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PARKS AND WILDLIFE SERVICE

Monitoring Source Populations of Fauna for the Dirk Hartog Island National Park Ecological Restoration Project - 2023

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Monitoring Source Populations of Fauna for the Dirk Hartog Island National Park Ecological Restoration Project - 2023

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June 2024

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This document is available in alternative formats on request.

Cover image Pre-dawn trapping for brush-tailed mulgara and desert mice, Indee Station, WA. Credit: Jacqueline Roberts.

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Acknowledgments

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Summary

Monitoring of source populations of seven mammal and one bird species was undertaken by the Department of Biodiversity, Conservation and Attractions (DBCA), Biodiversity and Conservation Science in 2023 to obtain information on the distribution, abundance, and health of the wild source populations for translocations occurring as part of the Dirk Hartog Island National Park Ecological Restoration Project (DHINPERP).

Pre-harvest source population monitoring of brush-tailed mulgara (and desert mice) at Matuwa Kurrara Kurrara National Park (MKKNP) showed that population sizes of mulgara were adequate to proceed with translocation to DHI that was undertaken in June 2023. No desert mice were recorded.

Post-harvest monitoring of Shark Bay mice on Bernier Island, western grasswren at both Hamelin Station Reserve and Peron Peninsula, and dibbler (Jurien Bay Islands) showed that source populations continue to remain at similar levels to pre-harvest monitoring and harvesting does not appear to have had adverse effects on source populations.

Monitoring data for Shark Bay bandicoots and boodies on Bernier Island was gathered opportunistically and adds to the long-term population status information of bandicoots post-harvest, as well as contributing long-term monitoring data for the boodie prior to future harvesting for translocation to DHI in 2025/26.

Heath mouse surveys undertaken at Lake Magenta Nature Reserve captured just one individual and recorded only a few heath mice on camera traps, indicating they are at very low densities. Surveys at Dragon Rocks Nature Reserve and the Fitzgerald River National Park area did not detect the species at these locations.

Preliminary pre-harvest source population surveys were carried out for the brush-tailed mulgara and desert mouse at various sites in the Pilbara (Millstream Chichester National Park, northern Turner River, Port Hedland and eastwards). Only one desert mouse and no mulgara were captured on Indee Station (Turner River area). Camera traps recorded desert mice at two locations within Millstream Chichester National Park, and within the Port Hedland township and airport areas, but the results indicate that these likely represent relatively small, low-density populations. Very few desert mice were recorded elsewhere. These low detections, below average rainfall, and relatively poor environmental conditions makes it highly unlikely that large enough populations of either species will be found in the Pilbara in the short-term to support translocations. As such, mulgara translocation is now considered complete (given 100 were sourced from MKKNP) and recommendations made to delay desert mice translocation, until conditions improve.

1 Introduction

This report documents the monitoring activities undertaken from March to December 2023 for both pre-harvest and post-harvest source monitoring of fauna as part of the Dirk Hartog Island National Park Ecological Restoration Project (DHINPERP).

Pre-source monitoring was undertaken for the brush-tailed mulgara (*Dasycercus blythi*) and desert mouse (*Pseudomys desertor*) in Matuwa Kurrara Kurrara National Park, Millstream Chichester National Park and other areas of the northwestern Pilbara (Port Hedland surrounds and nearby pastoral properties to the south and east).

Post-harvest source monitoring was conducted on Bernier Island for Shark Bay mice (*Pseudomys gouldii*), Hamelin Station and Peron Peninsula for western grasswren (*Amytornis textilis*), and in Jurien Bay for dibblers (*Parantechinus apicalis*). Additional monitoring data was also gathered from Bernier Island for Shark Bay bandicoots (*Perameles bougainville*) and Shark Bay boodies (*Bettongia lesueur lesueur*).

Surveys for the heath mouse (*Pseudomys shortridgei*) were conducted at Lake Magenta Nature Reserve in May and October 2023, and at Dragon Rocks Nature Reserve in May and Fitzgerald River National Park in April 2023.

2 Methods

2.1 Surveys

2.1.1 Shark Bay bandicoots and boodies

A third year of post-harvest monitoring of Shark Bay bandicoots was undertaken on Bernier Island for four nights between 29th March – 1st April 2023, during the Shark Bay mouse post-harvest source monitoring as an opportunity to gather additional long-term data on the population. Similarly, trapping on the large grid also allowed information to be gathered on boodies to add to long-term data trends for this species and contribute to an understanding of population condition and dynamics prior to planned translocation to DHI in 2026. The permanent large grid, comprising 64 trap sites, was used for monitoring the bandicoots and boodies, with each site having one medium Elliott and one collapsible cage trap (see Sims et al., 2020 for further details).

As per previous surveys, bandicoots were visually checked for clinical signs of BPCV1 infection. No suspicious lesions were recorded and as a result, no samples were collected to analyse for viral confirmation.

2.1.2 Shark Bay mouse

Post-harvest source monitoring of Shark Bay mice was conducted for five nights from 29th March – 2nd April 2023 on Bernier Island. Three grids were used, the first being a large grid as described in 2.1.1.1. with both cage and Elliott traps at each point (opened for four nights 29th March – 1st April). The two smaller grids, each with 21 medium Elliott traps (arranged in 3 lines of 7), were also opened for four nights (30th March – 2nd April). As these were designed specifically to target Shark Bay mice, they included modifications to traps to limit interference from larger mammals like boodies and Shark Bay bandicoots. The ‘trap-excluder’ modifications are different in each of these grids, with those of the more westerly one described in detail in Sims et al. (2020). The different ‘trap-excluder’ design used on the more eastern of these ‘Shark Bay mouse’ grids is described in Sims et. al. (2022).

2.1.3 Dibbler

2.1.3.1 Boullanger and Whitlock Island

Trapping was undertaken for dibblers on Boullanger and Whitlock Islands on 23rd - 27th October 2023 using the established trapping grids (Sims et al. 2021) on each island (Boullanger 480 trap nights; Whitlock 160 trap nights). Since it has been more than two years since either population was harvested for the Perth Zoo breeding colony, biannual surveys were no longer required and just one survey was undertaken. Spring surveys are preferred to allow for an assessment of the number of new individuals in each population after the breeding season.

2.1.3.2 Escape Island

Surveys for dibblers on Escape Island were conducted on 23rd – 27th March 2023, using the established trapping grid (Sims et al. 2021) (300 trap nights). Due to warmer than expected conditions, after the first two nights only half the traps were opened to reduce the likelihood of any adverse events arising due to heat stress.

2.1.4 Brush-tailed mulgara

The brush-tailed mulgara translocation to DHI was planned to commence in June 2023. The location identified as the best primary source for DHI founders was Matuwa Kurrara Kurrara National Park (MKKNP) due to its historically high density of mulgara and representative genetics. Further genetic and population surveys were carried out in several areas within the northern Pilbara as potential supplementary sources (Figure 1).

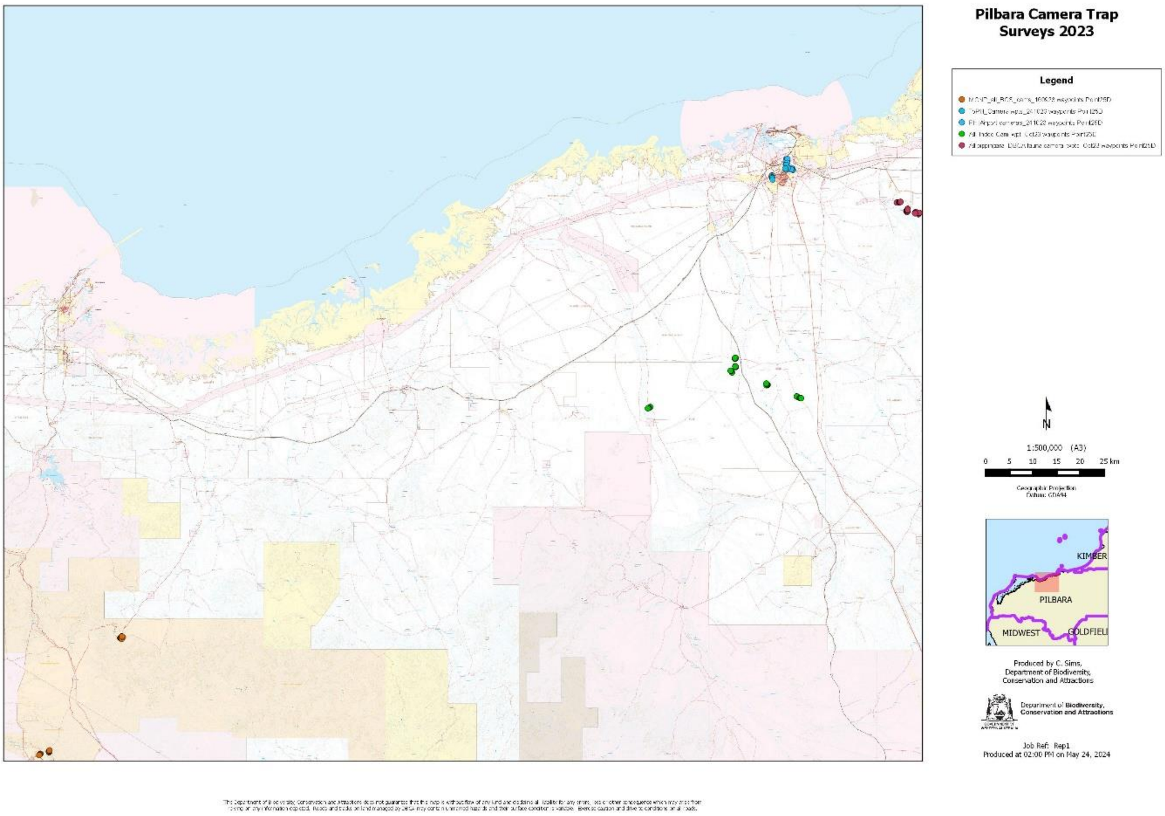

Figure 1. Locations in the Pilbara surveyed in 2023 for possible source populations of brush-tailed mulgara (and desert mouse) for translocation to DHI.

2.1.4.1 *Genetic Analysis and PVA modelling of meta-population.*

Recently collected (2022/23) and historical tissue samples (<20 years old, sourced from museums) were accessed and used to carry out genetic analysis and population modelling of mulgara translocation scenarios. Samples were obtained from possible source sites in Western Australia including Matuwa (on MKKNP) and Jundee in the Goldfields, Kennedy Range National Park (KRNP) and Mooloogool-Doolgunna in the Midwest, and various sites in the Pilbara. Additional samples across the brush-tail mulgara distribution (central Northern Territory and central Queensland) were included in the analysis to provide better context in assessing the genetic health of Western Australian source populations. Sample sources included Midwest (n = 11), Goldfields (n = 49), Gascoyne (n = 4), Pilbara (n = 68), central Northern Territory (n = 25) and central Queensland (n = 23).

Tissue samples were sent to Diversity Arrays Technology (http://www.diversityarrays.com) for genome-wide SNP sequencing.

2.1.4.2 *Matuwa Kurrara Kurrara National Park*

Pre-harvest surveys were undertaken at MKKNP for four nights from 24th - 28th April 2023. Four grids of 25 trap locations (5 x 5 at ~40-50m spacings) were set with medium Elliott traps (Figure 2). Two of the grids were opened for three nights only due to rain on the first day. Each trap was baited with universal bait (peanut butter, rolled oats and sardines), wrapped in hessian, and where possible, placed under vegetation. A neoprene 'stubby holder' trimmed to allow free triggering of the treadle plate was also placed in each trap to provide additional insulation and refuge for trapped animals. All traps were checked and closed within 3 hours of sunrise and re-baited and reopened in the late afternoon, and a 1% solution of Coopex™ (Permethryn), sprayed under and around the trap to minimise ant problems.

During this time, two adult mulgara were brought into captivity for 24 hours in purpose designed small 'terrarium-style' enclosures to test procedures for fitting of prototype radio-collars and observe animals' tolerance of collar design, prior to the translocation (Figure 3).

Fifteen lured camera traps (Reconyx™ HyperFire™ PC900), lured with universal bait (peanut butter, rolled oats and sardines) were also placed adjacent to roads at ~500m intervals, in another spinifex dominated habitat in the northeast of Matuwa (within MKKNP) for 4 nights during this time giving a total of 60 trap nights. Camera trap stations were deployed as described below in 2.1.4.3, except for baits being placed in perforated sample containers rather than tea infusers.

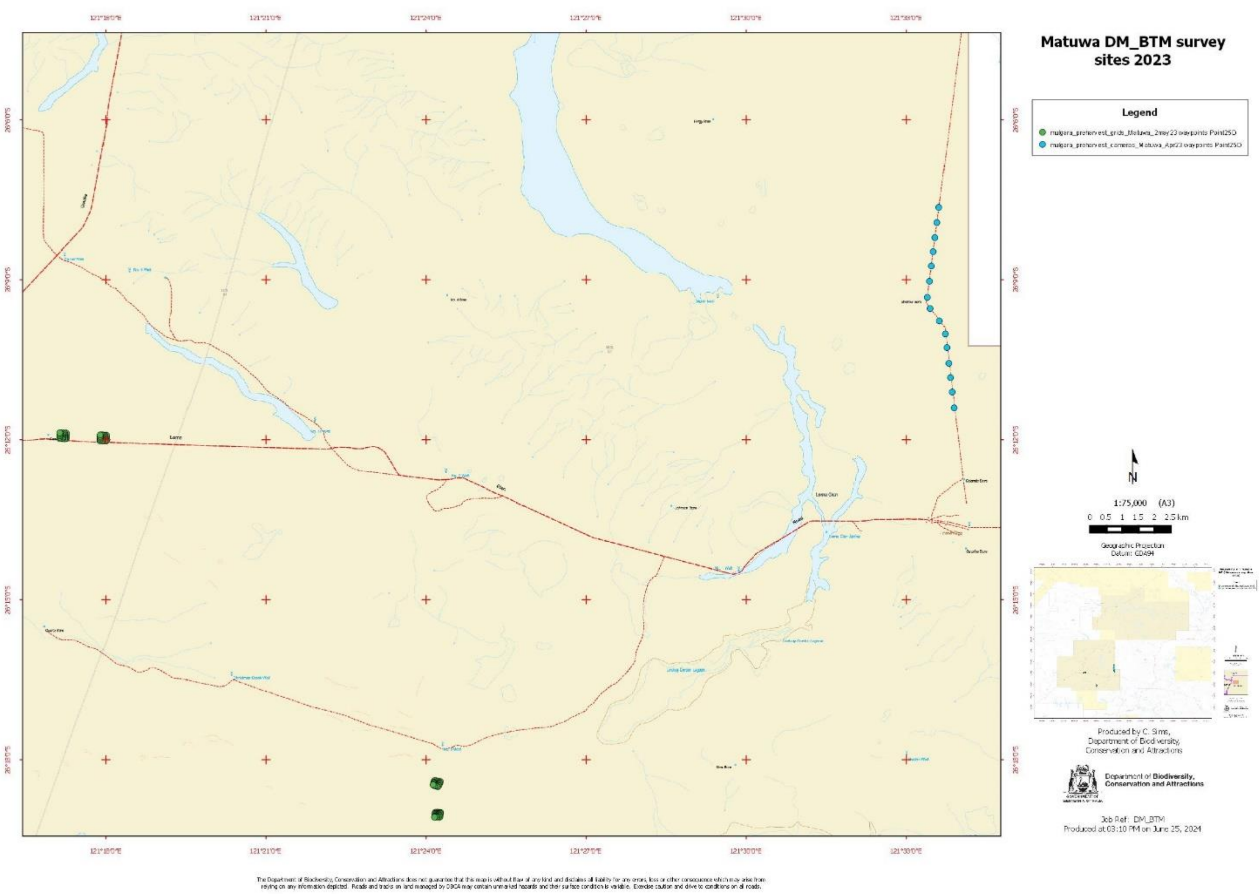

Figure 2. Location of trapping grids (green dots) and camera traps (blue dots) at MKKNP for April 2023 pre-harvest monitoring.

