Rangelands Restoration: Fauna recovery at Matuwa (Lorna Glen), Western Australia

Annual Report 2016

Colleen Sims, Keith Morris and Mark Blythman

Science and Conservation Division

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Department of Parks and Wildlife

Department of Parks and Wildlife
Locked Bag 104
Bentley Delivery Centre WA 6983
Phone: (08) 9219 9000
Fax: (08) 9334 0498

www.dpaw.wa.gov.au

This report was prepared by Colleen Sims, Keith Morris and Mark Blythman.

Questions regarding the use of this material should be directed to:
Animal Science Program Leader
Science and Conservation Division
Department of Parks and Wildlife
Locked Bag 104
Bentley Delivery Centre WA 6983
Phone: 08 94055159, 0400 746 645
Email: keith.morris@dpaw.wa.gov.au

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Cover photograph: Wild ‘Matuwa’ golden bandicoot *Isoodon auratus.* Department of Parks and Wildlife.

Contents

1 Introduction

Operation Rangelands Restoration commenced in 2000 with the acquisition of Lorna Glen (Matuwa) and Earaheedy (Kurrara Kurrara) pastoral leases by the Western Australian Government. This 600,000ha area lying across the Gascoyne and Murchison IBRA regions was chosen as the site for an ecologically integrated project to restore rangeland natural ecosystem function and biodiversity. The Matuwa area (244,000ha) has been actively managed by the Department of Parks and Wildlife (Parks and Wildlife) and its predecessors in partnership with the Martu people since the Projects inception. Exclusive Native Title was awarded over both pastoral leases in 2014 and they now form the Matuwa - Kurrara Kurrara Indigenous Protected Area (MKK IPA) that has a formal indigenous management group who approve all activities. The joint management relationship between Parks and Wildlife and the Martu continues under this new arrangement.

The area now comprising Matuwa once supported a diverse mammal fauna that was representative of the rangelands and deserts to the north and east. These areas have suffered the greatest in terms of mammal declines in Western Australia (Burbidge and McKenzie 1989). The original vision for the *Western Shield* fauna recovery program was to expand introduced predator control and translocations beyond the south-west once an operational feral cat control program had been developed, and this was also recommended by the independent review of Western Shield in 2003 (Possingham *et al.* 2004).

Potentially Matuwa could support one of the most diverse mammal assemblages in arid Australia, and contribute significantly to the long-term conservation of several threatened species. Consequently, an important component of the Project is the reintroduction of 11, locally extinct (mainly threatened), arid zone mammal species following the control of feral cats and foxes (Morris *et al*. 2007). Mammal reconstruction in this area will also contribute significantly to the restoration of rangeland ecosystems through activities such as digging the soil and grazing / browsing vegetation, and assist in the return of fire regimes that are more beneficial to the maintenance of biodiversity in the arid zone. The reintroduction process and establishment of populations also provides considerable potential for students and other researchers to study arid zone mammal biology and ecology and related issues.

This report provides a summary of fauna recovery activities at Matuwa and results of work undertaken in 2016.

2 Project background

Predation by introduced predators is a significant threatening process that is consistently identified as a primary cause of arid mammal decline and extinctions, and significant impediment to successful reintroductions (Burbidge and McKenzie 1989; Dickman 1996; Environment Australia 1999; Christensen and Burrows 1995; Fischer and Lindenmayer 2000; Gibson *et al*. 1995; Moseby *et al*. 2011). Following successful control of feral cats on Matuwa from 2004, using predominantly aerial 1080 baiting with *Eradicat* ® cat baits, and some targeted leg-hold trapping, the TAI (Track Activity Index) used to assess trends in the cat population (Burrows *et al*. 2015), had reduced from 32% to <10%, and remained sufficiently and consistently low enough for initial free range releases of bilby (*Macrotis lagotis*) and southwest common brushtail possum (*Trichosurus vulpecula hypoleucus*) to occur in 2007/2008. Possum survival was good, and after initial high predation rates on bilbies, survival of this species was significantly improved in subsequent releases in new habitat (Morris and Dunlop 2008, Miller *et al*. 2010). A free range release of mala

