



THARRA GREATER BILBY CONSERVATION PROJECT

Field Survey Report

September 2024





Acknowledgement of Country

We acknowledge the Palyku people, who are the Traditional Custodians of Tharra (Woodstock Protected Reserve) and the areas described within this report. We pay our respects to the Elders past, present, and emerging, and to their continuing cultural and spiritual connections to their lands.

This report leans heavily on the Traditional Knowledge of the Palyku people of the central Pilbara, whose knowledge is shared with permission.

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CONTENTS

Field Survey Report	1
Acknowledgement of Country	2
1. Background.....	4
2. Project Logic	5
Species profile	5
Project area	8
Methodology	11
Data management.....	15
Data Analysis	16
3. Results	18
4. Discussion and Management Recommendations.....	25
Occupancy	25
Priority Habitat	26
Establish a Baseline Monitoring Approach	27
Key threatening processes	27
Grazing Pressure.....	27
Predation	28
Altered Fire Regimes	28
Conclusion	30
References.....	32
Appendix 1: Plot Photos	35
Appendix 2: Remote sensor camera images.	155
Appendix 3: Desktop Research.....	159
Appendix 4: Project contacts	179
Copyright	180
Disclaimer	180
Version Control.....	180
.....	181

1. Background

The Pilbara Environmental Offset Fund (PEOF), administered by the Department of Water and Environmental Regulation (DWER), provides funding for environmental offset projects as a counterbalance to impacts from Pilbara activities. This is delivered in partnership with regional programs (including ranger teams), to provide offset projects targeted towards strategic, landscape-scale priority targets.

The Woodstock Abydos Protected Reserve (WAPR), located within the Chichester sub-bioregion, falls within the PEOF's Priority Area 1 for offset projects. The reserve is protected under section 19 of the *Aboriginal Cultural Heritage Act 2021 (WA)* and represents a high concentration of priority environmental matters required to be offset. The southern half of the reserve (Tharra) lies with the Palyku Native Title Determination Area. Tharra is actively managed by the Budadee ranger team, a Palyku owned and operated Caring for Country program administered by Budadee Aboriginal Corporation (Budadee).

On-country consultation between DWER and Budadee was held in 2022 and identified areas for collaboration towards environmental offset objectives. One such opportunity was in the protection of habitat for the Greater Bilby (*Macrotis lagotis*). Greater Bilby (bilby) habitat is recognised as a Matter of National Environmental Significance under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and is a condition in Ministerial Statements which the PEOF is required to offset. For Budadee, concerns have been high that bilby habitat at Tharra is threatened by increasing levels of development, introduced species and a lack of fire management.

The Tharra Greater Bilby Conservation Project was co-designed by DWER and Budadee with the aim of establishing Tharra as an actively managed refuge for identified bilby populations. As the first stage of a larger management program, this project targeted knowledge gaps in our understanding of the bilby population of Tharra, defining their area of occupancy and providing a baseline data set for bilby monitoring. The groundwork was also laid for assessing the management priorities required for protecting bilby habitat in stage two of the project.

A survey methodology for assessing bilby occupancy was designed based on established occupancy modelling for bilbies in the Pilbara, and desktop research was conducted to predict potential distribution across Tharra (past survey effort, bilby ecology, vegetation and substrate structure, refer to Tharra Greater Bilby Conservation Project, Desktop Research 2023, Appendix 3). A three-day reconnaissance survey was then conducted in August 2023 with Palyku Elders and knowledge holders to refine the field methodology and map indicative survey plot areas using a combination of traditional knowledge and predicted distribution. Access limitations across Tharra, known avoidance areas (cultural avoidance areas) and additional habitat indicators were also assessed and recorded.

Between October 2023 and June 2024, the Budadee rangers undertook four five-day field surveys to collect track-based survey data on bilby occupancy across Tharra. A total of 240 hectares were surveyed across Tharra from 64 individual 2 ha plot sampling locations (56 of which were surveyed twice). At selected areas of recent

bilby activity, motion-sensor cameras were also established to capture visual confirmation of bilby presence. This document is a field survey report presenting the results of these surveys. In line with the strategy of the Greater Bilby Conservation Project, it has the following objectives:

- Identify bilby occupancy within Tharra
- Delineate priority bilby habitat within Tharra
- Establish baseline data and a monitoring approach to evaluate bilby habitat and quantify changes to bilby occupancy over time
- Assess key threatening processes to bilby habitat and identify management priorities.

2. Project Logic

Species profile

The Greater Bilby (*Macrotis lagotis*) is a medium-sized, desert marsupial endemic to Australia. It is the only remaining species from the family Thylacomyidae, after the other known member, *Macrotis leucura*, was declared extinct in the 1960s (Jackson and Groves 2015). From a historical distribution that covered more than three quarters of Australia's landmass, the bilby is now only found within northern deserts of Western Australia and the Northern Territory, and from one small population in south-west Queensland. It is estimated that this distribution reflects less than 20% of their former range, with a declining population of fewer than 10,000 mature individuals (Southgate 1990; Woinarski et al. 2014). Bilbies are listed as vulnerable under the *Biodiversity Conservation Act 2016 (WA)* and the EPBC Act and are listed as vulnerable under the IUCN Red List of Threatened Species (IUCN Red List of Threatened Species, 2015). The bilby is one of 100 priority species selected as part of the Australian Government's Threatened Species Strategy.

Across their known distribution, bilby habitat is characterised by sandplains, claypans, dune fields, laterite, mulga bushland, and creeklines, preferring spinifex (*Triodia spp.*) grasslands and medium/soft substrate (Woinarski et al. 2014). Bilbies are primarily nocturnal and cover large individual ranges in search of food and shelter (Woinarski et al. 2014). They are omnivorous, with a diet consisting of invertebrates, seeds, bulbs and fungi and they typically dig for their food, burrowing to a depth of two and a half metres (Gibson 2001). Bilbies have extensive foraging ranges and move across country, using numerous burrows scattered across the landscape (Moseby and O'Donnell 2003). It is not uncommon for bilbies to travel distances of 3 to 5 km in a single day (Southgate and Carthew 2007).

Tharra is located along the southwestern boundary of the bilby's estimated current distribution (Recovery Plan for the Greater Bilby 2023). It contains a range of habitat

suitable for supporting bilby populations and bilby signs (sightings, tracks, scats and burrows) have been documented from historical surveys dating back to the 1960s.

Bilbies have long been recognised as being part of Tharra's landscape. Palyku people have a strong knowledge of the animals on Palyku Country, including bilbies. Palyku people, especially the old people, understand the country, and the conditions and habitat that support bilbies.

On Palyku Country, there are many bush foods that are eaten by bilbies. This includes insects, *bardi* (large insect larvae i.e. witchety grubs), seeds, fruits, and tubers. The presence and relative abundance of these foods on country can signal suitable bilby habitat, infer the health of country, and help to refine survey effort. Bilbies find food from different sources in different areas of Palyku Country. Understanding and identifying these sources across Palyku Country can help to define and protect bilby habitat.



Plate 1: Gnarlgu (Cyperus bulbosa) were commonly found dug up adjacent to bilby burrows and are an important part of the bilbies diet at Tharra.

Within Tharra's river systems and along drainage lines, bilbies dig for *bardi* in the roots of trees such as *wantanypa* (*Acacia aneura*) and *munduru* (*Acacia cyperophylla*) and for termites amongst *baru* (spinifex, *Triodia wiseana*). They will dig for the tuberous roots of *ngarlgu* (bush onions, *Cyperus bulbosa*) sometimes digging out the whole plant. Roots and seeds of bush carrot (*Daucus glochidiatus*), *mungalin* (*Iponoea spp.*), bush bean (*Vigna lanceolata*), *marta* (sweet bush potato, *Dioscorea hastifolia*) and *ngarbruda* (bush cucumber, *Cucumis melo*) also provide a food and water source.

On *baru* country (spinifex flats), bilbies dig for termites and *bardi*, particularly on recently burnt country. Plants that have *bardi* on *baru* country include *budadee* (*Acacia inaequilatera*), *jiggarda* (*Eucalyptus leucophloia*), *burgu* (*Hakea lorea*) and cockroach bush (*Senna notabilis*). Bilbies may also eat the *wogola* (bush coconuts) fallen from the *bunara* tree (*Corymbia opaca*). Fruits from *galumbu* (bush tomato, *Solanum phlomoides*), and *wanyalie* (bush banana, *Marsdenia australis*) may also be eaten.

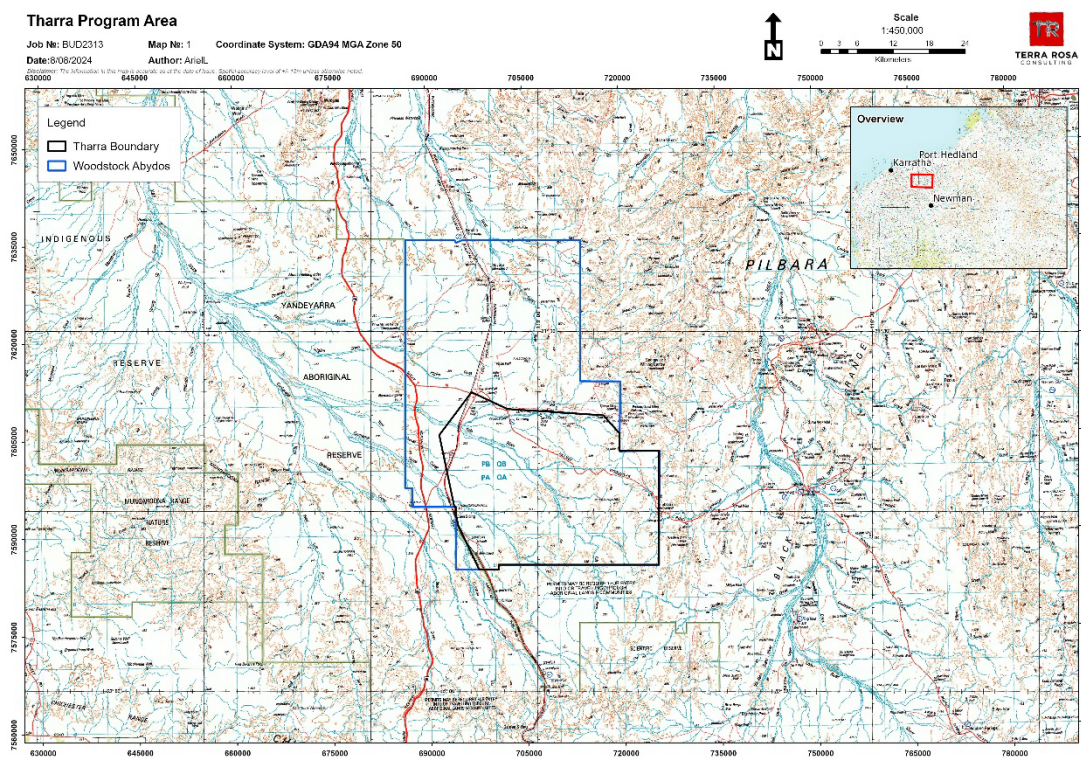
"At Woodstock [Tharra], [bilbies] gotta be in soft country. Mostly on the banks of the creeks. Food they eat is the *bardi* (witchety) grub. In amongst the mini ritchi on the riverbanks. Soft soil to dig. *Bardi* grub is the main food. They break the roots open. They travel around a bit, size of a rabbit. Travel a fair bit. They go and come back. The mini ritchi needs the soft sand as well, in Woodstock there, well, where their burrows are, not far away are the mini ritchi. When we look around, we'll see the *bardi* diggings." – Kevin Stream (pers. comm. 29/06/2023).



Plate 2: Bilby diggings under a young mini ritchi tree on a riverbank at Tharra

Project area

Tharra Karnparnmana (also known as the Woodstock Abydos Protected Reserve) is a 154,102 ha heritage reserve located in the Chichester bioregion of the central Pilbara. Its borders represent the amalgamation of the historic Abydos and Woodstock pastoral properties, that were merged into a single reserve before being recognised for protection under the *Aboriginal Heritage Act 1972 (WA)*. Tharra (*pronounced duh-ra*) refers to the Country of the Palyku Traditional Owners within the reserve and falls within the Palyku Native Title Determination Area (WC1998/071). Tharra covers an area of approximately 74,000 hectares and includes the southern and eastern half of the amalgamated reserve, roughly analogous with the historic Woodstock pastoral station boundary. Upper catchments of the Yule and Shaw Rivers snake through Tharra, with water collecting in numerous permanent and semi-permanent rock holes and springs. Tharra is a place of enormous cultural significance, with songlines, engravings, and stories that connect Palyku people to their law, culture, and community.



Map 1: Tharra program area and Woodstock Abydos Protected Area boundary.

Tharra is dominated by gently undulating stony and sandy plains, punctuated by granite ranges. It is intersected by two river systems, the upper catchment of the Yule River and the Shaw branch of the De Grey River. Tharra's plains typically support a shrub steppe of *budadee* (*Acacia inaequilatera*) over *baru* (spinifex) hummock

grasslands (*Triodia wiseana*) with tree steppes of *jiggarda* (white wood tree, *Eucalyptus leucophloia*) dominating the ranges. A shade of *dalgoolbooda* (*Malaleuca spp.*) and *munduru* (*Acacia cyperophylla*) is common across the river systems, with banks dominated by *baru* (*Triodia wiseana*) and introduced buffel (*Cenchrus ciliaris*) grasses.