Figure 3. Collar trials on mulgara in overnight enclosures at Matuwa (Lorna Glen Homestead Laboratory facilities), MKKNP.

2.1.4.3 Elliott and camera trapping Indee Station (Turner River area, Pilbara)

Live trapping on Indee Station was carried out between 18th – 21st October 2023 using four trapping grids of 24 medium Elliott traps. Each grid comprised 4 lines (~70-100m apart) of 6 traps, at ~ 40-50m spacings.

Between October and December 2023, 10 baited camera traps were also deployed at six locations (60 total), across Indee Station, using initial ground survey observations to target potential desert mice and mulgara habitat near small drainage lines, or spinifex dominated vegetation where possible mulgara and other small mammal tracks were observed (Figure 4).

Each camera trapping site utilised a random combination of 8 passive infrared (Reconyx™ HyperFire™ PC900) and 2 white flash (Reconyx™ PC850 and/or HyperFire 2™ HP2W) Professional Research Series camera traps. Each camera trap used high capacity, low self-discharge NiMH rechargeable batteries (Fujitsu HR-3UTC), 32GB SD card (SanDisk Ultra SDHC 120MB/s, Class 10), and was programmed using the RapidFire™ picture interval (up to 2 frames per second), 3 pictures per trigger with no delays between trigger events, high sensitivity and 24-hour motion schedule (i.e. camera trap was always on). Camera traps within these areas ran outward from existing tracks at ~ 50-100m intervals.

Each camera trap was secured facing ~south (~10-12cm above ground level) to a black plastic sand peg using a combination of thread screws and/or metal brackets, with a small (4.5cm diameter) mesh tea ball infuser encapsulating a ball of universal bait (Peanut butter, rolled oats and sardines) pegged to the ground ~ 1-1.5m in front of the camera trap using a small metal tent peg.

Following camera trap collection, the MegaDetector image recognition application model 'EcoAssist' was used to separate the majority of animal from non-animal detections then uploaded into a Colorado Parks and Wildlife (CPW) Photo Warehouse Microsoft Access database where images were classified to species-level where possible. Independent detection events (IDE) were determined by assigning a minimum interval of 60 minutes for consecutive images of the same species at a given camera trap location.

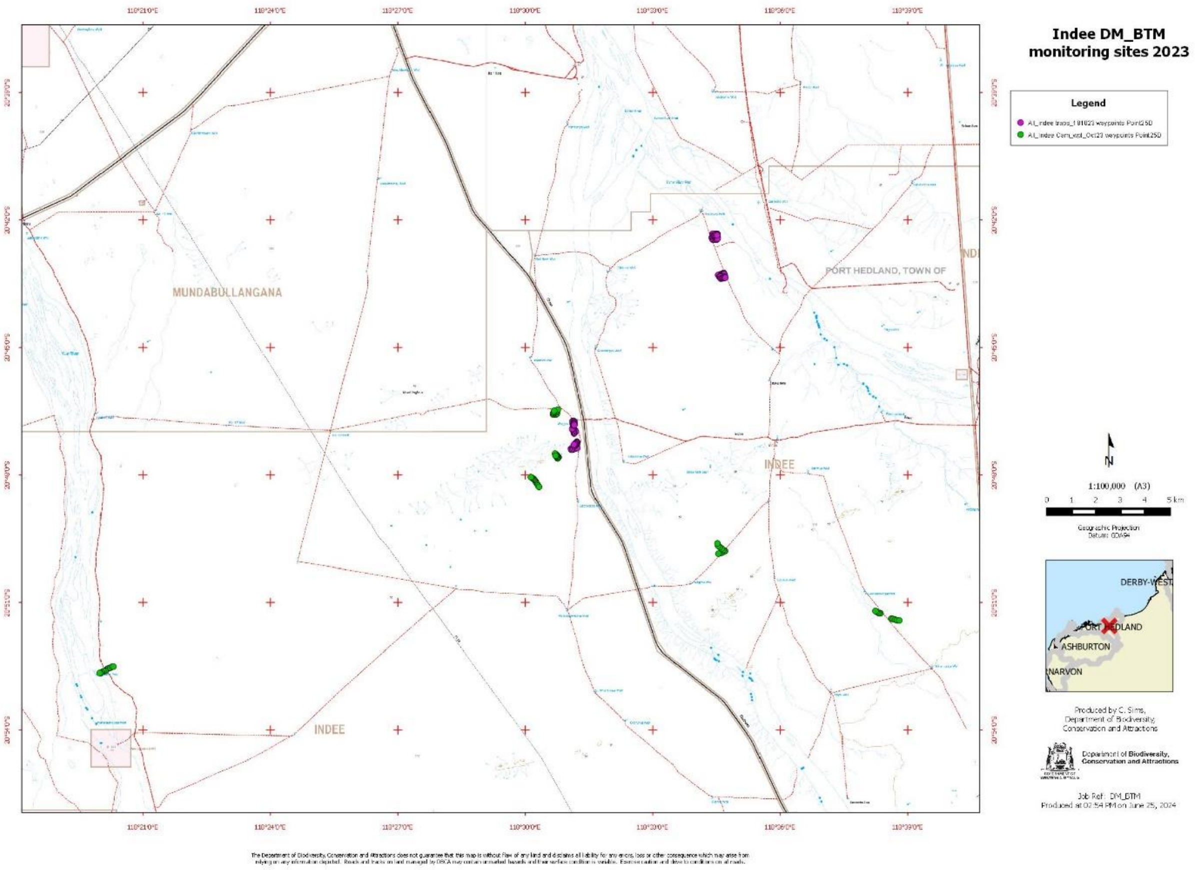

Figure 4. Locations of camera traps (green dots) and Elliott traps (pink dots) on Indee Station, October – December 2023.

2.1.4.4 Town of Port Hedland proposed development sites and Port Hedland International Airport lands (Pilbara)

In response to multiple historical records and recent communication of potential presence of mulgara in an area to be cleared for development in the vicinity of Port Hedland, site visits and ground assessment of multiple locations were carried out on 23rd and 24th October 2023.

Between 23rd October and 6th December 2023, 20 baited camera traps were deployed at four locations around the South Hedland area, on Town of Port Hedland (ToPH) and Port Hedland International Airport (PHIA) managed lands. Ground survey observations were used to investigate possible suitable habitat in spinifex sandplain and low scrub/heath where potential mulgara and other small mammal signs (e.g. scats, tracks, diggings and burrows) were observed. Two locations of five traps were deployed within the restricted fenced (permeable to small mammals) surrounds of PHIA for a total of 440 trap nights, (Figure 5) and a further two sites of five camera traps were deployed on lands earmarked for future development (both ToPH and PHIA) that had unrestricted access (Figure 6) for a total of 420 trap nights.

All cameras were infrared Reconyx™ HyperFire™ PC900 Professional Research Series, and camera trap locations were targeted near the most likely active areas, at least 35m from tracks and 90m from each other.

All other details of setup and image management were as described above in 2.1.4.3.

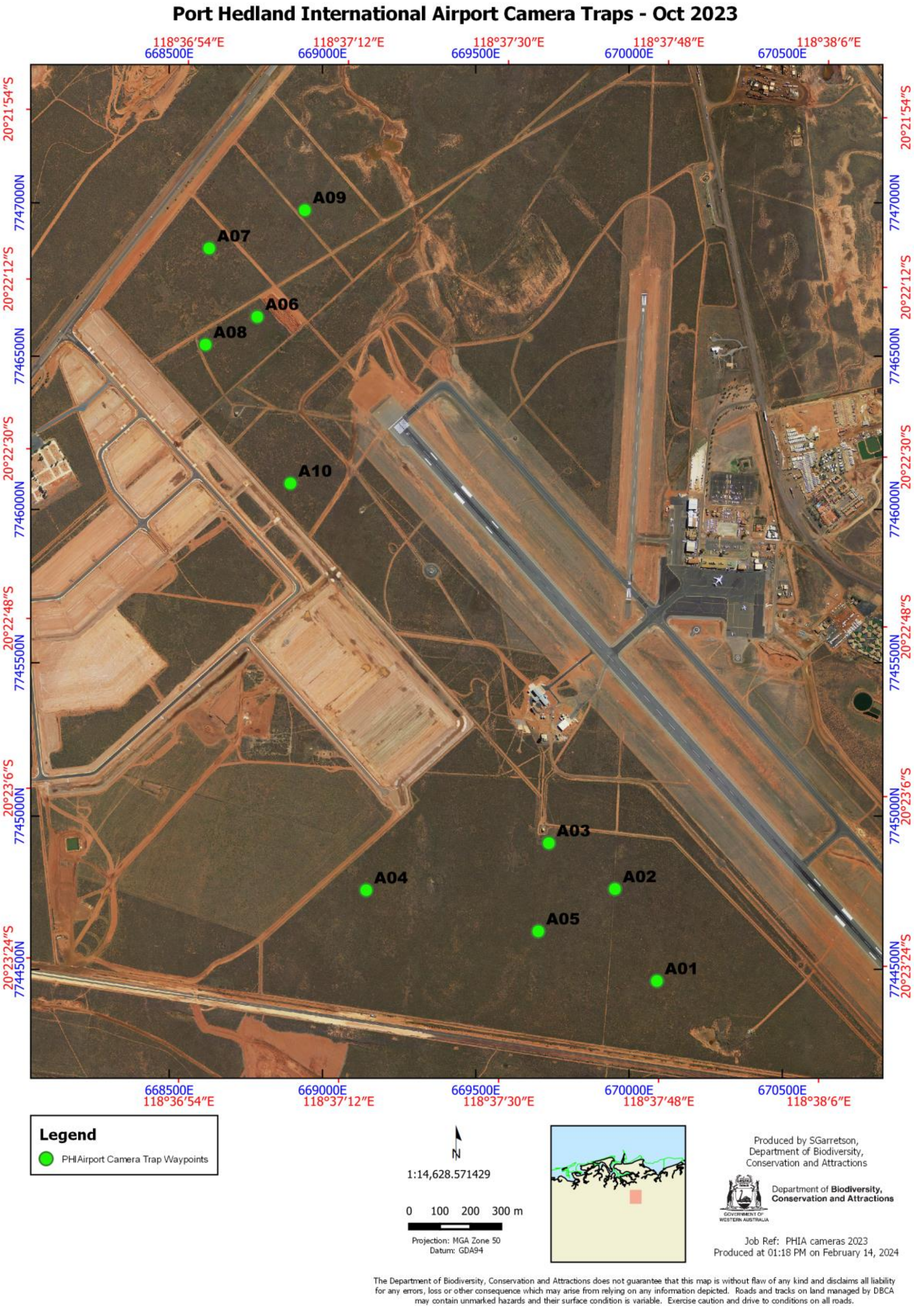

Figure 5. Camera trap locations inside access fence Port Hedland International Airport 23rd October – 6th December 2023

Figure 6. Camera trap locations on uncleared ToPH and PHIA lands 24th October – 5th December 2023

2.1.4.5 *Pippingarra Station (Nyamal country)*

Between 25th October and 30th November 2023, a total of 40 baited camera traps were deployed at six locations on Pippingarra Station (Figure 7), using initial ground survey observations to target potentially suitable habitat in spinifex sandplain where possible mulgara and other small mammal tracks were observed. Locations were selected based on Nyamal Rangers' traditional knowledge of country followed by visual inspections of potentially suitable sandplain habitat, and considered habitat quality, fire-age history, level of disturbance, and identification of recent animal sign (e.g. scats, tracks, diggings and burrows).

Camera trap setup and image management was as described in 2.1.4.3 above. Camera traps were placed at least 40m from existing tracks and were spaced approximately 50-100m from the nearest camera within suitable habitat.

Individual camera trap stations were in place for between 35-36 days.

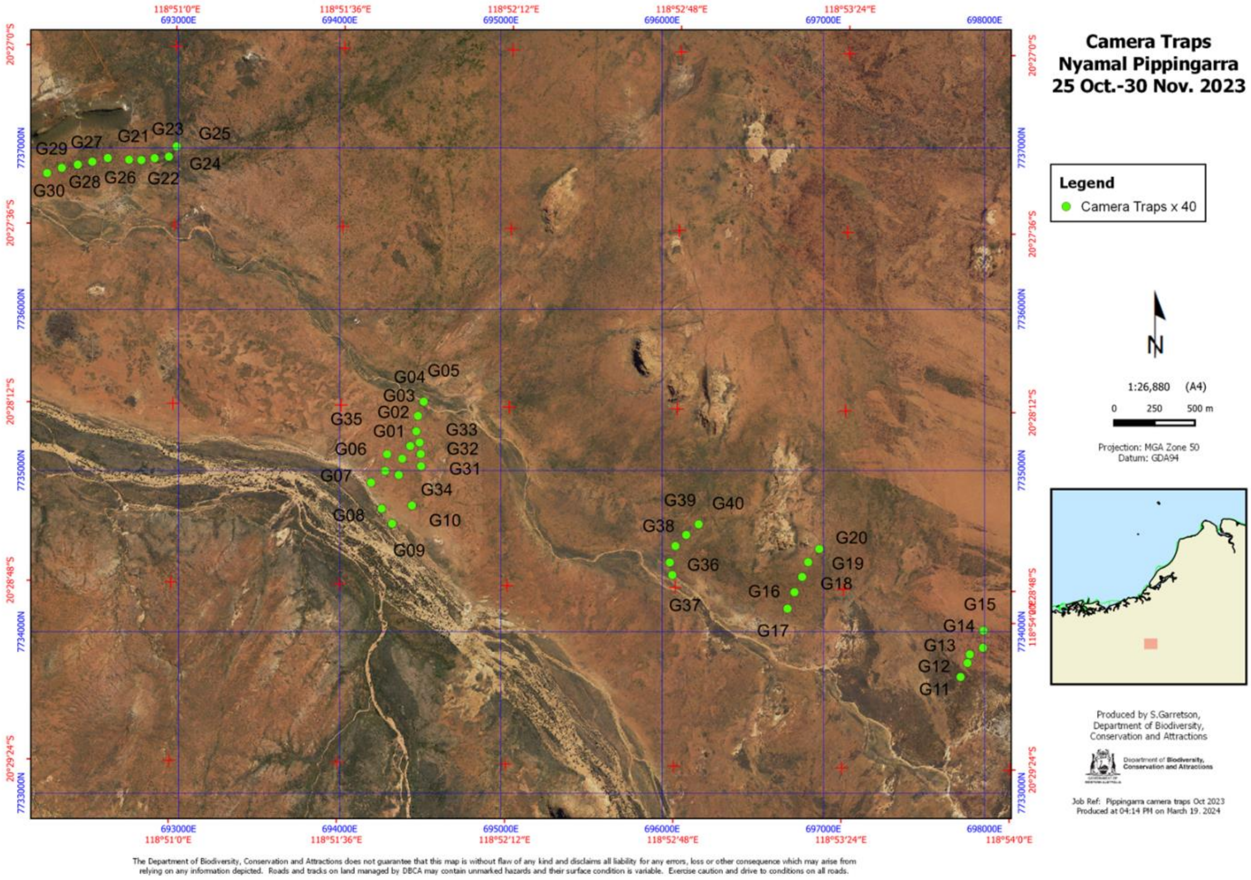

Figure 7. Camera trap locations on Pippingarra Station (Nyamal) 25th October – 30th November 2023.

