November period. A similar length sample period would probably be adequate. The sampling of other road culverts more broadly on the Peninsula would also be beneficial to determine whether the pattern of culvert use was similar spatially.

A lack of clear communication resulted in the failure to conduct sign-based sampling at each culvert site and for searches to be conducted at site along the BCLR. It is unlikely this omission would have affected the outcome of the monitoring in 2022 because of the evident scarcity of bilbies occurring on the Peninsula. Further searching for bilby sign along the BCLR and more broadly using the 2 ha protocol would be beneficial determine the status the bilby population of the Dampier Peninsula.

Acknowledgements

I would like to thank John Silver (MRWA) for managing the project, assisting with the collation of cameras, downloading of images from the camera cards and transfer of data. The Nyul Nyul Rangers provided great assistance in conducting the 2 ha plot monitoring and the deployment and retrieval of cameras, temporary removal of cameras from the culverts when heavy rainfall and flooding was predicted and trimming away shrubs from the focal area of cameras. Bruce Greatwich (DBCA) provided assistance and support in the hire of cameras from DBCA and Joe Meadham (Ecoscape) assisted in the initial set up of the cameras in 2021 and Bruce Turner (Ecoscape) and Harriet Davie (Roy Hill) provided background information about the culvert monitoring in the Pilbara.

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Moseby, K., Nano, T., and Southgate, R. (2009). 'Tales in the sand. A guide to identifying Australian arid zone fauna using spoor and other signs'. (Ecological Horizons: South Australia.)

Appendix 1 The occurrence of bilby activity along the Broome-Cape Leveque Rd. Grey shading indicates when plots where resampled three times per year.

Spp s	<2012	GHD Dec-12	GHD Oct-15	GHD Nov-15	GHD Dec-15	EnvK Sep-17	Biota May-18	Nyul Nyul May-18	RS Jul-18	RS Sep-18	Nyul Nyul Oct 21
slk01	2002		0	0	0	0					
slk02			0								
slk03			0				1		0	0	
slk04			0				0				
slk05			1	1	1		0			0	
slk06			0								
slk07			0								
slk08			0								
slk09			0				1			0	
slk10			0				0		0	0	
slk11			0								
slk12			0				0				
slk13			0								
slk14			0								
slk15			0				0		0	0	
slk16			0				1		0	0	
slk17			0				1			1	
slk18			0								
slk19			0								
slk20			0						0	0	
slk21			0				1			0	
slk22			0	0	0		1			0	
slk23			0				1			0	
slk24			1	1	1		0		0	0	0
slk25			0								
slk26			0								
slk27			0								
slk28			0								
slk29			0			0					
slk30		0	0	0	0					0	0
slk31			0								
slk32			0								
slk33			0								
slk34			0								
slk35		0	0								
slk36			0								
slk37			0								
slk38			0								
slk39			0	0	0				0	0	0
slk40			0								
slk41			0								
slk42			0								
slk43			0			0					
slk44			0								
slk45			0	0	0				0	0	0
slk46			0								
slk47			0								
slk48		1	0	0	0				0	0	
slk49		0	0								
slk50			0								
slk51			0								
slk52			0								
slk53			0	0	0				0	0	0
slk54		0	0								
slk55			0								
slk56			0								
slk57			0								
slk58		0	0								
slk59			0								
slk60			0								
slk61		0	0								
slk62			1	0	0				0	0	0
slk63			0			0					
slk64			0								
slk65	1963		1	1	0				1	0	0
slk66			0								
slk67			0								
slk68			0								
slk69			0								

slk70	1963		0					0	0	0	
slk71	1963		0	0	0			0	0	0	0
slk72			0					0	0	0	
slk73			0					0			
slk74			0					0		0	
slk75			0			0		0			
slk76			0					0			
slk77			0					0			
slk78			0					0			
slk79			0					0	0	0	
slk80			0	0	1	0		0	0	0	0
slk81			0					0	0	0	
slk82			0					0			
slk83			0					0			
slk84			0					0			
slk85			0					0	0	0	0
slk86			0					0			
slk87			0					0	0	0	0
slk88			0					0	0	0	
slk89		1	0	0	0	0		0	0	0	
slk90			0					0	0	0	0
slk91			0	0					0		
slk92	1987		0					0			
slk93	1987		0					0			
slk94			0					0			
slk95		0	0					0	0	0	
slk96			0					0		0	
slk97			0					0		1	0
slk98			0	0	1			1		0	
slk99		0	0					0	0	0	
slk100		0	1	1	1			0	0	0	0
slk101		0	0			0		0	0		
slk102		0						0			
slk103								0	0	0	0
slk104									0	0	

Appendix 2 Camera settings used in cameras set along the BCLR

Cameras were not baited and set using the following Reconyx specific parameters
TRIGGER
- Motion Sensor = ON
- Sensitivity = HIGH
- Pics Per Trigger = 3
- Picture Interval = RAPIDFIRE
- Quiet Period = NO
TIME LAPSE
- AM Period = OFF
- PM Period = OFF
RESOLUTION
- 3.1 MP
NIGHT MODE
- Shutter

The top of the camera unit was positioned 500 mm above ground, with the camera facing slightly downwards—aimed at a point on the ground approximately 4.5 metres away. Cameras need to face south to limit interference and false triggering caused from the sun and shadow movement.

Appendix 3 The coordinates for camera locations monitored along the BCLR in 2022

Underpass Id	Culvert&Camera	Location	Latitude	Longitude
CH41700	CUL61CAM1	Culvert opening	17.55200	122.37917
	CUL61CAM2	Radius	17.55188	122.37889
CH63600	CUL62CAM1	Culvert opening	17.42214	122.52586
	CUL62CAM3	Radius	17.42210	122.52523
CH74199	CUL63CAM1	Culvert opening	17.32711	122.53664
	CUL63CAM2	Radius	17.32719	122.53580
CH80792	CUL64CAM1	Culvert opening	17.26756	122.53767
	CUL64CAM2	Radius	17.26760	122.53728
CH87760	CUL65CAM1	Culvert opening	17.20747	122.55642
	CUL65CAM2	Radius	17.20715	122.55537
CH88775	CUL66CAM1	Culvert opening	17.19897	122.55961
	CUL66CAM3	Radius	17.19892	122.55941
CH104200	CUL67CAM1	Culvert opening	17.08628	122.60564
	CUL67CAM2	Radius	17.08648	122.60591

Appendix 2: 2022 Roadkill Monitoring Report (Final)

Roadkill Monitoring Report

Broome-Cape Leveque Road, Western Australia

SLK 25 – 102.6

D23#1014338
October 2023

Contents

1 INTRODUCTION

The Broome-Cape Leveque Road (BCLR) is located in the Shire of Broome and runs from the Broome Highway, east of Broome townsite, to the northern Dampier Peninsula for a length of approximately 200 kilometres (km). The road is a main transport link, providing access for Aboriginal communities (including Beagle Bay, Lombadina/Djarindjin, Kooljaman and Ardyaloon/One Arm Point) and outstations, pastoral stations, pearling industries and tourist destinations.

Various sections of the BCLR have been upgraded to a sealed standard over the last ten years. Main Roads Western Australia (Main Roads) upgraded 77.6 km (Straight Line Kilometre (SLK) 25 to 102.6) of the unsealed section of the BCLR (Figure 1). The upgrade involved construction of a new road generally parallel to the existing unsealed road. Road user safety and reduced maintenance are two of the key reasons for the upgrade.

The road was widened to 8 m, the roadside batters were flattened and parking bays were installed at regular intervals to provide rest stop opportunities. The road was completed and officially opened in November 2020 (Main Roads, 2021).

1.1 Approval under the *Environment Protection and Biodiversity Conservation Act 1999*

On 3 September 2013, the Department of Agriculture, Water and the Environment (DAWE) (then Department of Sustainability, Environment, Water, Population and Communities) received a referral under the EPBC Act from Main Roads (Main Roads Western Australia 2013) to upgrade the road between SLK 25 and 102.6.

On the 27 September 2013, Main Roads received formal advice from DAWE that the proposed upgrade was considered to be a 'controlled action' requiring assessment and approval under the EPBC Act. The proposed action was assessed at the Preliminary Documentation level of assessment.

Main Roads received approval from DAWE on the 6 July 2015 subject to a number of Conditions (EPBC 2013/6984) (Appendix A).

1.2 Purpose of this Report

A Roadkill Monitoring and Adaptive Management Plan (RMAMP) (GHD, 2016) was produced as per Condition 10 of EPBC 2013/6984. As per Sections 2.5, 2.6 and 2.7 of the RMAMP, roadkill monitoring along the BCLR was required prior to commencement of construction, during construction and during operation of the road, respectively. This was required to determine if roadkill rates along the BCLR increased in response to the upgrade of the road or other factors.

As per Section 2.7 of the RMAMP, an annual Roadkill Monitoring Report is required for each monitoring cycle (GHD, 2016). For the purpose of this report, the monitoring period is considered to be December 2021 – July 2023, however, monitoring data for the years preceding this monitoring period (i.e. monitoring data from pre-construction and construction) have also been included.

Results of the monitoring data will be reported in the 2021/2022 EPBC 2013/6984 Annual Compliance Report to DAWE and the 2022 CPS 6078 Annual Clearing Report to the Department of Water and Environmental Regulation (DWER).

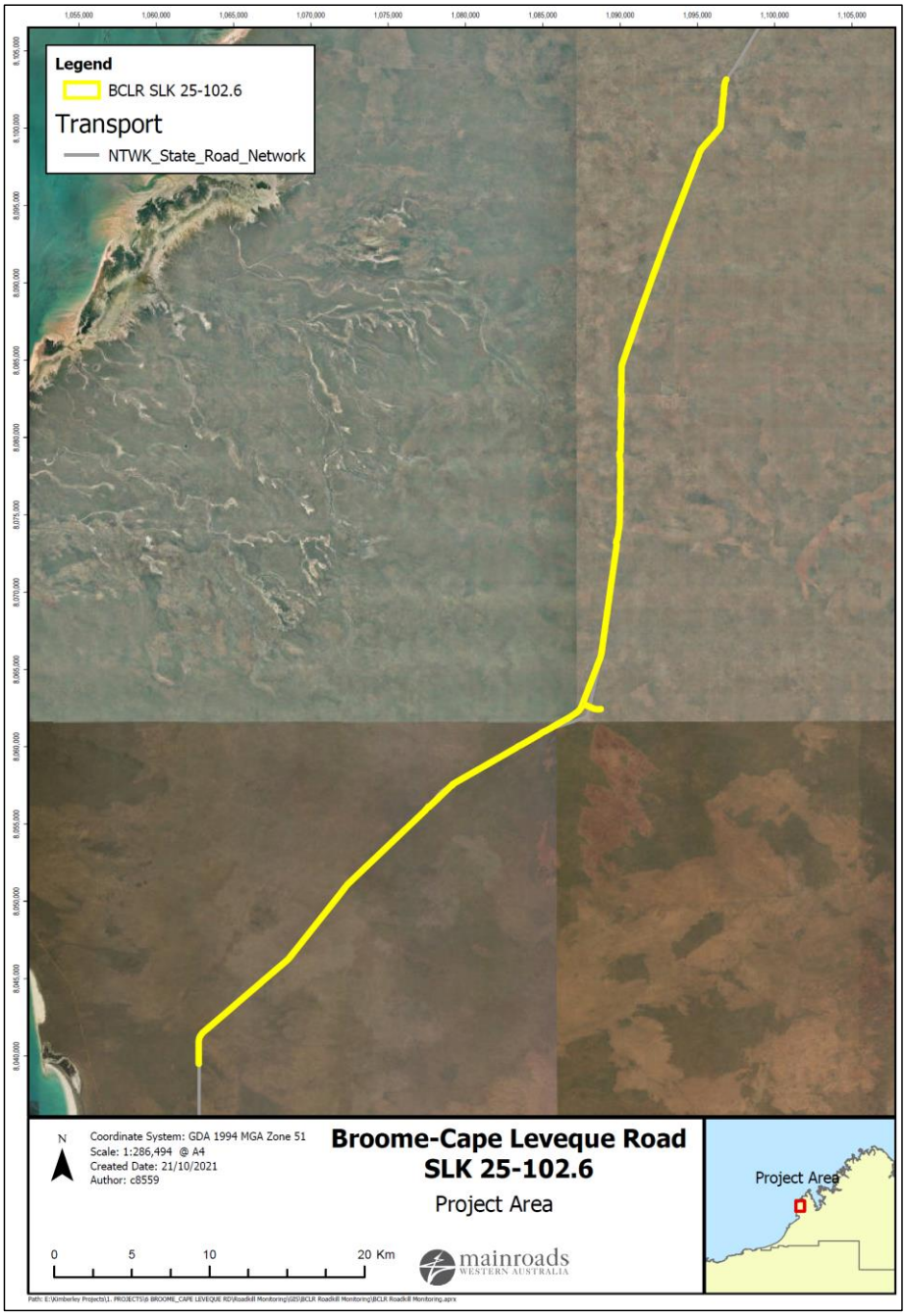

Figure 1: Project Area

2 METHODOLOGY

Roadkill monitoring along the BCLR has been undertaken in accordance with requirements of the RMAMP (GHD, 2016).

Prior to construction, monitoring was required twice a week for a period of eight weeks. Monitoring was not to be undertaken on the same day each week but undertaken on any day within any given week. The following data was required to be collected:

- Date.
- Time.
- GPS location coordinates.
- Photographic evidence of the roadkill (where the species is not known) and all Bilbies, to assist with animal identification.
- A DNA sample of the Bilby (depending on the condition of the roadkill) to determine sex, and where possible, age.
- Any noteworthy circumstances including circumstances of injury death where relevant and known.
- Lunar cycle.
- Weather condition preceding the survey.

Any roadkill identified was also removed from the edges of the road to a distance of approximately 40 m. Monitoring was undertaken at a speed of 50 km/hr.

During construction, roadkill monitoring was undertaken using the same methodology listed as for pre-construction monitoring. Monitoring was undertaken twice a week.

During operation of the road, the RMAMP required monitoring, using the same methodology as listed above, as a minimum twice a week for sixteen weeks post-construction, then once a week for three months. This post-construction monitoring is then to be undertaken annually until such time that monitoring data can demonstrate there is no decline in the local Greater Bilby population as a result of roadkill on the BCLR for three successive years (GHD, 2016).

Weather and lunar cycle data were not recorded at the time of monitoring and have been included at the time of writing this report. Lunar cycle data was obtained from the Perth Observatory website (Perth Observatory, 2021) and weather data was obtained from the Bureau of Meteorology website (BoM, 2021).

2.1 Definitions

The following descriptions were used to define carcass condition.

- **Fresh**: Blood may be coagulated, but no odour (flies may be present).
- **Initial Decay**: Signs of insect activity (maggots), some odour.
- **Putrefaction**: Bloating of carcass, internal decomposition, strong odour.
- **Black Putrefaction**: Collapsed carcass, black flesh, strong, cheesy-butyric acid odour.
- **Dry Decay**: No soft tissue remaining, skeletal, dried connective tissues or skin remain.

3 RESULTS

3.1 2015 - Pre-Construction

In 2015 between the months of July and November, 31 roadkill individuals were recorded from 24 monitoring days (Table 1). These comprised 21 wallabies, two cats, two Southern Boobooks, two Northern Blue-tongue Skinks, one Corella, one snake, one Butcherbird and one cow. No Greater Bilby individuals were recorded. The majority of road kills appear to be located between SLK 60 – 83, however, they do not appear to be clustered and are spread along the road (Figure 2). Lunar cycle does not appear to influence level of roadkill.

Table 1: Roadkill Monitoring Results – 2015

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2015	July	28	71.1	Wallaby	Black Putrefaction	122.533989	-17.36151		Sunny	Waxing Gibbous
2015	July	28	71.95	Cat	Dry Decay	122.535129	-17.353833		Sunny	Waxing Gibbous
2015	July	28	79.3	Snake	Dry Decay	122.537082	-17.288141		Sunny	Waxing Gibbous
2015	July	28	101.3	Butcherbird	Black Putrefaction	122.599327	-17.102133		Sunny	Waxing Gibbous
2015	July	28	63	Wallaby	Dry Decay	122.521753	-17.433764		Sunny	Waxing Gibbous
2015	August	6	16.65	Cat	Dry Decay	122.279399	-17.731392		Sunny	Last Quarter
2015	August	6	70.23	Wallaby	Dry Decay	122.534065	-17.361375		Sunny	Last Quarter
2015	August	6	70.67	Wallaby	Fresh	122.534565	-17.357355		Sunny	Last Quarter
2015	August	6	74.84	Wallaby	Black Putrefaction	122.536305	-17.320152		Sunny	Last Quarter
2015	August	11	16.23	Cow	Initial Decay	122.279444	-17.7425		Sunny	Waning Crescent
2015	August	11	57.73	Wallaby	Putrefaction	122.498611	-17.468056		Sunny	Waning Crescent
2015	August	11	63.00	Wallaby	Black Putrefaction	122.523333	-17.433612		Sunny	Waning Crescent
2015	August	11	63.06	Wallaby	Black Putrefaction	122.523333	-17.433056		Sunny	Waning Crescent

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2015	August	11	70.38	Wallaby	Dry Decay	122.533888	-17.368056		Sunny	Waning Crescent
2015	August	20	77.67	Wallaby	Black Putrefaction	122.53695	-17.30115		Early fog, scattered clouds 0.2mm	Waxing Crescent
2015	August	20	88.21	Wallaby	Fresh	122.55579	-17.20892		Early fog, scattered clouds 0.2mm	Waxing Crescent
2015	August	28	78.8	Southern Boobook	Putrefaction	122.536984	-17.292426		Passing clouds	Waxing Gibbous
2015	August	28	72.6	Northern Blue-tongue Skink	Putrefaction	122.536639	-17.349065		Passing clouds	Waxing Gibbous
2015	August	28	51.5	Northern Blue-tongue Skink	Initial Decay	122.536639	-17.349065		Passing clouds	Waxing Gibbous
2015	September	3	61.72	Wallaby	Dry Decay	122.52112	-17.44111		Haze	Waning Gibbous
2015	September	10		NO ROADKILL FOUND					Passing clouds	Waning Crescent
2015	September	17	69.9	Wallaby	Fresh	122.53493	-17.35911		Sunny Passing clouds	Waxing Crescent
2015	October	6		NO ROADKILL FOUND					Passing clouds	Waning Crescent
2015	October	9		NO ROADKILL FOUND					Passing clouds	Waning Crescent
2015	October	13	57.09	Wallaby	Black Putrefaction	122.49293	-17.4701	40km of road received heavy rain	Partly sunny	New Moon
2015	October	16		NO ROADKILL FOUND					Scattered clouds	Waxing Crescent
2015	October	20	117.15	Wallaby	Black Putrefaction	122.701133	-17.022678		Passing clouds	First Quarter
2015	October	20	44.76	Wallaby	Fresh	122.399743	-17.533651		Passing clouds	First Quarter

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2015	October	23	62.289	Wallaby	Dry Decay	122.52196	-17.43986		Overcast to scattered clouds	Waxing Gibbous
2015	October	23	62.411	Wallaby	Dry Decay	122.52215	-17.43877		Overcast to scattered clouds	Waxing Gibbous
2015	October	27		NO ROADKILL FOUND					Partly sunny	Full Moon
2015	October	29	88.38	Southern Boobook	Black Putrefaction	122.55575	-17.20926		Passing clouds	Waning Gibbous
2015	October	29	80.39	Corella	Black Putrefaction	122.53755	-17.27832		Passing clouds	Waning Gibbous
2015	November	3		NO ROADKILL FOUND					Passing clouds	Last Quarter
2015	November	6	75.78	Wallaby	Putrefaction	122.53654	-17.31969		Scattered clouds	Waning Crescent
2015	November	11		NO ROADKILL FOUND					Scattered clouds	New Moon
2015	November	13	70.7	Wallaby	Black Putrefaction	-17.364127	122.534578		Passing clouds	Waxing Crescent
2015	November	13	96.4	Wallaby	Black Putrefaction	-17.141744	122.582406		Passing clouds	Waxing Crescent
2015	November	18		NO ROADKILL FOUND					Haze Passing clouds	First Quarter
2015	November	19		NO ROADKILL FOUND					Haze Passing clouds	First Quarter
2015	November	25		NO ROADKILL FOUND					Partly sunny	Full Moon
2015	November	26		NO ROADKILL FOUND					Passing clouds	Full Moon

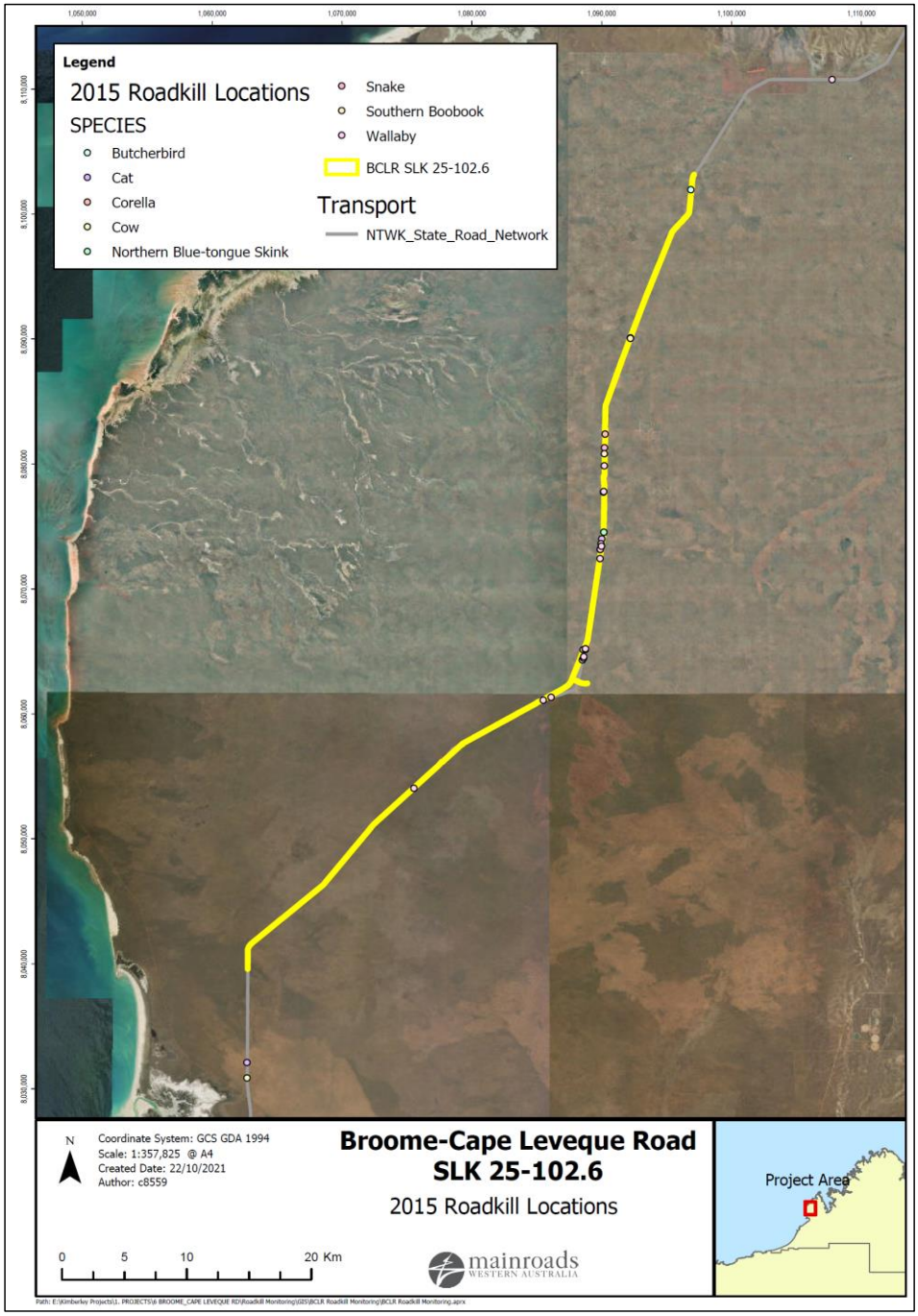

Figure 2: 2015 Roadkill Locations

3.2 2017 – Pre-Construction

In 2017 between the months of June and October, 13 roadkill individuals were recorded from 7 monitoring days (Table 2). These comprised five wallabies, two cats, one Black Headed Python, one Northern Blue-tongue Skink, one Euro, one raptor, one donkey and one Zebra Finch. No Greater Bilby individuals were recorded. The road kills are scattered along the length of the road and there does not appear to be any clusters of activity (Figure 3). Lunar cycle does not appear to influence level of roadkill.