(*Lagorchestes hirsutus*) in 2008 was not successful, and it was clear that this species was considerably more sensitive to predation by feral cats in particular. In response to this, an 1100ha introduced predator proof fenced enclosure was constructed in 2009 (Bode *et al*, 2012) to, a) serve as a safe refuge for species that are extremely vulnerable to even low densities of cats, and b) acclimatize species to be reintroduced to parts of Matuwa outside the enclosure. Boodies (*Bettongia lesueur*) from Barrow Island and the Return To Dryandra (RTD) woodland enclosures, and golden bandicoots (*Isoodon auratus barrowensis*) from Barrow Island were translocated into this enclosure in 2010, and intensive monitoring as part of a PhD project indicated generally good survival, health and reproduction. An attempt to reintroduce some of the (RTD) boodies to relict warrens outside the enclosure in late 2010 failed largely due to wild dog predation. Translocations of mala and Shark Bay mice (*Pseudomys fieldi*) occurred into the enclosure in 2011, 2012 and 2013 (mala only). Mala have successfully survived and reproduced, and have established a breeding population, despite being subject to predation by birds of prey. Assessment of mala survival and recruitment within the enclosure has been difficult due to dense habitat, trap shyness and interference from the large populations of boodies and bandicoots. Some Shark Bay mice were recorded up to 4-6 months post release, but long term survival is unlikely, with evidence of predation by resident mulgara (*Dasycercus blythi*) soon after release. Other native predators (barn owls, varanids, and snakes) resident within the enclosure are also likely to have impacted the success of this translocation.

There were four feral cat incursions into the fenced enclosure between 2011 and 2014 but these were identified and removed within a short time (~1-2 weeks). Monitoring techniques for identifying feral cat incursions were changed in 2014 from periodic dragging and track reading, to a system of permanent camera traps along tracks at 1 km intervals inside the enclosure, monitored on a weekly basis. Fence modifications were also made (additional electrified wires) and a rapid response protocol for cat incursions put in place. There have been no further cat incursions since August 2014.

Young golden bandicoots are able to move through the 'rabbit' mesh fence, and survival to adulthood of individual golden bandicoot 'escapees' was recorded occasionally throughout 2010-2011. However, a trial translocation of this species outside the enclosure in August 2012 was unsuccessful, due primarily to predation by cats, dingoes and foxes. From 2011-2014, above average rainfall resulted in an increase in native fauna prey, and in dingoes and feral cats. This was reflected in sustained high cat TAIs and less effective feral cat baiting. Subsequently, technical problems with aerial 1080 cat bait delivery resulted in a failure to significantly reduce cat numbers and no further attempts at free range releases were attempted until 2015. In 2015 another 'wild' release of golden bandicoots outside the enclosure experienced much greater success, with high survival, improved condition, and reproduction recorded in the first three months after release (Sims, 2015).

3 Summary of 2016 program

The main focus of 2016 activities was aimed at ongoing monitoring of the 2015 translocation of golden bandicoots from the fenced enclosure to the wild, and continuing to keep pressure on the introduced predators in the vicinity of the enclosure. The annual monitoring of the fauna populations within the enclosure was also carried out in autumn, as it has been since 2011. An assessment of the genetic health and population viability of the brush tail possum population at Matuwa was also completed.

Additional work was carried out by Graham Liddelow and Neil Burrows along with volunteers, running camera trap monitoring on old track count survey lines, to monitor effectiveness of the aerial bait program, with pre and post-bait estimates of cat and dingo occurrence/activity. Further bilby scat surveys were done in May by Martin Dziminski, Fiona Carpenter, and Frank Morris.

3.1 Field trips

Field trips completed in 2016 were mostly shorter trips of one week or less, and only two longer trips of ~two weeks duration. The field activities were purposely limited due to budget constraints in the second half of the 2015/16 financial year, following the extensive and costly spring 2015 golden bandicoot release and monitoring program.

Appendix 1 provides a complete list of trip dates, personnel and activities for 2016.

A total of eight field trips, varying in duration from 5 to 16 days, resulted in a total of ~68 calendar days with people 'in the field' and roughly equates to a conservative approximation of 273 'person-days' (7.5hr days, and not including penalty equivalents) spent on fauna activities (~142 paid + ~126 person-days of unpaid volunteer time).

4 2016 Fauna program activities

4.1 Enclosure fauna monitoring

4.1.1 Enclosure trapping

The standard annual pen trap was carried out in April/May 2016, with the session involving 368 trap nights targeting medium mammals using Thomas and Sheffield cage traps, and a further 184 Elliott trap nights aimed at small mammals which excludes the larger species. Table 1 indicates the numbers of individuals, capture rates and population estimates of the two main medium sized mammal species.