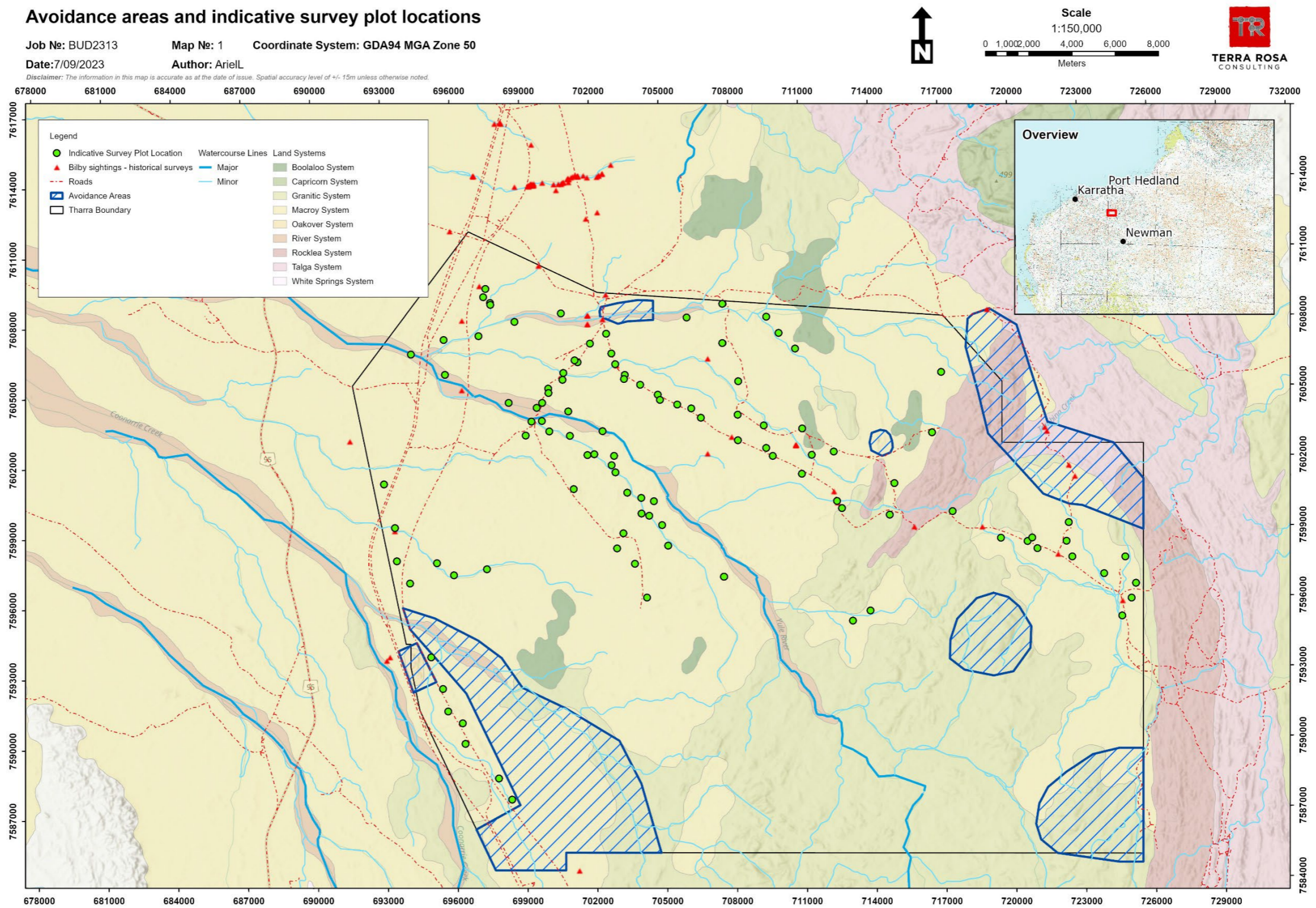
Pre-survey desktop research identified habitat with suitable geological and biological characteristics for bilbies across an estimated 63,000 hectares (or 85% of Tharra). This includes Macroy, Granitic, River and Boolaloo Land Systems (refer to table 1). Historical survey data reveals documented records of bilbies from 21 secondary sign sightings (tracks, burrows, and scats) between 1969 and 2017. These sightings are skewed towards the northern sections of Tharra with 16 within Macroy and four within River Land Systems. These recordings are primarily focussed on road and rail infrastructure corridors (reflective of survey effort). For example, 14 of the documented sightings within Tharra represent surveys conducted in 2014 adjacent to the Hillside-Woodstock Road. Data is sourced from the following databases:

- Threatened and Priority Fauna (DBCA-037)
- Atlas of Living Australia
- Index of Biodiversity Surveys for Assessments (IBSA)
- Protected matters search tool – heatmap
- NatureMaps (pre-2021 data).

Table 1: Representative coverage (estimate) of major Land Systems within Tharra with potential bilby habitat highlighted in green.

Land Systems within Tharra		Tharra coverage
Macroy	Stony plains and occasional tor fields based on granite supporting hard and soft spinifex shrubby grasslands.	~45%
Boolaloo	Granite hills, domes, tor fields and sandy plains supporting spinifex grasslands with scattered shrubs.	<5%
Granitic	Rugged granitic hills supporting shrubby hard and soft spinifex grasslands.	~35%
River	Narrow, seasonally active flood plains and major river channels supporting moderately close, tall shrublands or woodlands of acacias and fringing communities of eucalypts sometimes with tussock grasses or spinifex.	<5%
Rocklea	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex and occasionally soft spinifex grasslands with scattered shrubs.	<10%

Map 1: Historical bilby sightings at Tharra and proposed 2 ha survey plot sampling locations showing identified cultural avoidance areas and Land Systems.



Methodology

Ground-based assessment of bilby presence was undertaken using the 2 ha sign plot method. Two ha sign plots are a method of track-based survey that standardises survey effort and area. The 2 ha sign plot method allows direct comparisons between plots and enables estimations on the probability of detection and occupancy (Southgate et al. 2019). Coupled with systematic re-sampling to control for detection probability, the 2 ha sign plot method is the recommended approach for large area surveys (>1600 ha) that require quantifiable data (DBCA 2018). The methodology has a few limitations that should be noted. It is labour intensive, requiring field-based surveys with suitably trained personnel. It provides limited information on individuals or measurements of abundance, and plot allocation is skewed to areas with suitable access (for example within proximity of roads and tracks). Despite these limitations, it remains an effective method for detecting bilbies, was deemed the most suitable survey method for the project area and is widely used to detect bilbies and define bilby occupancy (DBCA 2018, Southgate 1990, Paltridge 2016).

The 2 ha sign plot methodology was used to define detection and occupancy of bilbies at Tharra. Detection here is defined as the probability of detecting evidence of the focal species given the species uses the location, and occupancy is defined as the proportion of locations used by the species (Moore 2022). Given the relative scarcity of bilbies within landscapes, and the large defined project area at Tharra (~74,000 ha), a suitably large number of plots was sampled to ensure data collected is statistically robust (n=120). A total of 64 plots were assigned across four potential habitat zones. These were ground-truthed and allocated during an initial reconnaissance survey (August 2023), considering traditional ecological knowledge, cultural protocols (for example avoidance areas), range of post-fire aged habitat, suitable soil type and access limitations across country (refer to map 2).

The 2 ha sign plot surveys were conducted over four, 5-day field trips by a team of Budadee rangers (refer to table 2 and table 3). Survey effort was focussed within survey plots with a defined area of 200 m by 100 m (2 ha), with observers searching for bilby and feral predator signs (such as tracks and scats) for a set duration of 25 minutes (adjusted for team size). Observations of bilby signs were captured on a custom digital survey form (refer to plate 4, alongside observation data on heritage values, fire age, threatening processes and any indicator species relevant to bilbies (such as food sources). Other information relevant to ongoing management of Tharra was collected as identified including other priority listed species (priority flora, conservation-listed fauna), species of cultural importance (traditional land-use species such as ceremony, food and medicine species) and any undocumented heritage values. Each plot was photographed from the southwest corner, and GPS points and track logs were captured.

Table 2: Field survey dates

Survey Name	2 ha plot numbers	Date
Field Survey 1	1 – 30	10 – 15 October 2023
Field Survey 2	31 – 60	6 – 11 November 2023
Field Survey 3	Replicates 1 – 30	12 – 17 March 2024
Field Survey 4	Replicates 31 – 56 New plots 61 – 64	27 May – 01 June 2024

To insure against issues of imperfect detectability, sampling was replicated at 56 of the 64 plots approximately four months after the baseline survey (refer to table 2). Four sites established in 2023 were not replicated in 2024 after advice from Palyku Elders on cultural sensitivities in the area, and instead four new plots were established.



Plate 3: Fresh bilby scats identified at active burrows during field surveys.

Where high confidence in recent bilby activity was detected, motion-sensor cameras were set up to detect bilby and feral predator activity. A total of three cameras (Reconyx HS2X Hyperfire 2) were established adjacent to recent bilby activity outside of survey plot 30 (refer to map 3). One camera was set in May 2023 (BC01), and two cameras were set in July 2024 (BC02, BC03). These were collected and reviewed in November 2023 (BC01) and September 2024 (BC02, BC03). A total of 41 nights in 2023, and 24 nights in 2024 were monitored across the three cameras, equating to a total of 65 survey nights. Each camera was fixed firmly to a 1.5 m black galvanised star picket and oriented horizontally relative to active bilby burrow sites. Cameras were set to high sensitivity, taking bursts of three photos with a 15 second (photo-free) interval. No bait was used.

Table 3: Project participants

Budadee rangers	Position	Field survey
Natalie Stream	Senior Ranger/Cultural Advisor	1
Gavin Cabales	Ranger Coordinator/Cultural Advisor	1, 2, 3, 4
Hazel Lockyer	Ranger	1, 3
Duane Stream	Ranger	1
Keniesha Cabales	Ranger	1, 2
Damien Ball	Ranger	1, 3
Michael Coffin	Ranger	1, 3, 4
Zakiesha Clinch	Ranger	1, 3, 4
Margaret Stewart	Ranger	1, 3
Stephen Stewart Snr	Elder	1, 2, 3
Biddy Norman	Elder	1
Fred Stream	Elder	1
Annabel Stream	Ranger/Cultural Advisor	1, 2, 3
Steven Stewart Jnr	Ranger	1, 2, 3
Weston Stream	Ranger	1
Madison Fraser	Ranger	1
James Dolin	Ranger Coordinator	1, 2, 3, 4
Danika Penson	Environmental Consultant	1
Andrew Hatswell	Consultant	2, 4
Judith Giraldo	Environmental Consultant	2
Amanda Stream	Ranger	2
Diana Flanagan	Ranger	2
Kylie Ryan	Ranger	2, 3, 4
Leo Cabales	Ranger	2
Leroy Clinch	Ranger	2
Sandra Francis	Ranger	2
Stan Ball Jnr	Ranger	2
Brandon Dhu	Ranger	3, 4
Catherine Biljabu	Ranger	4
Raylene Robinson	Ranger	4
Hayley Malana	Ranger	4
Valerie Aspro	Ranger	4
Janissa Booth	Ranger	4
Tasma Francis	Ranger	4

Data management

Two hectare survey plot data was recorded in-field using a custom 2 ha survey form through Survey123 (ArcGIS) and recorded on Samsung tablets (see plate 4 for an example). This form was designed using standard fields for threatened species surveys provided by the Department of Biodiversity, Conservation and Attractions (DBCA) and reviewed by DBCA's Animal Science team prior to deployment. Additional spatial data, including the location of the survey plots and placement of motion-sensor cameras, was collected on handheld GPS devices (Garmin GPS). All collected data, including digital and field notes, were uploaded to Budadee's secure SharePoint System for later analysis.

Motion-sensor camera images were uploaded to Budadee's photo library on SharePoint from relevant SD cards and reviewed by the Budadee ranger team on-country for an initial assessment. These will be made available to DBCA once they have been formally reviewed by Budadee's ranger coordinators.

Cultural information, including photos and spatial data, was vetted in situ by elders and/or relevant Palyku knowledge holders and, when appropriate, were restricted or deleted as necessary.

Plate 4: Example page from the digital survey form designed to capture bilby signs.

Greater bilby (*Macrotis lagotis*) conservation at Tharra Kampar...

Bilby observation sheet

What are they eating

Are they eating here? Food plants nearby? Are they digging into the roots of plants? Are they digging for ants/termites? Is there anything obvious in their acacia?

1000

Age and breeding status

Are there juveniles present (for example from size of tracks)? How old is the animal? How much bilby sign is there (lots of diggings and/or tracks)?

1000

Threats

Are there any threats to country here? Are there invasive plants or animals? Does this place need fire? Does this place need traps? Any other management?