Table 2: Roadkill Monitoring Results - 2017

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2017	June	23	75.69	Wallaby	Fresh	122.53656	-17.320475			New Moon
2017	June	23	89.53	Cat	Dry Decay	122.559402	-17.199589			New Moon
2017	June	26	27.08	Wallaby	Fresh	122.28286	-17.645613	Blind corner - photo taken after moving	Waxing Crescent	
2017	July	10	94.28	Black Headed Python	Fresh	122.575183	-17.159644			Full Moon
2017	July	10	12.94	Wallaby		122.281919	-17.771962			Full Moon
2017	July	14	56.62	Wallaby		122.489108	-17.472096			Waning Gibbous
2017	July	14	103.38	Wallaby		122.605879	-17.085679			Waning Gibbous
2017	September	1	71.49	Northern Blue-tongue Skink	Fresh	122.535346	-17.3582		Cloudy 0.2mm	Waxing Gibbous
2017	September	1	51.08	Euro		122.443835	-17.49654		Cloudy 0.2mm	Waxing Gibbous
2017	October	4		NO ROADKILL FOUND						Waxing Gibbous
2017	October	26	113.01	Cat	Dry Decay	122.661757	-17.022675			First Quarter
2017	October	26	113.09	Bird - Raptor	Dry Decay	122.662535	-17.022598			First Quarter
2017	October	26	117.5	Donkey	Black Putrefaction	122.7014607	-17.014607			First Quarter
2017	October	26	104.6	Zebra Finch	Dry Decay					First Quarter

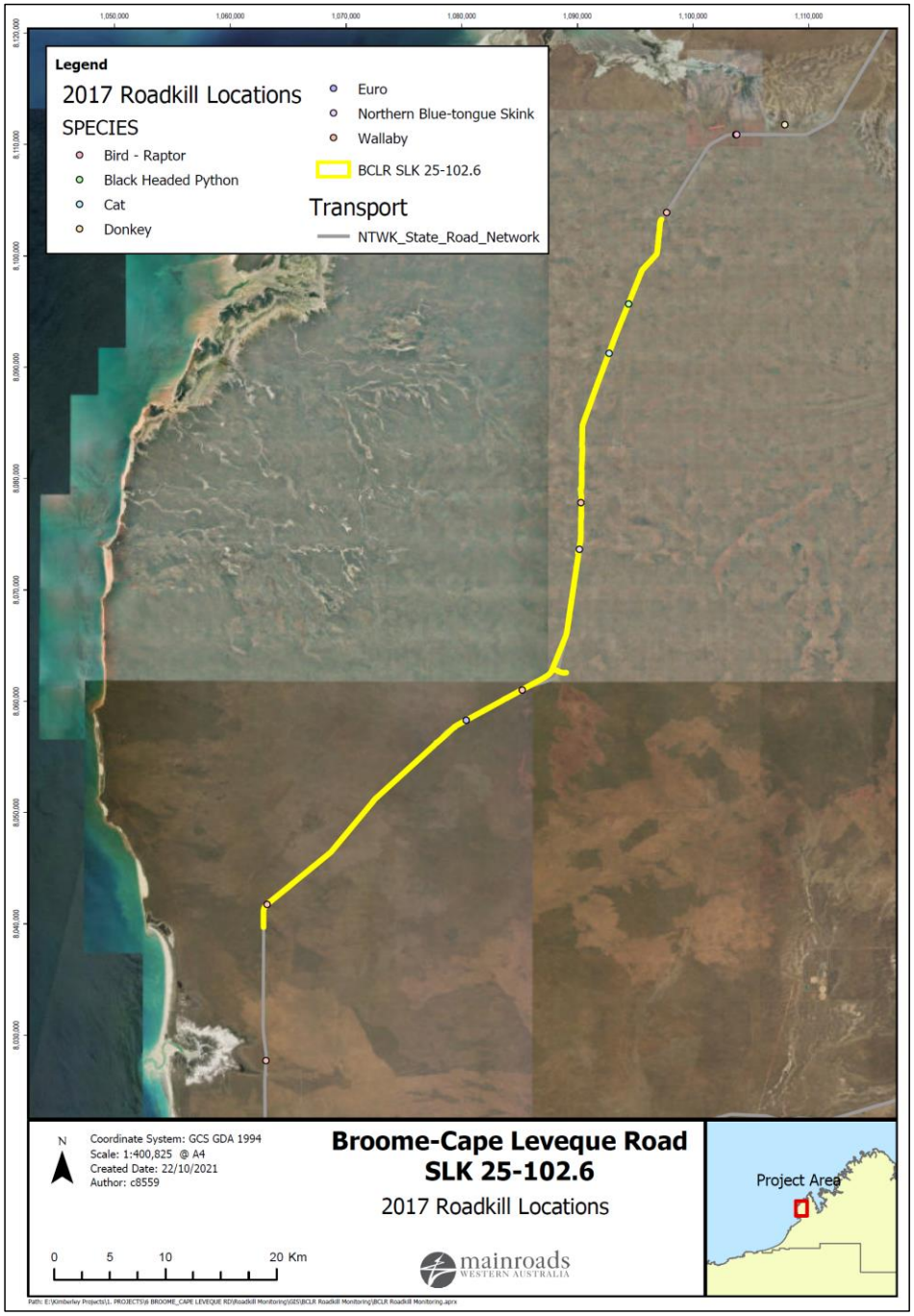

Figure 3: 2017 Roadkill Locations

3.3 2018 – Pre-Construction

In 2018, pre-construction of the BCLR (January – December), 47 roadkill individuals were recorded from 66 monitoring days (Table 3). These comprised 11 Agile Wallabies, seven wallabies, four Black Headed Pythons, four Southern Boobooks, three Stimson's Pythons, two Dingos/dogs, two kites/falcons, one Euro, one Frogmouth, one raptor, one cow, one Bungarra, one Australian Bustard, one crow, one Carpet Python, one Butcherbird, one cat, one owl, one Wallaroo, one bird of prey (unknown) and one bull. No Greater Bilby individuals were recorded. The road kills appear to be spread along the length of the road (Figure 4). Lunar cycle does not appear to influence level of roadkill.

Table 3: Roadkill Monitoring Results – Pre-Construction 2018

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2018	January	23	21.17	Euro	Black Putrefaction	122.279	-17.698		Hot 5.6mm	First Quarter
2018	March	21	3.16	Frogmouth	Fresh	122.27627	-17.8593	Sealed section, around from turnoff	Passing clouds	Waxing Crescent
2018	March	21	11.30	Dingo/Dog	Dry Decay	122.28101	-17.78662	LHS drain	Passing clouds	Waxing Crescent
2018	March	21	11.36	Raptor	Initial Decay	122.28107	-17.7861	Sealed. LHS	Passing clouds	Waxing Crescent
2018	March	21	60.23	Kite/Falcon	Fresh	122.51759	-17.45784	Straight unsealed section	Passing clouds	Waxing Crescent
2018	March	21	111.47	Black Headed Python	Dry Decay	122.64838	-17.02667	Sealed section	Passing clouds	Waxing Crescent
2018	April	9	53.73	Kite/Falcon	Fresh	122.46555	-17.48491	Sealed section		Last Quarter
2018	April	9	87.60	Cow	Dry Decay	122.55335	-17.21589	Straight unsealed section		Last Quarter
2018	April	9	49.49	Wallaby	Initial Decay	122.43105	-17.50378	Straight unsealed section		Last Quarter
2018	April	10	10.5	Southern Boobook	Fresh	122.28099	-17.79294	Sealed	Hot 0.2mm	Waning Crescent

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2018	April	10	11.7	Southern Boobook	Fresh	122.28122	-17.78313	Sealed	Hot 0.2mm	Waning Crescent
2018	April	10	11.9	Stimson's Python	Initial Decay	122.28137	-17.78108	Sealed, moved off seal for pic id	Hot 0.2mm	Waning Crescent
2018	April	10	10.8	Bungarra	Fresh	122.28097	-17.79061	Sealed	Hot 0.2mm	Waning Crescent
2018	April	13	62.18	Black Headed Python	Initial Decay	122.52167	-17.44088	Unsealed		Waning Crescent
2018	April	13	10.39	Australian Bustard	Initial Decay	122.28102	-17.7948	Sealed		Waning Crescent
2018	April	13	7.62	Crow	Dry Decay	122.28119	-17.81977	Sealed		Waning Crescent
2018	April	23	0.9	Southern Boobook	Initial Decay	122.27545	-17.87925	Sealed		First Quarter
2018	May	1		NO ROADKILL FOUND						Full Moon
2018	May	4		NO ROADKILL FOUND						Waning Gibbous
2018	May	7	16.99	Black Headed Python	Fresh	122.27964	-17.73567	Unsealed		Last Quarter
2018	May	7	29.34	Carpet Python	Fresh	122.29893	-17.63251	Unsealed		Last Quarter
2018	May	9	9.09	Butcher Bird	Fresh	122.28108	-17.80655	Sealed		Last Quarter
2018	May	9	102.2	Cat	Initial Decay	122.60059	-17.09646	Unsealed		Last Quarter
2018	May	14		NO ROADKILL FOUND						New Moon
2018	May	17	83.43	Wallaby	Initial Decay	122.54042	-17.25137	Unsealed		Waxing Crescent
2018	May	21	77.16	Wallaby	Initial Decay	122.53683	-17.30737	Unsealed	Passing clouds	First Quarter
2018	May	25	97.76	Owl	Initial Decay	122.5876	-17.130085	Unsealed		Waxing Gibbous
2018	May	30	60.04	Wallaroo	Initial Decay	122.51717	-17.45966	Unsealed, after bend	Scattered clouds	Full Moon

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2018	June	2		NO ROADKILL FOUND						Waning Gibbous
2018	June	5		NO ROADKILL FOUND						Last Quarter
2018	June	8	37.58	Stimson's Python	Fresh	122.35367	-17.58056	Unsealed		Waning Crescent
2018	June	12	80.86	Southern Boobook	Initial Decay	122.53.778	-17.27406	Unsealed		Waning Crescent
2018	June	14	83.41	Wallaby	Putrefaction	122.54059	-17.25159	Unsealed, drain		New Moon
2018	June	19		NO ROADKILL FOUND						First Quarter
2018	June	22		NO ROADKILL FOUND						Waxing Gibbous
2018	June	26		NO ROADKILL FOUND						Waxing Gibbous
2018	June	29	61.59	Black Headed Python	Initial Decay	122.52045	-17.44609	Unsealed		Full Moon
2018	June	29	60.88	Wallaby	Initial Decay	122.51895	-17.45222	Unsealed		Full Moon
2018	June	29	31.92	Wallaby	Black Putrefaction	122.31736	-1761751	Unsealed		Full Moon
2018	July	2		NO ROADKILL FOUND						Waning Gibbous
2018	July	5	43.78	Wallaby	Black Putrefaction	122.24368	-17.94378	Unsealed		Last Quarter
2018	July	11		NO ROADKILL FOUND						Waning Crescent
2018	July	13		NO ROADKILL FOUND						New Moon
2018	July	16		NO ROADKILL FOUND						Waxing Crescent
2018	July	16	32.55	Agile Wallaby	Initial Decay	122.32194	-17.61375	Unsealed		Waxing Crescent
2018	July	20	1.24	Stimson's Python	Fresh	122.27468	-17.87627	Sealed		First Quarter
2018	July	20	14.14	Agile Wallaby	Fresh	122.2813	-17.76116	Unsealed		First Quarter

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2018	July	20	71.28	Dingo/Dog	Dry Decay	122.5352	-17.36004			First Quarter
2018	July	30	56.99	Agile Wallaby	Initial Decay	122.49198	-17.47044			Waning Gibbous
2018	July	30	63	Agile Wallaby	Putrefaction	122.52337	-17.43371			Waning Gibbous
2018	July	30	69.82	Agile Wallaby	Initial Decay	122.53328	-17.37315			Waning Gibbous
2018	July	30	70.34	Agile Wallaby	Putrefaction	122.53394	-17.36848			Waning Gibbous
2018	July	30	71.54	Agile Wallaby	Fresh	122.53543	-17.3578			Waning Gibbous
2018	August	6	72.92	Bird of Prey	Fresh	122.53697	-17.34548			Waning Crescent
2018	August	6	67.41	Agile Wallaby	Putrefaction	122.53016	-17.39465			Waning Crescent
2018	August	9		NO ROADKILL FOUND						Waning Crescent
2018	August	13		NO ROADKILL FOUND						Waxing Crescent
2018	August	16		NO ROADKILL FOUND						Waxing Crescent
2018	August	20		NO ROADKILL FOUND						Waxing Gibbous
2018	August	23		NO ROADKILL FOUND						Waxing Gibbous
2018	August	31		NO ROADKILL FOUND						Waning Gibbous
2018	September	10		NO ROADKILL FOUND						New Moon
2018	September	13	52.23	Agile Wallaby	Initial Decay	122.45325	-17.49168	Unsealed		Waxing Crescent
2018	September	19		NO ROADKILL FOUND						Waxing Gibbous
2018	September	21		NO ROADKILL FOUND					Passing clouds	Waxing Gibbous

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2018	September	25		NO ROADKILL FOUND						Full Moon
2018	September	27	65.8	Agile Wallaby	Initial Decay	122.52788	-17.40892	Unsealed	0.2mm	Waning Gibbous
2018	October	3		NO ROADKILL FOUND						Last Quarter
2018	October	9		NO ROADKILL FOUND					Passing clouds	New Moon
2018	October	10		NO ROADKILL FOUND						New Moon
2018	October	16		NO ROADKILL FOUND						First Quarter
2018	October	18		NO ROADKILL FOUND						Waxing Gibbous
2018	October	23		NO ROADKILL FOUND						Full Moon
2018	October	26		NO ROADKILL FOUND						Waning Gibbous
2018	October	30		NO ROADKILL FOUND					Scattered clouds	Last Quarter
2018	November	2		NO ROADKILL FOUND						Waning Crescent
2018	November	5		NO ROADKILL FOUND						Waning Crescent
2018	November	8		NO ROADKILL FOUND						New Moon
2018	November	12		NO ROADKILL FOUND						Waxing Crescent
2018	November	15		NO ROADKILL FOUND						First Quarter
2018	November	21		NO ROADKILL FOUND						Waxing Gibbous
2018	November	22	12.18	Bull	Fresh	122.28156	-17.77877	Sealed	Scattered clouds	Full Moon
2018	November	26		NO ROADKILL FOUND					Passing clouds	Waning Gibbous

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2018	November	27		NO ROADKILL FOUND					Overcast	Waning Gibbous
2018	November	29		NO ROADKILL FOUND					Passing clouds	Last Quarter
2018	December	3		NO ROADKILL FOUND					Passing clouds	Waning Crescent
2018	December	11		NO ROADKILL FOUND						Waxing Crescent
2018	December	12	81.16	Agile Wallaby	Fresh	122.53772	-17.27142	Unsealed, pinkie alongside	Overcast	Waxing Crescent
2018	December	13		NO ROADKILL FOUND					Passing clouds	Waxing Crescent

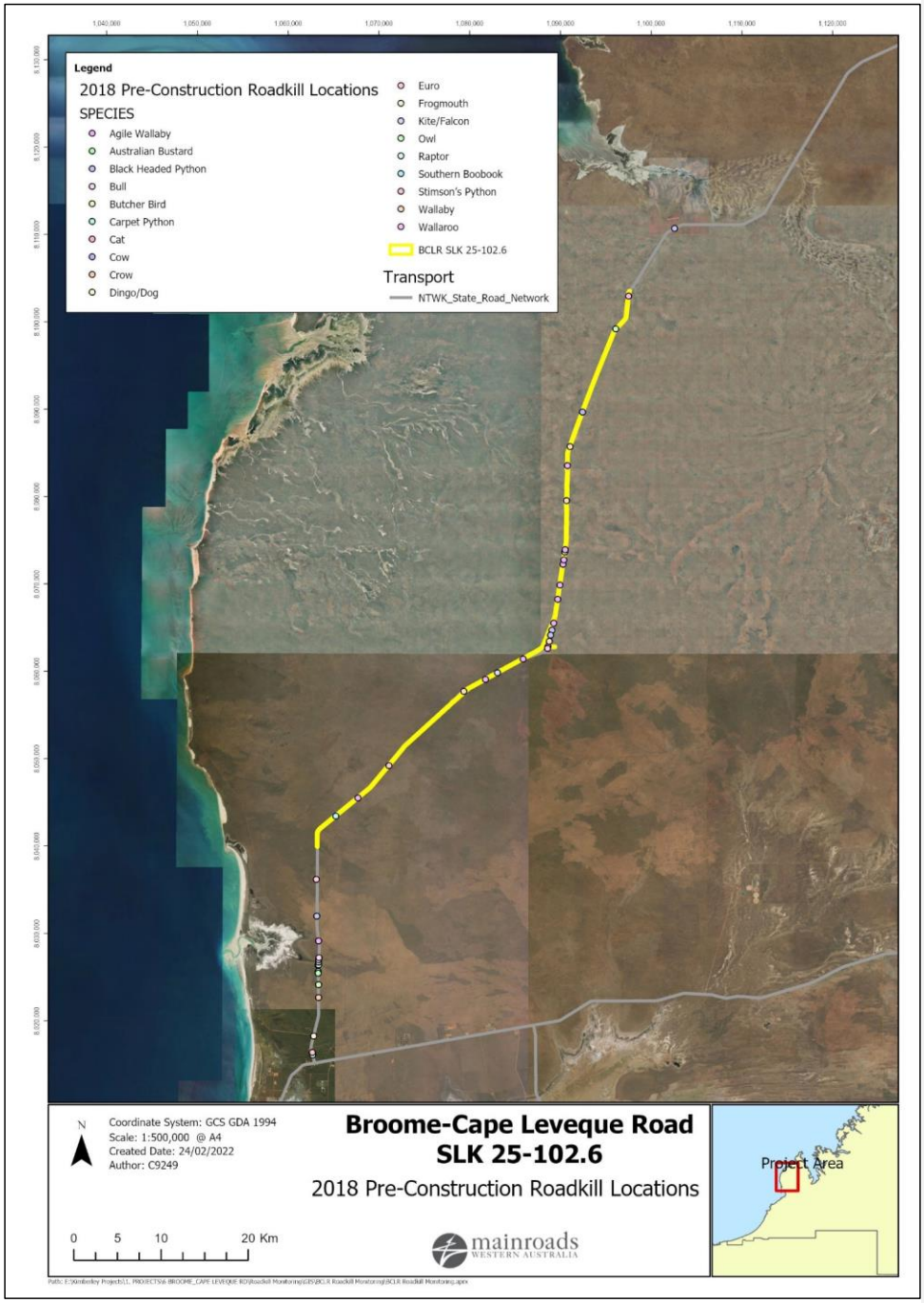

Figure 4: 2018 Pre-Construction Roadkill Locations

3.4 2018 – Construction

In 2018, during construction of the BCLR (June – December), 17 roadkill individuals were recorded from 43 monitoring days (Table 4). These comprised 13 Little Corellas, two birds of prey and two Agile Wallabies. No Greater Bilby individuals were recorded. The majority of road kills appear to be located between SLK 83 – 88, with Little Corellas being the most common species recorded within this section. There appears to be a small cluster of roadkill recordings at a bend in the road at SLK 83.6 (Figure 5). Lunar cycle does not appear to influence level of roadkill.

Table 4: Roadkill Monitoring Results – Construction 2018

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2018	June	8		NO ROADKILL FOUND						Waning Crescent
2018	June	12		NO ROADKILL FOUND						Waning Crescent
2018	June	19		NO ROADKILL FOUND						First Quarter
2018	June	26		NO ROADKILL FOUND						Waxing Gibbous
2018	June	29		NO ROADKILL FOUND						Full Moon
2018	July	16	83.57	Little Corella	Initial Decay	122.54093	-17.25019	Unsealed		Waxing Crescent
2018	July	16	83.57	Little Corella	Initial Decay	122.54093	-17.25019	Unsealed (2 together)		Waxing Crescent
2018	July	16	87.3	Little Corella	Fresh	122.55221	-17.21852	Unsealed		Waxing Crescent
2018	July	23	83.56	Little Corella	Fresh	122.5407	-17.25021	Unsealed	0.2mm	Waxing Gibbous
2018	July	26	83.65	Little Corella	Fresh	122.54102	-17.24946	Unsealed		Full Moon
2018	July	26	84.1	Little Corella	Fresh	122.54235	-17.24565	Unsealed		Full Moon
2018	July	26	84.19	Little Corella	Fresh	122.54265	-17.24483	Unsealed		Full Moon
2018	July	26	85.53	Little Corella	Fresh	122.54673	-17.23349	Unsealed		Full Moon
2018	July	30	86.7	Little Corella	Fresh	122.55045	-17.22358	Unsealed		Waning Gibbous
2018	July	30	84.45	Bird of Prey	Fresh	122.54342	-17.24267	Unsealed		Waning Gibbous
2018	August	6	81.08	Little Corella	Fresh	122.53774	-17.27216	Unsealed		Waning Crescent

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2018	August	6	86.37	Little Corella	Fresh	122.54941	-17.22639	Unsealed		Waning Crescent
2018	August	6	83.98	Little Corella	Fresh	122.54204	-17.24664	Unsealed		Waning Crescent
2018	August	6	83.72	Little Corella	Fresh	122.54129	-17.2489	Unsealed		Waning Crescent
2018	August	9		NO ROADKILL FOUND						Waning Crescent
2018	August	13		NO ROADKILL FOUND						Waxing Crescent
2018	August	16		NO ROADKILL FOUND						Waxing Crescent
2018	August	20		NO ROADKILL FOUND						Waxing Gibbous
2018	August	23		NO ROADKILL FOUND						Waxing Gibbous
2018	August	31		NO ROADKILL FOUND						Waning Gibbous
2018	September	10		NO ROADKILL FOUND						New Moon
2018	September	12	84.51	Bird of Prey	Initial Decay	122.54367	-17.24212	Unsealed		Waxing Crescent
2018	September	19		NO ROADKILL FOUND						Waxing Gibbous
2018	September	21		NO ROADKILL FOUND						Waxing Gibbous
2018	September	25		NO ROADKILL FOUND						Full Moon
2018	September	27		NO ROADKILL FOUND					0.2mm	Waning Gibbous
2018	October	3		NO ROADKILL FOUND						Last Quarter
2018	October	9		NO ROADKILL FOUND					Passing clouds	New Moon
2018	October	10		NO ROADKILL FOUND						New Moon

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2018	October	16	81.74	Agile Wallaby		122.53838	-17.25723	Unsealed, with joey		First Quarter
2018	October	18	78.13	Agile Wallaby		122.53701	-17.29862			Waxing Gibbous
2018	October	23		NO ROADKILL FOUND						Full Moon
2018	October	26		NO ROADKILL FOUND						Waning Gibbous
2018	October	30		NO ROADKILL FOUND					Overcast to scattered clouds	Last Quarter
2018	November	2		NO ROADKILL FOUND						Waning Crescent
2018	November	5		NO ROADKILL FOUND					Overcast	Waning Crescent
2018	November	8		NO ROADKILL FOUND						New Moon
2018	November	12		NO ROADKILL FOUND						Waxing Crescent
2018	November	15		NO ROADKILL FOUND						First Quarter
2018	November	21		NO ROADKILL FOUND						Waxing Gibbous
2018	November	22		NO ROADKILL FOUND					Passing clouds	Full Moon
2018	November	26		NO ROADKILL FOUND					Passing clouds	Waning Gibbous
2018	November	27		NO ROADKILL FOUND					Overcast	Waning Gibbous
2018	November	29		NO ROADKILL FOUND					Passing clouds	Last Quarter
2018	December	3		NO ROADKILL FOUND					Passing clouds	Waning Crescent
2018	December	11		NO ROADKILL FOUND						Waxing Crescent
2018	December	12		NO ROADKILL FOUND						Waxing Crescent