It is clear that the population of boodies inside the enclosure is still abundant with a population estimate equal to the highest previously recorded and a capture rate over 54% (Table 1). Breeding and recruitment also appear healthy with over 30% new recruits (similar to previous three years) and 64% females still reproductive (although this is lower than some previous years of 70-85%, it is similar to the 67% in 2014).

Conversely, the golden bandicoot population estimate of 89 is the lowest recorded (compared to estimates of 198 and 360 in May 2014 and May 2015 respectively), as is the capture rate at <13% (compared to capture rates of 31% and 34% for the last two years).
A lower population size and capture rate is an expected response to the removal of 93 adult bandicoots from the population in September 2015. The apparent decline in the bandicoot population was probably also exacerbated by the presence of the boodies in the enclosure. Both boodies and bandicoots are highly trappable, and with boodies in large numbers, trap rates remain high and many other traps are interfered with by boodies and become 'unavailable' to either species. This means trap rates of one species can influence trap rates of the other in a session, and in previous years there has been a variable and inverse correlation between boodie and bandicoot capture rates (and population estimates), whilst overall total capture rate of the two species has stayed about the same at ~65-75% (66.8% in 2016). The

lower capture rate and thus apparent decline in the population estimate for bandicoots in 2016 may also be influenced by smaller, younger, new recruit animals that may be even less likely to find and enter traps before boodies. This is supported by data, showing mean body weight for bandicoots is reduced by ~ 15% compared to 2015, and 72% of the captured individuals were new recruits (compared to 42% and 50% in 2014 and 2015 respectively), indicating that the population is responding in a positive way to the removal of large numbers of mature adults, which may tend to monopolise traps when present.

Only 25% of female bandicoots showed signs of reproductive activity (compared to 83% and 55% of females in 2014 and 2015 respectively). This would not be expected in a population which is responding to reduced density, and which would be expected to have a higher proportion of reproductive females. However, there may also be an effect of a higher proportion of smaller, younger females in the population that were still too young to breed at the time of monitoring. We anticipate that female reproductive rates will be higher in 2017.

Another factor which may be slowing the recovery of the bandicoot population is the sex ratio (M:F) of ~2:1, although this male bias is similar to previous years (1.6:1 to 2.7:1). It is not clear if this is an accurate reflection of the sex ratio of the overall population, or if it is an artifact due to variability in 'trapability' between males and females, with males being more mobile and finding traps earlier. A male sex bias has also been recorded in the Hermite Island population (N. Thomas, *pers comms.*). However, if this male bias is real we would expect a slower population recovery, with relatively fewer females in the population. A highly male biased sex ratio could also be an indicator of potentially problematic genetic health of the population if it is present at birth. We have not previously recorded sex of pouch young due to the risk of compromising their survival, but this may be warranted in future in order to characterise this demographic factor and interpret its potential effect on population health.

Table 1. Results of annual enclosure monitoring in 2016.