1000

Cultural heritage

Is there any cultural values here that should be recorded or avoided? Are there any heritage values that need protecting here?

1000

Back
Submit

Page 6 of 6

Data Analysis

Occupancy modelling was undertaken by the DBCA courtesy of Dr Harry Moore and Natasha Harrison (Biodiversity and Conservation Science). Statistical analysis was undertaken using the unmarked R package (R v4.4.1) using a single-season occupancy model that accounts for imperfect detectability and occupancy (Mackenzie et al. 2002, Moore 2022). This was done by adjusting the naïve occupancy (i.e. non-adjusted proportion of locations used by focal species) with a measure of detectability. The parameter ψ (occupancy, i.e. the probability that site i is occupied by the focal species) and p (detection probability, i.e. the probability of the focal

species being detected at site i on day j , conditional upon its presence) was used to formulate the occupancy model.

A range of occupancy covariates (i.e. covariates influencing occupancy probability) were considered. These were grazing pressure (impact of grazing on habitat quality), substrate type (type of ground surface for example clay or sand), and time since burn (the time elapsed since the last fire event, hereby referred to as tsb). A fourth covariate, feral cat presence, was recorded in situ but not included in analysis due to discrepancies in data collection across sites and limited available data. No detectability covariates were used in this study.

The occupancy model selection was based on Akaike's Information Criterion corrected for small sample sizes (AICc). Models with lower AICc values were considered better fits to the data, balancing model complexity and explanatory power (pers. comm. Dr Harry Moore July 2024).

It should be noted that the occupancy model works under the assumptions that a) detection of species at sites is independent of detection at other sites; b) there are no false detections and c) occupancy remains constant over the sampling period. Due to restrictions of access and the large number of sites sampled over a relatively small area, site independency cannot be safely ensured (many sites were sampled less than the recommended 2 km distance from each other). In addition, the 2024 survey events were separated by a three-month period due to inclement weather, potentially affecting the constant occupancy assumption. Whilst these discrepancies are hard to measure, it is of the professional opinion of the author and analysis team at DBCA that these effects are likely not sufficient to undermine the validity of the model and analysis results.

3. Results

Field surveys collected data from a total of 64 sites, 56 of which were surveyed twice and eight sites surveyed only once (a total of 120 plot surveys). From these sites, positive detection of bilby presence was recorded from a total of 22 survey plots across 16 sampling plot locations, 14 during the first sampling events (October and November 2023) and 8 during the second (replicate sampling event, March and June 2024, refer to figure 1). Bilby signs recorded included tracks, diggings, burrows, and scats. Naïve occupancy was recorded at 0.34 (number of sites detected divided by total number of sites sampled). Detectability was recorded at 0.61, indicating that there is a 61% probability of detecting bilbies if they are present in the surveyed area. This relatively high detectability suggests that the methods used for surveying were effective in identifying the presence of bilbies.



Plate 5: Active bilby burrow with fresh tracks detected during field surveys.

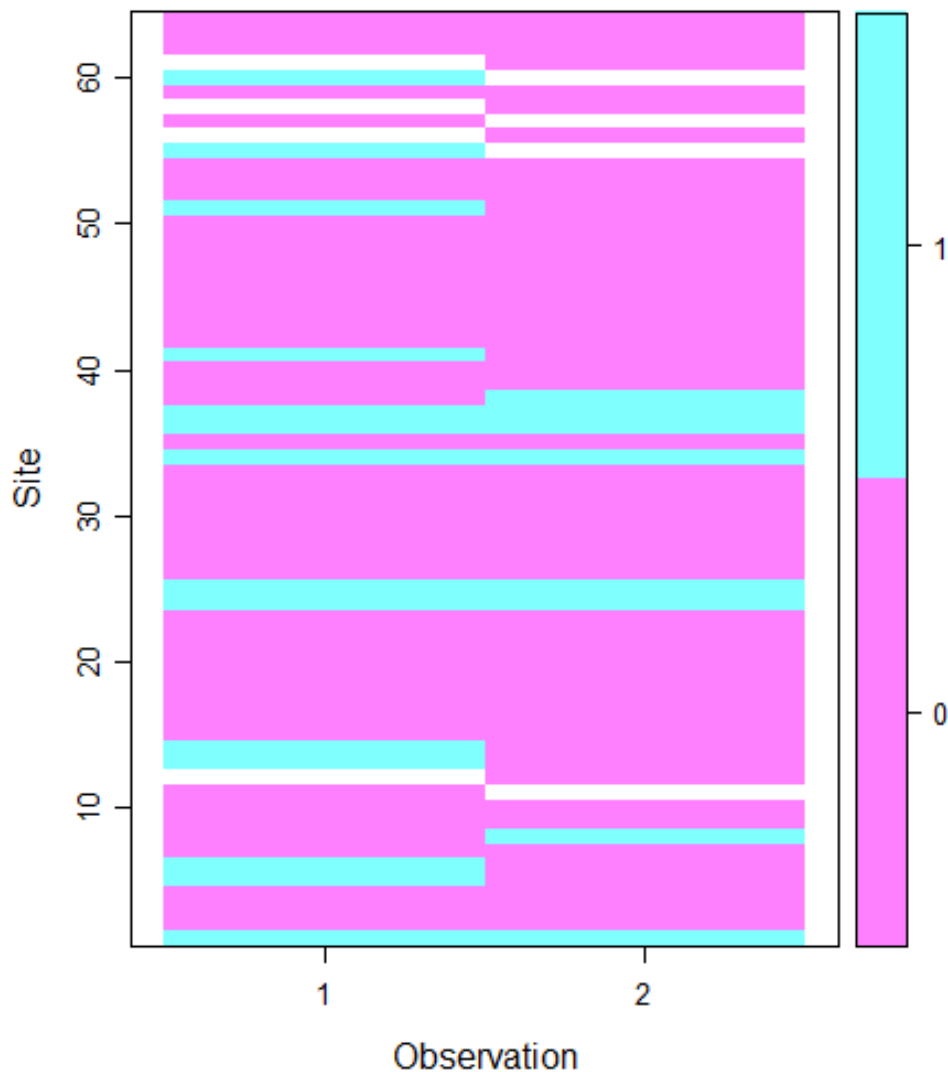


Figure 1. Detection history of bilbies across 64 sites and two survey events. Each row represents a different site, while each column represents a survey event. Blue bars indicate detected presence (1) of bilbies, and pink bars indicate non-detection (0). White bars indicate no survey was undertaken at that site. Courtesy of DBCA.

Positive detections of bilby presence were distributed broadly across Tharra, with sightings along the eastern, northwestern and western margins of the reserve, as well as two positive detections in the centre (refer to map 3). The highest proportion of positive detections were located to the northwest, with eight sightings located within a five km radius of Rabbitohs Well (see plot 40, map 3 for reference). Almost all detections were found within Macroy Land Systems, typified by stony plains and occasional tor fields based on granite supporting hard and soft spinifex shrubby grasslands. Two detections (plots 30 and 58) were in River Land Systems adjacent to Macroy Land Systems.

Motion-sensor cameras were established adjacent to active bilby burrows at three locations close to survey plot 30, near Rabbitohs Well (refer to map 3 and table 4). Vegetation condition at these sites was considered poor, with obvious signs of damage caused by human activities including grazing, aggressive weeds (*Vachelia farnesiana*) and clearing for infrastructure. These sites are also close to road and rail infrastructure.

Table 4: Camera location and habitat information

Reference Location Number	Land System	Condition Score (EPA)	Site	Coordinates	
				Latitude	Longitude
BC01	Macroy	Poor	Tharra	-21.612140	118.9096882
BC02	Macroy	Poor	Tharra	-21.611144	118.9091246
BC03	Macroy	Poor	Tharra	-21.611194	118.9086327

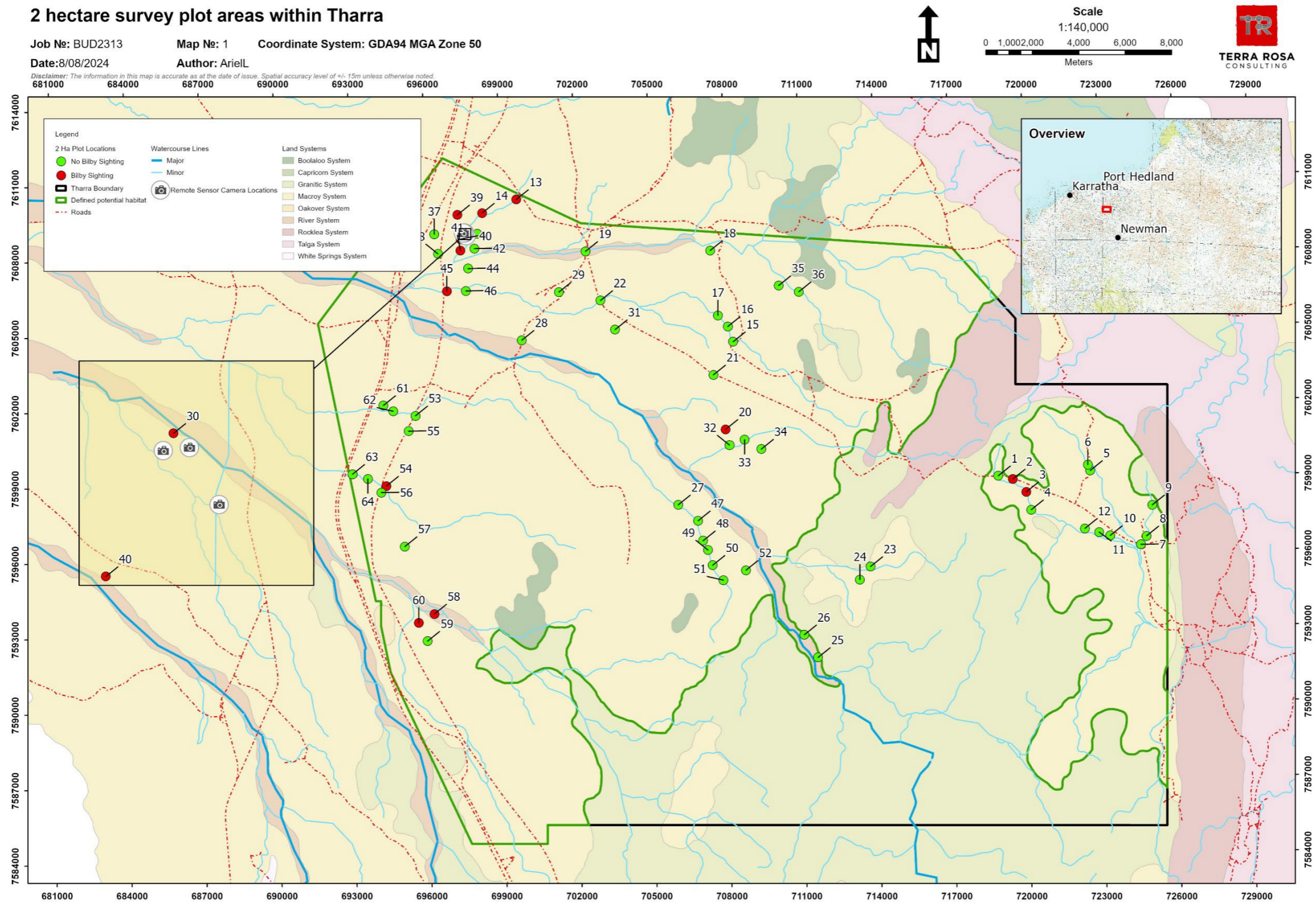
BC01, BC02 and BC03 have been reviewed for the 2023/2024 survey season, noting bilby presence and introduced predators and herbivores. Across the three cameras a total of 4434 photos were taken over 65 days. BC01 took 3179 photos over a 49-day period, including 2070 photos of bilbies, 1 photo of a dingo, and 304 photos of feral cats. BC02 took 1005 photos over a 21-day period, including 170 photos of bilbies, 407 photos of dingoes, 4 photos of cattle, and 20 photos of a feral cat (single individual). BC03 took 250 photos over a 3-day period, including 11 photos of bilbies (refer to table 5).

Table 5: Remote sensor camera detections

Date Range	Reference Location Number	No. of photos with a Bilby present	No. of photos with a Dingo present	No. of photos with a Cat present	No. of photos with Cattle present	No. of photos with a Fox present	Total No. of Photos taken
25/05/2023-12/07/2023	BC01	2070	1	304	0	0	3179

26/07/2024- 15/08/2024	BC02	170	407	20	4	0	1005
24/07/2024- 26/07/2024	BC03	11	0	0	0	0	250

Map 3: 2 ha survey plot locations, showing areas of recorded bilby sightings and placement of motion-sensor cameras.



Single-season occupancy modelling was undertaken on the field data, based on Akaike's Information Criterion corrected for small sample sizes (AICc). The occupancy covariates of grazing pressure, substrate type, and time since burn (tsb), as well as interactions between covariates, were assessed to determine the best fit for final model selection. Of these, grazing pressure was identified as the best fit for the model (AICc=103.9, refer to table 6).

Table 6: Occupancy model selection table (courtesy of DBCA).