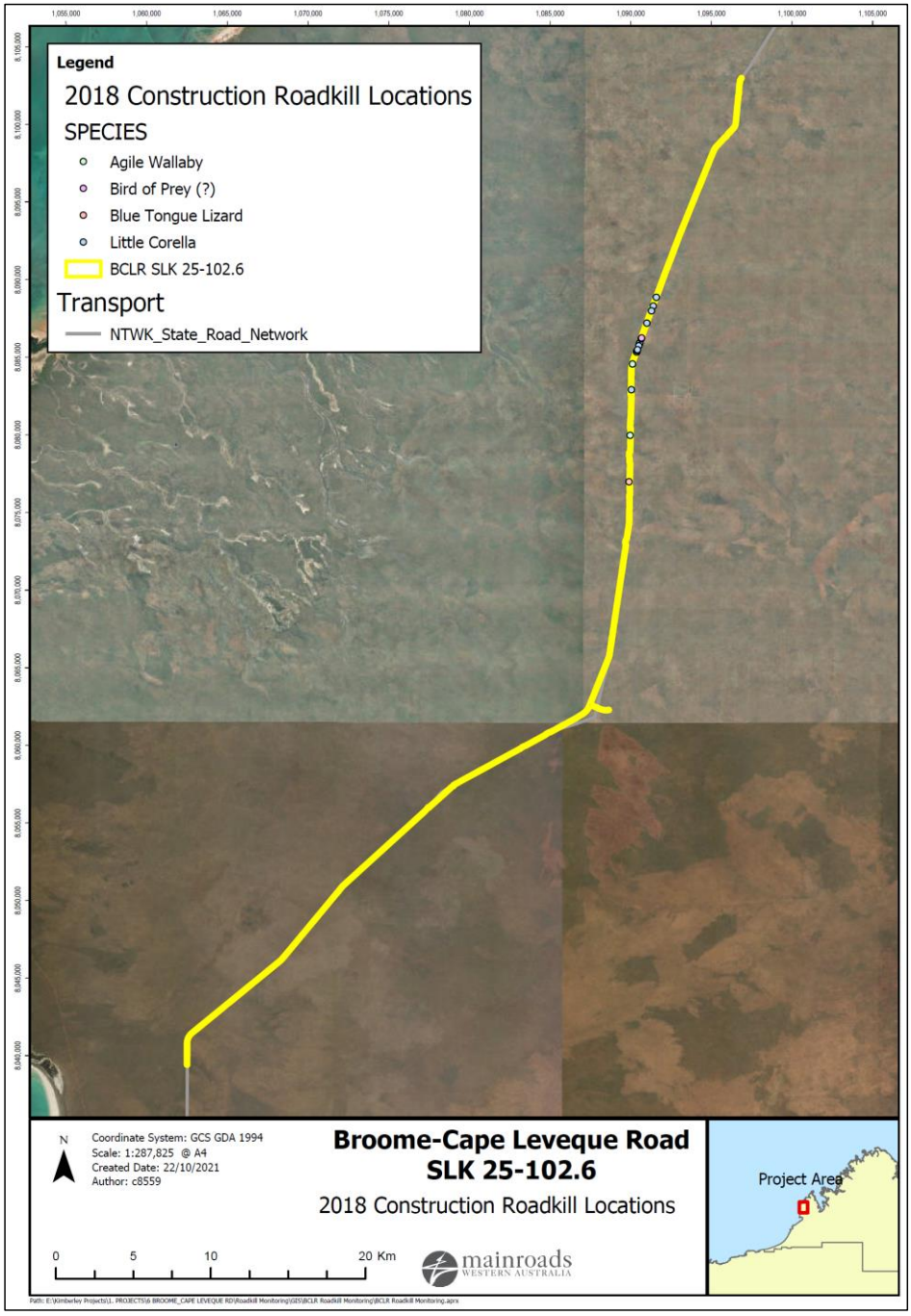

Figure 5: 2018 Construction Roadkill Locations

3.5 2019 – Construction

In 2019 between the months of April and December, 15 roadkill individuals were recorded from 64 monitoring days (Table 5). These comprised seven Agile Wallabies, three falcons, two wallabies, one Dingo, one Black Headed Python and one Brown Honey Eater. No Greater Bilby individuals were recorded. The road kills appear to be spread along the length of the road (Figure 6). Lunar cycle does not appear to influence level of roadkill.

Table 5: Roadkill Monitoring Results - 2019

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2019	April	16	98.63	Agile Wallaby	Putrefaction	122.5929	-17.12493			Waxing Gibbous
2019	April	18	96.26	Agile Wallaby	Putrefaction	122.58168	-17.14298			Full Moon
2019	April	18	102.42	Agile Wallaby	Putrefaction	122.60137	-17.09304			Full Moon
2019	April	19		NO ROADKILL FOUND						Full Moon
2019	April	24	96.26	Agile Wallaby		122.58168	-17.142898			Waning Gibbous
2019	April	24	102.42	Agile Wallaby		122.60137	-17.09304			Waning Gibbous
2019	April	26		NO ROADKILL FOUND						Last Quarter
2019	April	27		NO ROADKILL FOUND						Last Quarter
2019	April	30		NO ROADKILL FOUND						Waning Crescent
2019	May	1		NO ROADKILL FOUND						Waning Crescent
2019	May	3		NO ROADKILL FOUND					Overcast	New Moon
2019	May	7		NO ROADKILL FOUND						Waxing Crescent
2019	May	10		NO ROADKILL FOUND					Passing clouds	Waxing Crescent
2019	May	13		NO ROADKILL FOUND					Scattered clouds	Waxing Gibbous
2019	May	17		NO ROADKILL FOUND						Full Moon

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2019	May	21		NO ROADKILL FOUND					Overcast	Waning Gibbous
2019	May	23		NO ROADKILL FOUND						Waning Gibbous
2019	May	28		NO ROADKILL FOUND						Waning Crescent
2019	May	29		NO ROADKILL FOUND						Waning Crescent
2019	June	5		NO ROADKILL FOUND						Waxing Crescent
2019	June	9		NO ROADKILL FOUND						First Quarter
2019	June	11		NO ROADKILL FOUND						First Quarter
2019	June	13		NO ROADKILL FOUND						Waxing Gibbous
2019	June	18		NO ROADKILL FOUND						Full Moon
2019	June	20		NO ROADKILL FOUND					Overcast	Waning Gibbous
2019	June	24	51.51	Agile Wallaby	Putrefaction	122.4474	-17.4948			Last Quarter
2019	June	27		NO ROADKILL FOUND						Waning Crescent
2019	July	4		NO ROADKILL FOUND						Waxing Crescent
2019	July	10		NO ROADKILL FOUND						First Quarter
2019	July	10		NO ROADKILL FOUND						First Quarter
2019	July	10		NO ROADKILL FOUND						First Quarter
2019	July	15		NO ROADKILL FOUND						Full Moon
2019	July	25		NO ROADKILL FOUND						Last Quarter

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2019	August	6		NO ROADKILL FOUND						First Quarter
2019	August	8		NO ROADKILL FOUND						First Quarter
2019	August	14	56.34	Agile Wallaby	Fresh	122.48679	-17.47339			Full Moon
2019	August	16		NO ROADKILL FOUND						Full Moon
2019	August	20		NO ROADKILL FOUND						Waning Gibbous
2019	August	23		NO ROADKILL FOUND						Last Quarter
2019	August	26		NO ROADKILL FOUND						Waning Crescent
2019	August	28	41.03	Falcon	Fresh	122.37427	-17.55674			Waning Crescent
2019	August	30		NO ROADKILL FOUND						New Moon
2019	September	3		NO ROADKILL FOUND					0.2mm	Waxing Crescent
2019	September	6		NO ROADKILL FOUND					Passing clouds	First Quarter
2019	September	10	100.95	Falcon	Fresh	122.59952	-1710606		Sunny	Waxing Gibbous
2019	September	10	100.95	Falcon	Fresh	122.59952	-1710606		Sunny	Waxing Gibbous
2019	September	12		NO ROADKILL FOUND						Waxing Gibbous
2019	September	17		NO ROADKILL FOUND					0.2mm	Waning Gibbous
2019	September	20		NO ROADKILL FOUND						Waning Gibbous
2019	September	24		NO ROADKILL FOUND						Waning Crescent
2019	September	26		NO ROADKILL FOUND						Waning Crescent

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2019	October	1		NO ROADKILL FOUND						Waning Crescent
2019	October	4		NO ROADKILL FOUND						First Quarter
2019	October	8	73.53	Dingo	Initial Decay	122.53694	-17.33997			Waxing Gibbous
2019	October	8	94.75	Black Headed Python	Fresh	122.57659	-17.15567			Waxing Gibbous
2019	October	12		NO ROADKILL FOUND					0.2mm	Full Moon
2019	October	14		NO ROADKILL FOUND						Full Moon
2019	October	18		NO ROADKILL FOUND						Waning Gibbous
2019	October	21	1008	Brown Honey Eater	Fresh	122.52613	-17.42062			Last Quarter
2019	October	23		NO ROADKILL FOUND						Waning Crescent
2019	October	25		NO ROADKILL FOUND						Waning Crescent
2019	October	29		NO ROADKILL FOUND						Waxing Crescent
2019	October	31		NO ROADKILL FOUND						Waxing Crescent
2019	November	5	71.05	Wallaby	Fresh	122.53465	-17.3621			First Quarter
2019	November	7		NO ROADKILL FOUND						Waxing Gibbous
2019	November	13		NO ROADKILL FOUND						Full Moon
2019	November	14		NO ROADKILL FOUND						Waning Gibbous
2019	November	19		NO ROADKILL FOUND						Last Quarter
2019	November	20		NO ROADKILL FOUND					Passing clouds	Last Quarter

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2019	December	7	62.500	Wallaby	Fresh					Waxing Gibbous

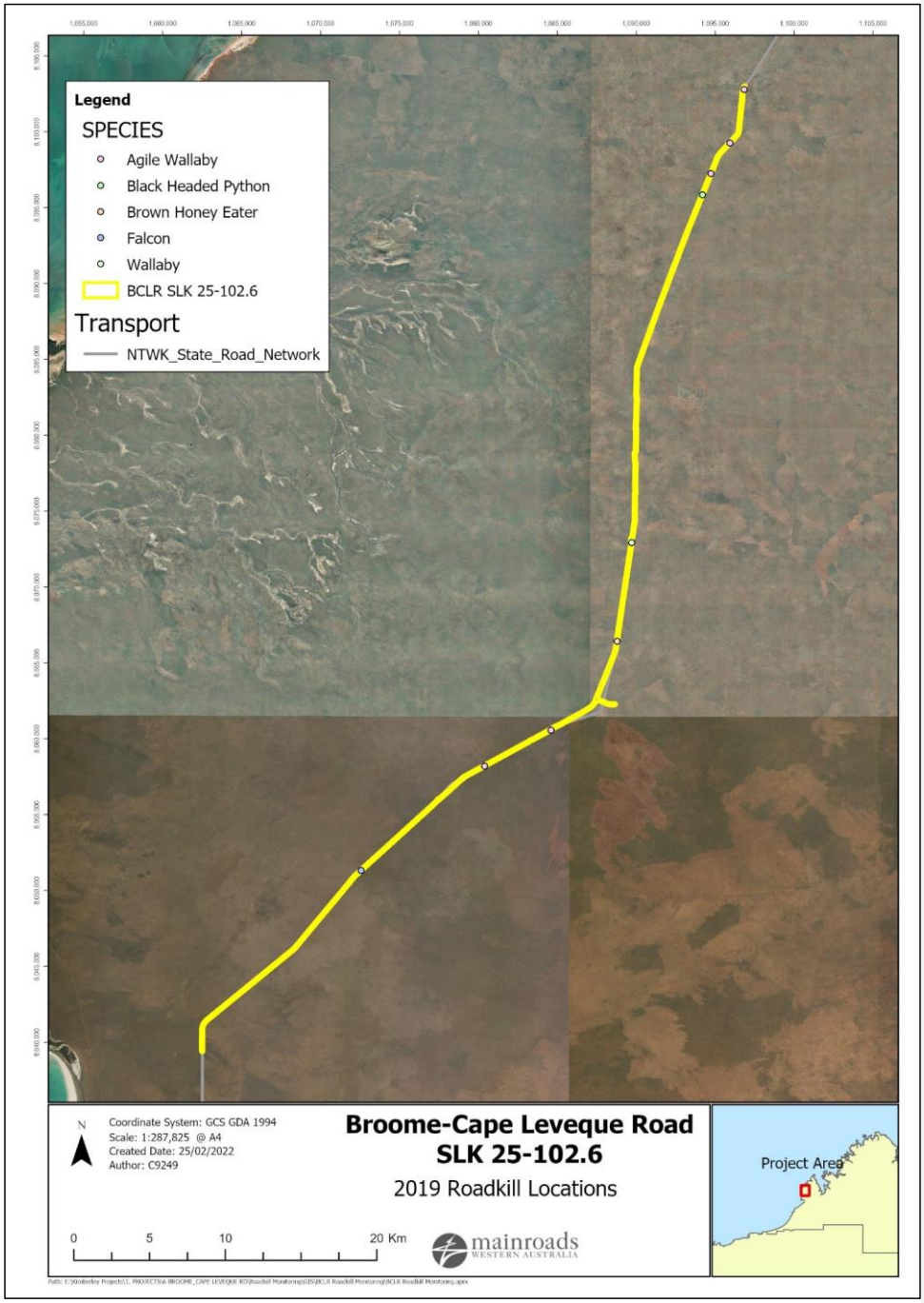

Figure 6: 2019 Roadkill Locations

3.6 2020 – Construction

In 2020 between the months of January and December, 13 roadkill individuals were recorded from 45 monitoring days (Table 6). These comprised seven Agile Wallabies, one Frilled Neck Lizard, three Bungarra (Sand Goanna), one Bird of Prey and one Black Head Python. No Greater Bilby individuals were recorded. The road kills appear to be spread along the length of the road (Figure 7).

One roadkill Greater Bilby was reported to Main Roads by a DBCA officer on 8 October 2020. The roadkill was recorded on 2 October 2020 on BCLR near the McGuigan Road turn off, approximately at SLK 5.3. The officer collected ear and tail tissue samples for DNA analysis for comparison against scat samples previously collected from the area. The officer noted the specimen was in poor condition at the time of recording with several birds of prey eating it. As the roadkill was recorded outside the monitoring area (SLK 25 – 102.6), this record does not trigger the Greater Bilby management conditions in the RMAMP.

Lunar cycle does not appear to influence level of roadkill.

Table 6: Roadkill Monitoring Results – 2020

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LATITUDE	LONGITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2020	January	8		NO ROADKILL FOUND					Overcast	Waxing Gibbous
2020	January	21		NO ROADKILL FOUND					Overcast	Waning Crescent
2020	February	10		NO ROADKILL FOUND					Sunny	Full Moon
2020	February	24		NO ROADKILL FOUND					Sunny	Full Moon
2020	March	4		NO ROADKILL FOUND					Passing clouds	Waxing Gibbous
2020	March	10	73.98	Frilled Neck Lizard	Fresh	-17.33595	122.53682	Construction	Sunny	Full Moon
2020	March	10	65.42	Agile Wallaby	Fresh	-17.41228	122.52716	Construction	Sunny	Full Moon
2020	March	10	27.89	Bungarra	Fresh	-17.64097	122.28876	Construction	Sunny	Full Moon
2020	March	17		NO ROADKILL FOUND					Some clouds	Last Quarter
2020	March	24		NO ROADKILL FOUND						New Moon
2020	March	25		NO ROADKILL FOUND						New Moon

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LATITUDE	LONGITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2020	March	27		NO ROADKILL FOUND					Passing clouds	Waxing Crescent
2020	April	8		NO ROADKILL FOUND						Full Moon
2020	April	14		NO ROADKILL FOUND					Scattered clouds	Last Quarter
2020	April	21	3.99	Bungarra	Fresh	-17.85201	122.27793	Pre-construction		New Moon
2020	April	22		NO ROADKILL FOUND						New Moon
2020	May	12		NO ROADKILL FOUND						Waning Gibbous
2020	May	20		NO ROADKILL FOUND					Light rain, Overcast	Waning Crescent
2020	May	29		NO ROADKILL FOUND					Overcast	First Quarter
2020	June	2		NO ROADKILL FOUND						Waxing Gibbous
2020	June	12		NO ROADKILL FOUND						Last Quarter
2020	June	15	56.06	Agile Wallaby	Fresh	-17.47462	122.48457	Pre-construction Dinner Camp Bend		Waning Crescent
2020	June	17		NO ROADKILL FOUND						Waning Crescent
2020	June	18		NO ROADKILL FOUND						Waning Crescent
2020	June	26		NO ROADKILL FOUND						Waxing Crescent
2020	June	30		NO ROADKILL FOUND						Waxing Gibbous
2020	July	6		NO ROADKILL FOUND						Full Moon
2020	July	7		NO ROADKILL FOUND						Waning Gibbous
2020	July	15		NO ROADKILL FOUND						Waning Crescent

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LATITUDE	LONGITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2020	July	22		NO ROADKILL FOUND						Waxing Crescent
2020	August	4		NO ROADKILL FOUND						Full Moon
2020	August	12	62.55	Agile Wallaby	Initial Decay	-17.43762	122.52254	Post-construction	Overcast	Last Quarter
2020	August	21		NO ROADKILL FOUND						Waxing Crescent
2020	August	27		NO ROADKILL FOUND						Waxing Gibbous
2020	September	3	2.01	Bird of Prey	Initial Decay	-1786949	122.27365	Pre-construction		Full Moon
2020	September	8		NO ROADKILL FOUND				Pre-construction		Waning Gibbous
2020	September	15		NO ROADKILL FOUND					Passing clouds	Waning Crescent
2020	October	2		NO ROADKILL FOUND					Passing clouds	Full Moon
2020	October	9	52.47	Agile Wallaby	Fresh	-17.49051	122.45523	Post-construction		Last Quarter
2020	October	14	3.04	Agile Wallaby	Fresh	-17.86035	122.27604	Post-construction		Waning Crescent
2020	October	21	22.21	Black Head Python	Fresh	-17.688755	122.2798			Waxing Crescent
2020	October	25	38.87	Agile Wallaby	Fresh	-17.5714	122.3611	Post-construction	Partly sunny	Waxing Gibbous
2020	November	10	56.03	Agile Wallaby	Black Putrefaction	-17.47459	122.48414			Waning Crescent
2020	November	23		NO ROADKILL FOUND						First Quarter
2020	November	26	4.2	Bungarra	Fresh	-17.85018	122.27839	Pre-construction		Waxing Gibbous
2020	December	9		NO ROADKILL FOUND					Overcast	Waning Crescent
2020	December	17		NO ROADKILL FOUND					Overcast	Waxing Crescent

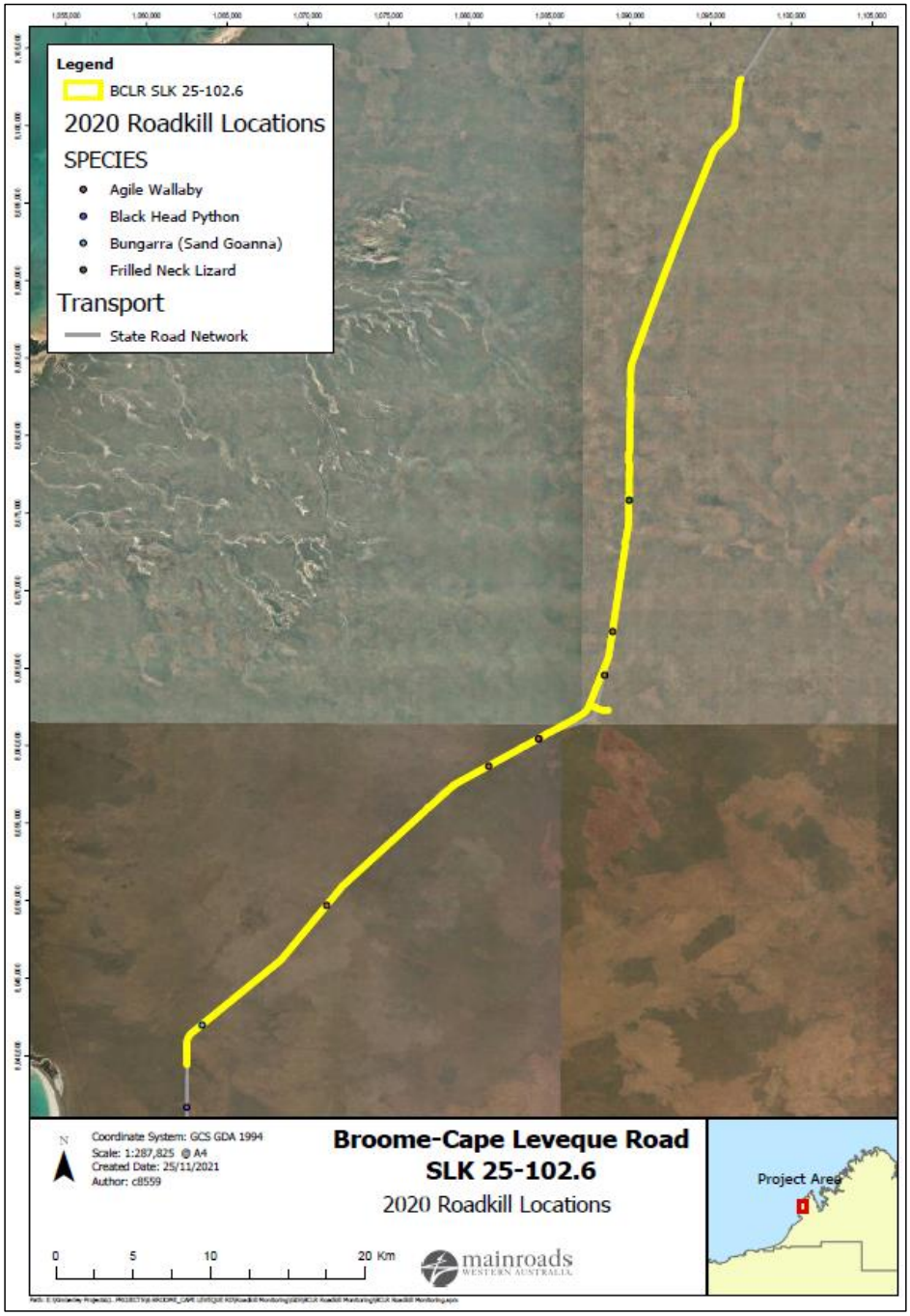

Figure 7: 2020 Roadkill Locations

3.7 2021 – Post Construction

In 2021 between the months of January and November, 30 roadkill individuals were recorded from 22 monitoring days (Table 7). These comprised 15 Agile Wallabies, four Birds of Prey, three Frilled Neck Lizards, two Cows, one Bungarra (Sand Goanna), one Top Notch Pigeon, one Black Head Python, one Bearded Dragon, one Brown Falcon and one Cat. No Greater Bilby individuals were recorded. The road kills appear to be spread along the length of the road (Figure 8). Lunar cycle does not appear to influence level of roadkill.