2.1.5 Desert mouse

It was assumed that desert mice would share many broadly similar habitat requirements as brush-tailed mulgara in most instances, and so all locations surveyed in 2023 were surveyed for both species.

2.1.5.1 Genetic analysis

Desert mice tissue samples (n = 94) were primarily sourced from the WA Museum for genetic analyses. These samples were only from the Pilbara where intense survey activity occurred between 1996 and 2015 (the majority from a peak irruptive phase during 1999-2006). There were relatively few samples available from other parts of their range, and recent work in the Midwest and Goldfields in 2022 indicated that desert mice at these locations were at extremely low densities and unlikely to be viable source populations for harvest. Tissue samples were sent to Diversity Arrays Technology (http://www.diversityarrays.com) for genome-wide SNP sequencing.

2.1.5.2 Matuwa Kurrara Kurrara National Park

The live trapping and camera trapping program for brush-tailed mulgara (as described above) was also used to survey desert mice.

2.1.5.3 Millstream Chichester National Park

Between August and October 2023, a total of 24 camera traps were deployed in several locations within Millstream Chichester National Park (MCNP) (Figure 8). Sites were selected based on previous trap records of desert mice (~10 years prior), recent fire history and on ground examination of habitat type and quality.

Cameras were deployed in lines of five cameras at each location and spaced ~ 100m apart. Fifteen non-lured white flash cameras were first deployed in early August. These camera traps were subsequently checked (and some moved) in mid-September and a further nine infrared flash cameras added to the deployment. At this time, all cameras had lures (universal bait) added. All cameras were collected in mid-late October. Individual camera trap stations were in place for total times ranging between 24 and 84 days.

Camera trap setup and image management was as described in 2.1.4.3 above.

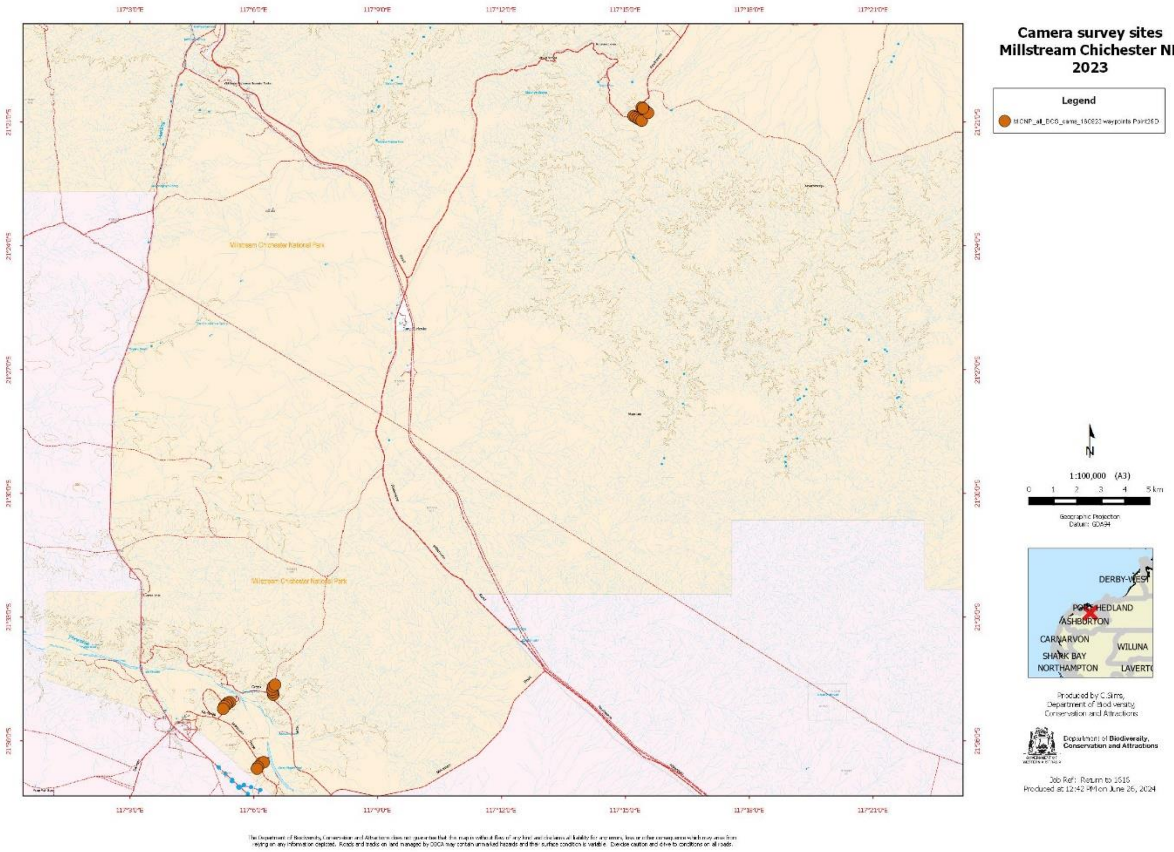

Figure 8. Camera trap locations in Millstream Chichester National Park, Aug-October 2023

2.1.5.4 Northern Pilbara (Indee Station [Turner River], Port Hedland area, Pippingarra Station).

Live trapping and camera trapping activities for brush-tailed mulgara at Indee Station, Pippingarra Station and the Port Hedland area (as described above), also targeted desert mice.

2.1.6 Western grasswren

Western grasswren monitoring at harvested and unharvested territories was undertaken at both Hamelin Station Reserve and Peron Peninsula in August 2023, 10 months after the translocation of 85 birds to Dirk Hartog Island in October 2022. A total of 246 territories were surveyed: 98 at Hamelin and 148 at Peron. Grasswren presence was determined by noting calls, songs or visual encounters. Call playback was also used to elicit a response if passive observations did not result in a detection of birds. Known territories were deemed ‘occupied’ if birds were detected within a 100m radius of the GPS point allocated to a particular territory, or ‘unoccupied’ if there were nil detections after 15 (Hamelin) or 10 (Peron – reduced due to the number of sites to cover) minutes of passive searching, followed by 4 minutes of playback and 2 minutes additional passive observations. Observers went in blind as to the status (harvested vs unharvested) of the territories and were randomly allocated.

2.1.7 Heath mice

Autumn 2023 surveys in Lake Magenta Nature Reserve occurred from 16th – 20th May (930 trap nights) and Dragon Rocks Nature Reserve from 30th May – 3rd June (295 trap nights). Surveys used grids of Elliott traps with 25m spacing.

A further trapping survey at Lake Magenta took place between 10th -13th October 2023 (740 trap nights), again using Elliott traps. Grids of lured camera traps with 125m spacing were also deployed at Lake Magenta in October 2023.

Surveys took place in Fitzgerald River National Park (FRNP) and adjacent Unallocated Crown Land from 19th – 22nd April 2023 for 1075 trap nights (using trap grids and transects).

2.2 Data Analysis

2.2.1 Trapping data analysis

Trapping data were analysed for density estimates using Spatially Explicit Capture Recapture with the package ‘secr’ (Efford, 2022) in R version 4.2.1 (R Core Team, 2022). Density estimates were made for Shark Bay bandicoots, boodies and Shark Bay mice on Bernier Island and brush-tailed mulgara on MKKNP.

2.2.2 Camera data analysis

Camera trap data were processed using the EcoAssist program (Beery et al., 2019; van Lunteren, 2022) and CPW Photo Warehouse (v4.3.0.4) (Newkirk, 2016).

2.2.3 Genetic analysis and PVA modelling

The SNP datasets generated for brush-tailed mulgara and desert mouse tissue samples were quality checked and resulted in neutral SNP datasets of 2099 and 12,491 loci, respectively. Descriptive population genetic parameters (observed and expected heterozygosity, private alleles) were estimated in the *dartR* R package (Gruber et al. 2018). Principal coordinate analysis (PCoA) and discriminant analysis of principal components (DAPC) were conducted to assess population genetic structure.

To investigate alternative sourcing strategies for brush-tailed mulgara, translocation scenarios were simulated in VORTEX (Lacy and Pollak 2021). Population allele frequencies estimated from a random subset of 1000 loci were used to estimate genetic diversity for each modelling scenario. Translocation scenarios tested the effects of different sourcing strategies and founder ratios on genetic diversity at year 1 (year of translocation). Scenarios comprised single-population sourcing from MKKNP, and different combinations and ratios of multi-population sourcing from MKKNP and either Mooloogool-Doolgunna, Kennedy Ranges or Pilbara populations. A founding population of 90 – 100 individuals was assumed. Estimates of expected heterozygosity were collated via the R package *vortexR* (Pacioni and Mayer 2017) and a pairwise Wilcoxon rank sum test with adjusted p-values (Benjamin & Hochberg 1995) determined if genetic diversity was significant different between translocation scenarios.

3 Results

3.1 Shark Bay bandicoot

Over the 256 trap nights on Bernier Island there was a total of 38 captures of 21 unique bandicoots (trap rate of 14.8% or 32.2% if excluding traps occupied by boodies). From the 21 known individuals, nine were recaptures and 12 were new individuals. There were 11 females and 9 males (plus one unknown). No females had pouch young, but pouch condition was recorded as virginal in five individuals and another five had regressing teats.

Density was estimated at 1.92/ha (0.48 SE), which if extrapolated across the island where there is suitable habitat reveals an estimated abundance of 7186 (95% CI 4487 - 11507). The population appears to have increased again from 2022 figures and is now estimated to be higher than any previous year since monitoring for this project commenced in 2016 (Figure 9).

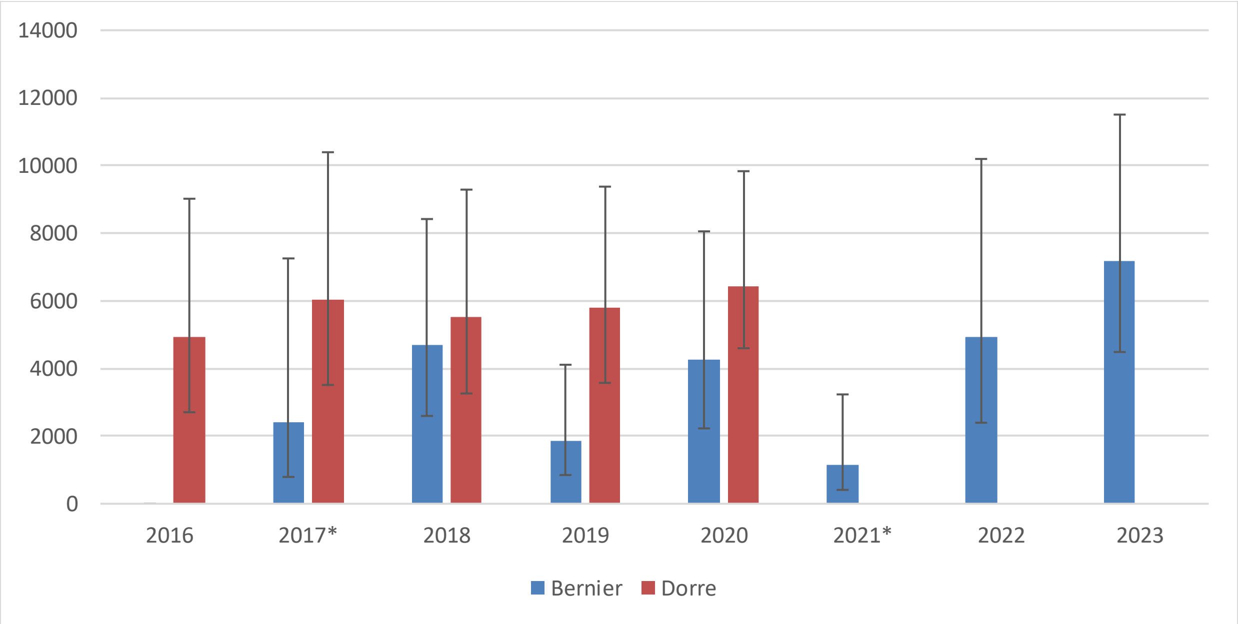

*Figure 9. Estimated abundance (95%CI) of Shark Bay bandicoots on Bernier and Dorre Islands (*denotes poor model fit)*

3.2 Boodie

Over the 256 trap nights on Bernier Island, a total of 138 captures of boodies was recorded (trap rate of 53.9% or 63.3% if excluding traps occupied by bandicoots), of which 57 were unique individuals. New animals made up 34 of these, and 23 were previously known recaptures. The sex ratio of individuals trapped was 27M:30F. Ten of the females were subadults with virginal pouches, but nine of the 20 adults (45%) had small pouch young (<20mm CR) and a further six had regressing teats.

The estimated density was 2.3/ha (0.42 SE) indicating an estimated abundance of 8767 (6194 - 12407) individuals (from available suitable habitat). The population appears to have increased substantially from 2022, with 2023 being the highest population size estimate of recent times (Figure 10).

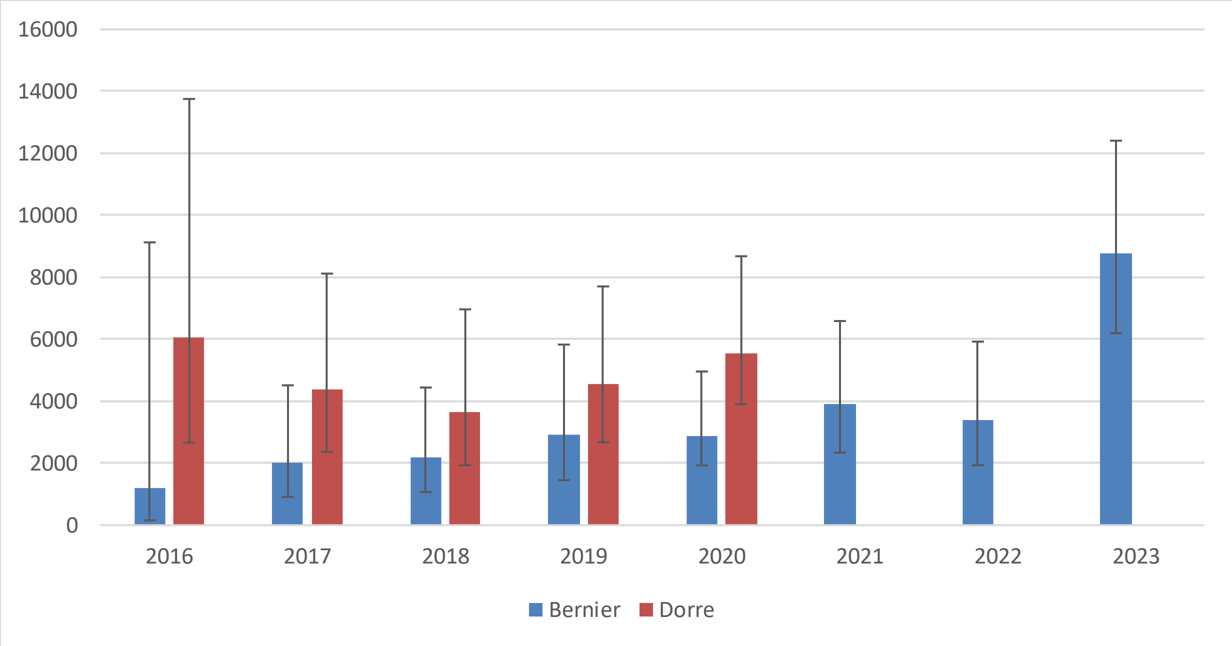

Figure 10. Estimated abundance (95%CI) of boodies on Bernier and Dorre Islands

3.3 Shark Bay mouse

Only Elliott trap captures on the large grid on Bernier Island were considered for this species (equalling 256 trap nights). Trapping on the smaller grids added a further 168 trap nights to give a total trap effort of 424 trap nights. Trapping on the large grid resulted in 42 captures of 30 individuals (14M:16F); plus one which escaped prior to identification. Only five additional captures of two individual Shark Bay mice (1M:1F) occurred across the two small grids, providing a total of 48 captures of 32 individuals for the entire session. This equates to a trap rate for Shark Bay mice of 11.8% or 25.7% if excluding traps occupied by ash-grey mice (*P. albocinereus*).