Formula	p(Int)	psi(Int)	df	AICc	delta
~ 1 ~ Grazing_pressure	0.45	-2.01	4	103.90	0.00
~ 1 ~ Grazing_pressure + tsb	0.45	-1.55	5	105.79	1.89
~ 1 ~ Grazing_pressure	0.44	-0.82	2	106.61	2.72
~ 1 ~ Grazing_pressure + tsb	0.45	-0.15	3	107.31	3.41
~ 1 ~ Grazing_pressure + Substrate	0.47	-7.84	7	107.74	3.84
~ 1 ~ Substrate	0.43	-7.69	5	109.30	5.40
~ 1 ~ Grazing_pressure + Substrate + tsb	0.48	-5.89	8	110.29	6.39
~ 1 ~ Substrate + tsb	0.44	-4.24	6	110.89	6.99

The final model included data from all 64 sites, of which 56 were surveyed twice and eight were surveyed once. Under the grazing pressure model, low grazing pressure significantly increased species presence (estimate = 2.89, SE = 1.42, z = 2.04, p = 0.04, refer to table 7 and figure 2).

Table 7: Summary of top occupancy model (courtesy of DBCA).

	<i>Estimate</i>	<i>SE</i>	<i>z</i>	<i>P(> z)</i>
(Intercept)	-2.01	1.08	-1.86	0.06
Grazing pressure - Low	2.89	1.42	2.04	0.04
Grazing pressure - Medium	0.93	1.15	0.81	0.42

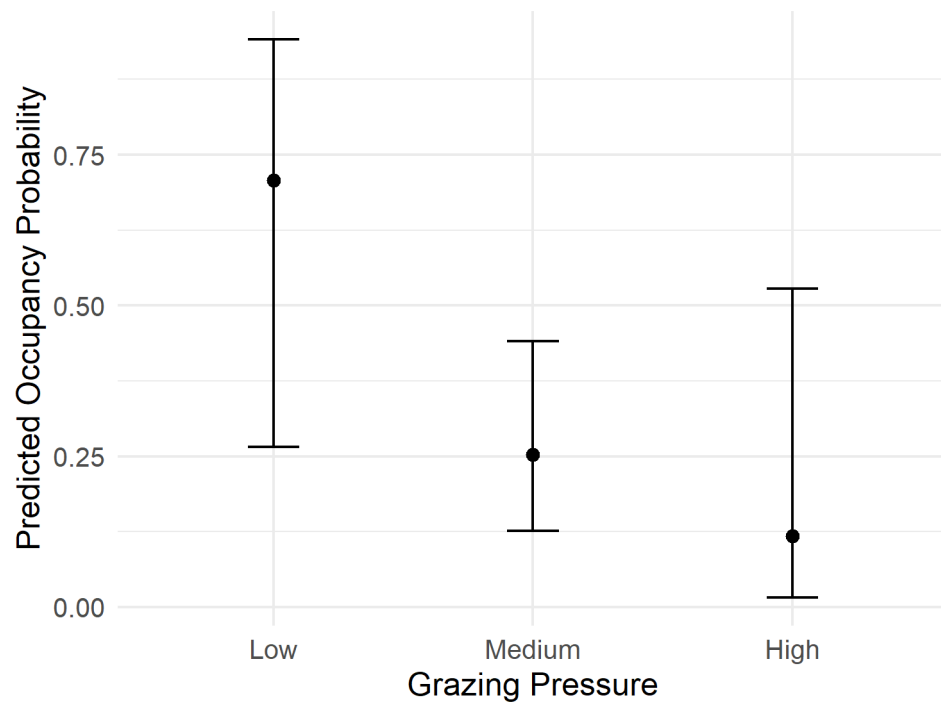


Figure 2: Predicted bilby occupancy in response to grazing pressure (courtesy of DBCA)

4. Discussion and Management Recommendations

As part of the Woodstock-Abydos Protected Reserve, Tharra is well placed to act as a refuge for the Greater Bilby. However, to actively manage the reserve and ensure proposed management effort was suitable or indeed even needed, significant knowledge gaps on Tharra's bilby ecology had to be addressed. Principle questions included, but are not limited to:

- Are bilbies still present in the landscape?
- How widespread is this presence across Tharra?
- What, if any, threats to bilbies exist at Tharra that need to be managed?
- How can we be sure that management effort is having a positive effect?

To address these questions, a coordinated survey effort was undertaken using best-practice survey methodology, in combination with traditional ecological knowledge. Specifically, survey methods and cultural knowledge captured aimed to:

- Identify bilby occupancy within Tharra;
- Delineate priority bilby habitat within Tharra;
- Establish baseline data and a monitoring approach to evaluate bilby habitat and quantify changes to bilby occupancy over time; and
- Assess key threatening processes to bilby habitat and identify management priorities.

Occupancy

The presence of bilbies was confirmed with 22 positive detections across Tharra within survey plots. The 2 ha sign plot field surveys, and subsequent occupancy modelling, were used to calculate bilby occupancy within Tharra. Specifically, the occupancy modelling identified the probability of presence of bilbies using repeat surveys to account for imperfect detectability. Based on the modelled occupancy and detection probabilities, bilby occupancy was estimated at 0.34 with a per survey detection probability of 0.61. In other words, bilbies can be expected to use 34% of surveyed 2 ha plots in the project area, and provided that a plot was used by a bilby, there is a 61% chance that that presence would be detected by the survey team in a single survey event.

Similar occupancy studies have been undertaken for bilby presence in Western Australia including the Fitzroy catchment region (Dziminski et al. 2021), La Grange area (Dziminski et al. 2018), Warralong (Dziminski, Carpenter and Cowan 2021), and at Matuwa (Lohr et al. 2021). Bilby occupancy at Tharra was estimated to be higher than the Fitzroy catchment region (occupancy of 0.21, with a survey detection probability of 0.49), and the La Grange area (occupancy of 0.22, survey detection

probability of 0.42), and comparable to Matuwa (occupancy of 0.32, detectability 0.18, but highly variable detectability based on vegetation structure covariates). It should be noted that Matuwa's occupancy modelling was based on motion-sensor cameras as opposed to track-based surveys, and thus may not be directly comparable.

Though not explicitly targeting bilbies, comparable levels of bilby occupancy were also detected from motion-sensor cameras at Warralong (approximately 200 km northeast of Tharra). Occupancy at Warralong was 0.31 from detections using 30 motion-sensor cameras, though occupancy from similar detections using 2 ha sign plot surveys (30 plots) was much lower, ranging from 0.05 to 0.1, with a detectability of 0.46 (Dziminski, Carpenter & Cowan 2021).

The results of the track-based surveys and occupancy modelling confirms that Tharra is an active habitat for bilbies, inclusive of foraging and burrowing habitats. The high level of occupancy and detectability relative to survey effort suggest that bilby occupancy at Tharra may be higher than typically recorded in the Pilbara and warrants continued survey effort to better understand density and distribution throughout the reserve.

Priority Habitat

A primary objective of the Tharra Greater Bilby Conservation Project is to delineate priority areas of bilby habitat within Tharra, for the purpose of allocating future management effort. The occupancy of 0.34, reflective of the large number of positive detections of bilbies (22 detections across 16 sampling locations), coupled with the relatively broad distribution of sightings across the survey area (some separated by 20 km), suggests that Tharra is broadly occupied by bilbies, at least within Macroy Land systems (approximately 32,400 ha). Positive detections of bilbies were found in *baru* country, and typically close to riverbanks (within 1 km). In all identified locations potential or confirmed food sources were identified by the ranger team, most notably *ngarlgu* (bush onions, *Cyperus bulbosa*) and *munduru* roots (*Acacia cyperophylla*). It should be noted that survey effort was largely skewed towards river systems due to access constraints (see map 3).

The distribution of positive detections across Tharra suggests the presence of multiple areas of occupancy occupied by different individuals. Estimates of short-term home range sizes in the Northern Territory have been found to vary from 1.1 to 3 km² (Southgate and Possingham 1995), and between 0.18 and 3.16 km² for females and males respectively in South Australia (Moseby and O'Donnell 2003). At Tharra, positive detections of bilbies tended to occur in high frequencies relative to a central plot (for example see plots 13, 14, 39 40, 41 and 42, map 3) or separated by distances of often more than 10 km. The highest frequencies of positive detections were found within a roughly 5 km radius of plot 40 (7 positive detections). This area lies close to the northwest boundary of Tharra and within 1 km of road and rail infrastructure. Other detections were located along the west and southwest margins (plot 54, 58 and 60), near ephemeral drainage lines towards the centre of the reserve (plot 20), and east of Mount Webber (plot 2 and plot 3), albeit at lower frequencies. Plots 2 and 3 are separated from the next nearest positive detection by 12 km, most of which is terrain deemed unlikely to support bilby populations (Granitic and Rocklea

Land Systems). Survey effort was restricted in the southwest due to cultural avoidance areas, however two of the three most southwest survey plots in this area showed signs of bilbies, suggesting that the area may be well-occupied. Taken together, these detections suggest a broad distribution of occupancy by numerous individuals across much of Tharra. This occupancy is associated with all three major drainage lines (Yule River, Coorong Creek and the Shaw River catchment).

To further delineate and narrow down the priority habitat, a 5 km radius from positive sightings (reflective of upper predictions of daily foraging range), was allocated to each positive detection from track surveys (refer to map 4). Limiting this radius to preferential land systems (Macroy and River Land Systems) within the boundaries of Tharra creates a priority habitat area covering approximately 30,000 ha.

Establish a Baseline Monitoring Approach

The survey methodology employed in the Tharra Greater Bilby Conservation Project was successful in establishing a baseline monitoring approach and generating baseline data for subsequent monitoring of bilby occupancy. Re-implementing the standardised survey and monitoring techniques used in this study will allow comparisons in occupancy over time, with a recommended two year interval between sampling occasions.

The lack of a standardised approach to capturing covariate data on feral predators prevented the effect of feral predators on occupancy to be analysed within the occupancy modelling. Future monitoring should endeavour to standardise the approach and data collection methodology for introduced species within 2 ha plots, as feral predators (cats and foxes) are known to be a major contributing factor to the decline of a range of marsupial populations, including bilbies (Woinarski et al. 2014).

Recommendations for subsequent monitoring include:

- Refining data collection for covariates analysis (fire frequency, introduced herbivores, introduced predators, vegetation cover).
- Introduce remote sensor cameras and image analysis into occupancy analysis.
- Explore the feasibility of abundance analysis and bilby population estimates for the project area.

Key threatening processes

Grazing Pressure

The study shows a significant effect of grazing pressure on bilby presence when covariates were introduced into the model. Specifically, low levels of grazing pressure significantly increased bilby presence (estimate = 2.89, SE = 1.42, $z = 2.04$, $p = 0.04$). This aligns with similar findings of correlations between absence or low abundance of livestock and bilby occupancy (Southgate 1990) including at Warralong (Dziminski, Carpenter & Cowan 2021) and in the Kimberley (Dziminski et al. 2021). Disturbances associated with cattle and other large, introduced herbivores are known

to have a negative impact on a range of small to medium-sized mammals in Western Australia (Radford et al. 2015). At Tharra, cattle-related impacts are a major source of cultural and environmental disturbance. Tharra is bordered by three unfenced pastoral stations, and cattle regularly migrate between the many permanent rockholes within the Yule, Shaw and Turner River catchments. Mustering reports from Woodstock provide an indication of cattle numbers within the reserve, with 479 head of cattle removed from Woodstock in 2021, and similar numbers in 2016 and 2017. Other large feral herbivores recorded at Tharra include donkeys, camels and horses (The Budadee Foundation 2015). Importantly, grazing disturbance at Tharra is not uniform, with cattle impacts regularly associated along areas of existing disturbance (such as road and rail infrastructure), standing water, and along river systems (Budadee Aboriginal Corporation, unpublished ranger reports 2022 - 2024).

Predation

Unfortunately, no analysis was undertaken to assess introduced predators on occupancy. Introduced predators are well documented within Tharra, with feral cats, foxes and wild dogs recognised as a threat to Tharra's threatened fauna (The Budadee Foundation 2015) and captured on remote sensor cameras by the Budadee rangers. Foxes and cats are responsible for range reductions and population declines of many native mammals (Burbidge and McKenzie 1989; Woinarski et al. 2011). Fox predation is well established in driving declines of the Greater Bilby and has been implicated as the principal factor in driving regional declines in southwestern Australia (Abbot 2001).

Burbidge, A. A., McKenzie, N.L. 1989, Patterns in the modern decline of western Australia's vertebrate fauna: Causes and conservation implications, *Biological Conservation*, Volume 50, Issues 1-4, Pages 143-198, ISSN 0006-3207, [https://doi.org/10.1016/0006-3207\(89\)90009-8](https://doi.org/10.1016/0006-3207(89)90009-8).
(<https://www.sciencedirect.com/science/article/pii/0006320789900098>)

To gain a better understanding of bilby – predator interactions at Tharra, remote sensor cameras were established adjacent to three active burrows. At two of the three camera locations, feral cats were detected waiting outside active burrow sites (see Appendix 2 for examples). Dingos were also captured at two of the three cameras locations, including footage of dingoes attempting to excavate bilby burrows. The relative impact of these species on bilby occupancy at Tharra remains unknown. While feral cat predation is known to limit or extirpate local bilby populations (Woinarski et al. 2014), there is some evidence that bilbies are resilient to some level of feral cat presence (DBCA 2021b). Dingos, while also predating on bilbies, may in fact improve habitat favourability for the Greater Bilby, as they are known to be an important predator of feral cats and may displace fox activity (Southgate and Carthew 2007). While no foxes were captured on any of the remote sensor cameras, their potential impact on Tharra's resident bilbies cannot be ruled out. Foxes have been detected at Tharra on remote sensor cameras during historical surveys and previous ranger fauna monitoring works.