Table 7: Roadkill Monitoring Results - 2021

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2021	January	4	93.41	Frilled Neck Lizard	Fresh	122.571926	-17.166823	Post-construction		Waning Gibbous
2021	January	4	92.03	Bird of Prey	Initial Decay	122.56734	-17.17866	Post-construction		Waning Gibbous
2021	January	4	91.98	Agile Wallaby	Putrefaction	122.5673	-17.17887	Post-construction		Waning Gibbous
2021	January	4	47.37	Bird of Prey	Initial Decay	122.41742	-17.51745	Post-construction		Waning Gibbous
2021	January	4	62.4	Agile Wallaby	Black Putrefaction	122.521966	-17.438809	Post-construction		Waning Gibbous
2021	January	4	64.23	Agile Wallaby	Black Putrefaction	122.52574	-17.422717	Post-construction		Waning Gibbous
2021	February	5		NO ROADKILL FOUND				Post-construction		Last Quarter
2021	February	23	79.56	Agile Wallaby	Initial Decay	122.53704	-17.285725	Post-construction		Waxing Gibbous
2021	February	23	99.36	Agile Wallaby	Fresh	122.598519	-17.116119	Post-construction		Waxing Gibbous
2021	March	11	29.31	Frilled Neck Lizard	Fresh	122.298773	-17.63255	Post-construction		Waning Crescent
2021	March	23	86.63	Agile Wallaby	Putrefaction	122.55017	-17022399	Post-construction		Waxing Gibbous
2021	April	7	92.67	Agile Wallaby	Fresh	122.569615	-17.172969	Post-construction		Waning Crescent
2021	April	22	57.13	Cow	Initial Decay	122.493296	-17.46977	Post-construction		Waxing Gibbous
2021	May	7	25.62	Agile Wallaby	Fresh	122.2801	-17.65796	Post-construction		Waning Crescent
2021	May	21		NO ROADKILL FOUND				Post-construction		Waxing Gibbous

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2021	June	2		NO ROADKILL FOUND						Last Quarter
2021	June	11	70.15	Agile Wallaby	Putrefaction	122.533524	-17.370079			New Moon
2021	June	22	47.12	Bungarra	Initial Decay	122.416027	-17.51903			Waxing Gibbous
2021	July	8	10.06	Top Notch Pigeon	Initial Decay	122.280994	-17.797799			New Moon
2021	July	19	97.31	Bird of Prey	Black Putrefaction	122.585348	-17.134264			Waxing Gibbous
2021	August	4	10.89	Cow	Fresh	122.2808	-17.79003		Passing clouds	Waning Crescent
2021	August	10	64.95	Agile Wallaby	Fresh	122.526563	-17.41658			Waxing Crescent
2021	August	23	4.59	Agile Wallaby	Fresh	122.27931	-17.84662			Full Moon
2021	September	6		NO ROADKILL FOUND						New Moon
2021	September	22	48.75	Bird of Prey	Initial Decay	122.42588	-17.50799			Full Moon
2021	October	1	27.51	Black Head Python	Initial Decay	122.2861	-17.6433			Waning Crescent
2021	October	29	95.64	Agile Wallaby	Black Putrefaction	122.57965	-17.14821			Last Quarter
2021	November	8	80.72	Agile Wallaby	Initial Decay	122.537812	-17.26721			Waxing Crescent
2021	November	8	86.19	Agile Wallaby	Black Putrefaction	122.54882	-17.22778			Waxing Crescent
2021	November	8	86.2	Agile Wallaby	Black Putrefaction	122.54884	-17.22773			Waxing Crescent
2021	November	8	85.94	Cat	Black Putrefaction	122.54801	-17.22997			Waxing Crescent
2021	November	8	81.3	Bearded Dragon	Fresh	122.537618	-17.270057			Waxing Crescent
2021	November	8	36.38	Brown Falcon	Fresh	122.346684	-17.588929			Waxing Crescent
2021	November	8	26.49	Frilled Neck Lizard	Fresh	122.280337	-17.650166			Waxing Crescent

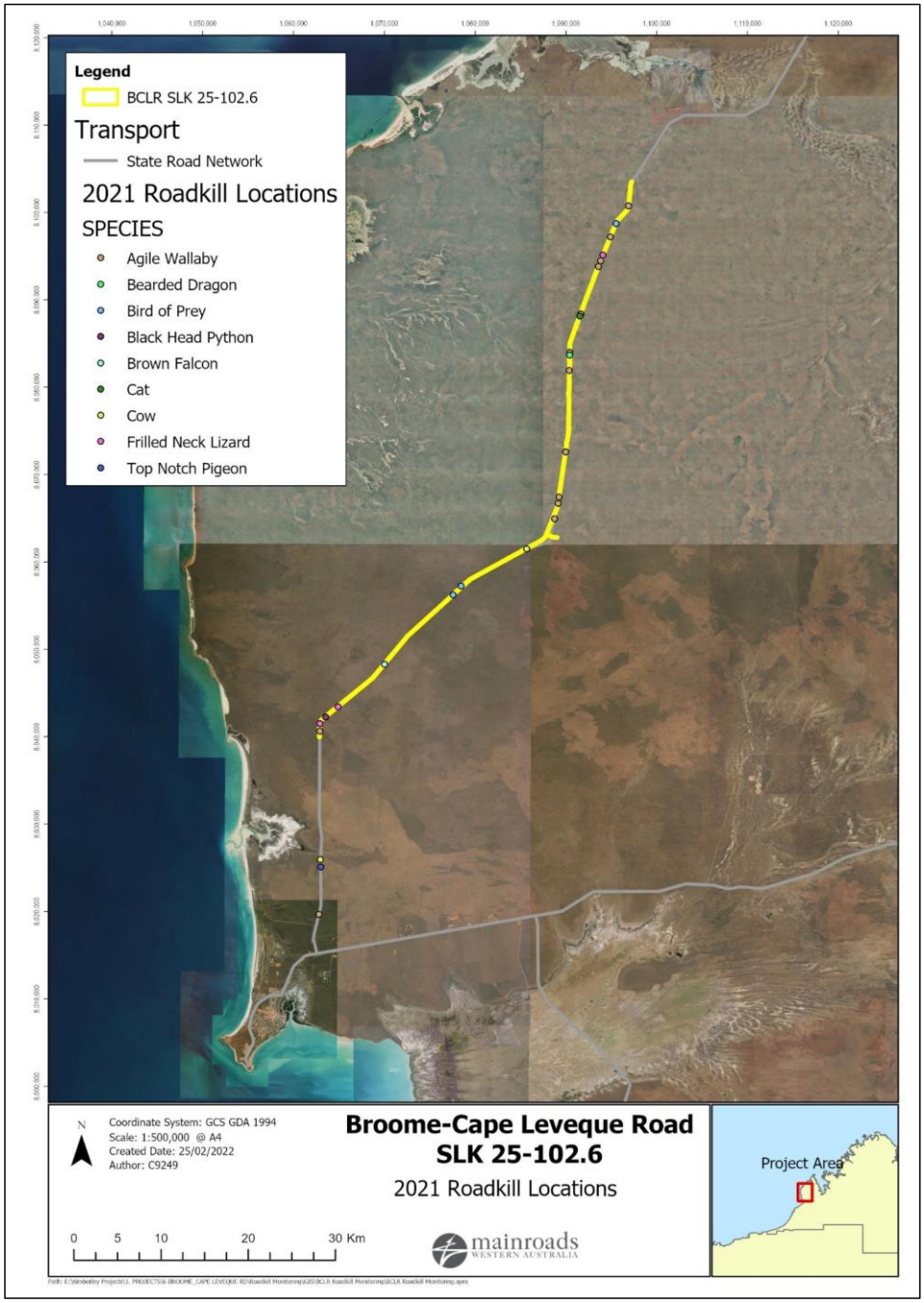

Figure 8: 2021 Roadkill Locations

Table 8: Roadkill Monitoring Results – 2022/23

YEAR	MONTH	DATE	SLK	SPECIES	CARCASS CONDITION	LONGITUDE	LATITUDE	COMMENTS	WEATHER	LUNAR CYCLE
2021	December	7	103.1	Frilled Neck Lizard	Fresh	122.6045	-17.08775	post construction	sunny	Waxing Crescent
2021	December	7	102.66	Honey Eater	Fresh	122.53663	-17.31583	post construction	sunny	Waxing Crescent
2021	December	7	75.93	Frilled Neck Lizard	Fresh	122.53646	-17.31583	post construction	sunny	Waxing Crescent
2021	December	7	75.03	Agile Wallaby	Black Purification	122.536640	-17.323881	post construction	sunny	Waxing Crescent
2021	December	7	54.96	Blue Tongue Lizard	Fresh	122.47545	-17.4794	post construction	sunny	Waxing Crescent
2021	December	14	67.3	Sand Goanna	Fresh	122.530210	-17.392553	post construction	partly cloudy	Waxing Gibbous
2021	December	14	70.23	Butcherbird	Fresh	122.534098	-17.366611	post construction	partly cloudy	Waxing Gibbous
2021	December	14	56.36	Sand Goanna	Fresh	122.4841	-17.4746	post construction	partly cloudy	Waxing Gibbous
2021	December	14	44.73	Frilled Neck Lizard	Fresh	122.3988	-17.5343	post construction	partly cloudy	Waxing Gibbous
2022	February	2		NO ROADKILL FOUND				post construction	overcast	Waxing Crescent
2022	February	4	30.46	Frilled Neck Lizard	Fresh	122.3068	-17.6259	post construction	partly cloudy	Waxing Crescent
2022	February	7	90.05	Finch sp.	Fresh	122.56165	-17.1934	post construction	partly cloudy	Waxing Crescent
2022	February	11	41.62	Frilled Neck Lizard	Fresh	122.3794	-17.55196	post construction	overcast	Waxing Gibbous
2022	February	15	67	Black Headed Python	Fresh	122.529812	-17.395209	post construction	sunny	Waxing Gibbous
2022	February	25		NO ROADKILL FOUND						Waning Crescent
2022	March	9		NO ROADKILL FOUND						Waxing Crescent
2022	March	15	87.84	Agile Wallaby	Initial Decay	122.554041	-17.21333	post construction	partly cloudy	Waxing Gibbous
2022	March	26	81.07	Whip Snake	Fresh	122.53764	-17.27222	post construction	partly cloudy	Waning Crescent

2022	March	26	84.63	Stimson Python	Fresh	122.5439	-17.24114	post construction	partly cloudy	Waning Crescent
2022	March	26	90.46	Bird of Prey sp.	Black Purification	122.56231	-17.1917	post construction	partly cloudy	Waning Crescent
2021	March	30		NO ROADKILL FOUND				post construction	sunny	Waning Crescent
/2022	April	13	100.83	Agile Wallaby	Fresh	122.5993	-17.10709	post construction	sunny	Waxing Gibbous
2022	April	13	69.91	Monitor Lizard	Fresh	122.53324	-17.37227	post construction	sunny	Waxing Gibbous
2022	April	13	38.22	Monitor Lizard	Fresh	122.3574	-17.57601	post construction	sunny	Waxing Gibbous
2022	April	27		NO ROADKILL FOUND						Waning Crescent
2022	May	18	87.82	Cow	Purification	122.55382	-17.214	post construction	sunny	Waning Gibbous
2022	June	2		NO ROADKILL FOUND						Waxing Crescent
2022	June	7		NO ROADKILL FOUND						First Quarter
2022	June	17		NO ROADKILL FOUND						Waning Gibbous
2022	July	5		NO ROADKILL FOUND						Waxing Crescent
2022	July	10		NO ROADKILL FOUND						Waxing Gibbous
2022	July	25	48.51	Feral Bull	Initial Decay	122.42438	-17.51099	post construction	sunny	Waning Crescent
2022	July	30	68.88	Agile Wallaby	Fresh	122.53194	-17.38143	post construction	sunny	Waxing Crescent
2022	August	2	76.31	Dingo / Dog	Dry Decay	122.53643	-17.31250	post construction	sunny	Waxing Crescent
2022	August	3		NO ROADKILL FOUND						Waxing Crescent
2022	August	8		NO ROADKILL FOUND						Waxing Gibbous
2022	August	23		NO ROADKILL FOUND						Waning Crescent
2022	September	14		NO ROADKILL FOUND						Waning Gibbous

2022	September	20		NO ROADKILL FOUND						Waning Crescent
2022	September	28		NO ROADKILL FOUND						Waxing Crescent
2022	October	7	81.23	Agile Wallaby	Fresh	122.53779	-17.26873	post construction	sunny	Waxing Gibbous
2022	October	18		NO ROADKILL FOUND						Last Quarter
2022	October	26		NO ROADKILL FOUND						Waxing Crescent
2022	November	8		NO ROADKILL FOUND						Waxing Gibbous
2022	November	17		NO ROADKILL FOUND						Waning Crescent
2022	November	18		NO ROADKILL FOUND						Waning Crescent
2022	December	5		NO ROADKILL FOUND						Waxing Gibbous
2022	December	13	30.22	Black Headed Python	Fresh	122.3051	-17.6273	post construction	overcast	Waning Gibbous
2022	December	14		NO ROADKILL FOUND						Waning Gibbous
2022	December	17		NO ROADKILL FOUND						Waning Crescent
2023	January	20		NO ROADKILL FOUND						Waning Crescent
2023	January	23	45.02	Agile Wallaby	Purification	122.40076	-17.53253	post construction	sunny	Waxing Crescent
2023	January	25		NO ROADKILL FOUND						Waxing Crescent
2023	February	21		NO ROADKILL FOUND						Waxing Crescent
2023	March	5		NO ROADKILL FOUND						Waxing Gibbous
2023	March	19		NO ROADKILL FOUND						Waning Crescent
2023	March	31		NO ROADKILL FOUND						Waxing Gibbous
2023	April	18	76.99	Black Headed Python	Fresh	122.53676	-17.30635	post construction	sunny	Waning Crescent

2023	April	24	63.13	Agile Wallaby	Initial Decay	122.524347	-17.42949	post construction	sunny	Waxing Crescent
2023	May	7		NO ROADKILL FOUND						Waning Gibbous
2023	May	10		NO ROADKILL FOUND						Waning Gibbous
2023	May	24		NO ROADKILL FOUND						Waxing Crescent
2023	May	25		NO ROADKILL FOUND						Waxing Crescent
2023	June	8		NO ROADKILL FOUND						Waning Gibbous
2023	June	20	56.08	Black Headed Python	Fresh	122.483836	-17.47507	post construction	partly cloudy	Waxing Crescent
2023	July	4		NO ROADKILL FOUND						
2023	July	11	82.94	Agile Wallaby	Fresh	122.53952	-17.25333	post construction	sunny	Waning Crescent
2023	July	24		NO ROADKILL FOUND						
2023	July	31		NO ROADKILL FOUND						

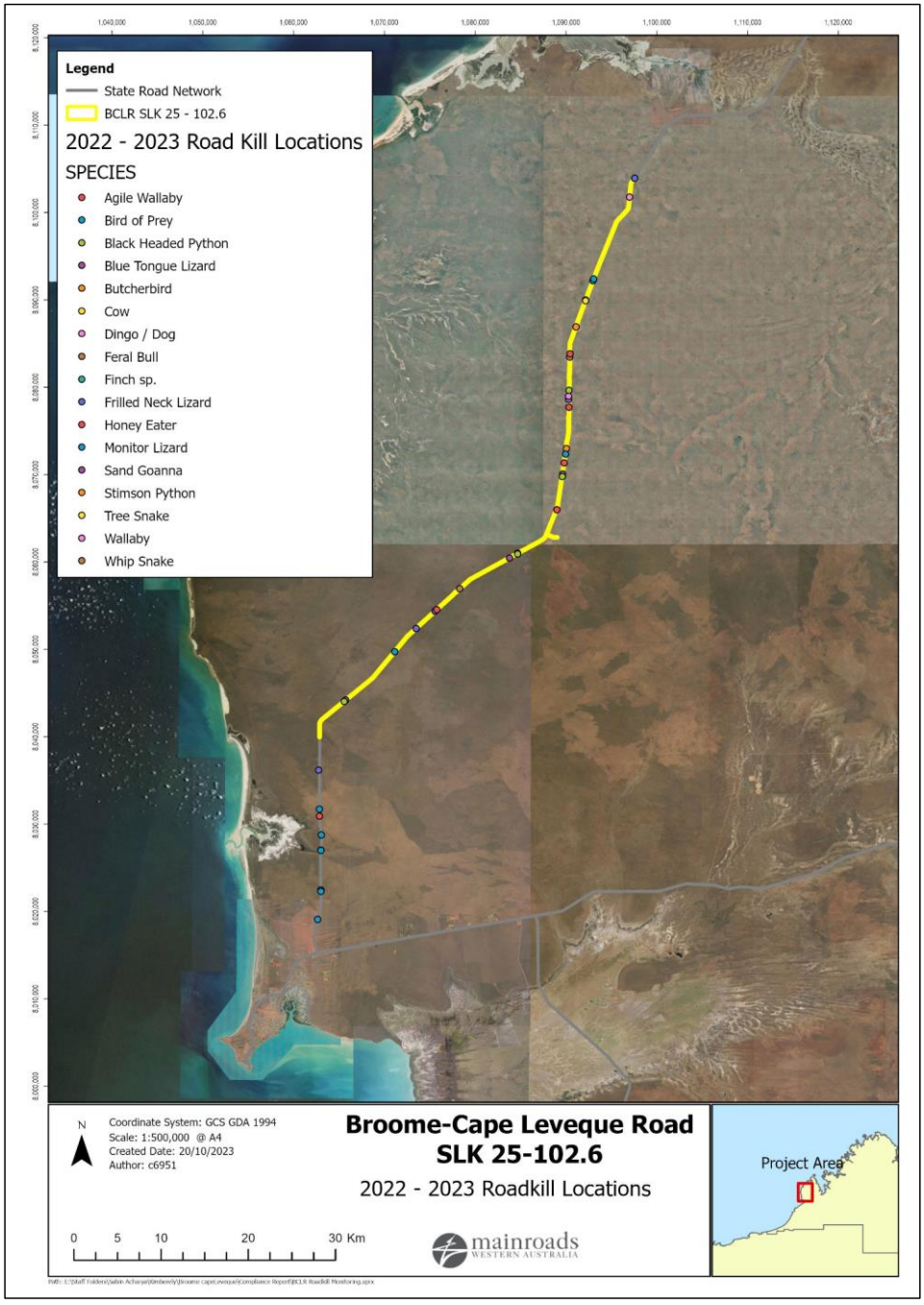

Figure 9: 2022 - 2023 Roadkill Locations

Commented [SA1]: Figure Updated

4 DISCUSSION

In total 167 roadkill individuals from 350 monitoring days have been recorded on BCLR between SLK 25 and 102.6 and between the years of 2015 and 2023 (Table 8, and Figure 10 below):

Table 8. Roadkill individuals and monitoring days

Year	Phase	Individuals	Monitoring Days
2015		31	24
2017		13	7
2018 (P)	Pre construction	47	66
2018 (C)	Construction	18	44
2019		15	64
2020		13	45
2021	Post construction	30	22
2022 / 2023	Post construction	33	69

Lunar cycle and weather patterns do not appear to impact the level of roadkill recorded on the BCLR.

Monitoring records from 2018 show a minor concentration of roadkill around SLK 83.6 during construction activities, however considering the species behaviour includes flocking and therefore an increased risk of multiple fatalities from one impact event, and the lack of any repetition of records at this location, it is considered that the distribution of roadkill along the entire road length appears random and not subject to any clusters or concentration points.

Pre-construction (2015 - 2018), the number of roadkill individuals recorded increased with greater monitoring effort, however, during the construction period (2018 – 2020) roadkill rates appeared to be significantly reduced compared to the monitoring effort (Figure 9). This can potentially be attributed to disturbance (noise and vibrations) from construction activities encouraging fauna to avoid the road and reduced signed speeds in construction areas encouraging motorists to drive with more care than usual. Post-construction (2021-23) when the road was opened fully to motorists, road kill rates appear to begin to return to the pre-construction road kill rates with increased monitoring effort, continued monitoring would be required to determine if this is indeed the case.

No Greater Bilby roadkill individuals have been recorded on the BCLR during any of the monitoring periods. One Greater Bilby roadkill individual was recorded in 2020, however, as the record was outside the monitoring area, it does not trigger any Greater Bilby management conditions as specified in the RMAMP.

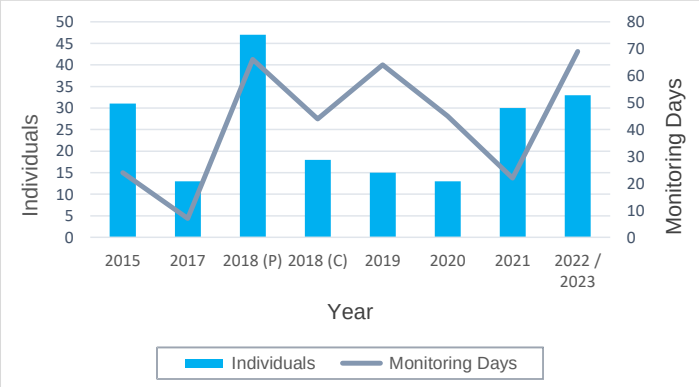

Figure 10: Roadkill Rates and Monitoring Effort

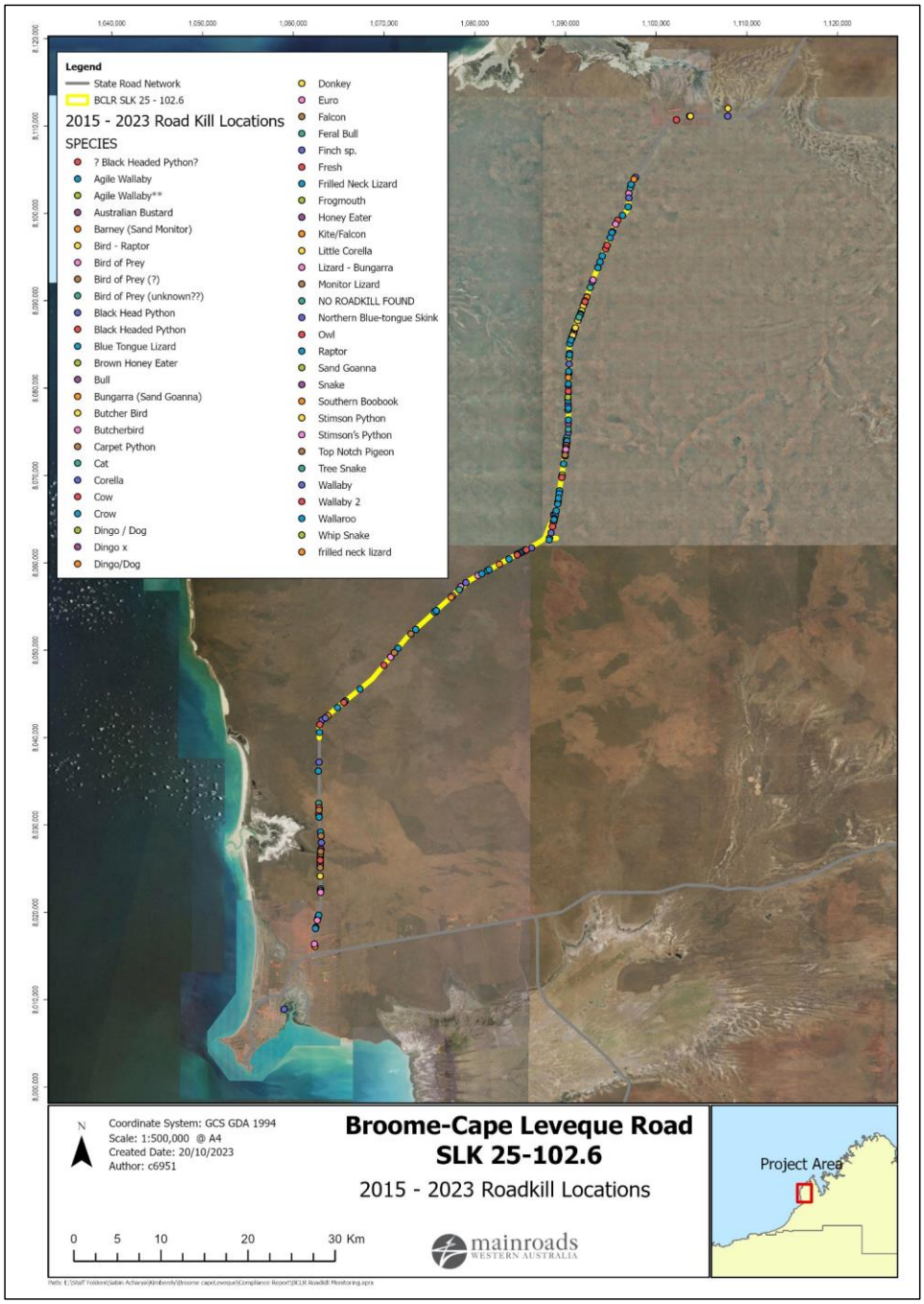

Figure 11: 2015 – 2023 Roadkill Locations

5 REFERENCES

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6 APPENDICES

Appendix A: EPBC 2013/6984 Approval Notice

Australian Government
Department of the Environment

Approval

Cape Leveque Road upgrade (SLK 25-102.6) Shire of Broome, Western Australia (EPBC 2013/6984)

This decision is made under sections 130(1) and 133 of the *Environment Protection and Biodiversity Conservation Act 1999*.