Ash-grey mice were numerous at this time, with captures and individuals outnumbering Shark Bay mice by factors of 5:1 and 6:1 (237 captures of 203 individuals with 125 captures on the large grid plus 112 captures on the small ones), and > 55% of traps occupied by ash-grey mice).

SECR analysis combining all grids provided a density estimate of 1.27/ha (SE 0.33), leading to an estimated abundance of 4774 (95% CI 2916 - 7817) for 2023. This population estimate is even higher than the pre-harvest estimate and higher than any previous years since monitoring for the project commenced (Figure 11). This post-harvest monitoring provided positive evidence that populations were still very high despite removing 50 individuals for the translocation to DHI 12 months before.

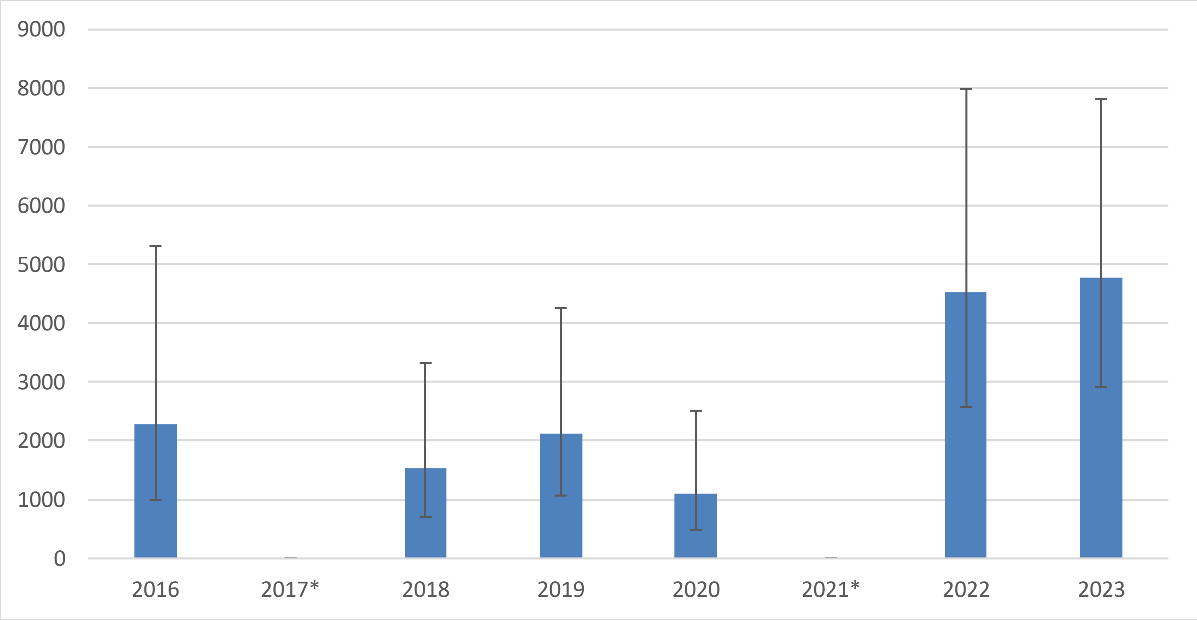

Figure 11. Estimated abundance (95% CI) for Shark Bay mice on Bernier Island.

3.4 Dibbler

3.4.1 Boullanger Island

Twenty-seven dibblers (7M:20F) were captured on Boullanger. This total comprised one recaptured and 6 new males, with 4 recaptured and 16 new females. Two of the recaptured adult females and one new adult female showed signs of breeding in 2023, while one new and two recaptured females apparently bred in 2022 but not in 2023. Capture success rate, at 5.4 individuals per 100 trap nights, showed a substantial decrease from 8.8 recorded in 2022 and 7.6 in the shortened trapping session in October 2021. However, this was still higher than in 2020 (2.6) and 2019 (2.0). A lower proportion of captured females had bred (3/7) compared with 9/9 in 2022.

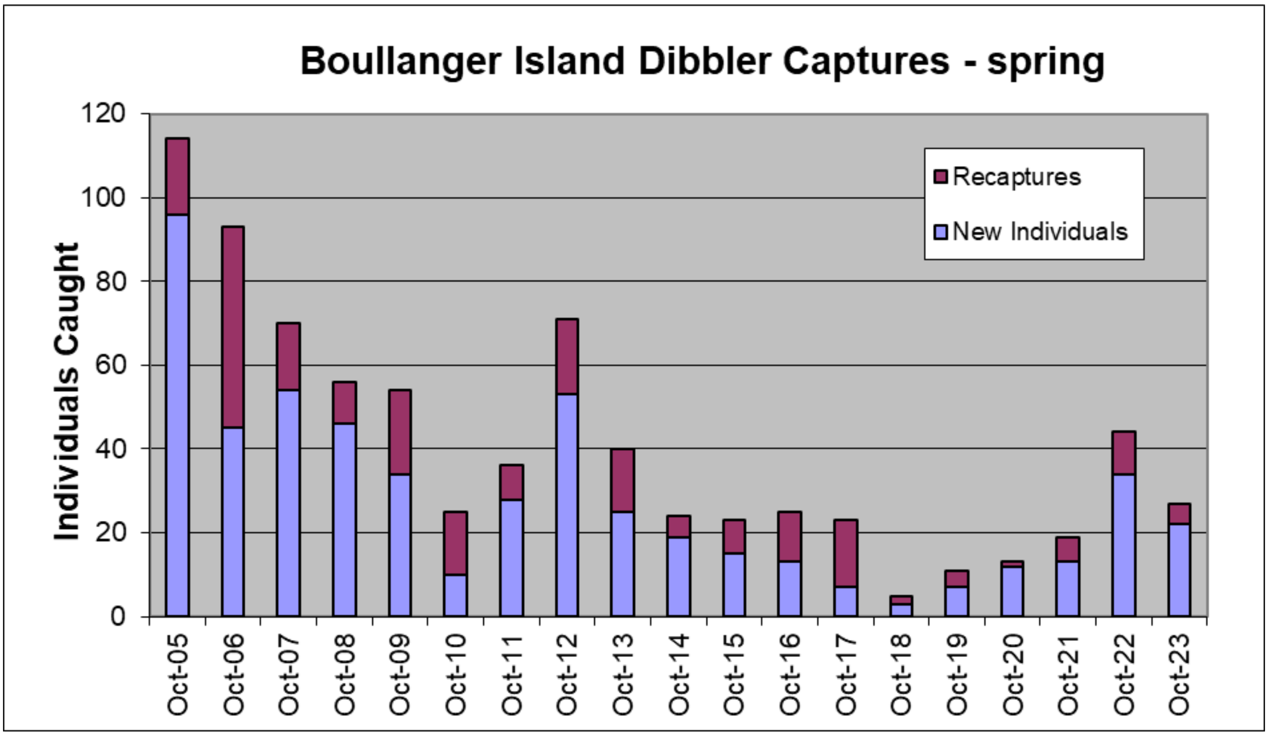

Figure 12. Number of individual dibblers captured during the Boullanger Island trapping in October each year since 2005.

3.4.2 Whitlock Island

The Whitlock trapping detected 21 individual dibblers (14M:7F), comprising six new and eight recaptured males and two new and five recaptured females. Only three of the six adult females had bred in 2023. Capture success rates expressed as individuals per 100 trap nights on Whitlock Island had decreased to 13.1, compared with 21.3 in 2022. Capture success rates recorded over the previous three spring trips were: 13.1 (October 2019), 6.3 (October 2020) and 13.8 (October 2021).

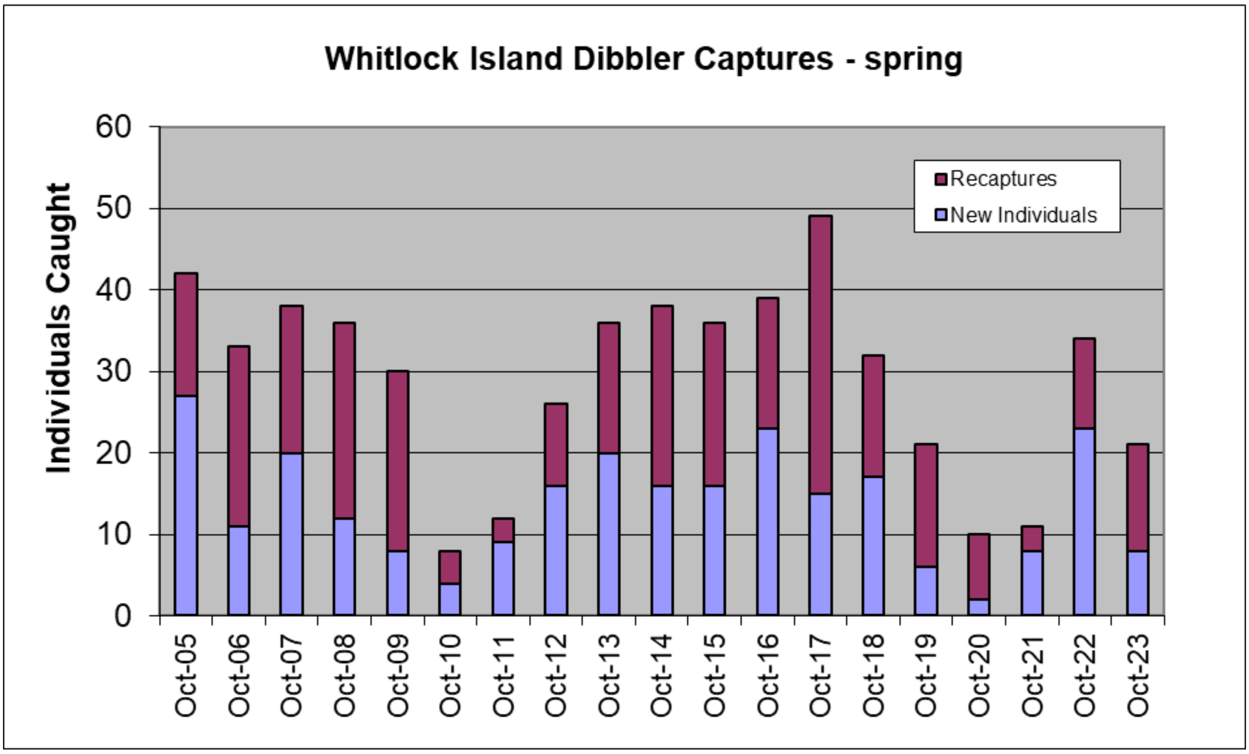

Figure 13. Number of individual dibblers captured during Whitlock Island trapping in October each year since 2005.

3.4.3 Escape Island

Despite the lower than usual number of trap nights, 71 individuals (28M:43F) were captured on Escape. Of these 19 males and 21 females were new. Four of the new females showed sign of previous breeding, indicating that we had missed them in the previous years. Most females showed some pouch development, indicative of the upcoming breeding season.

3.5 Brush-tailed mulgara and desert mouse

3.5.1 Genetics and PVA modelling

3.5.1.1 Brush-tailed mulgara

Genetic analysis revealed two genetic clusters within brush-tailed mulgara's range, with the Pilbara population distinct from the remaining distribution across Western and Central Australia (Figure B 1 in Appendix B). Genetic diversity of potential source populations (MKKNP, Midwest (including Mooloogol-Doolgunna) and Pilbara) was similar (observed heterozygosity H_O = 0.120 – 0.128), however, the Kennedy Range National Park had lower genetic diversity (HO = 0.088) and was considered a less favourable source population for translocations (Table B 1 in Appendix B).

Genetic outcomes from population viability analysis indicated that translocations sourced from multiple populations within the Goldfields/Gascoyne (i.e. MKKNP plus either Mooloogool-Doolgunna or Kennedy Ranges) did not provide significant benefit over sourcing from MKKNP alone (Figure B 2 in Appendix B). Translocation scenarios involving sourcing from MKKNP and the Pilbara resulted in an increase in genetic diversity relative to sourcing from MKKNP alone (Figure B 2 in Appendix B), although the genetic benefit entailed only ~5% increase in genetic diversity. When considering alternative locations in the Pilbara, we found the Turner River population (south of the town of Port Hedland) may provide the best genetic outcomes for potential supplementary source individuals (Figure B 3 in Appendix B).

3.5.1.2 Desert mouse

Genetic analysis of desert mouse samples from the Pilbara revealed a large effective population size (Ne = 2605, 95% CIs 2529 – 2686) and consistently high genetic diversity amongst the sub-regions sampled (West Hamersley, Central Hamersley, Chichester; Observed heterozygosity H_O = 0.213 – 0.217). There was no detectable genetic structure within the Pilbara, suggesting a panmictic population (Figure B 5 & Figure B 6 in Appendix B). Other areas within the Midwest and Goldfields regions were not analysed as samples and records were too few to consider as viable source populations.

Population viability analysis (PVA) was not completed for this species, but simulations based on sub-sampling the available genetic data indicated a minimum founder population of at least 40-50 individuals would be required to retain >99% of the desert mouse genetic diversity (Figure B 7 in Appendix B). Further modelling incorporating demographic variables (life span, mortality rates, reproductive rates, etc) and environmental stochasticity, is likely to recommend significantly higher founder size for successful establishment to account for natural population variability.

3.5.2 Matuwa Kurrara Kurrara National Park

During trapping on the four grids in April 2023, there were 62 captures (17.7% trap rate) of 43 individual mulgara in 350 trap nights. Two grids were more productive (45 in 200) than the other two (17 in 150). Of the 43 individuals, 19 were male and 24 female. All were in average or better condition (Body Score = 3-4 [1-5]), and mean tail width was 9.4mm (range = 4-13mm).

Estimated mean population density of mulgara based on SECR analysis from this trapping session was 1.73/ha (range 0.73-4.12). This density, when multiplied by the conservative estimate for the extent of preferred habitat (spinifex sandplain only; ~72,000ha) within the southwest corner (Matuwa section) of MKKNP, provided a potential population size of >120,000 mulgara from which to harvest founders for DHI.

Other mammals trapped included 32 captures of spinifex hopping mice (*Notomys alexis*), four sandy inland mice (*Pseudomys hermannsburgensis*), six house mice (*Mus musculus*) and one kultarr (*Antechinomys laniger*).

No desert mice were captured on MKKNP during the 350 trap nights in April 2023, or in the subsequent 600 trap nights when harvesting mulgara in June, during which, over 220 mulgara were trapped.

The small camera trap survey in April 2023 involved just 15 trap locations and totalled only 60 trap nights but resulted in mulgara being recorded at eight of the fifteen sites (53%), indicating that mulgara were widespread and common across all of the spinifex sandplain habitat surveyed at MKKNP (this was supported by the high trap rates during the harvest trapping in June). No desert mice were detected on cameras.