Altered Fire Regimes

During the three-day reconnaissance survey in August 2023 and subsequent field surveys, Palyku knowledge holders provided their assessment on the relative health of bilby habitat across Tharra, as well as the threats to the landscape. Across all the surveyed *baru* country (spinifex flats, best associated with Macroy Land Systems), the relative health of country was deemed to be poor. Developmental pressure (mining and road infrastructure), encroaching weeds, cattle impacts, and feral predators all contributed to this assessment, but it was the lack of cultural burning that was deemed to be the most significant factor.

To Palyku people, fire is an essential part of the landscape, one that protects nature and culture and fosters connection to Country. Cultural burning was once done at Tharra by Palyku people as they lived on Country. Later, during the Woodstock station days (c 1930s) cultural burning was done as they lived and worked on the sheep station. In the coming decades, fire management at Tharra decreased, with reports in both 1955 (Suijdendorp 1955) and in 1991 (Berry et al. 1991) recommending the re-introduction of active fire management to promote biodiversity. The lack of fire management has resulted in a relatively homogenous vegetation complex of old spinifex across much of the reserve. A buildup of dense vegetation provides excellent kindling for large-scale, hot wildfires that can wreak havoc across the landscape. In 2020, the Budadee rangers recorded approximately 3,000 ha of burnt country from three uncontrolled burns across the reserve. In 2023 an out-of-control fire across the eastern boundary of Tharra damaged the cultural landscape of Tambourah, and an additional wildfire in the southwest of Tharra damaged engravings at a registered cultural heritage site. Altered fire regimes (such as through the loss of Aboriginal burning practices) have been linked to reduced food availability for native fauna (Woinarski et al. 2011), enhanced predation pressure (McGregor et al. 2014) and are recognised as a significant contributor towards the decline of small to medium-sized mammal populations across northern Australia (Lawes et al. 2015; Santos et al. 2022).

At Tharra, Palyku people teach how a lack of fire has changed the food availability for bilbies. A range of food plants are promoted by a mixture of burnt and unburnt country. This includes *ngarlgu* (bush onions, *Cyperus bulbosa*), bush carrot (*Daucus glochidiatus*), *mungalin* (*Iponoea* spp.), bush bean (*Vigna lanceolata*), *marta* (sweet bush potato, *Dioscorea hastifolia*), *ngarbruda* (bush cucumber, *Cucumis melo*), *galumbu* (*Solanum phlomoides*), *wanyalie* (bush banana, *Marsdenia australis*) and cockroach bush (*Senna notabilis*). Without fire, old spinifex dominates to the detriment of these smaller herbaceous plants that thrive post-fire. Many of these plants are food sources for bilbies and other animals, as well as people. A mosaic of burnt and unburnt country provides food and shelter diversity that supports more animals and helps protect animals against feral predators (Palyku knowledge holders Kevin Stream, Fred Stream and Gavin Cabales, personal comms. August 2023).

The positive relationship between bilbies and right-way fire is well established. Bilbies are known to use a mixture of burnt and unburnt country, as well as in different post-fire age vegetation (Southgate 1990). A significant part of their diet is made up of seed from fire-promoted plants (Southgate 1990; Southgate and Carthew 2007), and bilbies have been documented foraging in areas of post-fire regrowth (Thomson and Thomson 2008), and in recently burnt areas, likely due to the higher availability of fire-promoted food plants (Southgate and Carthew 2007). A

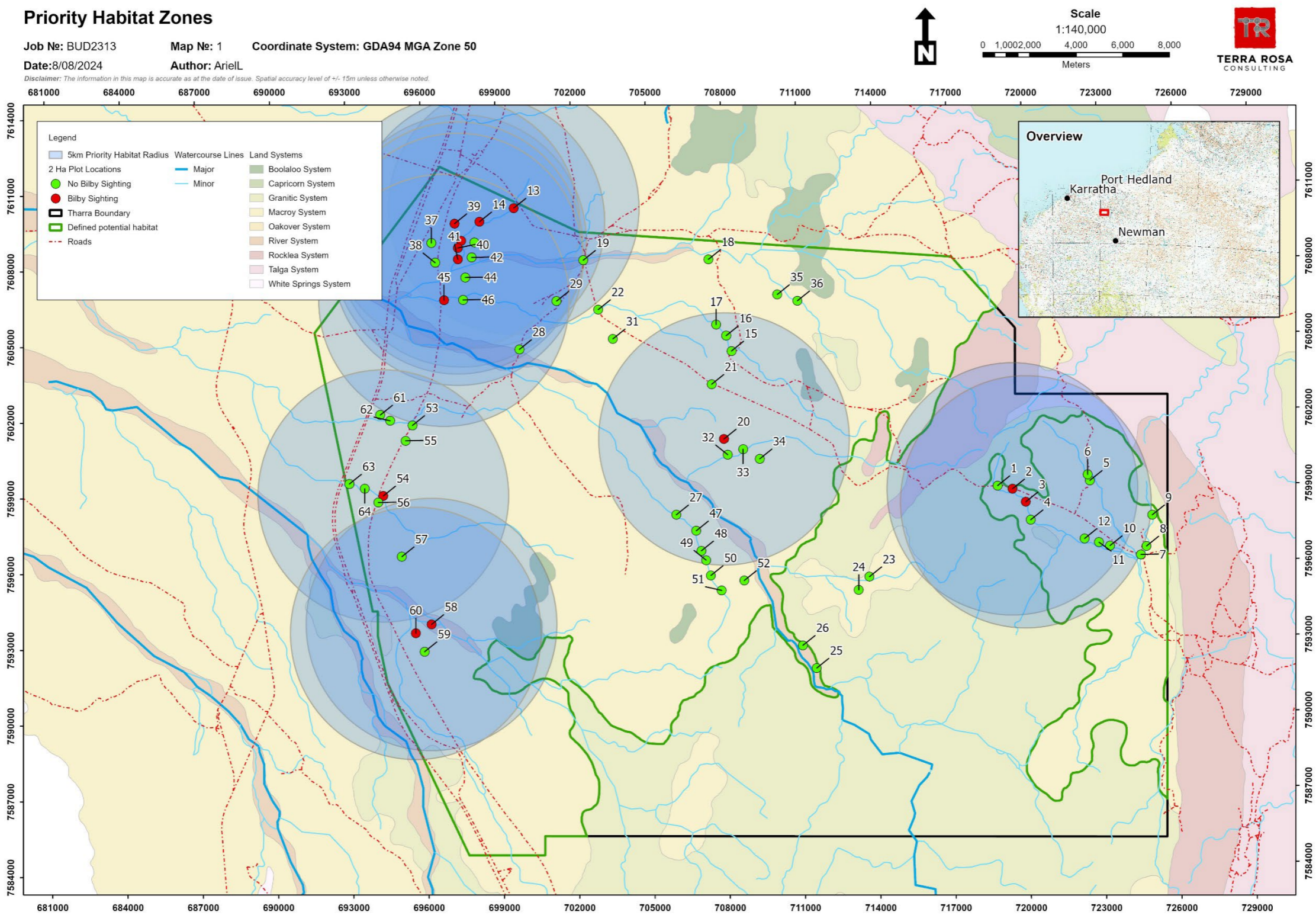
heterogeneity of fire age habitat is thought to best meet the habitat requirements for many medium-sized animals by creating a diversity of food availability and shelter from predators (Nimmo et al. 2018).

Conversely, a lack of fire management has been shown to pose a significant threat to bilby populations. A lack of fire may reduce habitat suitability, by both reducing the availability of food from fire-promoted vegetation and reducing bilby movement through the growth of dense, impenetrable vegetation cover (Bradley et al. 2015). Improper fire management also leads to large-scale, hot fires. These large-scale fires destroy large areas of bilby habitat, reducing food resources and increasing predation risk through a lack of shelter (Dziminski et al. 2020). The local extinctions of two bilby populations in the Pilbara (Pardoo and McPhee Creek) were attributed to large-scale, hot fires in areas lacking any active fire management (Dziminski et al. 2020).

Conclusion

Tharra is well positioned to be an actively managed refuge for Greater Bilby populations in the central Pilbara. As part of the greater Woodstock Abydos Protected Reserve, Tharra receives protection under section 19 of the *Aboriginal Cultural Heritage Act 2021 (WA)*, safeguarding it from future activities common to the region, particularly pastoral and mineral resource sectors. It also benefits from active cultural and environmental management through the Budadee ranger program, who routinely undertake Caring-for-Country management across the reserve. Tharra contains large tracts of habitat suitable for bilbies, alongside historic recordings of Greater Bilbies dating back to the 1960s. Results of the occupancy analysis confirm that bilbies are indeed still present across the reserve, with sighting from multiple locations, some separated by more than 20 km. A baseline monitoring approach has been established, and the high level of detectability provides confidence in the ability of the Budadee rangers to undertake effective bilby monitoring into the future. A range of threats to bilby habitat at Tharra were identified during the survey, including introduced predators, large, introduced herbivores, developmental pressure, altered fire regimes, and encroaching weeds. Of these threats, Palyku knowledge holders identified the lack of cultural burning as the most significant factor affecting the health of bilby habitat, and the primary contributing factor to the poor health of *baru* country (spinifex flats). Introduced predators (feral cats) were detected by remote sensor cameras at active bilby burrows. Occupancy analysis illustrated that low grazing pressure was positively associated with bilby occupancy. This aligned with the results of other bilby occupancy studies and suggests that large feral herbivores pose a significant threat to bilbies and bilby habitat.

Map 4: 5 km priority habitat zone radius centred on confirmed sightings of bilbies within Tharra.




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Appendix 1: Plot Photos


Plot ID	BUD080	
Plot sequence	Replicate	
Date recorded	31 May 2024 5:09 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD096	
Plot sequence	Replicate	
Date recorded	31 May 2024 4:40 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD091	
Plot sequence	Replicate	
Date recorded	31 May 2024 4:07 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD085	
Plot sequence	Replicate	
Date recorded	31 May 2024 11:55 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	1 year	


Plot ID	BUD086	
Plot sequence	Replicate	
Date recorded	31 May 2024 11:24 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	2 years	


Plot ID	BUD112	
Plot sequence	Replicate	
Date recorded	31 May 2024 10:23 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Stony plain	
Fire (time since burn)	2 years	


Plot ID	BUD098	
Plot sequence	Replicate	
Date recorded	31 May 2024 7:30 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	More than 5 years	


Plot ID	BUD097	
Plot sequence	Replicate	
Date recorded	31 May 2024 7:03 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Sand	
Fire (time since burn)	More than 5 years	


Plot ID	BUD094	
Plot sequence	Replicate	
Date recorded	30 May 2024 12:42 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD093	
Plot sequence	Replicate	
Date recorded	30 May 2024 12:23 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD092	
Plot sequence	Replicate	
Date recorded	30 May 2024 11:59 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD104	
Plot sequence	Replicate	
Date recorded	30 May 2024 10:52 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	4 years	


Plot ID	BUD103	
Plot sequence	Replicate	
Date recorded	30 May 2024 9:20 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	4 years	


Plot ID	BUD102	
Plot sequence	Replicate	
Date recorded	30 May 2024 9:03 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	4 years	


Plot ID	BUD101	
Plot sequence	Replicate	
Date recorded	30 May 2024 8:18 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	4 years	


Plot ID	BUD100	
Plot sequence	Replicate	
Date recorded	30 May 2024 7:53 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	4 years	


Plot ID	BUD111	
Plot sequence	Replicate	
Date recorded	29 May 2024 12:45 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	1 year	


Plot ID	BUD110	
Plot sequence	Replicate	
Date recorded	29 May 2024 12:18 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Stony plain	
Fire (time since burn)	1 year	


Plot ID	BUD109	
Plot sequence	Replicate	
Date recorded	29 May 2024 11:55 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Stony plain	
Fire (time since burn)	1 year	


Plot ID	BUD108	
Plot sequence	Replicate	
Date recorded	29 May 2024 11:36 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	1 year	


Plot ID	BUD107	
Plot sequence	Replicate	
Date recorded	29 May 2024 11:08 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Stony plain	
Fire (time since burn)	1 year	


Plot ID	BUD087	
Plot sequence	Replicate	
Date recorded	29 May 2024 10:43 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Soil/clay	
Fire (time since burn)	1 year	


Plot ID	BUD099	
Plot sequence	Replicate	
Date recorded	28 May 2024 12:50 PM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD105	
Plot sequence	Replicate	
Date recorded	28 May 2024 12:32 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	3 years	