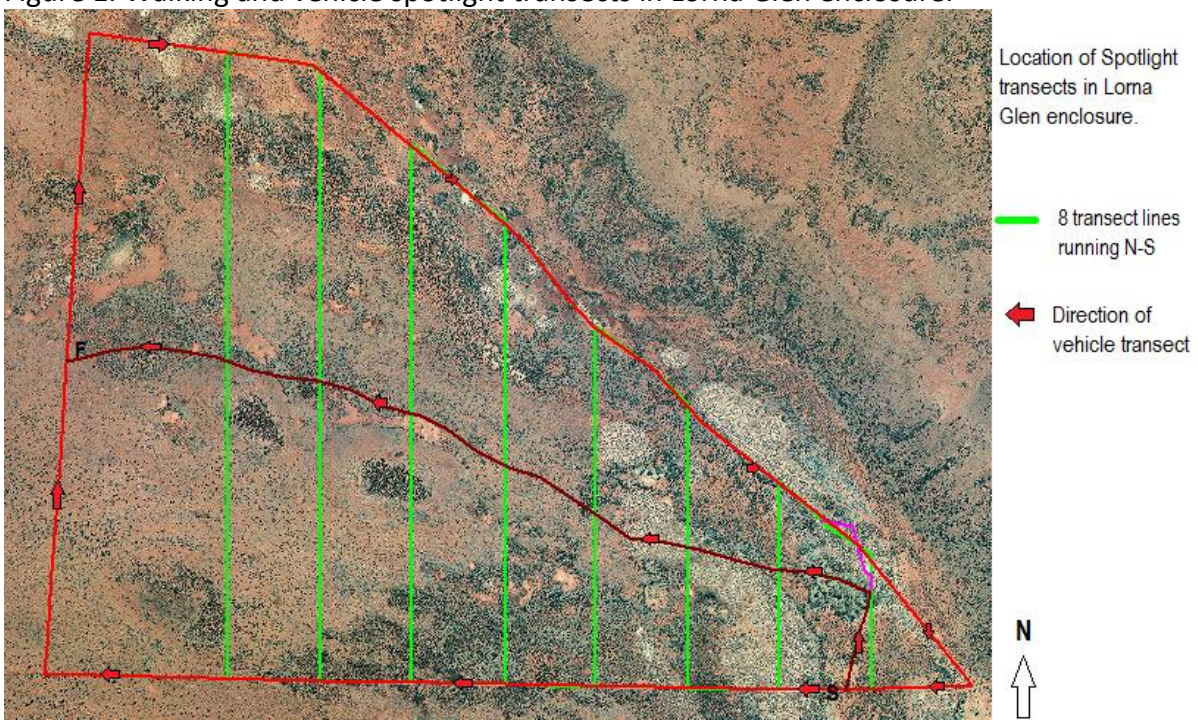
	Trap nights	**No. Captures**	**No. individuals**	**Capture rates**	**No. new individuals**	**% females breeding**	**Pop. Estimates (+/-SE)**
Boodies May 2016	368	199	165 (93:72)	54.1%	52 (32%)	64%	452 (+/-164)
Bandicoot May 2016	368	47	36 (24:12)	12.8 % (27.8% of avail?	26 (72%)	25%	89 (+/-19)
Total	368	246	201	66.8%			
Mulgara May 2016	184	9	8 (3:5)	4.9%	7 (87%)		

4.1.2 Enclosure spotlighting (vehicle and walking transects).

Vehicle spotlight monitoring was carried out on a total of six nights inside the enclosure in 2016. A walking spotlight session was undertaken in late November 2016, but proved unproductive, with only a small number of animals observed in the first two nights. This was abandoned due to other work commitments, and replaced with a vehicle spotlight transect, to confirm that there were still good numbers of animals observable using this method. It appears that the walking transects may not be an efficient survey method due to the poor

visibility and high likelihood of disturbing animals (due to noise of the observers movement through dense vegetation) into hiding/running before they can be recorded.

Figure 1. Walking and vehicle spotlight transects in Lorna Glen enclosure.