3.5.3 Millstream Chichester National Park

Over 6984 images of vertebrates from 1347 camera trap nights (both lured and un-lured) were analysed from Millstream Chichester National Park (MCNP). Camera placement focussed on areas of previous desert mouse detections on a mix of sandy/loamy and rocky substrates. No images of mulgara were recorded, however, there were multiple records (125 images/28 independent detections events) of little red kaluta (kaluta; *Dasykaluta rosamondae*). The kaluta is another small *Dasyuridae* of similar size, diet and habits, which often overlaps the range of the mulgara in the Pilbara. It produces similar secondary signs (scats, tracks, burrows and diggings) and has even been confused with mulgara on camera images in the past. (Table A 1 in Appendix A).

There were 622 images identified as desert mouse equal to 55 independent detection events (IDE) compared to 710 images/130 IDE for sandy inland mice, 97 images /13 IDE for house mice and 105 images/32 IDE for unidentified rodents. Desert mice were recorded at 17 of the 24 camera stations (71%) but most detection events (~68%) occurred at two locations either side of the Fortescue River in the SW corner of the park, (Figure 14). Desert mice were also detected multiple times (30% of all detections) at one other location near Python Pool, in the north of the park

(Figure 15). One camera station recorded 30% of all detections but likely represents a single animal which was clearly resident near the camera and appeared at the same time each day for over two weeks. Although these results indicate that there are not large numbers of desert mice in the area, they do confirm ongoing presence of desert mice at these locations where historical trapping data from ~ 2013/14 had recorded this species in reasonable numbers.

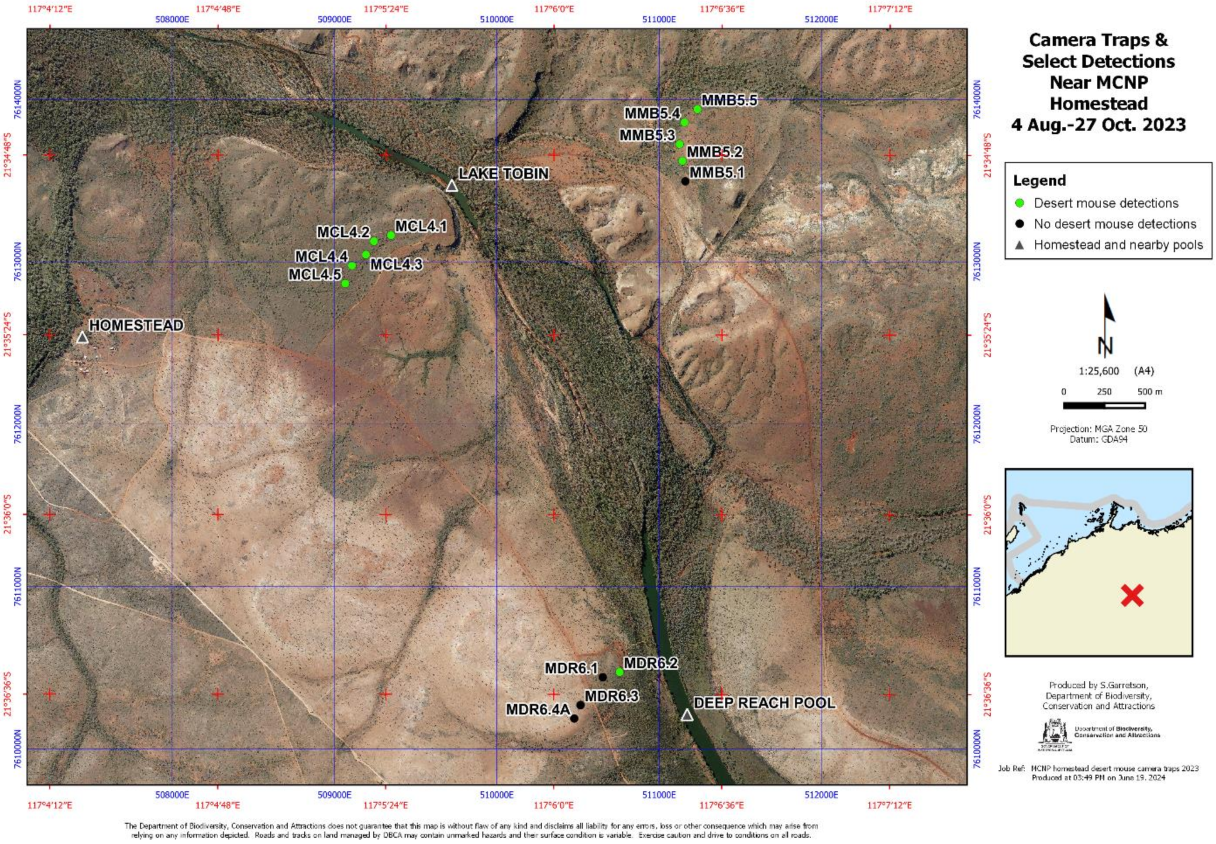

Figure 14. Cameras detecting Desert mice near Fortescue River and homestead in MCNP in spring 2023.

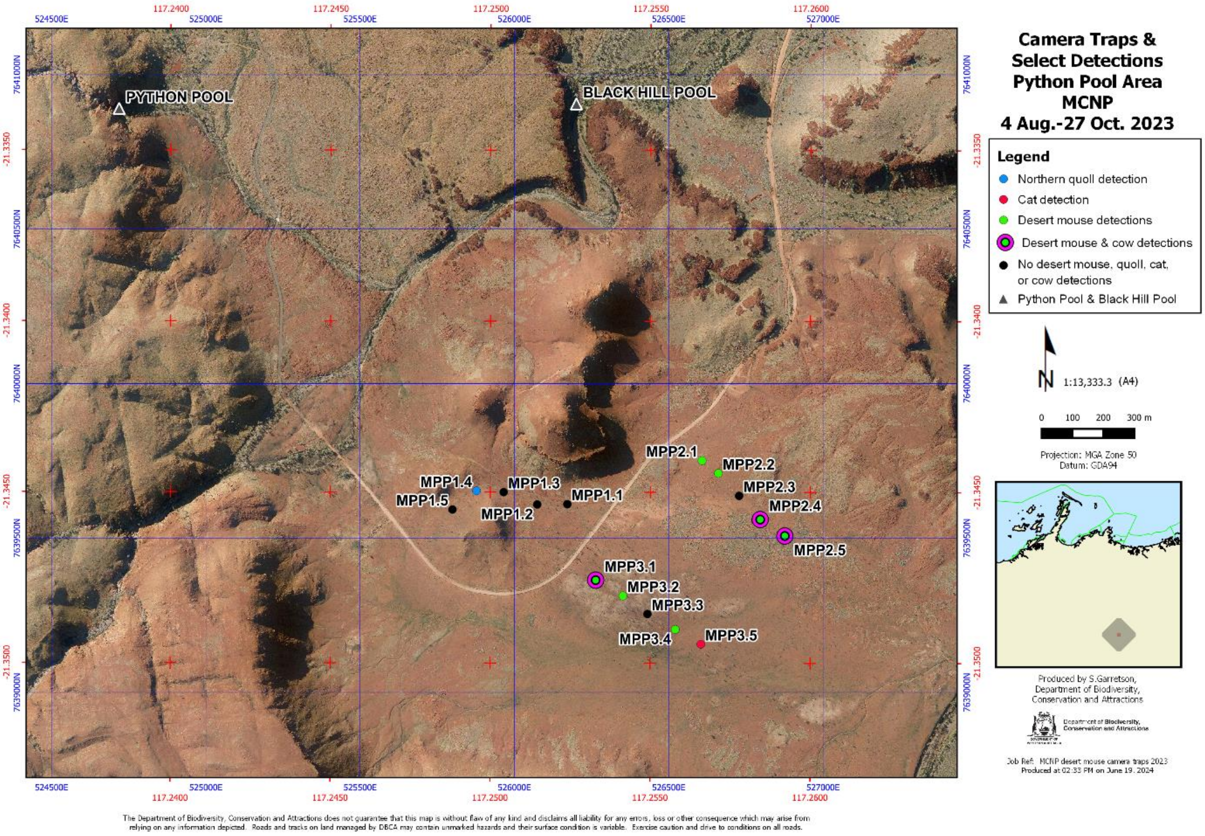

Figure 15. Cameras with Desert mice detection in Python Pool area (northern) MCNP in spring 2023.

Other species identified on the cameras are listed in Table A 1 Appendix A. There was one feral cat record, and quite a bit of disturbance from cattle evident in the northern part of the park.

3.5.4 Northern Pilbara

3.5.4.1 Indee Station (Turner River)

Elliott trapping on Indee Station resulted in 384 trap nights completed for just one desert mouse trapped, compared to nineteen captures of other *Pseudomys* spp. No mulgara were captured at any grids, but there were eight captures of kaluta across three grids (Table 1)

Table 1. Total captures of each species per trapping grid over 384 trap nights on Indee Station 19-22 Oct. 2023.

Common Name	Scientific Name	Trapping Grid	Captures per Grid	Total
Sandy Inland Mouse	*Pseudomys hermannsburgensis*	North A (INEA) North B (INEB) West TA (TA)	2 12 4	18
Little Red Kaluta	*Dasykaluta rosamondae*	North A (INEA) North B (INEB) West TA (TA)	3 3 2	8
Giant Desert Ctenotus	*Ctenotus grandis*	West TA (TA) West TB (TB)	6 2	8
Desert Mouse	*Pseudomys* desertor	North B (INEB)	1	1
Delicate Mouse	*Pseudomys delicatulus*	North B (INEB)	1	1
Dusky Ctenotus	*Ctenotus helenae*	North B (INEB)	1	1
Rock Ctenotus	*Ctenotus saxatilis*	West TA (TA)	1	1
			Total	**38**

Although there were a total of 2710 camera trap nights deployed on Indee Station, results were hampered by cattle disturbance at a number of stations. A total of 8114 images of vertebrates were analysed, of which 1644 were of cattle (Table A 2 in Appendix A.).

Despite recent records of mulgara on cameras at more distant locations on Indee in May 2023, no mulgara were recorded during this survey, although there were seventeen detection events for little red kaluta. There was only one detection of a desert mouse, compared to over 300 IDE (~2000 images) of sandy inland and spinifex hopping mice, and 58 IDE of stripe-faced dunnarts (*Sminthopsis macroura*).

3.5.4.2 *Pippingarra (Nyamal country) Station*

Observations of promising small mammal signs (old and fresh burrows and small dasyurid and other small mammal tracks) during searches of sandy substrate locations on Pippingarra Nyamal country, were used to select camera station placement. The resultant camera survey on Pippingarra Station produced a total of 2212 vertebrate images. These camera stations were in relatively small areas of potentially suitable habitat, surrounded by disturbance activities including cattle, recent fire scars and mining. There were also quite a few detections of feral cats and dingoes. No images of mulgara were recorded, but 168 images equal to 15 IDE of kaluta were recorded. No confirmed identifications of desert mice were recorded, but over 700 images, comprising at least 141 IDEs of other rodents (*Pseudomys* and *Notomys)* were recorded (Table A 3 in Appendix A.).

3.5.4.3 Town of Port Hedland

The ten camera stations provided 1311 vertebrate images for analysis. There were 25 images (3 IDEs) of mulgara on just two camera stations, compared to 233 images (17 IDEs) of kaluta on five camera stations (Figure 16), and only one detection of desert mouse compared to a combined 645 (81 IDEs) of sandy inland and spinifex hopping mice (Table A 4 in Appendix A.).

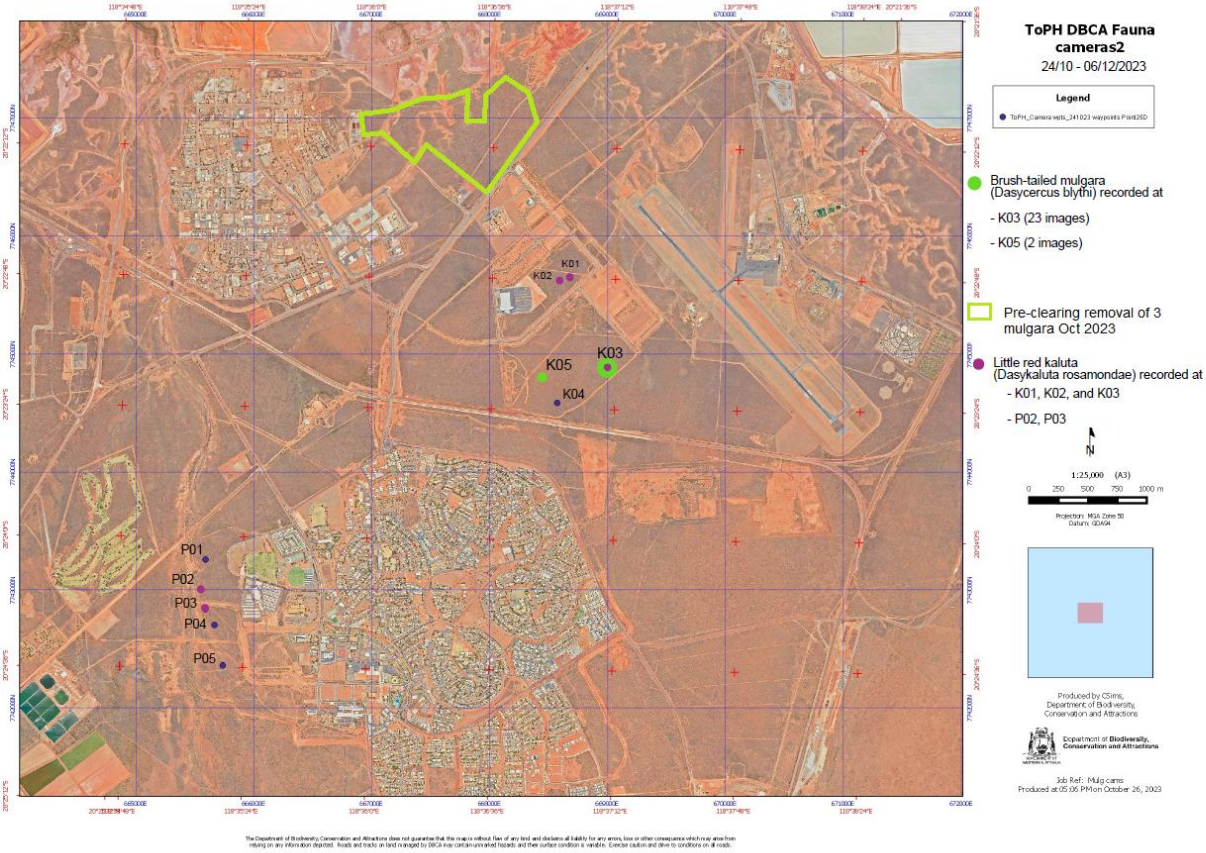

Figure 16. Locations of camera trap records of brush-tailed mulgara and kaluta in Port Hedland Oct-Dec 2023, plus area where three female mulgara were trapped and removed by consultants prior to clearing in early October 2023.

3.5.4.4 Port Hedland International Airport (Fenced)

Within this fenced area, 1311 animal images were recorded and analysed. No mulgara were identified, but 45 images (4 IDEs) of kaluta were recorded. There were 14 images (equal to 5 IDEs) of desert mice, but still relatively few compared to combined 615 images (86 IDEs) of sandy inland and spinifex hopping mice. Cats were also regular detections on these cameras (Table A 5 in Appendix A.).