Plot ID	BUD106	
Plot sequence	Replicate	
Date recorded	28 May 2024 12:11 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD113	
Plot sequence	Replicate	
Date recorded	28 May 2024 10:21 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	3 years	


Plot ID	BUD116	
Plot sequence	Replicate	
Date recorded	28 May 2024 10:01 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD114	
Plot sequence	Replicate	
Date recorded	28 May 2024 9:41 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	3 years	


Plot ID	BUD115	
Plot sequence	Replicate	
Date recorded	28 May 2024 9:19 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	3 years	


Plot ID	BUD117	
Plot sequence	Replicate	
Date recorded	28 May 2024 8:57 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Soil/clay	
Fire (time since burn)	5 years	


Plot ID	BUD084	
Plot sequence	Replicate	
Date recorded	16 March 2024 9:20 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD083	
Plot sequence	Replicate	
Date recorded	16 March 2024 9:05 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD095	
Plot sequence	Replicate	
Date recorded	16 March 2024 8:08 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	More than 5 years	


Plot ID	BUD077	
Plot sequence	Replicate	
Date recorded	16 March 2024 7:35 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	More than 5 years	


Plot ID	BUD076	
Plot sequence	Replicate	
Date recorded	16 March 2024 7:19 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	4 years	


Plot ID	BUD004(new plot location)	
Plot sequence	Initial survey	
Date recorded	15 March 2024 10:52 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	More than 5 years	


Plot ID	BUD003(new plot location)	
Plot sequence	Initial survey	
Date recorded	15 March 2024 10:27 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD002(new plot location)	
Plot sequence	Initial survey	
Date recorded	15 March 2024 9:53 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD001(new plot location)	
Plot sequence	Initial survey	
Date recorded	15 March 2024 9:29 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	1 year	


Plot ID	BUD074	
Plot sequence	Replicate	
Date recorded	15 March 2024 8:19 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD090	
Plot sequence	Replicate	
Date recorded	15 March 2024 7:44 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD073	
Plot sequence	Replicate	
Date recorded	15 March 2024 7:20 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD082	
Plot sequence	Replicate	
Date recorded	15 March 2024 6:34 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Stony plain	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD088	
Plot sequence	Replicate	
Date recorded	14 March 2024 11:59 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	No signs of grazing	
Substrate	Sand	
Fire (time since burn)	1 year	


Plot ID	BUD089	
Plot sequence	Replicate	
Date recorded	14 March 2024 11:41 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	

Plot ID	BUD078	
Plot sequence	Replicate	
Date recorded	14 March 2024 10:53 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Sand	
Fire (time since burn)	3 years	

Plot ID	BUD075	
Plot sequence	Replicate	
Date recorded	14 March 2024 10:21 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Hardpan (clay)	
Fire (time since burn)	1 year	


Plot ID	BUDD081	
Plot sequence	Replicate	
Date recorded	14 March 2024 9:43 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Stony plain	
Fire (time since burn)	1 year	


Plot ID	BUD072	
Plot sequence	Replicate	
Date recorded	14 March 2024 8:50 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	1 year	


Plot ID	BUD071	
Plot sequence	Replicate	
Date recorded	14 March 2024 8:17 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Soil/clay	
Fire (time since burn)	1 year	


Plot ID	BUD070	
Plot sequence	Replicate	
Date recorded	14 March 2024 7:55 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Hardpan (clay)	
Fire (time since burn)	1 year	


Plot ID	BUD069	
Plot sequence	Replicate	
Date recorded	14 March 2024 7:27 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Stony plain	
Fire (time since burn)	3 years	


Plot ID	BUD067	
Plot sequence	Replicate	
Date recorded	13 March 2024 1:10 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD068	
Plot sequence	Replicate	
Date recorded	13 March 2024 12:41 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD066	
Plot sequence	Replicate	
Date recorded	13 March 2024 10:23 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD065	
Plot sequence	Replicate	
Date recorded	13 March 2024 10:03 AM	
Significant fauna sighted	Turtle	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD064	
Plot sequence	Replicate	
Date recorded	13 March 2024 9:17 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD063	
Plot sequence	Replicate	
Date recorded	13 March 2024 8:52 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD062	
Plot sequence	Replicate	
Date recorded	13 March 2024 8:12 AM	
Significant fauna sighted		
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD061	
Plot sequence	Replicate	
Date recorded	13 March 2024 7:45 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand/Soil/clay	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD060	
Plot sequence	Initial survey	
Date recorded	10 November 2023 8:05 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD059	
Plot sequence	Initial survey	
Date recorded	10 November 2023 7:52 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	1 year	


Plot ID	BUD058	
Plot sequence	Initial survey	
Date recorded	10 November 2023 7:32 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD057	
Plot sequence	Initial survey	
Date recorded	10 November 2023 7:13 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	More than 5 years	


Plot ID	BUD056	
Plot sequence	Initial survey	
Date recorded	10 November 2023 6:47 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	More than 5 years	


Plot ID	BUD055	
Plot sequence	Initial survey	
Date recorded	10 November 2023 5:56 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD054	
Plot sequence	Initial survey	
Date recorded	9 November 2023 4:12 PM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD053	
Plot sequence	Initial survey	
Date recorded	9 November 2023 3:53 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Stony plain	
Fire (time since burn)	3 years	


Plot ID	BUD052	
Plot sequence	Initial survey	
Date recorded	9 November 2023 10:41 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	1 year	


Plot ID	BUD051	
Plot sequence	Initial survey	
Date recorded	9 November 2023 10:05 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	1 year	


Plot ID	BUD050	
Plot sequence	Initial survey	
Date recorded	9 November 2023 9:26 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	1 year	


Plot ID	BUD049	
Plot sequence	Initial survey	
Date recorded	9 November 2023 8:59 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD048	
Plot sequence	Initial survey	
Date recorded	9 November 2023 8:44 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Soil/clay	
Fire (time since burn)	1 year	


Plot ID	BUD047	
Plot sequence	Initial survey	
Date recorded	9 November 2023 8:20 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD046	
Plot sequence	Initial survey	
Date recorded	8 November 2023 10:37 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD045	
Plot sequence	Initial survey	
Date recorded	8 November 2023 10:24 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD044	
Plot sequence	Initial survey	
Date recorded	8 November 2023 10:00 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD043	
Plot sequence	Initial survey	
Date recorded	8 November 2023 8:38 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD042	
Plot sequence	Initial survey	
Date recorded	8 November 2023 8:09 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD041	
Plot sequence	Initial survey	
Date recorded	8 November 2023 7:38 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD040	
Plot sequence	Initial survey	
Date recorded	8 November 2023 7:00 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD039	
Plot sequence	Initial survey	
Date recorded	8 November 2023 6:27 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD038mhio	
Plot sequence	Initial survey	
Date recorded	7 November 2023 1:39 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD037	
Plot sequence	Initial survey	
Date recorded	7 November 2023 1:12 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD036	
Plot sequence	Initial survey	
Date recorded	7 November 2023 11:13 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD035	
Plot sequence	Initial survey	
Date recorded	7 November 2023 10:36 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD034	
Plot sequence	Initial survey	
Date recorded	7 November 2023 9:20 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD033	
Plot sequence	Initial survey	
Date recorded	7 November 2023 8:41 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD032	
Plot sequence	Initial survey	
Date recorded	7 November 2023 8:09 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD031	
Plot sequence	Initial survey	
Date recorded	7 November 2023 7:23 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD030	
Plot sequence	Initial survey	
Date recorded	14 October 2023 3:31 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	

Plot ID	BUD029	
Plot sequence	Initial survey	
Date recorded	14 October 2023 3:02 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD028	
Plot sequence	Initial survey	
Date recorded	14 October 2023 2:45 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	1 year	


Plot ID	BUD027	
Plot sequence	Initial survey	
Date recorded	14 October 2023 1:33 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD026	
Plot sequence	Initial survey	
Date recorded	14 October 2023 11:31 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Soil/clay	
Fire (time since burn)	1 year	


Plot ID	BUD025	
Plot sequence	Initial survey	
Date recorded	14 October 2023 11:12 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD024	
Plot sequence	Initial survey	
Date recorded	14 October 2023 7:29 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	


Plot ID	BUD023	
Plot sequence	Initial survey	
Date recorded	14 October 2023 7:08 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Soil/clay	
Fire (time since burn)	3 years	


Plot ID	BUD022	
Plot sequence	Initial survey	
Date recorded	13 October 2023 11:06 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Sand	
Fire (time since burn)	1 year	


Plot ID	BUD021	
Plot sequence	Initial survey	
Date recorded	13 October 2023 10:43 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Sand	
Fire (time since burn)	Less than 1 year	


Plot ID	BUD020	
Plot sequence	Initial survey	
Date recorded	13 October 2023 10:08 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	1 year	


Plot ID	BUD019	
Plot sequence	Initial survey	
Date recorded	13 October 2023 9:35 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD018	
Plot sequence	Initial survey	
Date recorded	13 October 2023 8:23 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Soil/clay	
Fire (time since burn)	2 years	


Plot ID	BUD017	
Plot sequence	Initial survey	
Date recorded	13 October 2023 7:27 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD016	
Plot sequence	Initial survey	
Date recorded	13 October 2023 7:05 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD015	
Plot sequence	Initial survey	
Date recorded	13 October 2023 6:40 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Stony plain	
Fire (time since burn)	5 years	


Plot ID	BUD014	
Plot sequence	Initial survey	
Date recorded	12 October 2023 11:59 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Sand	
Fire (time since burn)	More than 5 years	


Plot ID	BUD013	
Plot sequence	Initial survey	
Date recorded	12 October 2023 11:23 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD012	
Plot sequence	Initial survey	
Date recorded	12 October 2023 9:21 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	5 years	


Plot ID	BUD011	
Plot sequence	Initial survey	
Date recorded	12 October 2023 9:00 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	5 years	


Plot ID	BUD010	
Plot sequence	Initial survey	
Date recorded	12 October 2023 8:43 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	3 years	


Plot ID	BUD009	
Plot sequence	Initial survey	
Date recorded	12 October 2023 8:11 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	More than 5 years	


Plot ID	BUD008	
Plot sequence	Initial survey	
Date recorded	12 October 2023 7:40 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Stony plain	
Fire (time since burn)	2 years	


Plot ID	BUD007	
Plot sequence	Initial survey	
Date recorded	12 October 2023 7:20 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	High (lots of cow scat, tracks and/or damage)	
Substrate	Soil/clay	
Fire (time since burn)	2 years	


Plot ID	BUD006	
Plot sequence	Initial survey	
Date recorded	11 October 2023 12:44 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Soil/clay	
Fire (time since burn)	2 years	

Plot ID	BUD005	
Plot sequence	Initial survey	
Date recorded	11 October 2023 12:22 PM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Soil/clay	
Fire (time since burn)	2 years	

Plot ID	BUD004	
Plot sequence	Initial survey	
Date recorded	11 October 2023 9:22 AM	
Significant fauna sighted	Feral cat	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	

Plot ID	BUD003	
Plot sequence	Initial survey	
Date recorded	11 October 2023 8:37 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Sand	
Fire (time since burn)	2 years	

Plot ID	BUD002	
Plot sequence	Initial survey	
Date recorded	11 October 2023 7:59 AM	
Significant fauna sighted	Bilby	
Observed grazing pressure	Medium (some evidence of grazing impacts)	
Substrate	Soil/clay	
Fire (time since burn)	2 years	

Plot ID	BUD001	
Plot sequence	Initial survey	
Date recorded	11 October 2023 7:29 AM	
Significant fauna sighted	Nil	
Observed grazing pressure	Low (minimal signs of grazing)	
Substrate	Soil/clay	
Fire (time since burn)	2 years	

Appendix 2: Remote sensor camera images.



Plate 1: Remote sensor camera set up in front of active bilby burrow.



Plate 2: A bilby captured on remote sensor camera within WAPR on 27 July 2024.



Plate 3: A bilby captured on remote sensor camera within WAPR on 6 June 2024.



Plate 4: Bilby leaving burrow on 11 August 2024.



Plate 5: Dingo excavating the same bilby burrow on 12 August 2024.



Plate 6: A feral cat captured investigating bilby burrow on 15 August 2024.



Plate 7: Cattle activity at Tharra Pool on 25 July 2024.

Appendix 3: Desktop Research

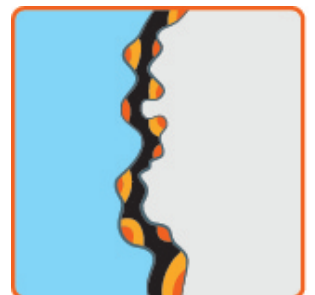


THARRA GREATER BILBY CONSERVATION PROJECT

Desktop Research

July 23

THARRA GREATER



BUDADEE
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Acknowledgement of Country

We acknowledge the Palyku people, who are the Traditional Custodians of Tharra (Woodstock Protected Reserve) and the areas described within this report. We pay our respects to the Elders past, present, and emerging, and to their continuing cultural and spiritual connections to their lands.

This report leans heavily on the Traditional Knowledge of the Palyku people of the central Pilbara, whose knowledge is shared with permission.