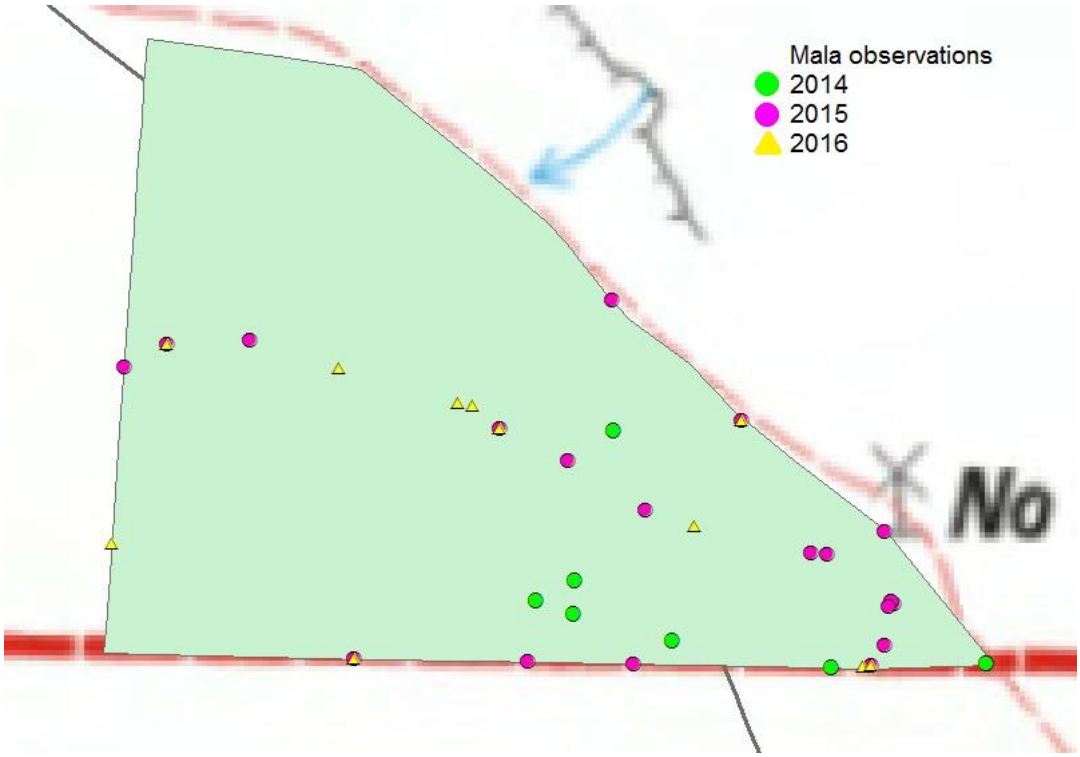
4.1.2.1 Mala

Due to the difficulty of trapping and monitoring mala in the enclosure in the presence of the large populations of gregarious boodies and bandicoots, alternative methods such as spotlighting and remote cameras have been used. Spotlight transects specifically recorded only four mala sightings, but a further 12 observations have been recorded for the first eight months of the year on the permanent cat monitoring cameras around the perimeter and central track (Table 2 and Fig 2). These numbers are reduced by 50% compared to 2015, but given the lower survey effort, this may not be significant. Camera images confirm animals are still breeding and recruiting.
Some estimates of size/age and occasionally sex/breeding condition can be obtained from the observations (spotlight and camera) of mala. These data were used to estimate some demographic parameters and vital rates for input into the Mala Recovery Team Population Viability Analysis process for the national meta-population.

Table 2. Mala sightings in 2016

Type of works	No. of sightings	Unit Effort (km)	No./Unit (km)
Spotlight transect (vehicle)	4	120km	1/30km
IR (cat monitor camera)	12	234 nights (x20 Cameras)	1/390 'trap nights'
Totals	16		

Figure 2. Distribution of mala sightings 2014-16



4.1.2.2 Other species

Spotlighting also provided the opportunity for additional data to be collected on the other visible species within the enclosure (Table 3.). These can contribute to estimating density indices and understanding the spatial distribution of the species' throughout the different habitat types, which will be helpful in interpreting trapping data, and predicting potential suitable habitats for future releases.

Table 3. Other species spotlight and camera trap sightings 2016

	Species	No. of sightings	Unit Effort (km)	No./Unit (km)
Vehicle transect	boodie	70	120km	1/1.7km
Vehicle transect	bandicoot	19	120km	1/6.3km
Vehicle transect	small mammal	7	120km	1/17.1km
Vehicle transect	possum	0	120km	0
Vehicle transects	rabbit	42	120km	1/ 2.86km
Totals				
IR cat monitor cameras	possum	6	234 nights (x20 Cameras)	1/780 'trap nights'
IR cat monitor camera	echidna	7	234 nights (x20 Cameras)	1/669 'trap nights'

4.1.3 Wedge-tailed eagle and barn owl predation on enclosure animals

Using a skilled volunteer and a high quality metal detector as part of our team in our first field trip during March 2016, an experiment was carried out to determine the potential of this technique in locating and identifying the unique PITs in and underneath the nests of aerial predators. The trial was a success and over the year, a total of 20 PITs were located and able to be connected to individual animals from both current and old wedge-tailed eagle nests within and nearby the enclosure. Another PIT was recovered from under a barn owl roost, but was unable to be identified due to fire damage.

The majority of PITs were from golden bandicoots (15) with only one mala and four boodies recorded. This limited sample would initially suggest that the predominant prey items being taken by wedge tailed eagles are golden bandicoots (75%). However, the selection of sites to search for PITs was restricted to those which could be identified from nests and their associated feeding roosts. Other feeding roosts are difficult to identify and therefore do not contribute to this sample. It is possible that the bandicoot bias in prey species at this time (June – December) may be associated specifically with feeding chicks (a smaller, more easily handled food item), and not be indicative of the type of prey targeted at other times of the year for adult consumption.