3.6 Western grasswren

Of the 246 territories surveyed, 193 (78%) were occupied. There was no statistically significant difference in rates of occupancy between 2022 and 2023 at harvested and unharvested sites ($p > 0.05$, Fisher Exact Test). Rates of occupancy at Peron were 81% at harvested sites (compared to 79% at unharvested sites) and at Hamelin both were 72%. Occupancy at both source populations was similar to the pre-harvest monitoring in 2022.

Table 2. Results of surveying territory occupancy by western grasswrens at the translocation source site approximately 10 months after the translocation: (a) Hamelin Station Reserve, (b) Peron Peninsula. Data represent minimum occupancy, because (due to the cryptic nature of the species) grasswrens may have been present but not detected at some sites.

(a) HAMELIN

	All	Harvested (min.)	Non-harvested (min.)
# sites surveyed	98	18	80
Occupied (<100m)	75	13	62
% Occupied (minimum)	77	72	78

(b) PERON

	All	Harvested (min.)	Non-harvested (min.)
# sites surveyed	148	26	122
Occupied (<100m)	118	21	97
% Occupied (minimum)	80	81	80

3.7 Heath mouse

No heath mice were trapped at Dragon Rocks Nature Reserve or the Fitzgerald River National Park area, but a single individual was captured at Lake Magenta in autumn 2023. No heath mice were trapped at Lake Magenta during surveys in October 2023.

Other species captured include western mouse (*P. occidentalis*), ash-grey mouse (*P. albocinereus*), Mitchell's hopping-mouse (*Notomys mitchellii*), bush rat (*Rattus fuscipes*) and three species of dunnart (*Sminthopsis* spp.).

Images from camera traps have not been fully processed, but it appears that from ~7,000 camera nights, at least three positive detections of heath mice have been obtained.

3.8 Rainfall

3.8.1 Shark Bay

Rainfall in the whole of the Shark Bay area was the lowest on record in 2023 (Figure 17). All Bureau of Meteorology (BOM) official weather stations received record low annual rainfall. For some stations this is over 80-130 years of continuous records. Carnarvon Airport received just 54mm (annual average 222mm) and Shark Bay Airport received 20mm (annual average 194mm), Steep Point received 61mm (annual average 253mm). Denham appears to have ceased recording in December 2023 (after 130 years of records), however, we can assume that December rainfall would have been 0.0mm (as experienced by every other weather station in Shark Bay), and so the annual 2023 rainfall figure for Denham was just 35mm (annual average 223mm). Shark Bay Airport BOM weather station has not been in operation for long enough to have an official annual rainfall average, but the 2023 annual rainfall figure of 20.0mm is barely 10% of the unofficial average of 194mm. Unfortunately, the rainfall data for Hamelin Station and Useless Loop BOM stations is no longer available (Bureau of Meteorology, 2024).

Remote weather stations have been established by DBCA on Bernier, Dorre and Dirk Hartog Islands. However, some of these automated stations can suffer outages during the year and are difficult to visit and repair due to the inaccessibility of the island locations. Maintenance flushing can also artificially increase totals, so annual rainfall figures may not always be reliable. Given this, Bernier and Dorre rainfall figures for 2023 may not be reliable. However, the estimated annual rainfall for these two islands is ~110mm maximum for Bernier and 5.6mm minimum for Dorre. However, DHI recorded just 64.6mm, which appears to be accurate and closely mirrors the annual rainfall received by Steep Point.

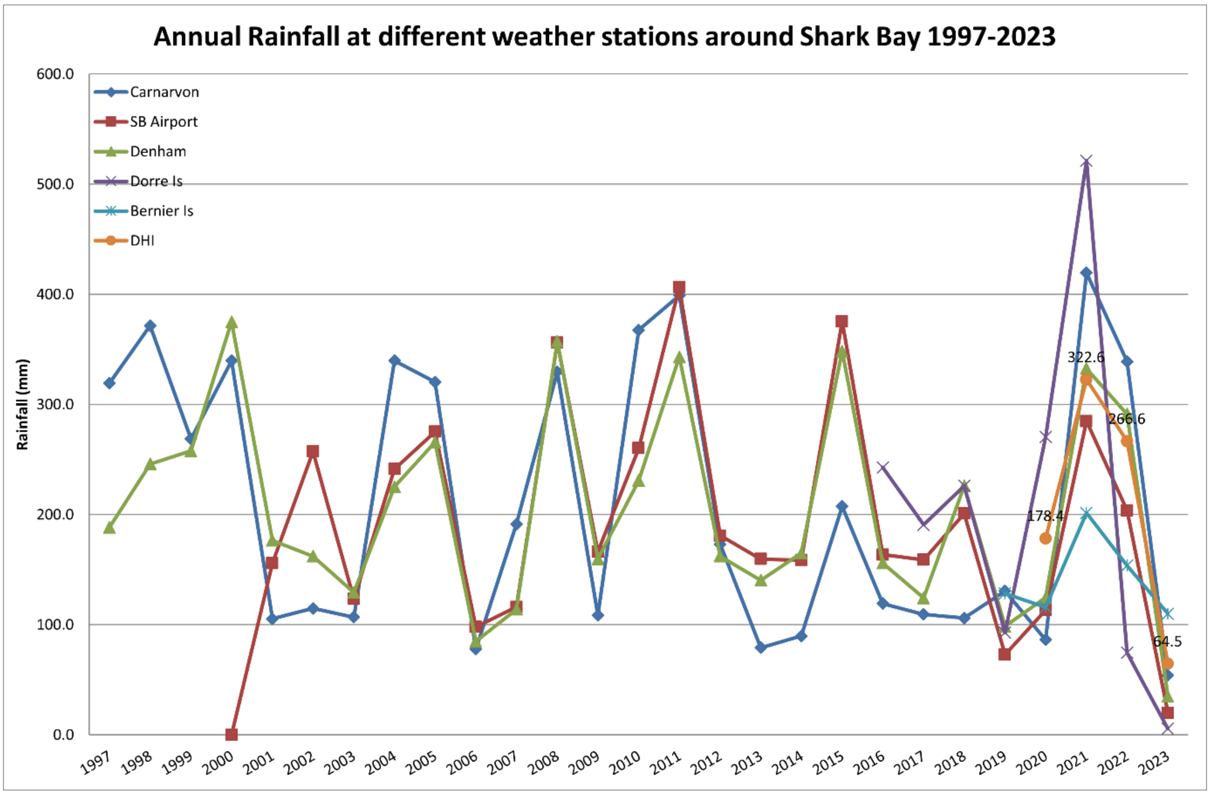

Figure 17. Annual Rainfall at Shark Bay Weather Stations (1997-2023).

3.8.2 Pilbara

Total annual rainfall at Port Hedland in 2023 was 183.0mm, which is significantly less (<60%) than the long-term mean of 316.8mm (Bureau of Meteorology, 2024). Rainfall records for Indee Station were incomplete for 2023. Annual rainfall for Karratha (nearest to Millstream Chichester National Park) was also below average for 2023 at 173.0mm compared to the mean of 294.6mm (also <60%).

3.8.3 Jurien Bay

Total annual rainfall in Jurien Bay for 2023 is unavailable due to one month of missing data, however the recorded total was just 214.0mm, which is well below the long-term average of 547.0mm (Bureau of Meteorology, 2024). Rainfall at both Leeman and Badgingarra (~50-60km away) in 2023, were well below average (only ~ 52-54%) and hence it is likely that Jurien Bay and its islands also experienced a year of rainfall that was similarly below average.

3.8.4 Matuwa Kurrara Kurrara National Park

Rainfall total at Matuwa (BOM Lorna Glen Station #013005) for 2023 was 184.9mm, which although lower than the mean of 260.7mm, followed three previous years of about average or slightly higher falls for this location (Bureau of Meteorology, 2024).

4 Discussion

4.1 Shark Bay bandicoot

As in the previous years, only Bernier Island was surveyed for bandicoots whilst carrying out the post-harvest source monitoring requirements for Shark Bay mice. Estimated population size was the highest recorded compared to all previous surveys. Limited rainfall data for Bernier Island makes it difficult to determine if rainfall is a driving factor of population dynamics, however, analysis of rainfall patterns from the main BOM recording stations, such as Carnarvon, have shown a relationship between population sizes of all threatened mammal species on Bernier and Dorre islands and annual rainfall approximately 18 months – 2 years prior (Chapman et. al. 2015). The relatively high rainfall in 2021 recorded in the Shark Bay area more generally, suggests that similarly high rainfall on Bernier Island in 2021 may have contributed to the population levels observed in 2023 (Figure 17).

The continued high population size of Shark Bay bandicoots indicates that previous harvests of animals for DHI in 2019 and 2020 have had no detrimental effect on the Bernier Island population.

4.2 Boodie

The population of boodies on Bernier Island continued to increase in 2023, with the estimated population size in early autumn at record levels. As discussed above, this could be linked to high rainfall in 2021, despite below average rainfall in 2022 and 2023. There is some concern that the extremely low 2023 rainfall across the Shark Bay area will result in significant population crashes of all species (including boodies) in the next year. However, rainfall of ~ 110mm on Bernier Island provides some hope that the predicted population crash may be less pronounced here.

No surveys were conducted on Dorre Island from 2021-23, but 2023 recorded rainfall was exceedingly low. Paired datasets since 2006 indicate that the abundance of boodies on Dorre Island has been consistently higher than on Bernier, and so the population is likely to have been in good condition in early 2023 but may have suffered a decline since.

The translocation of boodies to DHI is now scheduled to occur in 2025/26 and trap surveys for pre-harvest monitoring will be re-instigated on both Bernier and Dorre Islands in spring 2025. With no monitoring on either Bernier or Dorre scheduled for 2024, we will not know until 2025 what impact the record low rainfall in 2023 has had on these populations.

4.3 Shark Bay mouse

Shark Bay mice numbers appear to have increased on Bernier Island from the previous record highs of 2022, based both on the higher capture rates of individuals and density estimates. Population estimates in 2023 were the highest they have been since 2016, when recent monitoring efforts of this species commenced, and are even higher than the pre-harvest estimates from 2022. These are also likely to be underestimates of the population size given the competition for traps with high numbers of ash-grey mice.

With a total harvest of 50 individuals in 2022, representing only 1.1% of the estimated population size (or 1.9% of the conservative LCL estimate), and population estimates having increased post-harvest, we have confirmed that this harvest level has had no detrimental impact on the source population.

4.4 Dibbler

While the dibbler populations on Boullanger and Whitlock islands have slightly declined since 2022, this is likely to be a result of the lower-than-average winter rainfall in 2023 reducing reproductive productivity, as indicated by the low proportion of females showing signs of breeding activity. Given the increase in captures in 2021 and 2022, it is highly unlikely this recent decline is due to the harvesting of the small number of individuals (six from Whitlock Island and three from Boullanger Island) for the Perth Zoo breeding colony in 2018 and 2019.

The Escape Island population appears to be stable and remains the largest single population in Jurien Bay. Despite the reduced capture effort in 2023, there is no indication that harvesting for the Perth Zoo colony in 2022 has resulted in any measurable decline in the population.

The Perth Zoo dibbler breeding program wound up in 2023, with all offspring and breeding individuals released on DHI. No further harvesting of dibblers from the Jurien Bay Island populations is planned for the foreseeable future.

4.5 Brush-tailed mulgara

Pre-harvest trapping of mulgara at MKKNP confirmed the presence of a high-density population at this location, and were the highest densities ever recorded at the long-term trap monitoring locations (>12 years of data). Cameras confirmed this population was likely to be widely distributed in similar habitats across the Matuwa area.

The lack of captures of mulgara in Elliott traps or on camera at locations in the Pilbara (except for a few individuals within the boundaries of the Town of Port Hedland), demonstrates the difficulty in locating relatively sparse and low-density populations elsewhere in its range. As a result, the relatively small genetic benefit which might be gained from sourcing some founder animals from the Pilbara (Aline Gibson Vega, unpublished data) probably does not justify the likely significant investment of time and resources required to locate additional viable source populations. As such, this translocation is now considered complete based on the successful translocation of the 100 founders obtained from Matuwa in June 2023.

4.6 Desert mouse

Desert mice proved almost as elusive as brush-tailed mulgara, with the added difficulty of confidently identifying desert mice from other rodents in camera images. In any case, only a small number of desert mice were detected on either camera or live caught. In contrast, comparatively high numbers of other rodent species were detected. Even at Millstream Chichester National Park, where desert mice have been historically recorded in reasonably high numbers, particularly in favourable environmental conditions, our results suggest that the number of individuals are likely to be currently in relatively low numbers in the areas surveyed (i.e. tens, and not hundreds). It is well known that desert mice are generally present in very low densities in all but the most productive ‘boom’ years. In addition, the irruptive response of this species appears to be far slower and less frequently observed than for most other arid rodent species. Given the below average rainfall conditions in the Pilbara, a decision was made to delay any further surveys until conditions improve.

4.7 Western grasswren

Statistically, there was no difference in rates of occupancy between harvested and unharvested western grasswren territories in the source population, suggesting no significant impact of the translocation on the source population. This also indicates that we have met the relevant success criterion from the translocation proposal (Cowen *et al*. 2022): “No statistically significant difference in inter-annual occupancy of ‘harvested’ and ‘control’ territories at source subpopulations (12 months)”.

4.8 Heath mouse

Despite recording just one heath mouse capture from 1,000 trap nights, the single capture represents the first record at Lake Magenta Nature Reserve for over a decade (14 years) and the first record anywhere in WA since 2019. A monitoring program has now been established at Lake Magenta to better understand the status of the heath mouse on this reserve, and with the addition of camera traps, a few more heath mice have been detected. In general, low density and patchily distributed populations have made detecting heath mice particularly challenging.

4.9 Future monitoring plans

Future monitoring plans of source populations are outlined in Table 3. No monitoring is planned on Bernier or Dorre Island in 2024. Pre-harvest monitoring for boodies is planned to occur on both these islands in Mar/Apr 2025 to inform the proposed translocation of boodies in Autumn 2026.

No further post-harvest monitoring is required for the western grasswren at either Hamelin Station Reserve or Peron Peninsula.

As a component of a separate project, heath mouse surveys are planned for Lake Magenta in the first half of 2024, with further monitoring and management of camera traps in March and May, and live trapping in May 2024.

Ongoing dibbler monitoring will continue on all three islands in Jurien Bay in 2024, however no more individuals will be harvested for the DHINPERP.

Post-harvest source monitoring of brush-tailed mulgara will be undertaken at Matuwa Kurrara Kurrara National Park (MKKNP) in April 2024.

Pre-harvest monitoring of woylies will occur in Mar/Apr/May 2024 ahead of planned translocation in autumn/early winter 2025. Most potential woylie founder sources are regularly monitored by DBCA regional staff and Western Shield. However, this will be supplemented by some monitoring by the Return to 1616 fauna team at a few additional sites.

Table 3. Source monitoring plans for 2024

Species	Location	Anticipated timeframe
^Dibbler	Escape Island (*live trap*)	March
^*Dibbler	Boullanger/ Whitlock Islands (*live trap*)	October
^Heath mouse	Lake Magenta NR (*live trap, camera trap*)	March
^Heath mouse	Lake Magenta NR (*live trap, camera trap*)	May
***Brush-tailed mulgara**	Matuwa Kurrara Kurrara IPA (*live trap*)	April
^*Woylie	Dryandra NP and Woylie Numbat Sanctuary (*live trap*)	March
^*Woylie	Perup (Balban, Boyicup, Moopinup, Camelar), Kingston (Corbal, Warrup, Winnejup), and Perup Sanctuary (*live trap*)	April/May

* Return to 1616; ^ non-Return to 1616 (DBCA in kind).