Proposed action

person to whom the approval is granted	Main Roads Western Australia
proponent's ABN	50 860 676 021
proposed action	To upgrade approximately 77.6 kilometres of Cape Leveque Road (SLK 25 – 102.6) within the Shire of Broome, Western Australia; as described in the referral received by the Department on 3 September 2013 [See EPBC Act referral 2013/6984].

Approval

Controlling Provision	Decision
Listed threatened species and communities (sections 18 & 18A)	Approved
Listed migratory species (sections 20 & 20A)	Approved

conditions of approval

This approval is subject to the conditions specified below.

expiry date of approval

This approval has effect until 31 December 2035.

Decision-maker

name and position	Dr Simon Banks Assistant Secretary Assessments (NSW/ACT) and Fuel Branch
signature	Simon Banks
date of decision	6 July 2015

Conditions attached to the approval

1. Within 10 days after the **commencement of the action**, the person taking the action must advise the **Department** in writing of the actual date of commencement.

2. The person taking the action must maintain accurate records substantiating all activities associated with or relevant to the conditions of **approval**, including measures taken to implement the management plan required by this **approval**, and make them available upon request to the **Department**. Such records may be subject to audit by the **Department** or an independent auditor in accordance with section 458 of the EPBC Act, or used to verify compliance with the conditions of **approval**. Summaries of audits will be posted on the **Department**'s website. The results of audits may also be publicised through the general media.

3. Within three months of every 12 month anniversary of the **commencement of the action**, the person taking the action must publish a report on their website addressing compliance with the conditions of this **approval** over the previous 12 months, including implementation of any management plans as specified in the conditions. The compliance reports must remain on their website for a minimum of 12 months (beginning on the date of publication). Non-compliance with any of the conditions of this **approval** must be reported to the **Department** at the same time as the compliance report is published. The person taking the action must continue to annually publish the report on their website addressing compliance with each of the conditions of this **approval** until such time as agreed to in writing by the **Minister**.

4. The person taking the action must notify any non-compliance with this **approval** to the **Department** in writing within two business days of the person taking the action becoming aware of non-compliance.

5. Upon the direction of the **Minister**, the person taking the action must ensure that an independent audit of compliance with the conditions of **approval** is conducted and a report submitted to the **Minister**. The independent auditor must be approved by the **Minister** prior to the commencement of the audit. Audit criteria must be agreed to by the **Minister** and the audit report must address the criteria to the satisfaction of the **Minister**.

6. If the person taking the action wishes to carry out any activity otherwise than in accordance with the management plan as specified in the conditions**,** the person taking the action must submit to the **Department** for the **Minister**'s written approval a revised version of that management plan. The varied activity shall not commence until the **Minister** has approved the varied management plan in writing. The **Minister** will not approve a varied management plan unless the revised management plan would result in an equivalent or improved environmental outcome over time. If the **Minister** approves the revised management plan, that management plan must be implemented in place of the management plan originally approved.

7. If the **Minister** believes that it is necessary or convenient for the better protection of listed threatened species and communities to do so, the **Minister** may request that the person taking the action make specified revisions to the management plan specified in the conditions and submit the revised management plan for the **Minister**'s written approval. The person taking the action must comply with any such request. The revised approved management plan must be implemented. Unless the **Minister** has approved the revised management plan, then the person taking the action must continue to implement the management plan originally approved, as specified in the conditions.

8. If, at any time after five years from the date of this **approval**, the person taking the action has not **substantially commenced** the action, then the person taking the action must not **substantially commence** the action without the written agreement of the **Minister**.

9. Unless otherwise agreed to in writing by the **Minister**, the person taking the action must publish the management plan referred to in these conditions of **approval** on their website. The management plan must be published on the website within one month of being approved. The person taking the action must notify the **Department** within five business days of publishing the management plan on their website, and the management plan must remain on their website for the period this **approval** has effect.

Greater Bilby (*Macrotis lagotis*)

10. To ensure there is no decline in the **local Greater Bilby population** as a result of **roadkill** on the sealed **Cape Leveque Road**, the person taking the action must submit a Roadkill Monitoring and Adaptive Management Plan (RMAMP) for the **Minister**'s approval. The RMAMP must provide sufficient detail (timing, effort and methodology) to detect the level of impact of **roadkill** on the **local Greater Bilby population** during the **construction phase** and **operational phase**. **Commencement of the action** must not occur unless the **Minister** has approved the RMAMP. The approved RMAMP must be implemented. The RMAMP must:

    a. be developed and endorsed by a **suitably qualified ecologist** and a **linear infrastructure ecologist**

    b. include survey methodology and effort to be implemented that are sufficient to determine the baseline **local Greater Bilby population** and the location of **high density Greater Bilby areas**

    c. include sufficient monitoring methodology and effort to determine baseline Greater Bilby **roadkill** rates on the unsealed **Cape Leveque Road** prior to **commencement of the action**

    d. include sufficient monitoring methodology to determine Greater Bilby **roadkill** rates on the sealed **Cape Leveque Road** during the **construction phase** and **operational phase**

    e. include appropriate Greater Bilby **roadkill** trigger values and adaptive management measures to be implemented should Greater Bilby **roadkill** trigger values be reached during the **construction phase** and **operational phase**

    f. include the requirement for ongoing monitoring and adaptive management measures until such time as it can be demonstrated that there is no decline in the **local Greater Bilby population** as a result of **roadkill** for three successive years

    g. include the requirement to provide information to the annual compliance report required by the conditions attached to this **approval** reporting on survey findings, ongoing monitoring and effectiveness of adaptive management, until such time as it can be demonstrated that there is no decline in the **local Greater Bilby population** as a result of **roadkill** for three successive years.

11. To minimise impacts to the Greater Bilby during the **construction phase**, the person taking the action must develop a Greater Bilby Induction Training and Awareness Program (GBITAP). The GBITAP must:

    a. be delivered to all **employees and contractors** prior to the **commencement of the action** and to any new **employees and contractors** arriving during the **construction phase**

    b. provide education on the appearance, characteristics and behaviour of the Greater Bilby sufficient to allow **employees and contractors** to accurately identify the species

    c. include maps of **high density Greater Bilby areas**

    d. institute a signposted speed limit of no greater than 60km/hr, along with educational signage to increase awareness of Greater Bilby presence, at **high density Greater Bilby areas** and 200m either side of **high density Greater Bilby areas** to be observed by all **employees and contractors**

    e. include instructions on threats to the Greater Bilby and how to avoid or reduce impacts to the Greater Bilby through measures including, but not limited to, road awareness and waste management.

12. To minimise impacts to the Greater Bilby as a result of onsite works during the **construction phase**, the person taking the action must ensure that a **suitably qualified ecologist** implements the *Cape Leveque Road Greater Bilby Relocation Protocol, October 2014* in conducting pre-clearance surveys and relocation of Greater Bilby individuals, if present. All Greater Bilby deaths must be recorded.

13. To minimise impacts to the Greater Bilby of the sealed **Cape Leveque Road** during the **operational phase**, the person taking the action must ensure that the **Cape Leveque Road** upgrade is designed, constructed and maintained in a manner that minimises the potential for Greater Bilby **roadkill** from public use of the sealed road through avoidance, deterrence and increased visibility, including in particular:

    a. installation of signage educating the public of Greater Bilby presence at **high density Greater Bilby areas** and 200m either side of **high density Greater Bilby areas**.

    b. the use of **coloured pavement** at **high density Greater Bilby areas** and 200m either side of **high density Greater Bilby areas**

    c. the use of audible rumble strips at **high density Greater Bilby areas** and 50m either side of **high density Greater Bilby areas**.

14. In order to minimise the potential of the proposed action to facilitate the increased spread of feral cats, foxes and weeds, the person taking the action must:

    a. **fence** all **standing pools** of water resulting from the action

    b. remove or **fence** all **rubbish** generated as a result of the action at the end of each working day

    c. manage and control weeds in accordance with the *Cape Leveque Road Upgrade Revegetation Management Plan, October 2014.*

Offsets

15. To offset the residual significant impact to the Greater Bilby, the person taking the action must ensure that the **offsets program** is undertaken by a **suitably qualified ecologist**, including:

    a. a baseline survey to determine the area of occupancy of the Greater Bilby and its threats on the Dampier Peninsula must be developed and undertaken in conjunction with **DPaW** and Traditional Owner Rangers. The survey must use established techniques and record signs of Greater Bilby, signs of introduced predators, habitat characteristics, fire history and grazing pressure. This baseline survey must be undertaken on SLK 90-102.6 prior to **commencement of the action**. The baseline survey must be undertaken on SLK 25-90 prior **construction** occurring in SLK 25-90.

    b. an annual and ongoing survey must be developed and implemented in conjunction with **DPaW** and Traditional Owner Rangers. This survey must commence within six months of completion of the baseline survey and continue for at least two years, and monitor:

        i. at least four locations of the Greater Bilby population using DNA fingerprinting techniques

        ii. the population of introduced predators through the use of camera traps

        iii. grazing pressure, food resources and fire history.

    c. a threat management program must be submitted to the **Minister** for approval prior to implementation. The threat management program must be developed and implemented in conjunction with **DPaW** and Traditional Owner Rangers and must address either introduced predators, fire regimes or grazing pressure or a combination of these threats at high priority sites for the Greater Bilby. The threat management program must include an adaptive management component. Threat management must commence within one year of **commencement of the action** and continue for at least one year. At least $120,000 is to be spent on direct threat abatement action per year of the threat management program

    d. at a minimum, $600,000 is to be provided to **DPaW** to enable development and implementation of the **offsets program**. Evidence of expenditure must be provided to the **Minister** within three months of the final payment

    e. provision of information to the annual compliance report required by the conditions attached to this **approval** reporting on the survey findings, ongoing monitoring and effectiveness of adaptive management measures to address threats to the Greater Bilby, for the duration that the **offsets program** is implemented.

Definitions:

a) **Approval**: The approval to take the approved action under section 133 of the EPBC Act.

b) **Cape Leveque Road**: The approximately 77.6km length of Cape Leveque Road between SLK 25 and 102.6, illustrated in Attachment F of the referral, and any amendments.

c) **Coloured pavement**: Pavement of a shade that improves the visibility of the Greater Bilby by increasing the colour contrast between the species and the road surface.

d) **Commencement of the action**: The clearing of any vegetation or construction of any infrastructure, excluding fences and signage, associated with the proposed action.

e) **Construction**: Includes any preparatory works required to be undertaken including clearing vegetation, the erection of any onsite temporary structures and the use of heavy duty equipment for the purpose of breaking the ground or laying sealed road.

f) **Construction phase**: The time period from initial clearing of vegetation, breaking of ground or erection of onsite structures (whichever occurs first) until such time as the **Cape Leveque Road** upgrade is completed, all temporary onsite structures are removed and the road is open to the public and fully operational. The **construction phase** does not include regular road maintenance works.

g) **Department**: The Australian Government Department administering the *Environment Protection and Biodiversity Conservation Act 1999*.

h) **DPaW**: Western Australian Department of Parks and Wildlife and successor agencies.

i) **Employees and contractors**: Refers to any Main Roads Western Australia employees or employees contracted by Main Roads Western Australia working onsite.

j) **Fence**: Provision of a barrier sufficient to prevent access by feral cats and foxes.

k) **High density Greater Bilby area**: Any 6ha area that includes or is immediately adjacent to the **proposed disturbance route**, containing three or more signs of Greater Bilby. Signs of Greater Bilby may include sightings (in person or via camera), active burrows, inactive burrows, diggings, scratching or scats.

l) **Linear infrastructure ecologist**: Refers to an independent person, approved by the **Minister**, with relevant tertiary qualifications and a minimum of five years experience in the ecological impacts and management of linear infrastructure.

m) **Local Greater Bilby Population**: The population size and distribution of Greater Bilby that is determined by a **suitably qualified ecologist** as likely to be impacted by the proposed action as derived from surveys conducted prior to referral and the baseline population surveys required by this **approval**.

n) **Minister**: The Minister administering the *Environment Protection and Biodiversity Conservation Act 1999* and includes a delegate of the Minister.

o) **Offsets program**: The program outlined in *Bilby (Macrotis lagotis) Offset Priorities for Dampier Peninsula Populations, West Kimberley, October 2014*, published as part of Preliminary Documentation on Main Roads Western Australia's website.

p) **Operational phase**: The time period beginning at the completion of the **construction phase** and continuing for the life of the **approval**.

q) **Proposed disturbance route**: The proposed new road route (including borrow pits) as illustrated in Attachment F of the referral, and any amendments.

r) **Roadkill**: Vehicle(s) and/or equipment and/or machinery striking, colliding or crushing Greater Bilby in a manner that results in mortality to the Greater Bilby.

s) **Rubbish**: Consumable or any other waste that may be attractive to feral cats and foxes.

t) **Standing pool**: Pool of water greater than or equal to $2m^2$ that has the potential to persist for greater than or equal to one week created by human activity.

u) **Substantially commence**: As per **commencement of the action**.

v) **Suitably qualified ecologist**: Refers to an independent person, approved by the **Minister**, with relevant tertiary qualifications and a minimum of five years experience in Australian mammal fauna surveys in the region.

Appendix 3: DBCA Offsets Report: Dampier Peninsula Greater Bilby (Macrotis lagotis) Main Roads offset project: Final report

Biodiversity and Conservation Science

PARKS AND WILDLIFE SERVICE

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

Harry Moore, Bruce Greatwich, Martin Dziminski, Ruth McPhail, Fiona Carpenter, and Lesley Gibson

In partnership with:

NYUL NYUL RANGERS

YIMARDOO WARRA RANGERS NYIKINA MANGALA

BARDI JAWI OORANY RANGERS

YAWURU

KIMBERLEY LAND COUNCIL

environs KIMBERLEY SAVING THE NATURE OF THE KIMBERLEY

Final Report

June 2023

GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

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March 2023

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This document is available in alternative formats on request

Acknowledgments

We are grateful to the Kimberley Land Council, Rangelands NRM, WWF, Environs Kimberley for their support, advice and assistance on this project. We would like to thank and acknowledge the hard work, dedication and knowledge provided by our partnering Aboriginal Ranger Groups whom without this project would not have been possible; Yawuru Country Managers, Nykina Mangala Rangers, Bardi Jawi Oorany Rangers and Nyul Nyul Rangers. The project was funded by offset funds from Main Roads Western Australia.

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

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Contents

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.

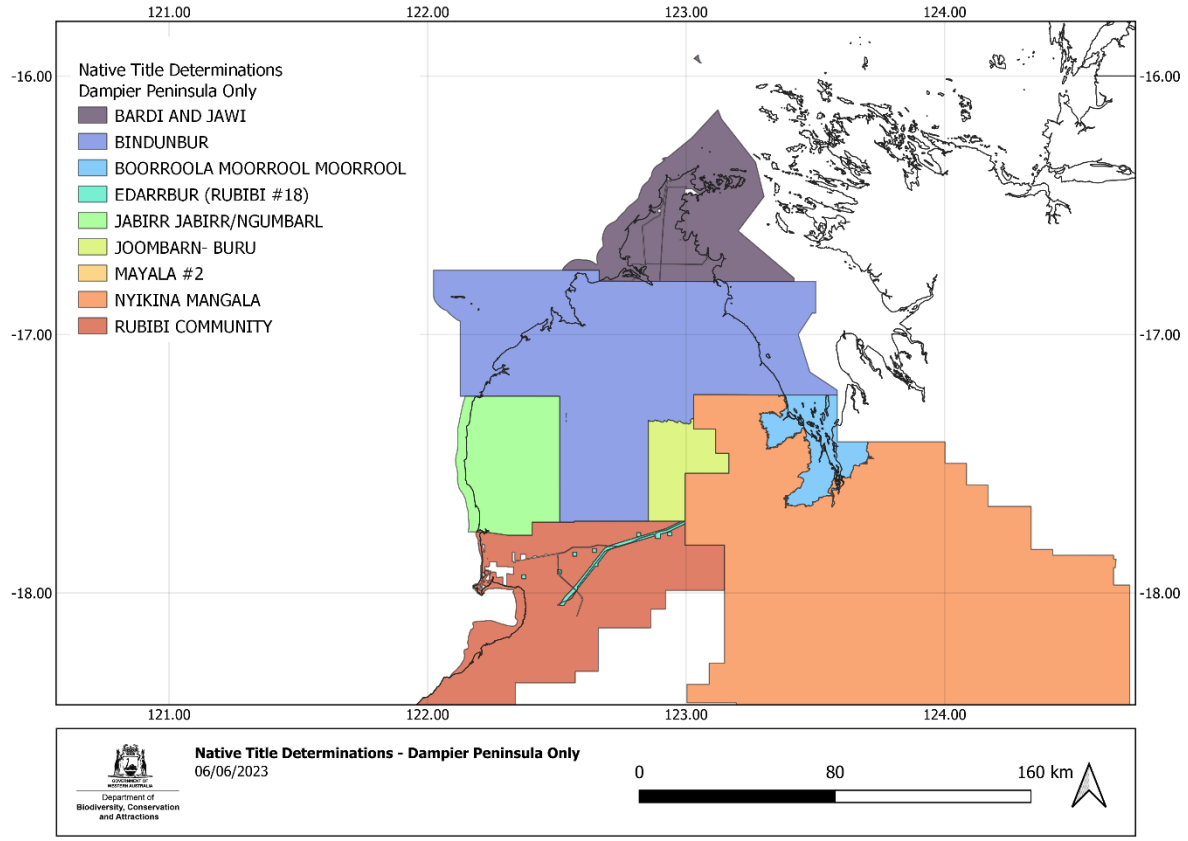

Figure 1 – Native Title determinations on the Dampier Peninsula.

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).

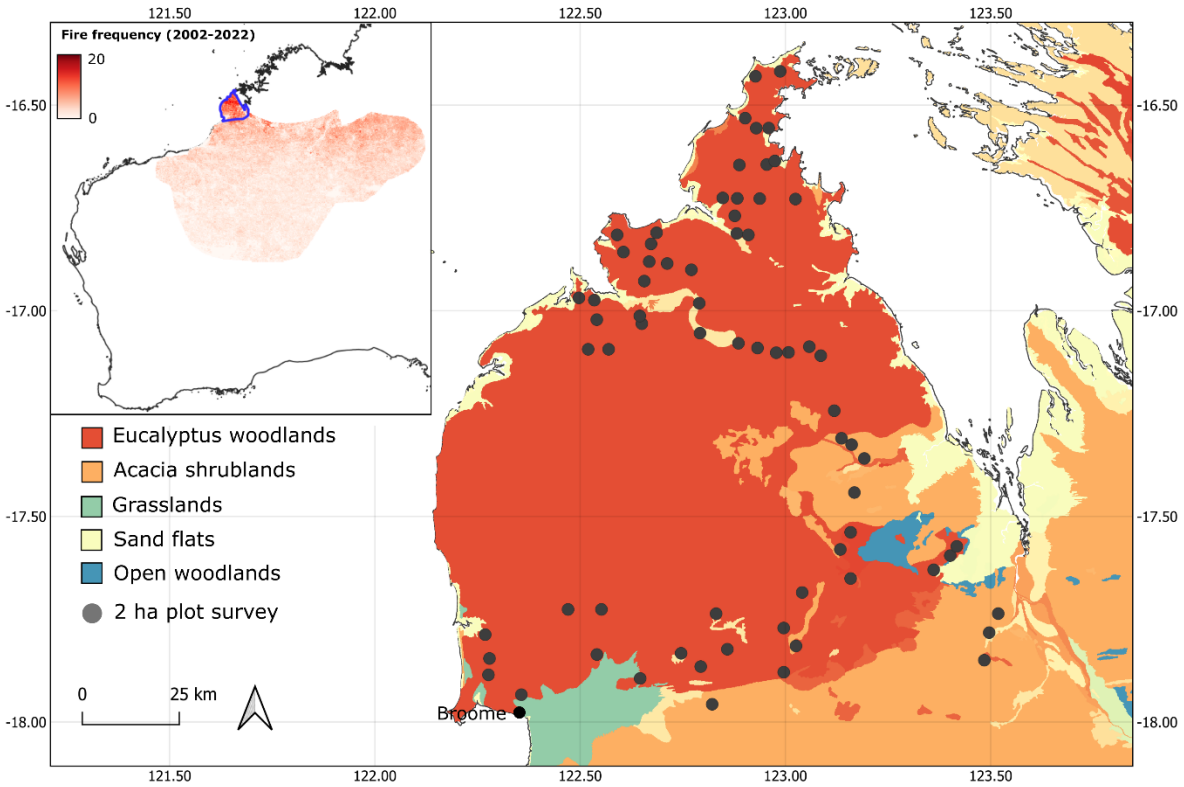

Figure 2 – Location of 2-ha sign plots located on the Dampier Peninsula in north-west Australia. Inset shows fire frequency across the greater bilby's (*Macrotis lagotis*) contemporary range (excluding the isolated Queensland population), with the study area outlined in blue.

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).

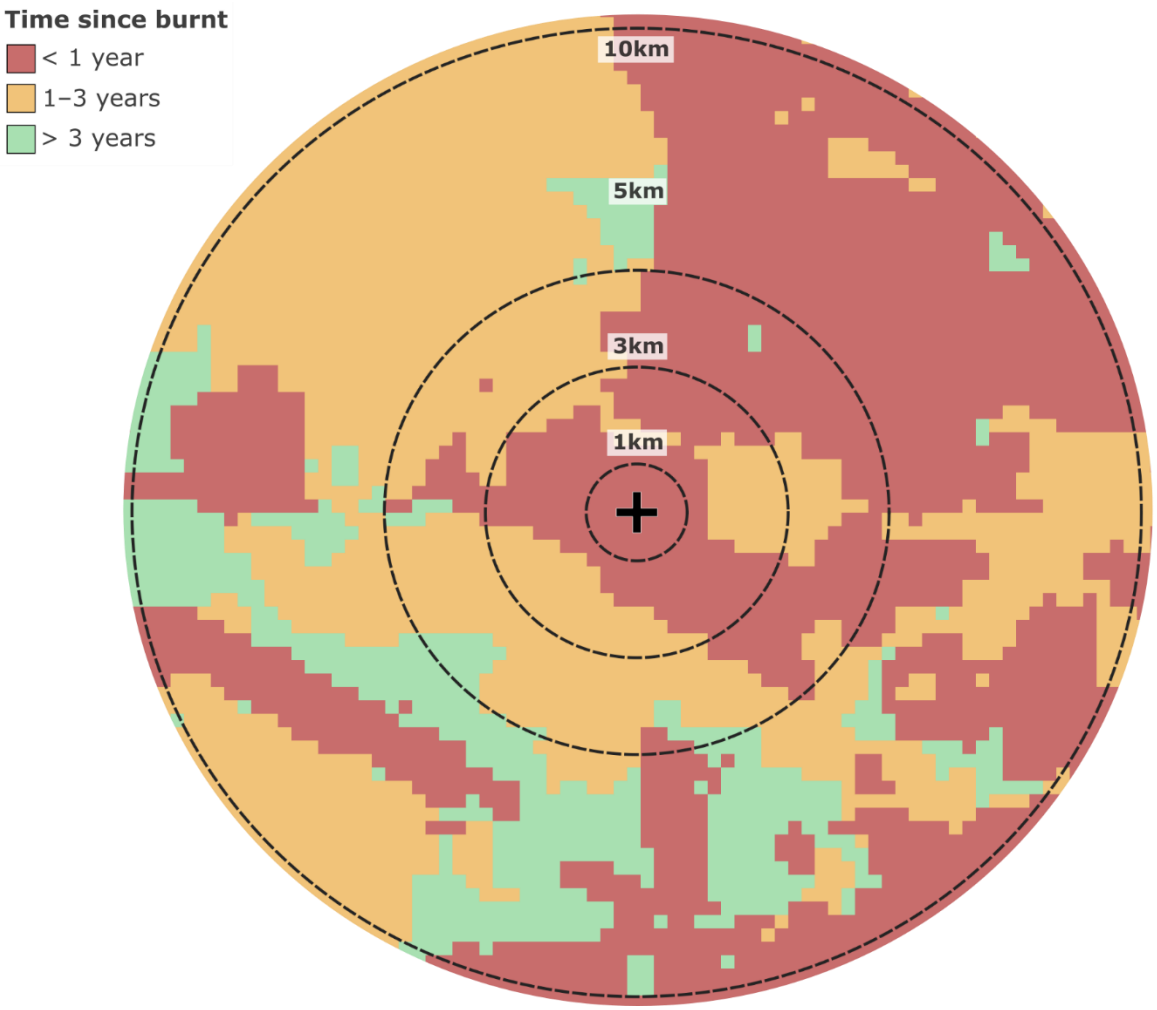

Figure 4 – Burn data used to measure fire attributes on the Dampier Peninsula in Northern Australia. The black cross represents the centre of a 2-ha plot site.