A scientific publication is currently in preparation describing the technique and the results.

4.2 Other native fauna monitoring

4.2.1 Brushtail possums

The last extensive possum monitoring session undertaken in 2015 identified a number of melanistic (black pelage) possums, and young animals appearing in several ‘wetland’ ‘gilgai’ areas. Trapping and tracking for feral cats around the No. 9 well area in spring 2015 and 2016, also indicated at least one young male possum present in that area. However, there is still little indication that possum populations have spread outside the *Eucalyptus camaldulensis* dominated drainage systems since their initial releases in 2007-2009. Despite some releases occurring at ‘Possum Lake’ and south of No. 1 Well, they do not appear to have persisted in any other habitat. The occasional record in *Acacia* woodland and *Triodia* dominated sandplain are probably dispersing or displaced males, and although they may survive for significant time periods, are not likely to be viable parts of the breeding population) (Fig 3a). Interestingly, possums do not appear to have established along the creek/drainage line at Lorna Glen (LG) soak despite there being a reasonable area of *E. camaldulensis* habitat. Twenty six possums were released at this site in 2009, but only three have been recorded there since 2012. Consequently, it appears that the possums at Matuwa have not dispersed away from original release sites and the effective population size is probably smaller than the founder population (possibly less than half of the original 95 founder size), and the sub-populations (LG homestead/East well/LG soak; No.1 Well; No.2 Well; No.10 Well/Possum Lake Rd) may also be isolated from each other. This suggests that additional work is required to examine the genetic health and potential long term viability of the population at Matuwa and to determine if restocking with additional possums is warranted.

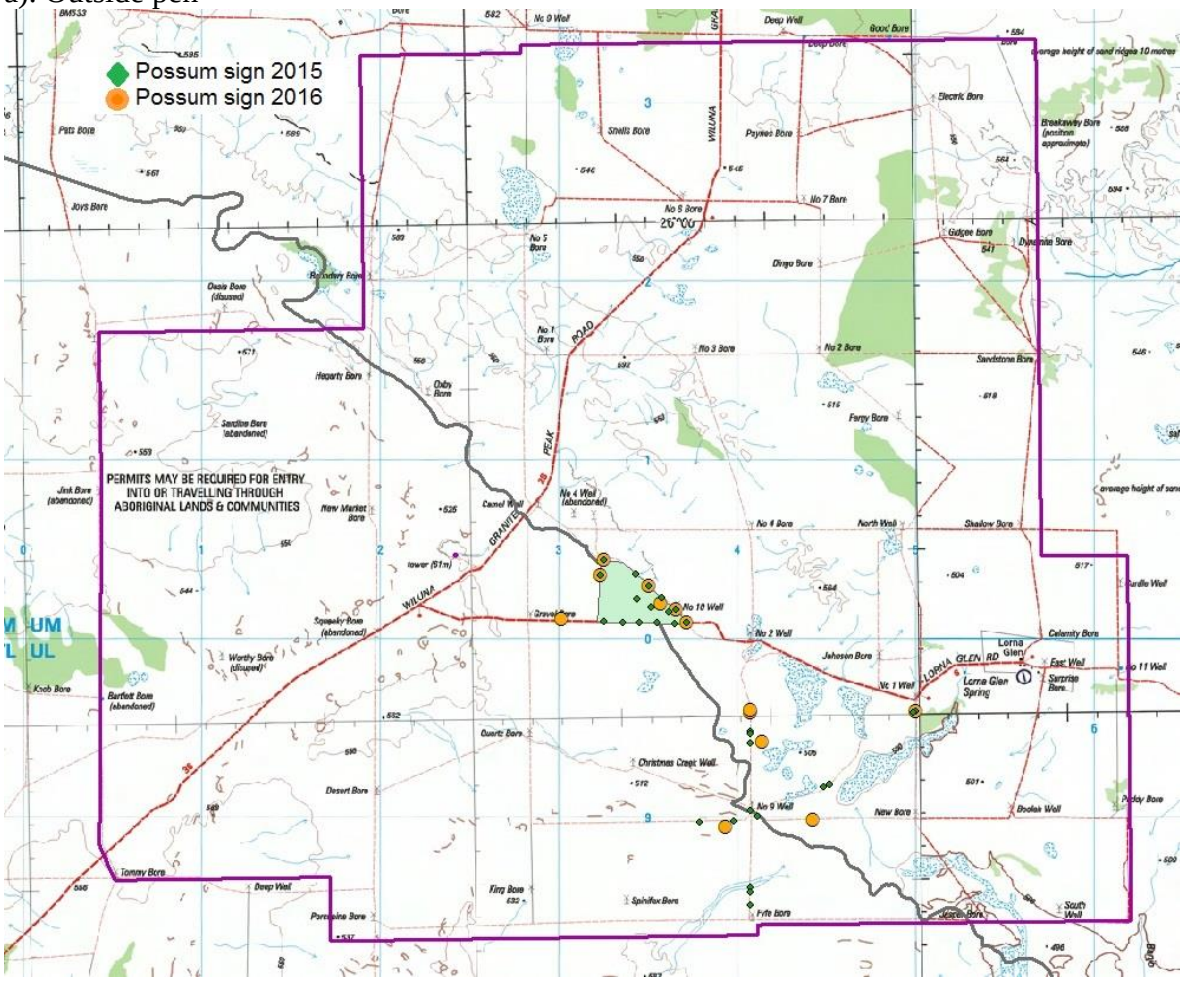
This work commenced in 2016 with a genetic analysis of the population. A Masters student, Lara Semple, with the assistance of Dr Kym Ottewell collated, analysed and described the genetic variability of this and several other southwest possum populations and then modeled