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6 Appendices

6.1 Appendix A. Tables of camera survey results.

Table A 1 Total images (each species) and independent detection events (select mammal species) recorded over 1347 camera trap nights on MCNP 6th Aug. – 27th Oct. 2023

Common Name	Scientific Name	Images	Independent Detection Events	Occasion
Australian Magpie	*Gymnorhina tibicen*	5	-	Camera Trap
Australian Owlet-nightjar	*Aegotheles cristatus*	870	-	Camera Trap
Australian Zebra Finch	*Taeniopygia castanotis*	6	-	Camera Trap
bird sp.		2	-	Camera Trap
Brown Quail	*Coturnix ypsilophora*	5	-	Camera Trap
Bynoe's Gecko	*Heteronotia binoei*	20	-	Camera Trap
Cat	*Felis catus*	6	1	Camera Trap
centipede sp.		5	-	Camera Trap
Central Military Dragon	*Ctenophorus isolepis*	1063	-	Camera Trap
Central Blue-tongue	*Tiliqua multifasciata*	73	-	Camera Trap
Cow	*Bos taurus*	246	5	Camera Trap
Corvus sp.	*Corvus*	86	-	Camera Trap
Ctenotus sp.	*Ctenotus*	238	-	Camera Trap
Desert Mouse	*Pseudomys desertor*	622	55	Camera Trap
Diamond Dove	*Geopelia cuneata*	11	-	Camera Trap
Diporiphora sp.	*Diporiphora*	7	-	Camera Trap
dragon sp.		43	-	Camera Trap
Dusky Ctenotus	*Ctenotus helenae*	7	-	Camera Trap
gecko sp.		40	-	Camera Trap
Giant Desert Ctenotus	*Ctenotus grandis*	42	-	Camera Trap
grasshopper sp.		1	-	Camera Trap
Gwardar	*Pseudonaja nuchalis*	18	-	Camera Trap
House Mouse	*Mus musculus*	97	13	Camera Trap
kangaroo sp.		448	-	Camera Trap
Leopard Ctenotus	*Ctenotus pantherinus*	73	-	Camera Trap
Little Buttonquail	*Turnix velox*	1082	-	Camera Trap
Little Red Kaluta	*Dasykaluta rosamondae*	125	28	Camera Trap
lizard sp.		32	-	Camera Trap

Common Name	Scientific Name	Images	Independent Detection Events	Occasion
Northern Quoll	*Dasyurus hallucatus*	3	1	Camera Trap
Painted Finch	*Emblema pictum*	7	-	Camera Trap
Peaceful Dove	*Geopelia striata placida*	27	-	Camera Trap
Perentie	*Varanus giganteus*	27	-	Camera Trap
Pheasant Coucal	*Centropus phasianinus*	20	-	Camera Trap
Pygmy Desert Goanna	*Varanus eremius*	43	-	Camera Trap
Racehorse Goanna	*Varanus tristis*	9	-	Camera Trap
Red-backed Kingfisher	*Todiramphus pyrrhopygius*	2	-	Camera Trap
Reticulated Whipsnake	*Demansia reticulata*	2	-	Camera Trap
Rock Ctenotus	*Ctenotus saxatilis*	26	-	Camera Trap
rodent sp.		105	32	Camera Trap
Sand Goanna	*Varanus gouldii*	5	-	Camera Trap
Sandy Inland Mouse	*Pseudomys hermannsburgensis*	710	130	Camera Trap
Short-tailed Pygmy Goanna	*Varanus brevicauda*	55	-	Camera Trap
skink sp.		11	-	Camera Trap
Southern Pilbara Beak-faced Gecko	*Diplodactylus savagei*	78	-	Camera Trap
spider sp.		23	-	Camera Trap
Spinifex Pigeon	*Geophaps plumifera*	3	-	Camera Trap
Spiny-tailed Goanna	*Varanus acanthurus*	10	-	Camera Trap
Stripe-faced Dunnart	*Sminthosis macroura*	154	30	Camera Trap
unknown mammal sp.		302	143	Camera Trap
Varanus sp.	*Varanus*	8	-	Camera Trap
Variable Fat-tailed Gecko	*Diplodactylus conspicillatus*	45	-	Camera Trap
Western Ring-tailed Dragon	*Ctenophorus caudicinctus*	11	-	Camera Trap
Whistling Kite	*Haliastur sphenurus*	54	-	Camera Trap

Table A 2. Total images (each species) and independent detection events (select mammal species) recorded over 2710 camera trap nights on Indee Station 18th Oct. – 8th Dec. 2023

Common Name	Scientific Name	Images	Independent Detection Events	Occasion
amphibian sp.		7	-	Camera Trap
Australian Bustard	*Ardeotis australis*	9	-	Camera Trap
Australian Pipit	*Anthus australis*	10	-	Camera Trap
Australian Zebra Finch	*Taeniopygia castanotis*	225	-	Camera Trap
Bearded Dragon	*Pogona minor*	2	-	Camera Trap
bird sp.		11	-	Camera Trap
Black-headed Python	*Aspidites melanocephalus*	3	-	Camera Trap
Bush Stone-curlew	*Burhinus grallarius*	6	-	Camera Trap
Cat	*Felis catus*	139	18	Camera Trap
Central Blue-tongue	*Tiliqua multifasciata*	73	-	Camera Trap
Central Military Dragon	*Ctenophorus isolepis*	1392	-	Camera Trap
Central Netted Dragon	*Ctenophorus nuchalis*	8	-	Camera Trap
Common Bronzewing	*Phaps chalcopetra*	6	-	Camera Trap
Cow	*Bos taurus*	1644	-	Camera Trap
Crested Pigeon	*Ocyphaps lophotes*	6	-	Camera Trap
crow sp.	*Corvus*	3	-	Camera Trap
Ctenotus sp.	*Ctenotus*	71	-	Camera Trap
Desert Mouse	*Pseudomys desertor*	2	1	Camera Trap
Diporiphora sp.	*Diporiphora*	4	-	Camera Trap
dragon sp.		136	-	Camera Trap
Eremiascincus sp.	*Eremiascincus*	3	-	Camera Trap
gecko sp.		37	-	Camera Trap
Giant Desert Ctenotus	*Ctenotus grandis*	163	-	Camera Trap
Horsfield's Bush Lark	*Mirafra javanica*	6	-	Camera Trap
kangaroo sp.		612	-	Camera Trap
Leopard Ctenotus	*Ctenotus pantherinus*	109	-	Camera Trap
Little Buttonquail	*Turnix velox*	272	-	Camera Trap
Little Red Kaluta	*Dasykaluta rosamondae*	106	17	Camera Trap
Long-nosed Dragon	*Gowidon longirostris*	1	-	Camera Trap
mammal sp.		81	-	Camera Trap
Mulga Snake	*Pseudechis australis*	3	-	Camera Trap

Common Name	Scientific Name	Images	Independent Detection Events	Occasion
Perentie	*Varanus giganteus*	18	-	Camera Trap
Pheasant Coucal	*Centropus phasianinus*	54	-	Camera Trap
Pilbara Ningaui	*Ningaui timealeyi*	4	1	Camera Trap
Purple-backed Fairywren	*Malurus assimilis*	6	-	Camera Trap
Pygmy Desert Goanna	*Varanus eremius*	27	-	Camera Trap
reptile sp.		32	-	Camera Trap
Rock Ctenotus	*Ctenotus saxatilis*	4	-	Camera Trap
rodent sp.		112	-	Camera Trap
Sand Goanna	*Varanus gouldii*	147	-	Camera Trap
Sandy Inland Mouse	*Pseudomys hermannsburgensis*	649	134	Camera Trap
Short-tailed Pygmy Goanna	*Varanus brevicauda*	1	-	Camera Trap
Singing Honeyeater	*Gavicalis virescens*	26	-	Camera Trap
skink sp.		24	-	Camera Trap
Smooth Knob-tailed Gecko	*Nephrurus levis*	9	-	Camera Trap
Spinifex Hopping-mouse	*Notomys alexis*	1341	170	Camera Trap
Spinifex Pigeon	*Geophaps plumifera*	15	-	Camera Trap
Spiny-tailed Goanna	*Varanus acanthurus*	12	-	Camera Trap
Stripe-faced Dunnart	*Sminthopsis macroura*	286	58	Camera Trap
Varanus sp.	*Varanus*	25	-	Camera Trap
Variable Fat-tailed Gecko	*Diplodactylus conspicillatus*	6	-	Camera Trap
Western Bowerbird	*Chlamydera guttata*	149	-	Camera Trap
White-breasted Woodswallow	*Artamus leucorynchus*	1	-	Camera Trap
White-plumed Honeyeater	*Ptilotula penicillata*	7	-	Camera Trap
White-winged Fairywren	*Malurus leucopterus*	4	-	Camera Trap
White-winged Triller	*Lalage tricolor*	2	-	Camera Trap
Yellow-spotted Goanna	*Varanus panoptes*	3	-	Camera Trap

Table A 3. Total images (each species) and independent detection events (select mammal species) recorded over 1420 camera trap nights on Nyamal Pippingarra lands 25th Oct. – 30th Nov. 2023.

Common Name	Scientific Name	Images	Independent Detection Events
Aspidites sp.	*Aspidites sp.*	3	-
Bearded Dragon	*Pogona minor*	6	-
bird sp.		3	-
Cat	*Felis catus*	36	9
centipede sp.		7	-
Central Military Dragon	*Ctenophorus isolepis*	469	-
Central Netted Dragon	*Ctenophorus nuchalis*	16	-
cockroach sp.		10	-
cricket sp.		2	-
Ctenotus sp.	*Ctenotus sp.*	90	-
Dingo	*Canis familiaris*	139	31
dragon sp.		3	-
Eremiascincus sp.	*Eremiascincus*	6	-
fairywren sp.	*Malurus sp.*	5	-
gecko sp.		35	-
Giant Desert Ctenotus	*Ctenotus grandis*	11	-
grasshopper sp.		1	-
Horsfield's Bush Lark	*Mirafra javanica*	3	-
Leopard Ctenotus	*Ctenotus pantherinus*	46	-
Little Buttonquail	*Turnix velox*	109	-
Little Corella	*Cacatua sanguinea*	12	-
Little Red Kaluta	*Dasykaluta rosamondae*	168	15
Pseudomys sp.	*Pseudomys sp.*	1	1
Pygmy Desert Goanna	*Varanus eremius*	3	-
reptile sp.		8	-
Rock Ctenotus	*Ctenotus saxatilis*	23	-
rodent sp.		47	-
Sand Goanna	*Varanus gouldii*	47	-
Sandy Inland Mouse	*Pseudomys hermannsburgensis*	377	79
Short-beaked Echidna	*Tachyglossus aculeatus*	18	1
skink sp.		14	-
Smooth Knob-tailed Gecko	*Nephrurus levis*	12	-
snake sp.		1	-

Common Name	Scientific Name	Images	Independent Detection Events
spider sp.		5	-
Spinifex Hopping-mouse	*Notomys alexis*	358	62
Spiny-tailed Goanna	*Varanus acanthurus*	3	-
Stripe-faced Dunnart	*Sminthopsis macroura*	53	16
unknown mammal sp.		56	-
Varanus sp.	*Varanus sp.*	4	-
Variable Fat-tailed Gecko	*Diplodactylus conspicillatus*	18	-
White-winged Fairywren	*Malurus leucopterus*	9	-

Table A 4 Total images (each species) and independent detection events (select mammal species) recorded over 420 camera trap nights within Town of Port Hedland boundary 24 Oct. - 5 Dec. 2023.

Common Name	Scientific Name	Images	Independent Detection Events
Brush-tailed Mulgara	*Dasycercus blythi*	25	3
Cat	*Felis catus*	2	1
Desert Mouse	*Pseudomys desertor*	3	1
fairywren sp.	*Malurus*	2	-
kangaroo sp.		113	-
Leopard Ctenotus	*Ctenotus pantherinus*	8	-
Little Red Kaluta	*Dasykaluta rosamondae*	233	17
Small mammal sp.		33	-
reptile sp.		2	-
rodent sp.		26	-
Sand Goanna	*Varanus gouldii*	3	-
Sandy Inland Mouse	*Pseudomys hermannsburgensis*	478	65
Spinifex Hopping-mouse	*Notomys alexis*	167	16
Stripe-faced Dunnart	*Sminthopsis macroura*	32	9
White-winged Fairywren	*Malurus leucopterus*	21	-
Yellow-spotted Goanna	*Varanus panoptes*	66	-
Yellow-throated Miner	*Manorina flavigula*	6	-

Table A 5. Total images (each species) and independent detection events (select mammal species) recorded over 435 camera trap nights within Port Hedland International Airport control fence 23rd Oct. – 6th Dec. 2023.

Common Name	Scientific Name	Images	Independent Detection Events
Australian Pipit	*Anthus australis*	12	-
bird sp.		1	-
Cat	*Felis catus*	131	13
Central Blue-tongue	*Tiliqua multifasciata*	3	-
Central Netted Dragon	*Ctenophorus nuchalis*	12	-
crow sp.	*Corvus*	20	-
Desert Mouse	*Pseudomys desertor*	14	5
fairywren sp.	*Malurus*	7	-
kangaroo sp.		272	-
Leopard Ctenotus	*Ctenotus pantherinus*	7	-
Little Red Kaluta	*Dasykaluta rosamondae*	45	4
mammal sp.		32	-
Pseudomys sp.	*Pseudomys*	5	-
Pygmy Desert Goanna	*Varanus eremius*	3	-
rodent sp.		27	-
Sand Goanna	*Varanus gouldii*	8	-
Sandy Inland Mouse	*Pseudomys hermannsburgensis*	337	47
Spinifex Hopping-mouse	*Notomys alexis*	278	39
Spiny-tailed Goanna	*Varanus acanthurus*	3	-
Stripe-faced Dunnart	*Sminthopsis macroura*	65	19
White-winged Fairywren	*Malurus leucopterus*	26	-
Yellow-spotted Goanna	*Varanus panoptes*	3	-

6.2 Appendix B. Genetics and PVA Tables and Figures.

Table B 1. Summary of observed and expected heterozygosity, and private alleles for brush-tailed mulgara putative source populations.