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).

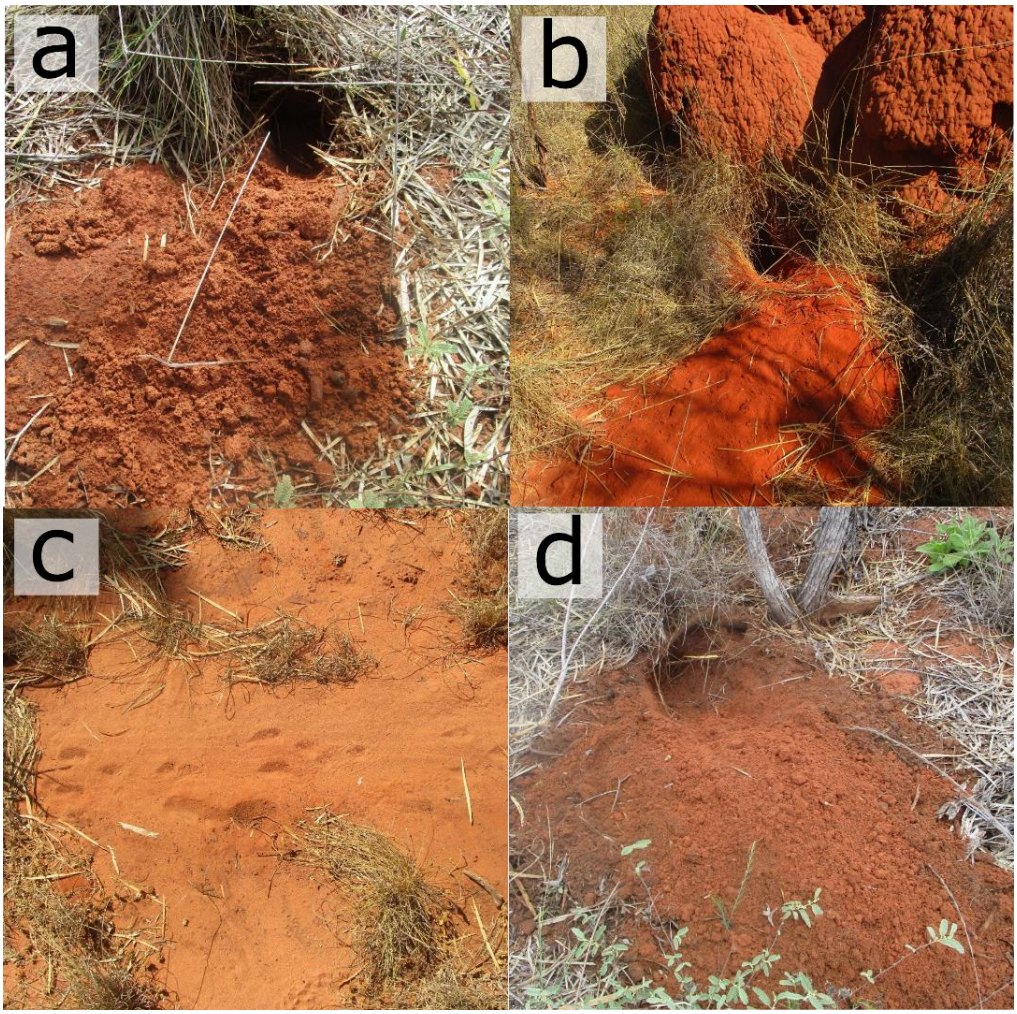

Figure 5 – Active bilby signs encountered to confirm presence during occupancy surveys, active burrow, diggings (note digging at base of *Acacia eriopoda* extracting root dwelling larvae), digging and scat and tracks.

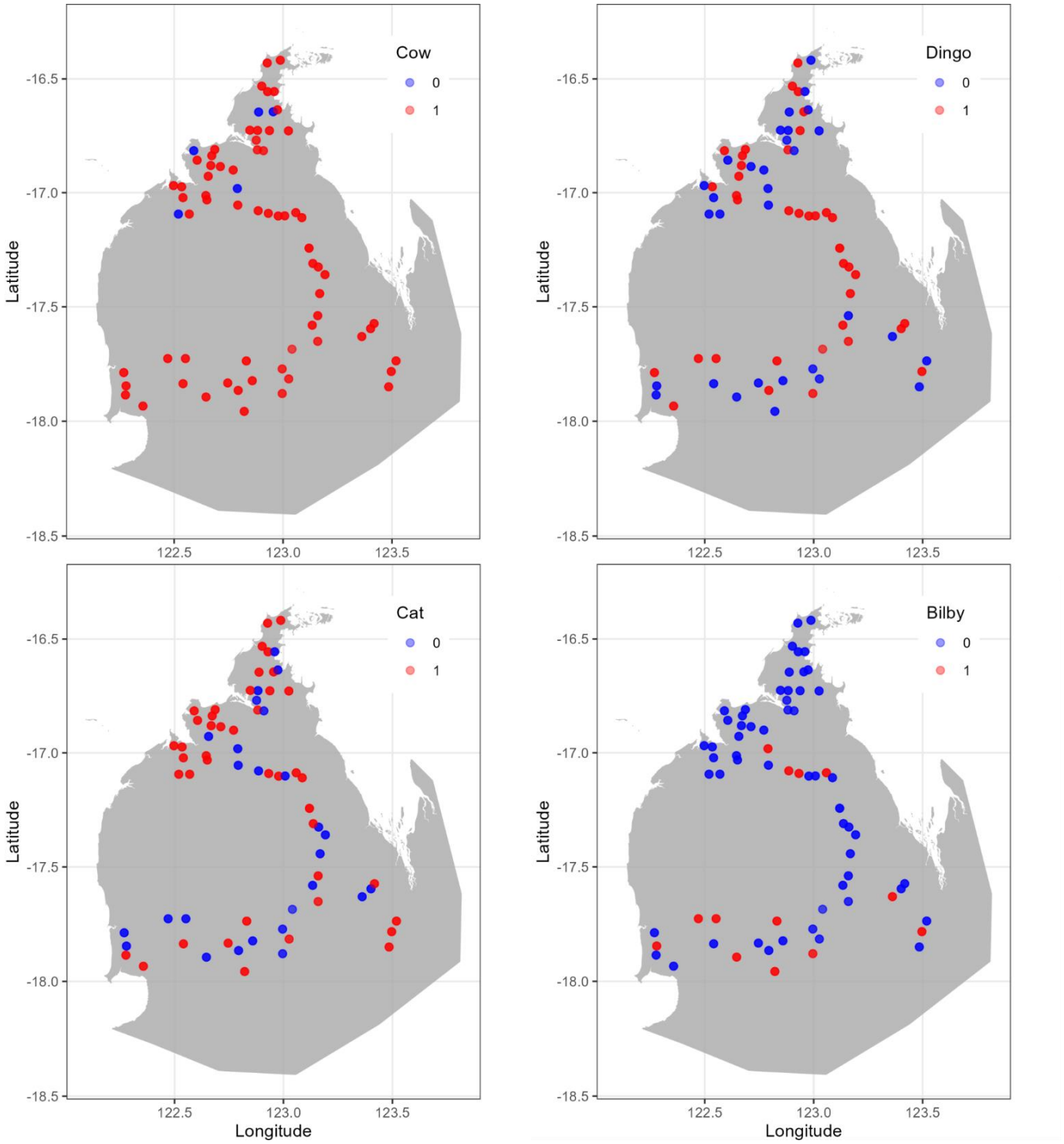

Figure 6 – Species occurrence data collected using 2-ha plot surveys on the Dampier Peninsula.

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).

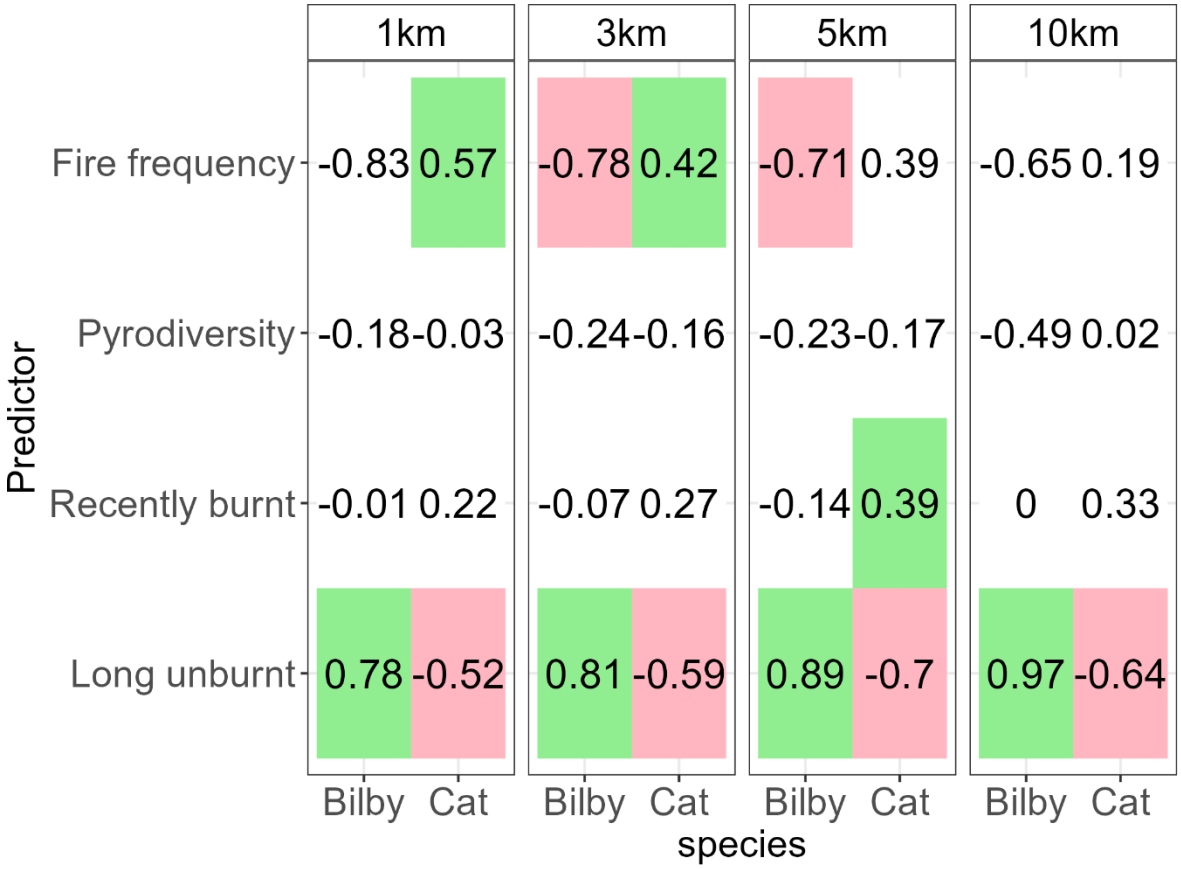

Figure 7 – Model estimates from generalized linear mixed-effects models testing the influence of fire attributes on the presence of greater bilbies and feral cats on the Dampier Peninsula in north-west Australia. Coloured cells show estimates where the effect was significant ($p < 0.05$). Red cells indicate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

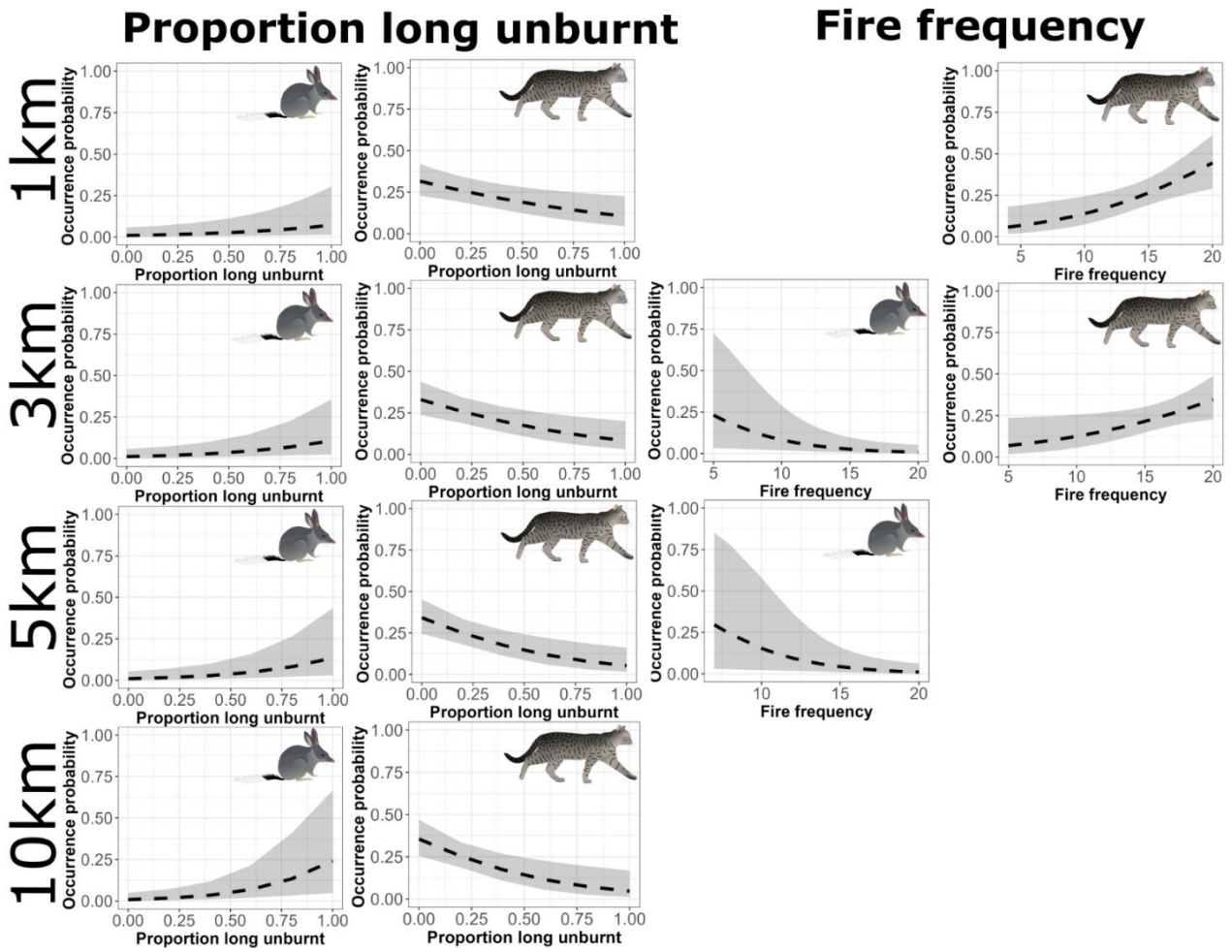

Figure 8 – Model predictions from generalized linear mixed-effects models testing the influence of fire attributes on the presence of greater bilbies and feral cats on the Dampier Peninsula in north-west Australia. Grey shading indicates 95% confidence intervals. Each row shows predictions from models 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

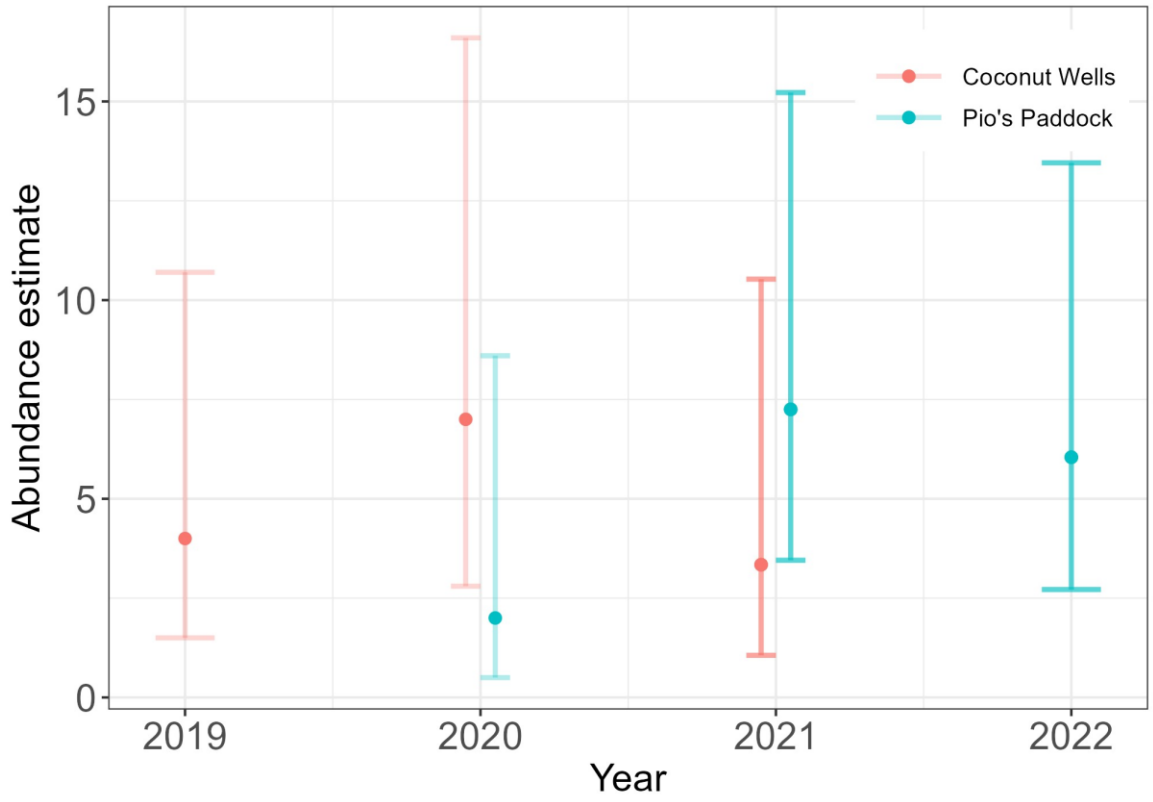

Figure 9 – Abundance estimates from Coconut Wells and Pio's Paddock populations between 2019 and 2022.

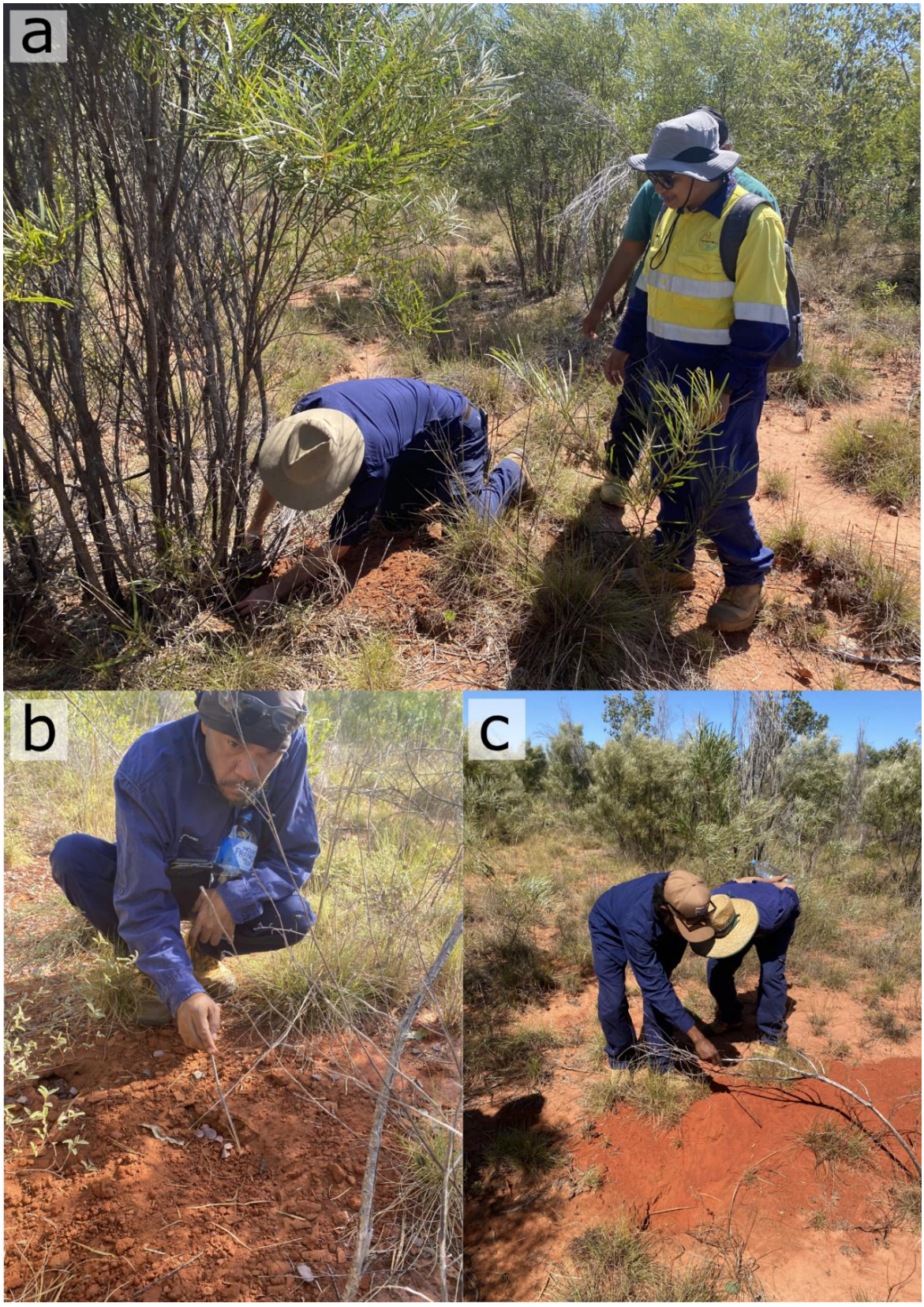

Figure 10 – Yawuru country managers and DBCA staff search for bilby scat material at Pio's Paddock

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

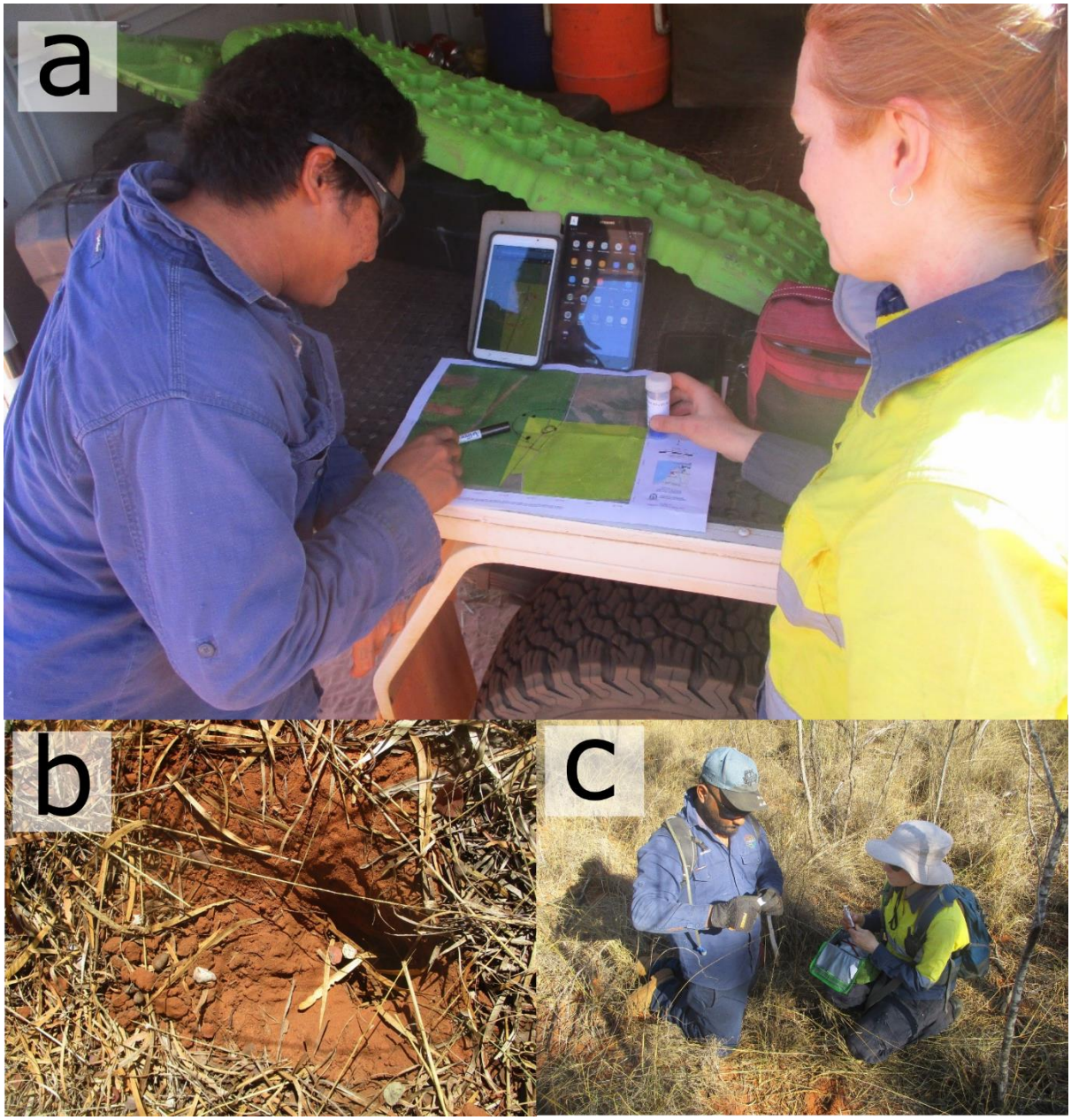

Figure 12 – Yawuru country managers and DBCA staff entering scat data.