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CONTENTS

Desktop Research..... 160

 Acknowledgement of Country 161

 Background..... 163

 Defining potential bilby habitat within Tharra..... 164

 Methodology 169

 References..... 176

 Appendix 1: Project contacts**Error! Bookmark not defined.**

 Copyright 177

 Disclaimer 177

 Version Control..... 177

Background

The greater bilby *Macrotis lagotis* is a medium-sized, desert marsupial. From a historical distribution that covered more than three quarters of Australia's landmass, they are now only found within northern deserts of Western Australia and the Northern Territory, and from one small population in south-west Queensland. It is estimated that this distribution reflects less than 20% of their former range, with a declining population of fewer than 10,000 mature individuals (Southgate 1990, Woinarski et al. 2014). Bilbies are listed as Vulnerable under the Biodiversity Conservation Act 2016 (Western Australia) and the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth) and are listed as endangered under the IUCN Red List of Threatened Species (2013, International).

Tharra Karnparnmana (also known as the Woodstock Abydos Protected Reserve) is a 154,000-hectare heritage reserve located in the Chichester bioregion of the central Pilbara. Its borders represent the amalgamation of the historic Abydos and Woodstock pastoral properties, that were merged into a single reserve before being recognised for protection under the Aboriginal Heritage Act (1972). Tharra (*pronounced duh-ra*) refers to the country of the Palyku Traditional Owners within the Reserve. Tharra covers an area of approximately 74,000 hectares and includes the southern and eastern half of the amalgamated Reserve. It is a place of enormous cultural significance, with songlines, engravings, and stories that connect Palyku people to their law, culture, and community.

Bilbies have long been recognised as being part of Tharra's landscape. Tharra is located along the south-western boundary of the estimated current distribution of the greater bilby (refer to Recovery Plan for the Greater Bilby, 2023). It contains a range of habitat suitable for supporting bilby populations and bilby signs (sightings, tracks, scats and burrows) have been documented from historical surveys dating back to the 1960's. Tharra's status as a protected reserve provides a high level of security for investing in management actions that protect bilbies and their habitat.

The Tharra Fauna project aims to establish Tharra as an actively protected refuge for local bilby populations, by addressing knowledge gaps in our understanding of the bilby population of Tharra Karnparnmarna, and equipping Budadee's ranger team with the skills and knowledge to actively protect bilby habitat.

This document presents the results of desktop research undertaken in 2023 as part of the Tharra Bilby project. It has the following objectives:

- Define potential bilby habitat within Tharra.
- Identify priority areas of defined habitat based on habitat indicators, sites of cultural significance and access limitations.
- Assign survey plots within priority areas for ground-based assessment of bilby presence using the 2-ha plot-based sampling technique.
- Refine field survey methodology, including data capture software.

Defining potential bilby habitat within Tharra

Palyku people have a strong knowledge of the animals on Palyku country, including bilbies. Palyku people, especially the old people, understand the country, and the conditions and habitat that supports bilbies. The following is a description of potential bilby habitat within Tharra, based on traditional ecological knowledge and the scientific literature.

Tharra is dominated by gently undulating stony and sandy plains, punctuated by granite ranges. It is intersected by two river systems, the upper catchment of the Yule River and the Shaw branch of the De Grey River. Tharra's plains typically support a shrub steppe of budadee (*Acacia inaequilatera*) over baru (spinifex) hummock grasslands (*Triodia wiseana*) with tree steppes of jiggarda (white wood tree, *Eucalyptus leucophloia*) dominating the ranges. A shade of dalgoolbooda (*Malaleuca spp.*) and munduru (*Acacia cyperophylla*) is common across the river systems, with banks dominated by baru (*Triodia wiseana*) and buffel (*Cenchrus ciliaris*, invasive) grasses.

"At Woodstock, [bilbies] gotta be in soft country. Mostly on the banks of the creeks. Food they eat is the bardi (witchety) grub. In amongst the mini ritchi [*munduru*, *Acacia cyperophylla*] on the riverbanks. Soft soil to dig. Bardi grub is the main food. They break the roots open. They travel around a bit, size of a rabbit. Travel a fair bit. They go and come back. The mini ritchi needs the soft sand as well, in Woodstock there, well, where their burrows are, not far away are the mini ritchi. When we look around, we'll see the bardi diggings." – Kevin Stream (pers. Comms 29/06/2023).

Across their known distribution, bilby habitat is characterised by sandplains, claypans, dune fields, laterite, mulga bushland, and creeklines, preferring spinifex (*Triodia spp.*) grasslands and medium/soft substrate (Woinarski et al., 2014). Bilbies are primarily nocturnal and cover large individual ranges in search of food and shelter (Woinarski et al., 2014). They are omnivorous, with a diet consisting of invertebrates, seeds, bulbs and fungi and they typically dig for their food, burrowing to a depth of two and a half metres (Gibson 2001). Bilbies have extensive foraging ranges and move across country, utilising numerous burrows scattered across the landscape (refer to Moseby and O'Donnell 2003). It is not uncommon for bilbies to travel distances of 3 kms, and up to 5kms, in a single day (refer to Southgate et al., 2007).

Table 1: Representative coverage (estimate) of major Land Systems within Tharra

Land Systems within Tharra		Tharra coverage*
Macroy	Stony plains and occasional tor fields based on granite supporting hard and soft spinifex shrubby grasslands.	~45%
Boolaloo	Granite hills, domes, tor fields and sandy plains supporting spinifex grasslands with scattered shrubs.	<5%
Granitic	Rugged granitic hills supporting shrubby hard and soft spinifex grasslands.	~35%
River	Narrow, seasonally active flood plains and major river channels supporting moderately close, tall shrublands or woodlands of acacias and fringing communities of eucalypts sometimes with tussock grasses or spinifex.	<5%
Rocklea	Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex and occasionally soft spinifex grasslands with scattered shrubs.	<10%

On Tharra, bilbies do not like the hill's country (for example rocklea and taiga landsystems) and prefer to make their burrows in the creeklines, moving out into the plains to forage. Baru (spinifex) provides cover, but they are more readily seen in open country where they can move around easily. Healthy bilby habitat should include areas of burnt and unburnt country, and bilbies are more easily tracked on burnt country.

"[Country] gotta be burnt, so they can move around. Likes the open plains. Likes it where it is burnt. Get away from dingos. [Good] for the other animals as well." - Kevin Stream (pers. Comms 29/06/2023).

On Palyku country, there are many bush foods that are eaten by bilbies. This includes insects, bardi (moth larvae i.e., witchety grubs), seeds, fruits, and tubers. The presence and relative abundance of these foods on country can signal suitable bilby habitat, infer the health of country, and help to refine survey effort. In different areas of Palyku country, bilbies find food from different sources. Understanding and identifying these sources across Palyku country can help to define and protect bilby habitat.

Within Tharra's River systems and along drainage lines, bilbies dig for bardi (large insect larvae) in the roots of trees such as wantanypa (*Acacia aneura*) and munduru (*Acacia cyperophylla*) and for termites amongst baru (spinifex, *Triodia wiseana*). They will dig for the tuberous roots of ngarlgu (bush onions, *Cyperus bulbosa*) sometimes digging out the whole plant. Roots and seeds of bush carrot (*Daucus glochidiatus*), mungalin (*Iponoea spp.*), bush bean (*Vigna lanceolata*), marta (sweet bush potato, *Dioscorea hastifolia*) and ngarbruda (bush cucumber, *Cucumis melo*) also provide a food and water source.

On baru country (spinifex flats), bilbies dig for termites and bardi, particularly on recently burnt country. Plants that have bardi of baru county include budadee (*Acacia*

inaequilatera), jiggarda (*Eucalyptus leucophloia*), burgu (*Hakea lorea*) and cockroach bush (*Senna notabilis*). Bilbies may also eat the wogola (bush coconuts) fallen from the bunara tree (*Corymbia opaca*). Fruits from galumbu (bush tomato, *Solanum phlomoides*), and wanyalie (bush banana, *Marsdenia australis*) may also be eaten.

"[Bilbies] hang around there [cockroach bush] for the bardis. Father was saying that they get the big grubs in there. The big bardis. [Bilbies] will go for termites too. You can eat them. Taste like a Bardi grub. The old people in Nullagine, they'll dig and eat them too. Yandee (*grind*) em up. – Kevin Stream (pers. Comms 29/06/2023)

Habitat with suitable geological and biological characteristics for bilbies have been identified across an estimated 63,000 hectares (or 90% of Tharra). This includes Macroy, Granitic, River and Boolalao Land Systems (refer to Table 1). Historical survey data reveals documented records of bilbies from 21 secondary sign sightings (tracks, burrows, and scats) between 1969 and 2017. These sightings are skewed towards the northern sections of Tharra with 16 within Macroy and 4 within River land systems. These recordings are primarily focussed on road and rail infrastructure corridors (reflective of survey effort). For example, 14 of the documented sightings within Tharra represent surveys in 2014 adjacent to the Hillside-Woodstock Road (refer to Map 1). Data is sourced from the following databases:

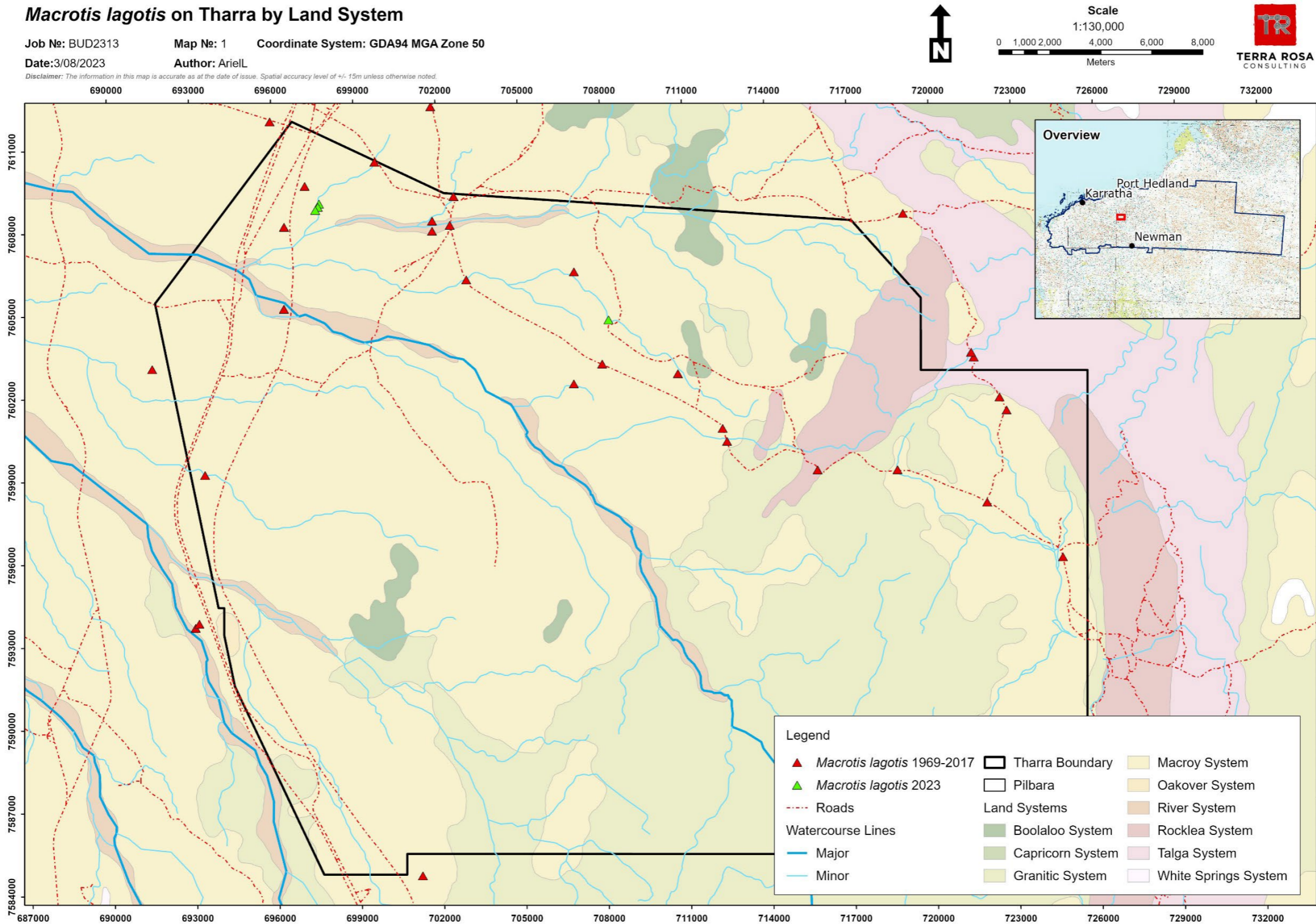
- Threatened and Priority Fauna (DBCA-037)
- Atlas of Living Australia
- Index of Biodiversity Surveys for Assessments (IBSA)
- Protected matters search tool – heatmap
- NatureMaps (pre-2021 data).

More recently, bilby signs were identified by Budadee Rangers from multiple locations off the Yule River in Tharra (Macroy system), and photographs of bilbies were captured on remote sensor cameras (refer to Plate 1).