Population	*N*	H_o (± SE)	H_e (± SE)	P_{AR}
Kennedy Ranges	3	0.088 (± 0.208)	0.082 (± 0.162)	32
Matuwa (MKKNP)	27	0.128 (± 0.142)	0.140 (± 0.148)	248
Midwest	5	0.120 (± 0.189)	0.122 (± 0.168)	24
Pilbara	60	0.127 (± 0.143)	0.138 (± 0.155)	380

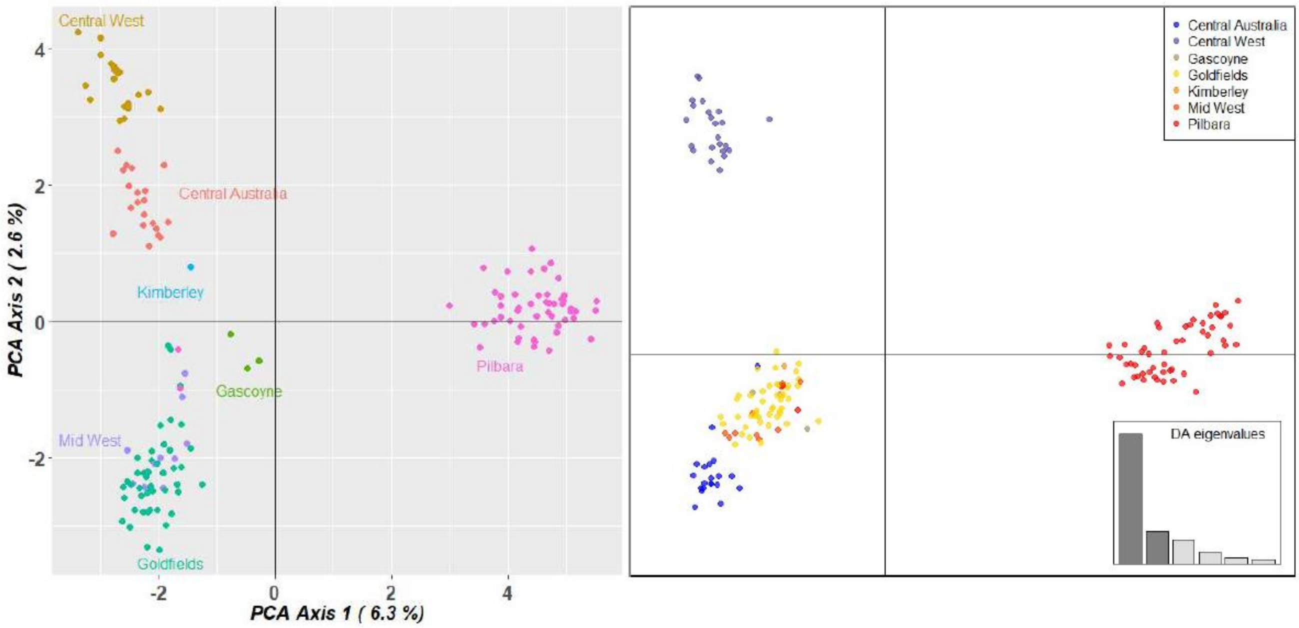


Figure B 1. Principal coordinate analysis and discriminant analysis of principal components of brush-tailed mulgara populations (Aline Gibson Vega, unpublished).

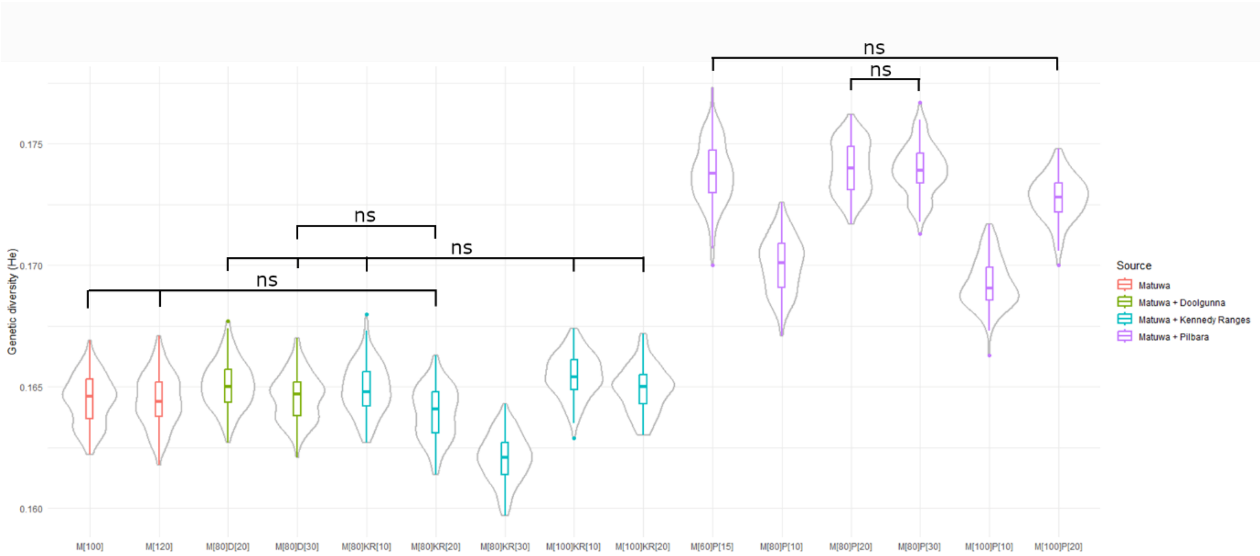


Figure B 2. Projected heterozygosity of founder populations with different source populations at different ratios (red = Matuwa, green = Matuwa and Doolgunna, blue = Matuwa and Kennedy Ranges, purple = Matuwa and Pilbara). Brackets indicate which pairwise comparisons are ***not*** *significantly different (Aline Gibson Vega, unpublished)*

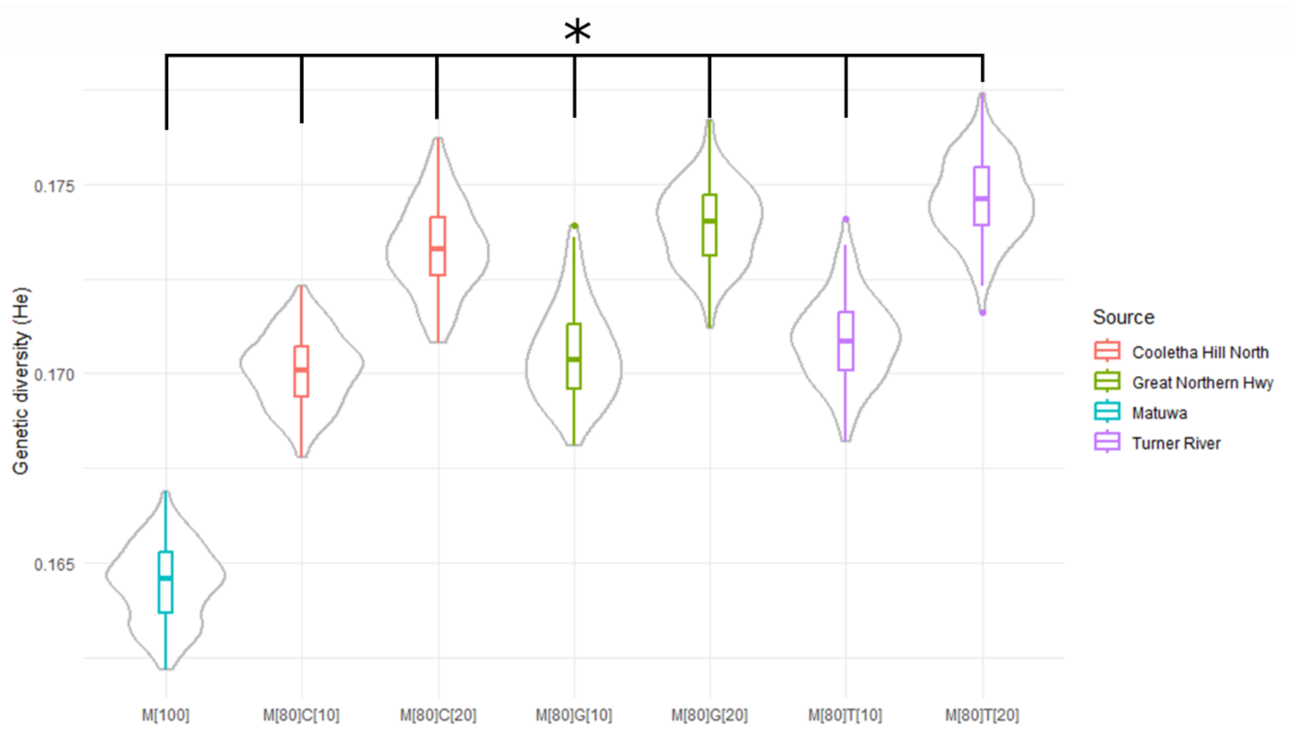


Figure B 3. Projected heterozygosity of DHI population with different source population scenarios and ratios. Cooletha Hill North, Great Northern Hwy and Turner River are all areas found within the Pilbara region. Asterisks denote which pairwise comparisons are significantly different ($p < 0.05$; adjusted pairwise Wilcoxon Rank Sum test) (Aline Gibson Vega, unpublished).

Population parameter			Inputs	
			Value	SD
Scenario settings	Iterations		100	
	Number of years		20	
Species description	Lethal equivalents		6.29 (default)	
	Percent of the genetic load that is due to recessive lethal alleles		50 (default)	
Reproductive system	Reproductive system		Polygynous	
	Duration of breeding cycle in days		365	
	Age of first offspring		1	
	Max age of reproduction		3	
	Max number of broods per year		1	
	Max number of progeny per brood		6	
	Sex ratio		50	
Reproductive rates	% females breeding		90	10
	Distribution of broods	0	0	
		1	100	
	Number of offspring per female per brood		5.7	0.1
Mortality rates (%)	Females	Age 0 to 1¶	30	5
		Age after 1	50	10

	Males	Age 0 to 1¶	30	5
		Age after 1	50	10
Mate monopolisation	% Males in breeding pool		100	
Genetics			1000 loci	

The scenarios of moving 90 - 100 animals in different source population combinations included:

1. 100 from Matuwa
2. 80 from Matuwa and 10 from Cooletha Hill
3. 80 from Matuwa and 20 from Cooletha Hill
4. 80 from Matuwa and 10 from Great Northern Hwy area (south of port hedland)
5. 80 from Matuwa and 20 from Great Northern Hwy area
6. 80 from Matuwa and 10 from Turner River
7. 80 from Matuwa and 20 from Turner River

Figure B 4. Demographic parameters and founder source scenarios for mulgara Vortex PVA

Genetic diversity by region

Population	Sample No.	Ho	He	F_{IS}	Ne	95% Confidence Interval
Central Hammersley	40	0.213±0.139	0.247±0.142	0.149	2311	2166 - 2477
Chichester	35	0.213±0.140	0.247±0.142	0.149	2253	2085 - 2450
West Hammersley	14	0.217±0.163	0.242±0.153	0.134	Sample size too small	
Overall	89	0.214±0.131	0.250±0.137	0.148	2605	2529 - 2686

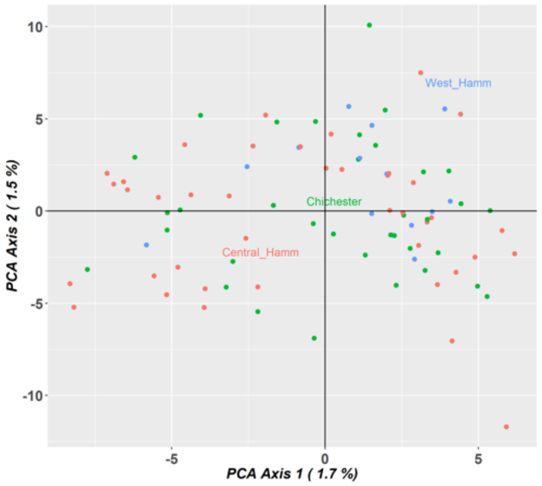
F_{ST} (P > 0.05)	Chichester	West Hammersley
West Hammersley	-0.00039	
Central Hammersley	-0.00009	-0.00003

1. Similar genetic diversity estimates across regions
2. Moderate levels of inbreeding coefficient
3. Large genetic effective population size
4. Low levels of genetic differentiation (Fst) between regions. Consistent with the population structure analysis

Figure B 5. Levels of genetic diversity in desert mouse populations from different Pilbara regions (Rujiporn Sun, unpublished).

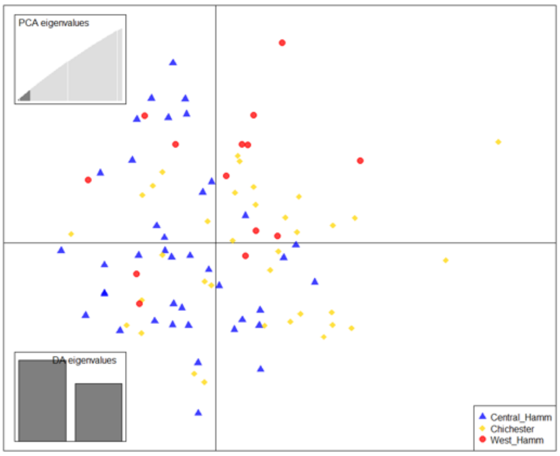
Population structure analysis

PCoA



No obvious grouping of samples from different regions

DAPC



Optimal PCA = 10
No obvious grouping in additional analyses by DAPC (not shown)

Figure B 6. Principal Coordinate Analysis and discriminant analysis of principal components of Pilbara desert mice (Rujiporn Sun, unpublished).

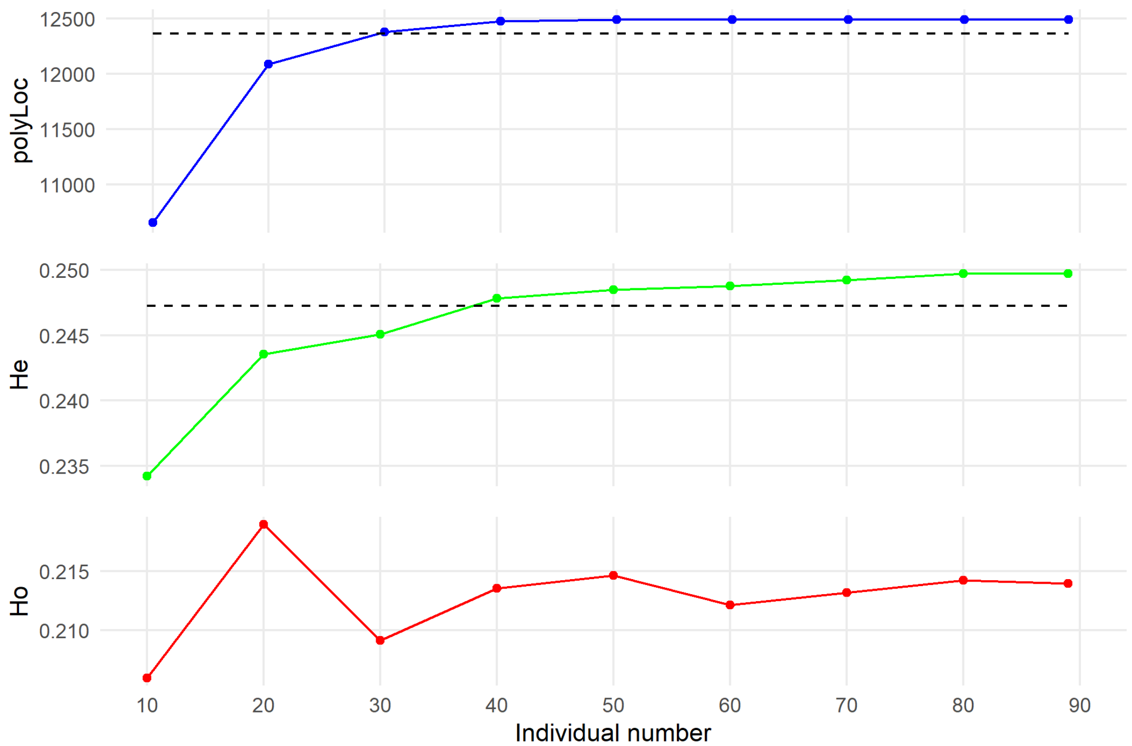


Figure B 7. Simulations of numbers of individuals required to represent >99% (dotted line) of the genetic diversity present in Pilbara desert mice in this study (Rujiporn Sun, unpublished). polyLoc = Number of polymorphic loci, He = Expected heterozygosity, Ho = Observed heterozygosity.