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.

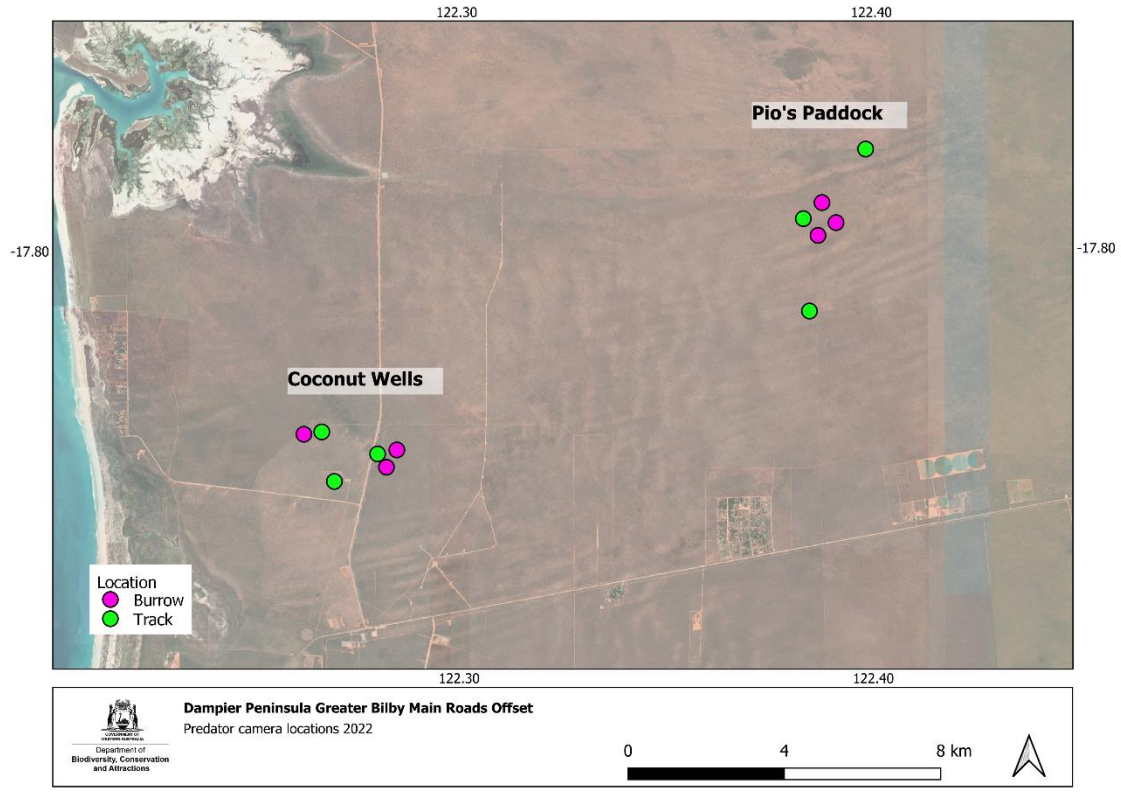

Figure 14– Predator camera locations at Coconut Wells and Pio's Paddock in 2022

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.

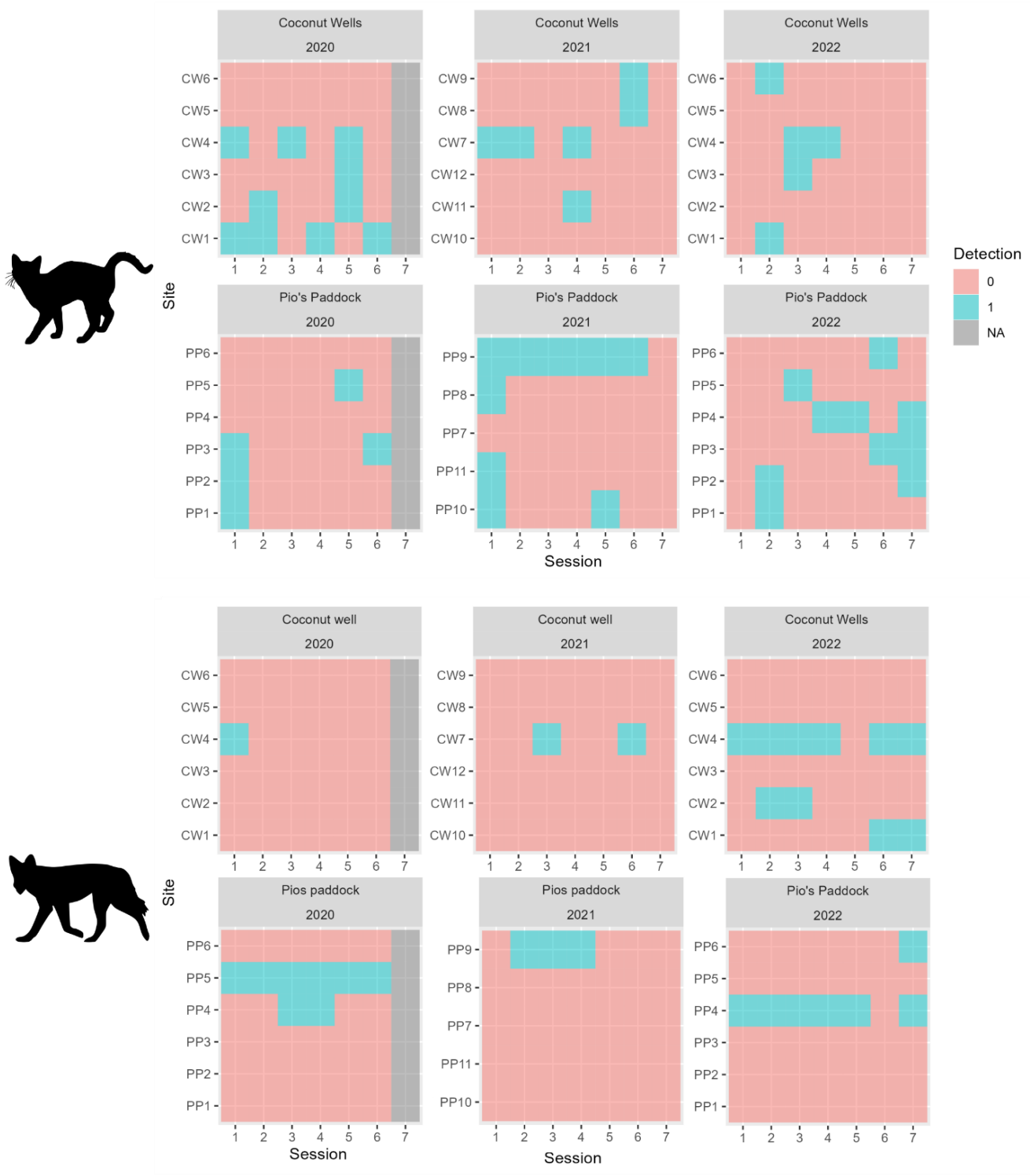

Figure 15– Feral cat and dingo detection histories at Coconut Wells and Pio's Paddock between 2020 and 2022.

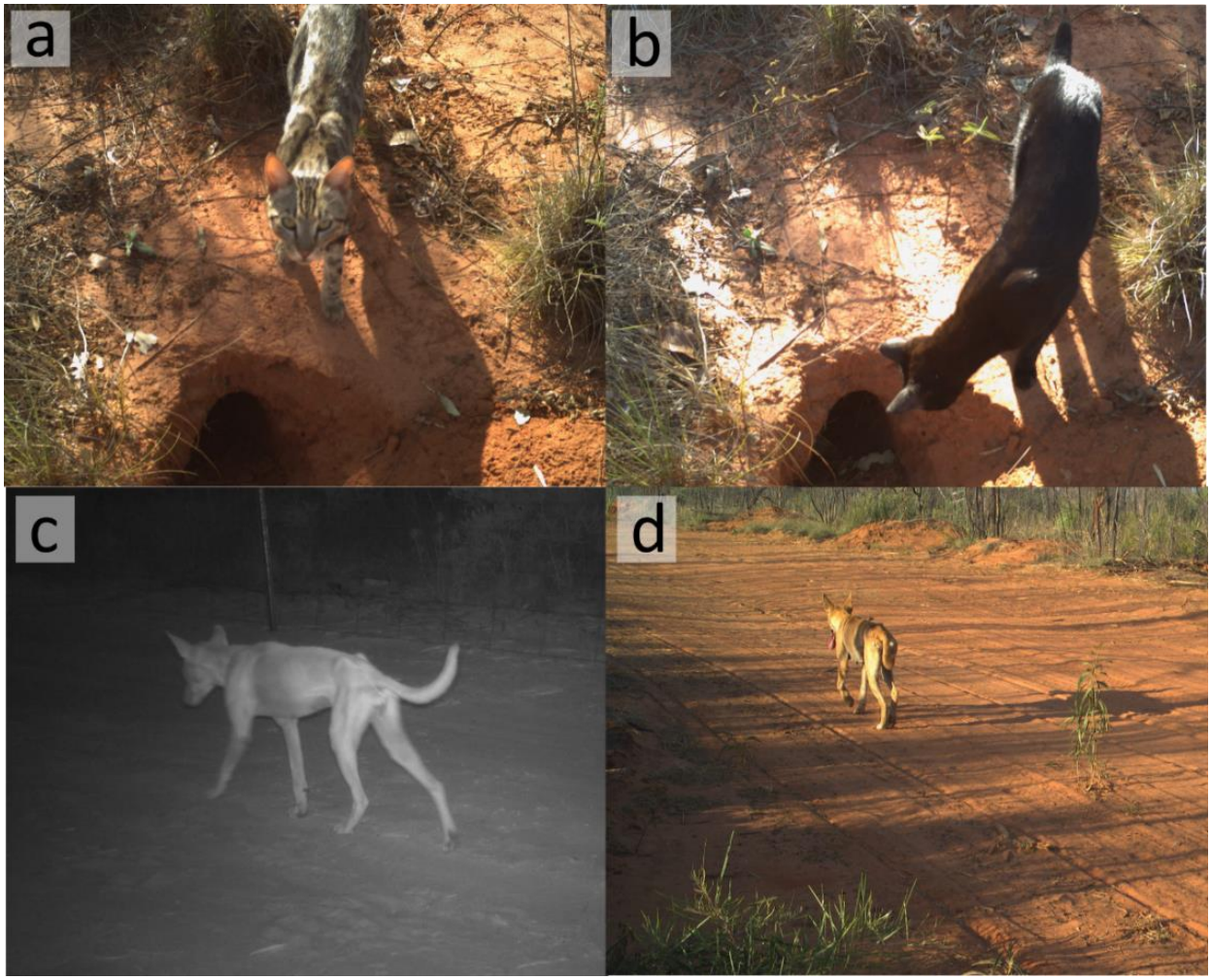

Figure 16 – Feral cat and dingoes detected on camera trap and Pio's Paddock and Coconut Wells in 2022.

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

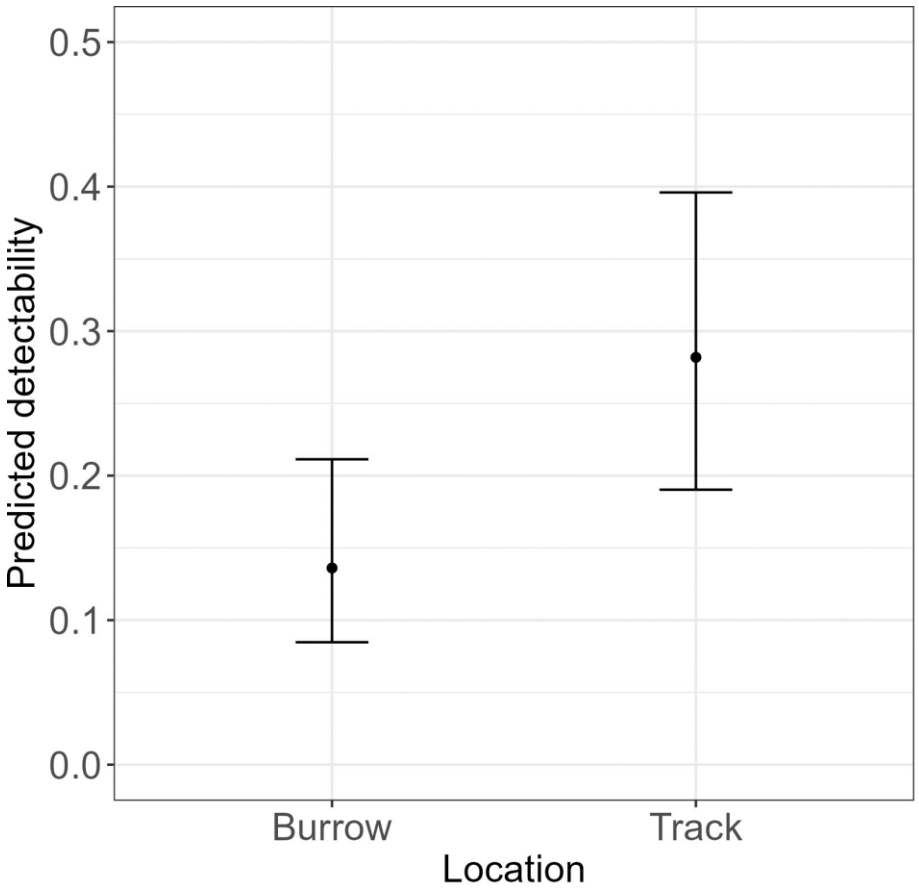

Figure 17 - A comparison of predicted feral cat detectability (per 2 week sampling period) between cameras located on burrows and tracks.

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).

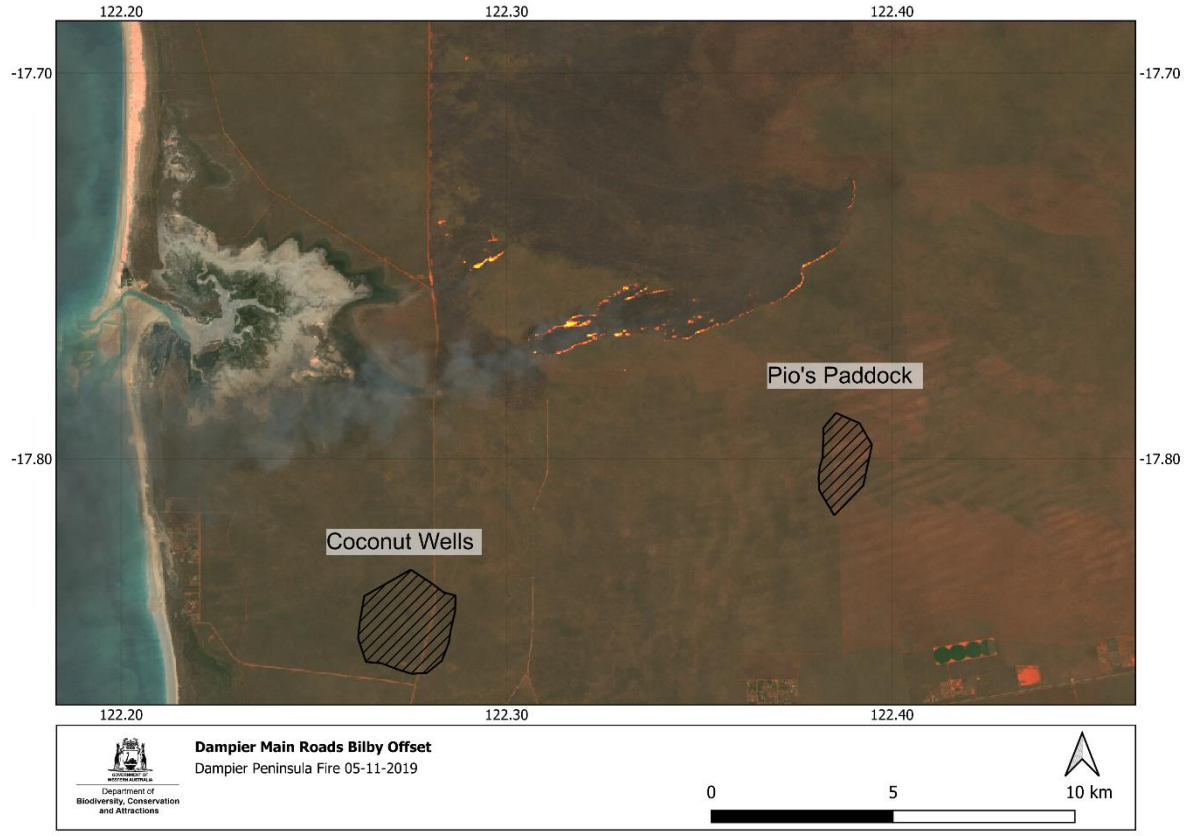

Figure 18 – Sentinel 2 satellite imagery showing the 2019 late dry season fire which impacted the Coconut Wells bilby population.

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).

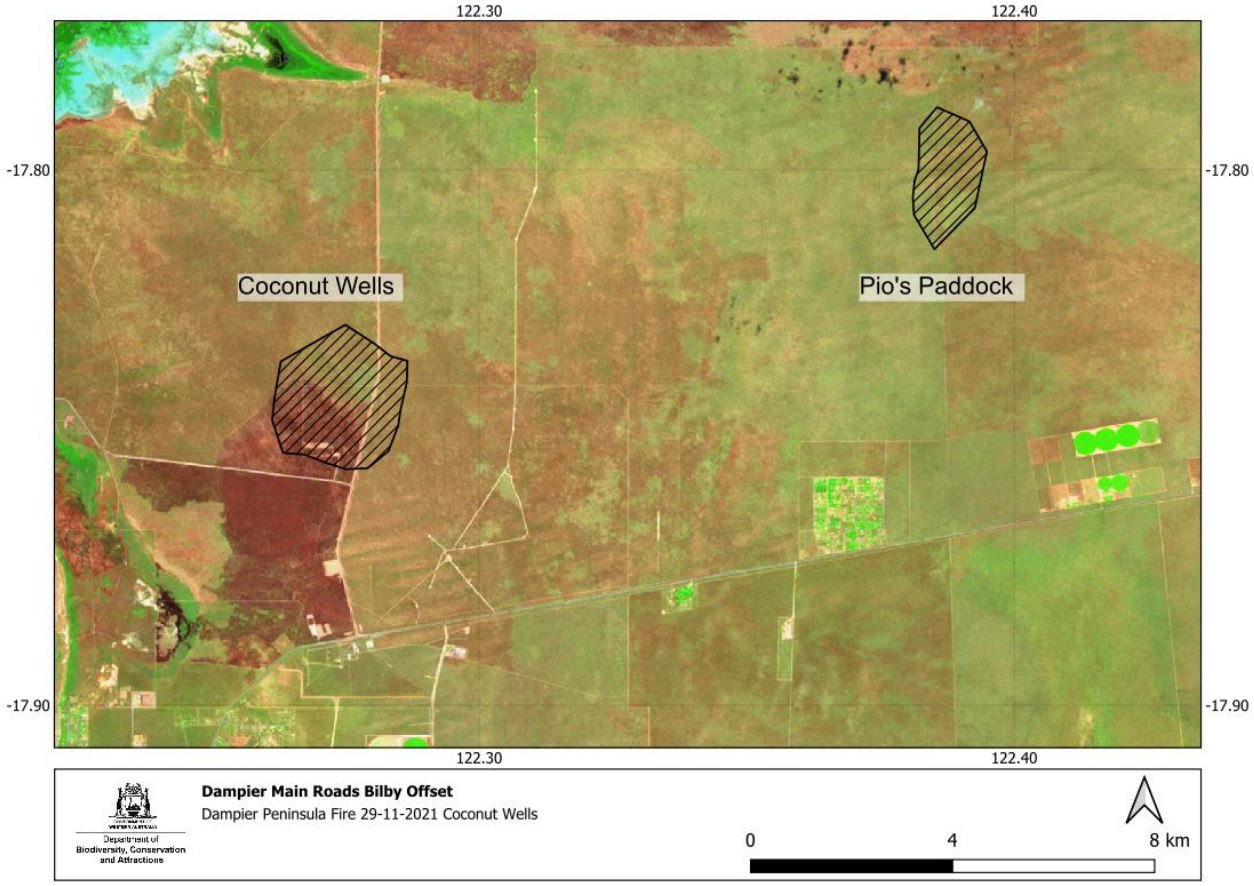

Figure 20 – Sentinel 2 imagery showing the 2021 late dry season fire which impacted the Coconut Wells bilby colony.

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.