*Plate 1: Bilby
(Macrotis lagotis)
captured on
camera by
rangers at
Tharra.*



Map 1: Project location showing historical sightings of *Macrotis lagotis*



Field Survey Methodology

Track based surveys are an effective method for detecting species that have large distributions, particularly over sandy soils, but are relatively rare within their range (*Threatened Species Recovery Hub, National Environmental Science Program*). They rely on sign-based data such as tracks, burrows, diggings, and scats to assess targeted species relative abundance or frequency of occurrence. For bilbies, who have distinctive signs, are scarce within their landscapes, travel across large ranges, and preferentially occupy sandy soil habitats, track based surveys are highly appropriate (Southgate 1990, Partridge 2016).

The 2-ha sign-plot methodology is a method of track-based survey that standardises survey effort and area. This allows direct comparisons between plots and enables estimations on the probability of detection and occupancy (Southgate et al. 2018). Coupled with systematic re-sampling to control for detection probability, the 2-ha sign plot method is the recommended approach for large area surveys (>1600 ha) that require quantifiable data (DBCA 2017). The methodology has a few limitations that should be noted. It is labour intensive, requiring field-based surveys with suitably trained personnel. It provides limited information on individuals or measurements of abundance, and plot allocation is skewed to areas with suitable access (for example within proximity of roads and tracks). Despite these limitations, it remains an effective method for detecting bilbies, and this sampling methodology is routinely used for bilby monitoring across the Pilbara, allowing data to be compared across monitoring sites and at a regional scale.

The 2-ha sign plot methodology will be used to define detection and occupancy of bilbies at Tharra. Detection here is defined as the probability of detecting evidence of the focal species given the species uses the location, and occupancy is defined as the proportion of locations used by the species (Moore, 2022). Given the relative scarcity of bilbies within landscapes, and the large defined project area at Tharra (~63,000 ha), a suitably large number of plots will be sampled to ensure data collected is statistically robust (n=160, 94.63% confidence interval). A total of 80 2-ha plots will be assigned evenly across four potential habitat zones (refer to Map 2), with approximately 2 km intervals of spacing between sampling plots to ensure independence. In smaller areas where this spatial distance cannot be achieved, a density of 2-4 plots per 100ha, or alternatively less plots with supplementary linear searches, will be applied. Allocation of sampling plots within the potential habitat zones will be at the discretion of Palyku Traditional Owners, who will base sampling plot allocation on traditional ecological knowledge, cultural protocols (for example avoidance areas), range of post-fire aged habitat, suitable soil type and access limitations across country. To insure against issues of imperfect detectability, sampling will be replicated at each plot. Bilby detectability in the Pilbara is not known to be impacted by seasonal timing, however it is optimal to conduct surveys during the dry season (May – October) to avoid disruptive and potentially hazardous climatic conditions associated with the Pilbara wet season (Harry Moore DBCA, pers. Comms July 2023).

Survey effort will be focussed within assigned survey plots with a defined area of 200 metres by 100 metres (2 ha), with observers searching for bilby and feral predator

sign (tracks, scats etc.) for a set duration of 25 minutes (adjusted for team size). Where these plots align next to a road of suitable substrate (dirt tracks) then this will be coupled with a 100 metre transect survey along the road. Observations of bilby sign will be captured on a custom digital survey form (refer to Plate 2), alongside observation data on heritage values, fire age, threatening processes, and any indicator species relevant to bilbies (food sources etc). Other information relevant to on-going management of Tharra will be collected as identified including other priority listed species (priority flora, conservations listed fauna), species of cultural importance (traditional land-use species such as ceremony, food and medicine species) and any undocumented heritage values. Each plot will be photographed from the south-west corner, and GPS points and track logs will be captured. Where high confidence in recent bilby activity is detected, remote sensor cameras will be set-up to detect bilby and feral predator activity.

Analysis of the occupancy data will be undertaken using a single season occupancy model that accounts for imperfect detectability and occupancy (see Mackenzie *et al.* 2002, and Moore, 2022). This will be done by adjusting the naïve occupancy (i.e., non-adjusted proportion of locations used by focal species) with a measure of detectability. The parameter ψ (occupancy, i.e., the probability that site i is occupied by the focal species) and p (detectability, i.e. the probability of the focal species being detected at site i on day j , conditional upon its presence) will be used to formulate the occupancy model. Assumptions of the model include:

- a) detection of species at sites is independent of species detection at other sites.
- b) there are no false detections.
- c) Occupancy remains constant over the sampling period.

The occupancy model will be used to compare differences in bilby occupancy against a range of physical and biological variables (for example vegetation structure, grazing pressure, fire age etc).

Plate 2. Screenshot taken from the digital survey form designed to capture bilby sign.

Greater bilby (*Macrotis lagotis*) conservation at Tharra Karnpar...

Bilby observation sheet

What are they eating
Are they eating here? Food plants nearby? Are they digging into the roots of plants? Are they digging for ants/termites? Is there anything obvious in their scats?

1000

Age and breeding status
Are there juveniles present (for example from size of tracks)? How old is the animal? How much bilby sign is there (lots of diggings and/or tracks?)

1000

Threats
Are there any threats to country here? Are there invasive plants or animals? Does this place need fire? Does this place need traps? Any other management?

1000

Cultural heritage
Is there any cultural values here that should be recorded or avoided? Are there any heritage values that need protecting here?

1000

Back

Submit

Page 6 of 6

Identify priority areas of defined habitat based on habitat indicators, sites of cultural significance and access limitations.

Thabitat

“Women’s site here. In our culture we dance for it. Still got spirits. Still alive here. They are watching.” Annabel Stream regarding Minyiburru gendered site (South Lukis Granites).

Access limitations pose a significant threat towards undertaking representative survey plots over the project area. Many of the tracks and access routes across Tharra are in poor condition, are unmapped, or have been overgrown such that they are near-impossible to spot. Furthermore, traversal across Tharra is restricted by cultural factors, such as avoidance areas and gendered sites, each of which has strict cultural protocols that must be observed to ensure the teams safety. To alleviate the risks posed by access restrictions and dangerous cultural sites, reconnaissance across Tharra was undertaken with Elders and other Palyku knowledge holders to place indicative sampling plot locations on known and accessible areas, and map routes that avoided culturally sensitive sites. Routes were logged using GPS tracks, avoidance areas were spatially mapped (ARCGIS), and eighty indicative plot locations were mapped (GPS point data, refer to Map 2).

Plate 2: Old station tracks such as the one pictured, are almost impossible to find without local guides.



Traditional knowledge was documented across Tharra to inform ideal sampling plot locations, and to discuss the relative health of bilby habitat. Bio-indicator species were documented and taught by knowledge holders across sites including ngarlu, dalgoolbooda, bunara (and wogoda), kalumbu, ngarbada, emu bush, minie ritchie, termites (pans and mounds).

Plate 3: Ngarlu (Cyperus bulbosus) from within bilby diggings found on barru country.



Multiple signs of bilbies were found on baru country (tracks, burrows, and scats) however the relative health of the country was deemed to be poor. Developmental pressure (mining and road infrastructure), encroaching weeds, cattle impacts, poor fire management and feral predators were all identified as detrimental to the health of bilby habitat. Of these threatening processes, the lack of cultural burning was deemed to be the most significant.

"Bad country [spinifex flats]. Should have been burnt. Make it fresh again... "Ngarbada [food plant] used to be here, gone now." Fred Stream (Palyku Elder).

Lack of cultural burning for a long time across Tharra has left much of the baru country unhealthy. Old spinifex dominates to the detriment of smaller herbaceous plants that thrive post fire. Many of these plants are food sources for bilbies and other animals, as well as people. A mosaic of burnt and unburnt country provides a food and shelter diversity that supports more animals and helps protect animals against feral predators.

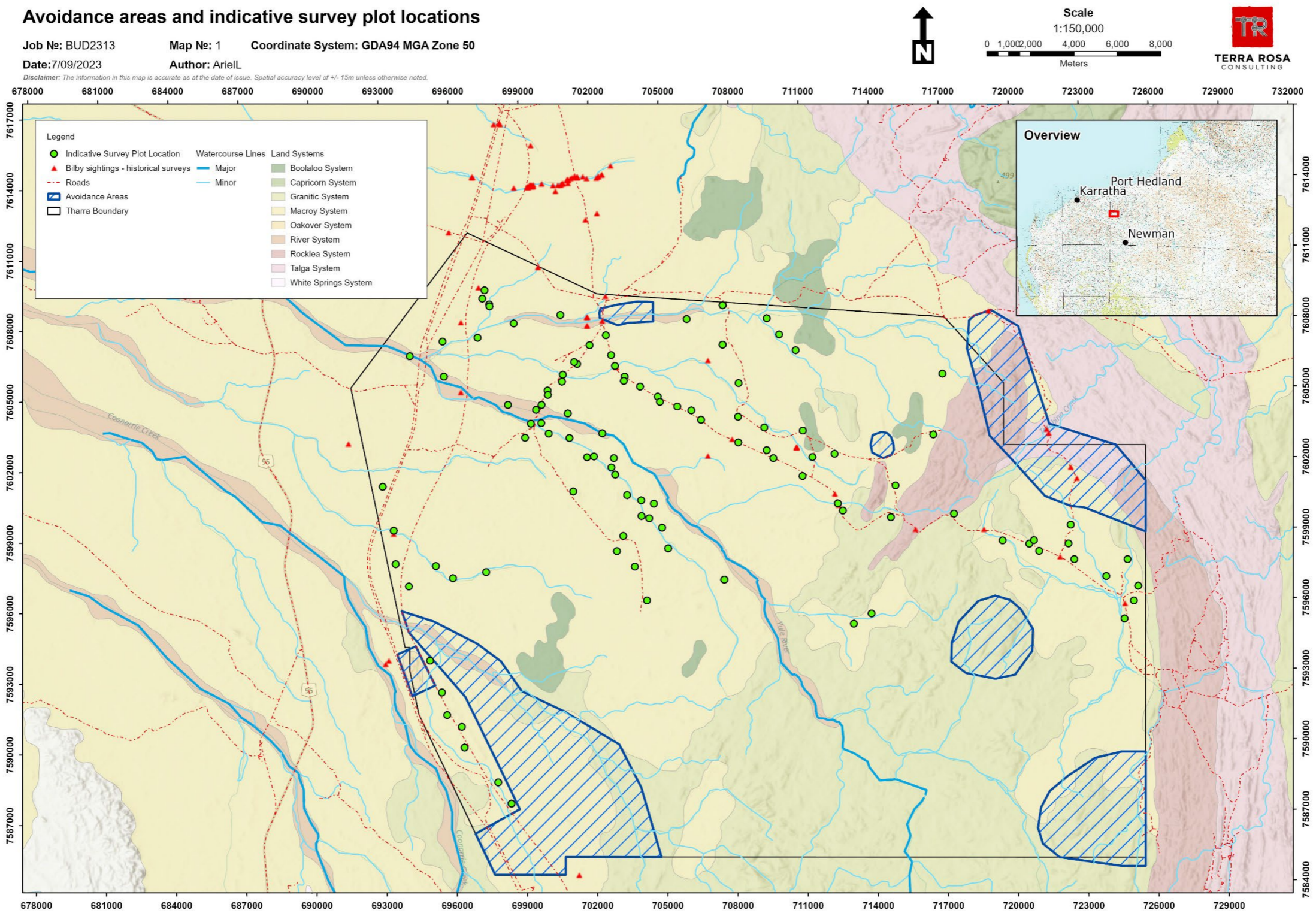
"Burn in bits and pieces, while you stay close. Every year, burn off. Every year better for the country." "[When the] government came, no more burning. Bad [for] country... Plants come up after burn. Right time for eating. Better for animals, they eat the young shoots. Animals come back to country. Lots of flowers too, peas [sturts desert pea], bush tucker for people. You never see them now. Haven't seen sturt flowers, anything like that." ... Fred Stream (Palyku Elder).

"[without burns] the animals starve. Can't feed, can't hunt."
Terry Jaffrey

*Plate 4: Cattle grazed
buffel grass (foreground)
encroaches on old baru
country (background). A
lack of proper fire harms
the overall health of baru
country.*



Map 2: Indicative survey plot points (ground-truthed) and cultural avoidance areas.



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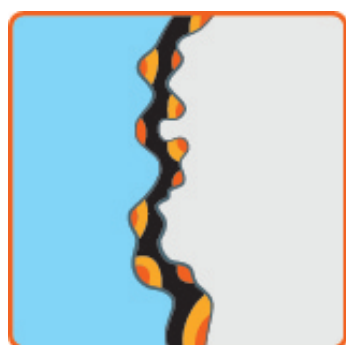
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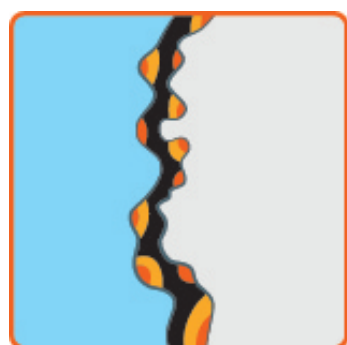
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