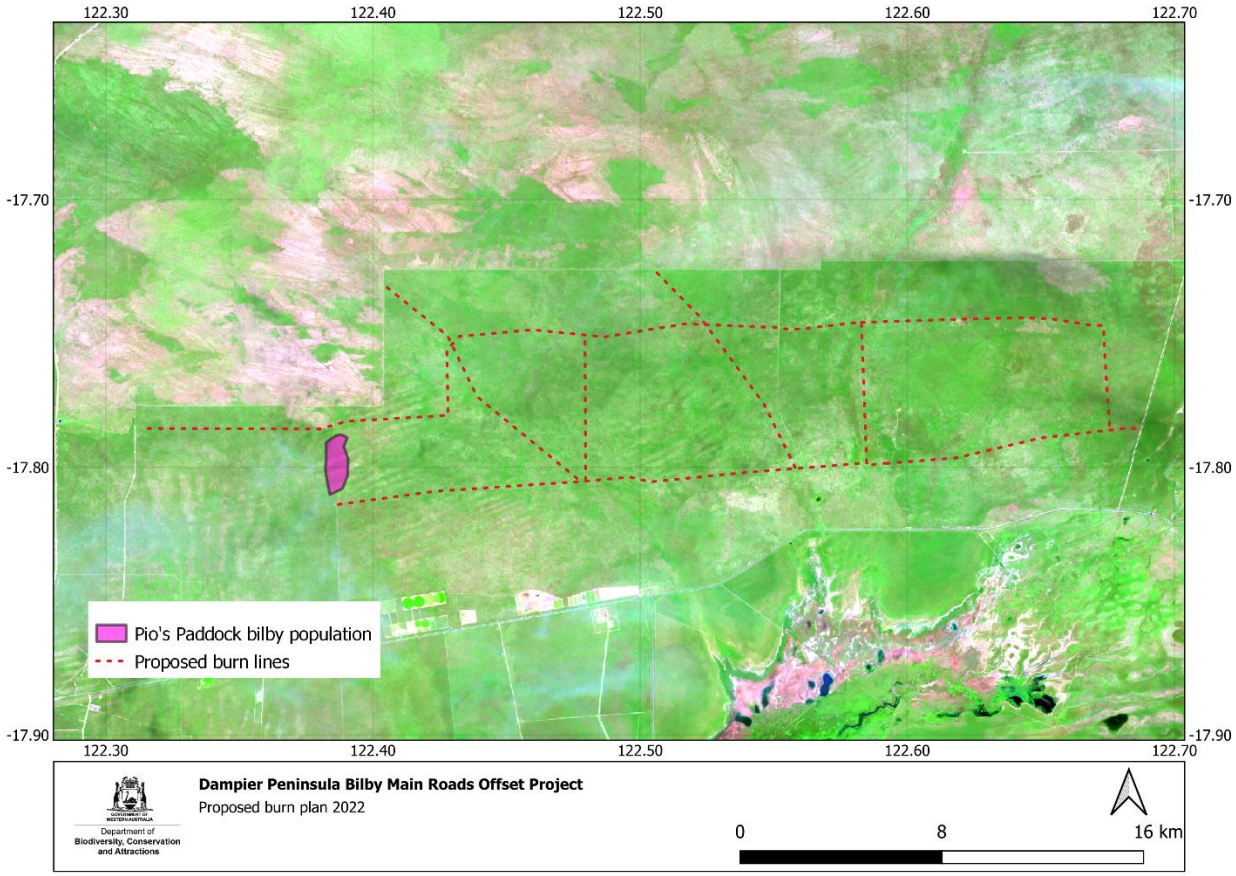

Figure 21 – 2022 proposed burn lines at Pio's Paddock on the Dampier peninsula.

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.

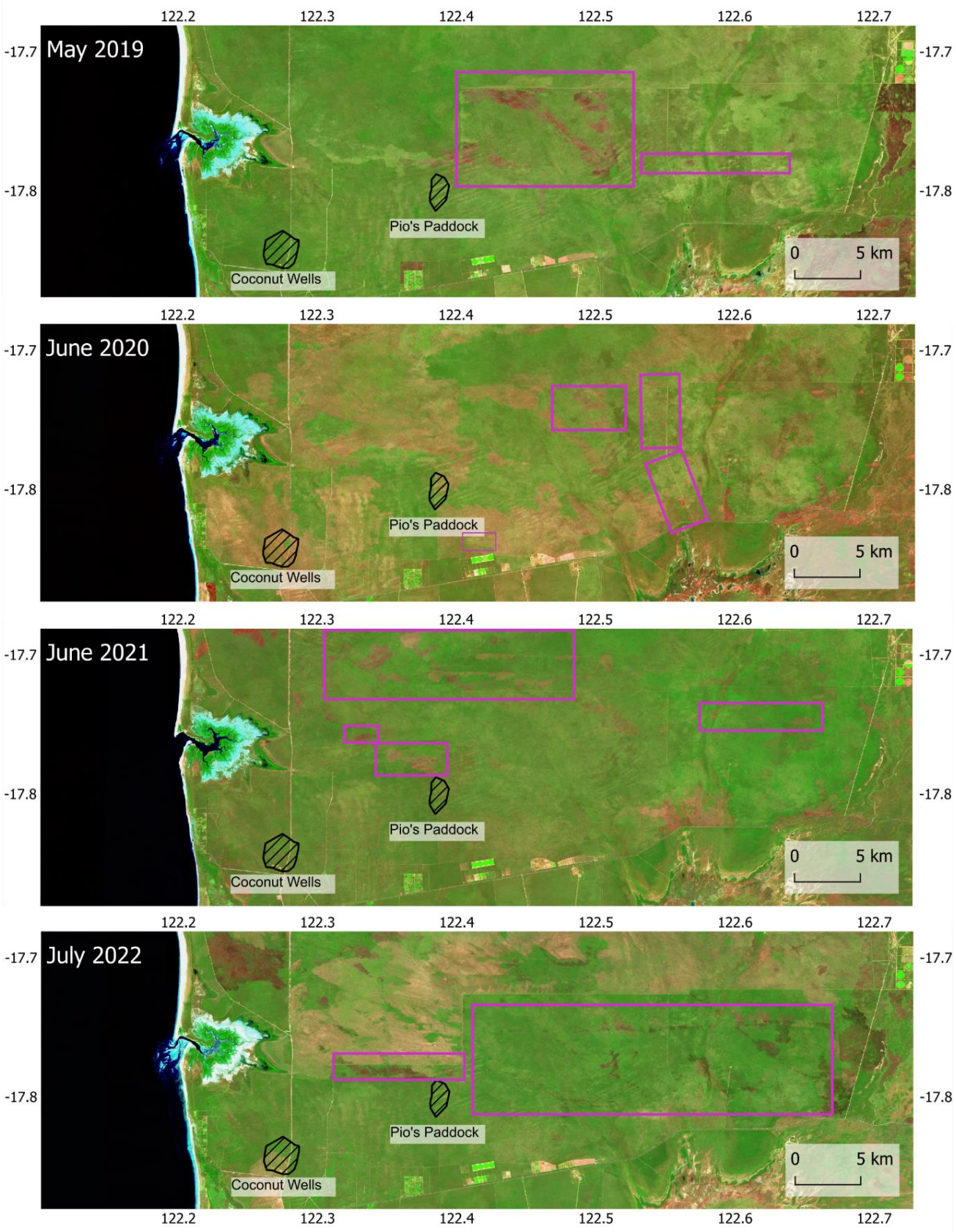

Figure 23 – Sentinel 2 imagery showing early dry season strategic burning implemented by DBCA between 2019 and 2022 near Pio's Paddock and Coconut Wells.

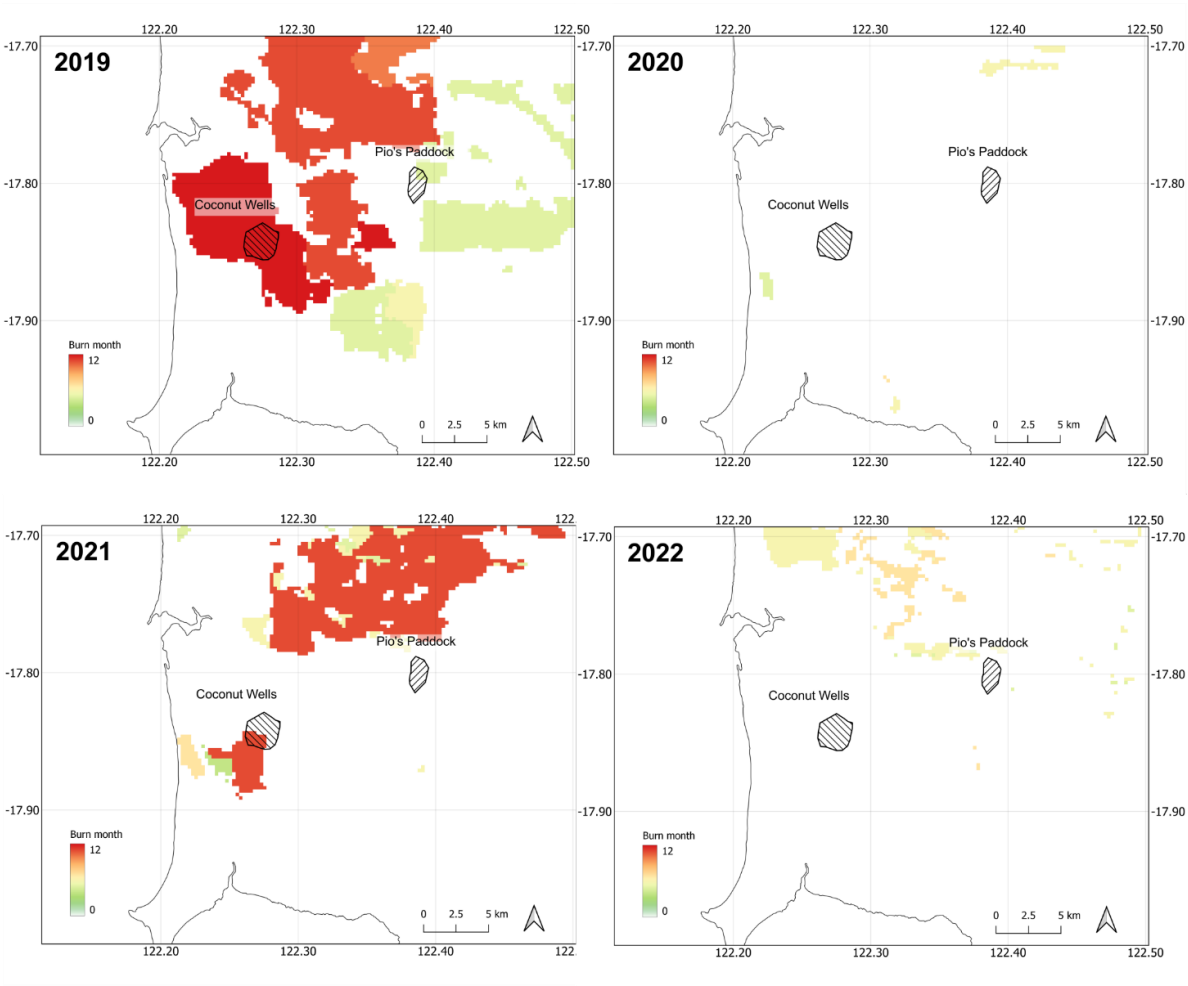

Figure 24 – Northern Australian Fire Information data showing fire histories at Pio's Paddock and Coconut Wells between 2019 and 2022.

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

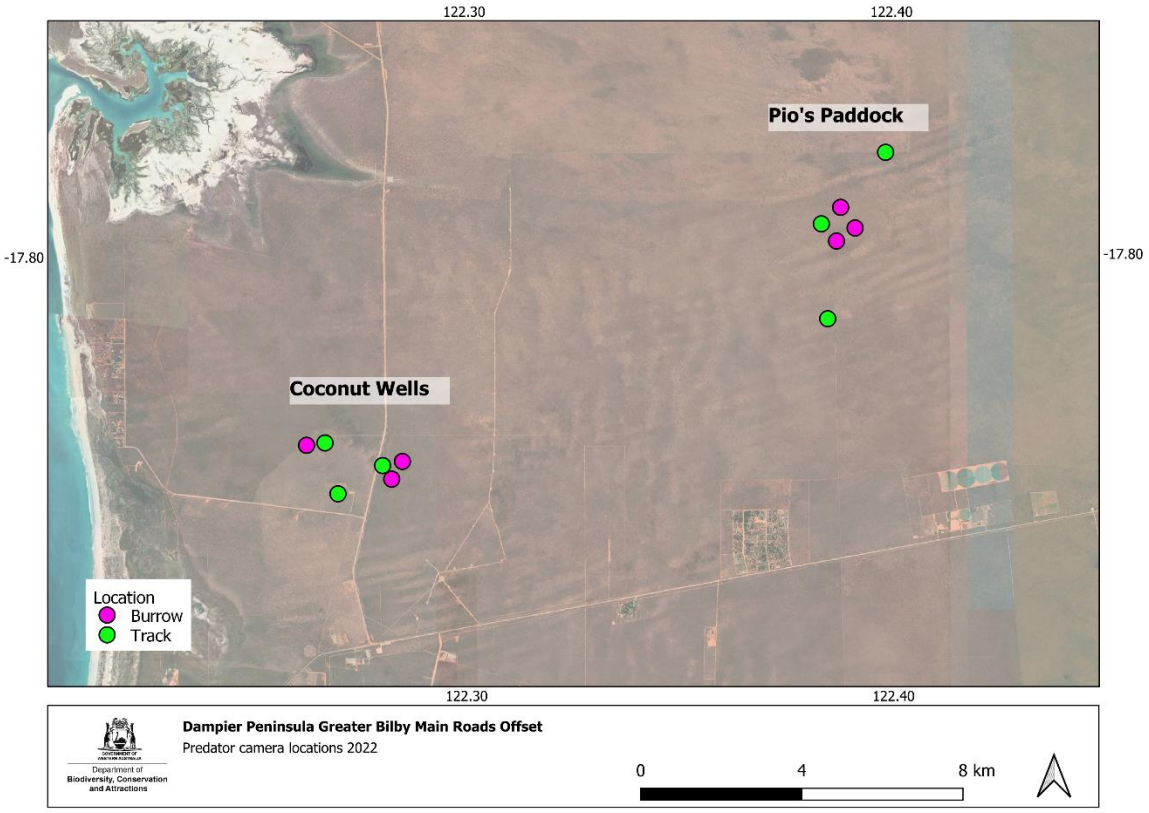


Figure S1 – Location of camera traps at Coconut Wells and Pio's Paddock bilby populations to monitor occurrence.

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.

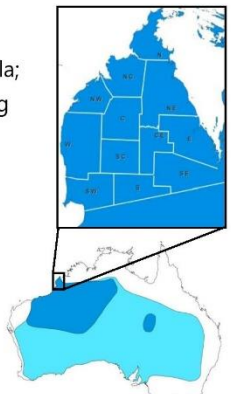
Coordinated by the Department of Biodiversity, Conservation and Attractions, this project will help fulfil a primary objective of the current interim bilby recovery plan (Bradley *et al.* 2015) and identified management priorities (Cramer *et al.* 2016). This is to retain/maintain the naturally-occurring 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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Department of Biodiversity, Conservation and Attractions

PARKS AND WILDLIFE SERVICE

Bradley, K., Lees, C., Lundie-Jenkins, G., Copley, P., Paltridge, R., Dziminski, M., Southgate, R., Nally, S., Kemp, L. (2015) *2015 Greater Bilby Conservation Summit and Interim Conservation Plan: an Initiative of the Save the Bilby Fund.* IUCN SSC Conservation Breeding Specialist Group, Apple Valley, MN.

Cramer, V. A., Dziminski, M. A., Southgate, R., Carpenter, F., Ellis, R. J., van Leeuwen, S. (2016) A conceptual framework for habitat use and research priorities for the greater bilby (*Macrotis lagotis*) in the north of Western Australia. *Aust. Mammal.*

Figure S2 – Dampier Peninsula Bilby Project flyer.

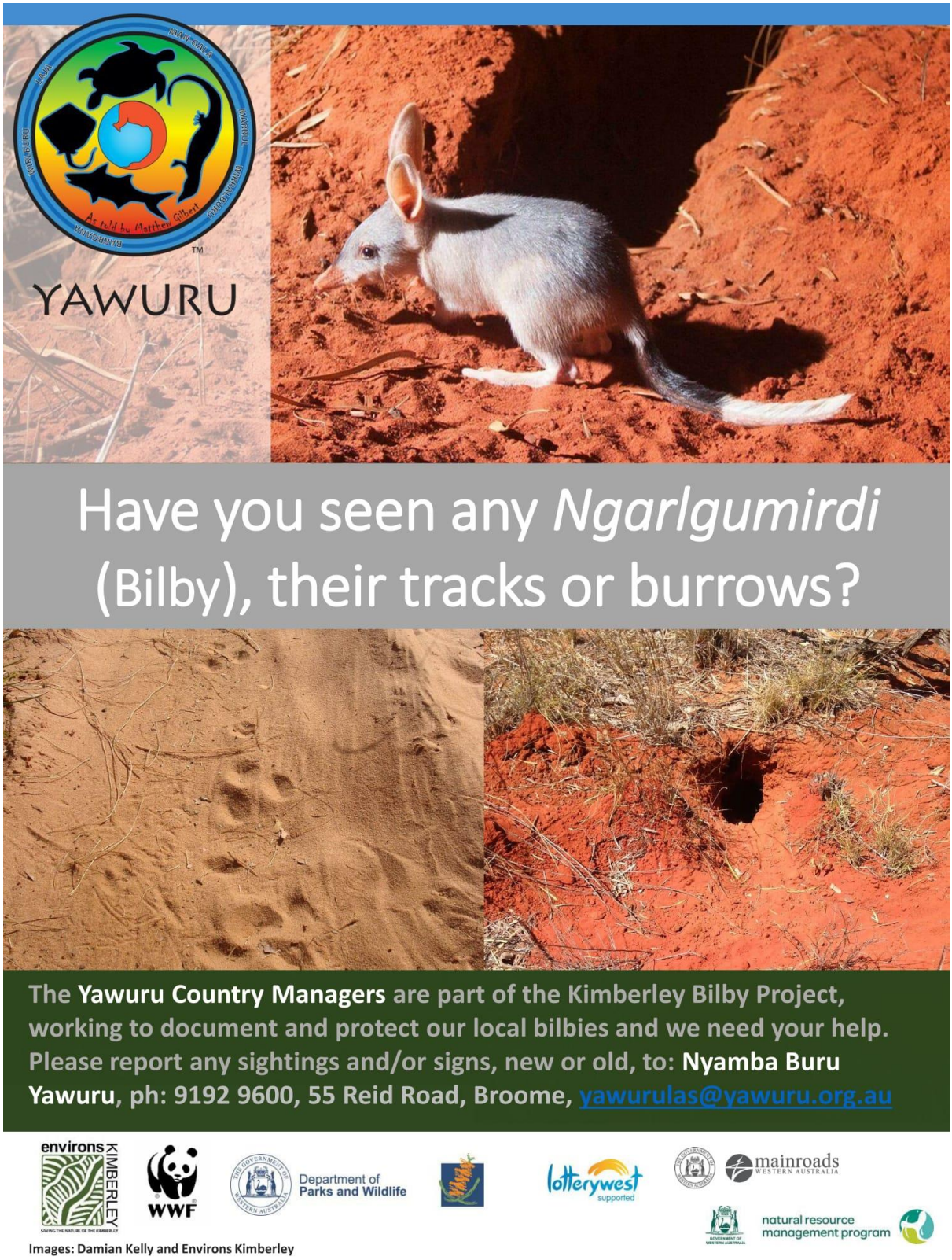

Figure S3 – Yawuru bilby information sheet.

Figure S4 – Nyul Nyul bilby information sheet.

Figure S5 – Nyikina Mangala bilby information sheet.

Figure S6 – Bardi Jawi bilby information sheet.

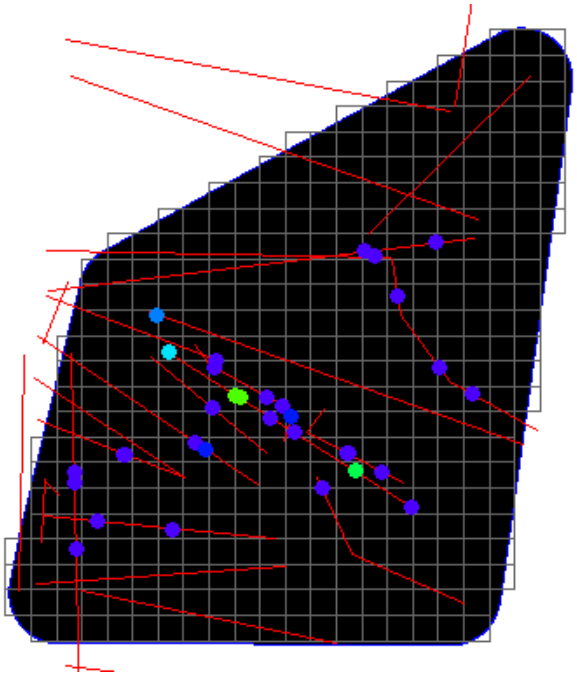

Figure S7 – Spatially Explicit Capture-Recapture (SECR) grid used to estimate bilby density at Pio's Paddock.

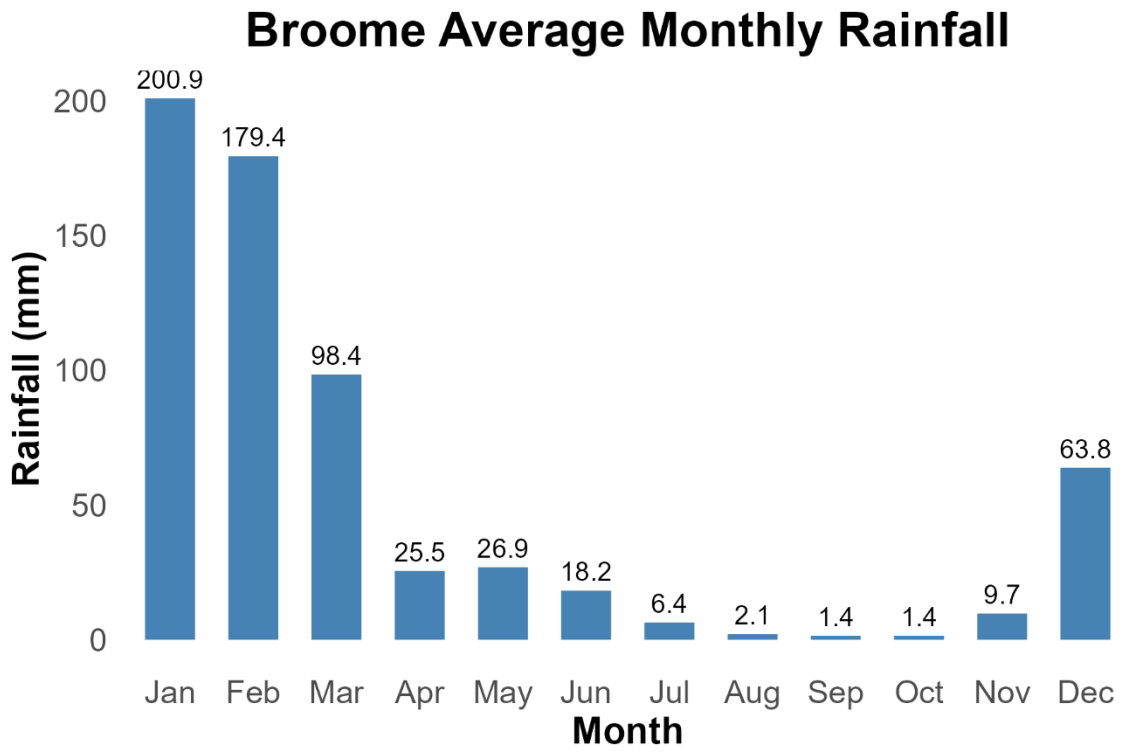

Figure S8 – Average monthly rainfall for the Coconut Wells and Pio's Paddock bilby populations.