a Population Viability Analysis (PVA) using Vortex v.10 for the Matuwa brush tail possum population (Semple, 2016).

Only a few original DNA samples from the founders could be located, but additional DNA samples were accessed from the Australian Wildlife Conservancy's Karakamia Sanctuary (a source site in 2008/9), other source populations (Return to Dryandra, Boyagin Nature Reserve) and additional southwest populations (Dryandra Woodland, Perup, Kingston and Julimar,) to compare to the Matuwa population. Tissue samples (33) collected from the Matuwa possums between 2012 and 2016 were analysed to assess the genetic status of the Matuwa population and compare these to the other populations. Results indicate that there was a positive effect of mixing several source populations in the original reintroduction of possums to Matuwa, producing a better genetic profile with lower levels of inbreeding and higher heterozygosity than several of the source populations and other remnant populations of brush tail possums in the southwest. However, there is evidence of recent bottlenecking producing lower allelic frequency at Matuwa, and high relatedness in at least one sub-population. These findings, along with the results of the PVA analysis reveal that the Matuwa population has a low effective population size (Ne) of only ~ 20, and a high probability of extinction in the next 15-20 years without further management.

Figure 3. Incidental brushtail possum records (trapping, camera traps and tracks) on Matuwa 2015/16.

a). Outside pen



b) Camera records inside pen

There continue to be regular track and camera records of resident and breeding possums within the enclosure (Fig 3b.), although none have been trapped, and attempts to investigate likely nesting hollows to try to obtain additional DNA samples for the genetics study in July were unsuccessful. Unfortunately, no tissue samples have been able to be collected from the enclosure since 2010, as genetic analysis could help to determine if this population has been further isolated from the rest of the No. 10 Well population since the fence was constructed. If possums had been able to move out (and possibly back into) the enclosure in the past, this may not now be the case, since additional electrified wires were added to the outside of the fence in 2015.

Table. 4 Possum trapping at Lorna Glen Homestead winter 2016.

Location	Trap nights	No. captures	Capture rate	No. individuals	No. new individuals	% females reproductive
Homestead	~10	2	20%	2(1:1)	0	100%

4.2.2 Bilby

The only targeted bilby monitoring to occur in 2016 was more scat surveys by the bilby team (Martin Dziminski and Fiona Carpenter). However, many opportunistic records of bilbies were collected from a variety of sources, providing an indication of minimum distribution and occurrence.

- The camera trap monitoring network used by Neil Burrows for cat bait monitoring captured bilbies (7 records on 7/50 stations over 74 nights) (Table 5.) in the sand plain areas south of Possum Lake and at Desert Bore. But bilbies were also recorded at North Well, No. 2 Bore and north of Shallow Bore, indicating persistence of a population near the release site in the mulga woodland of the Gascoyne IBRA region.
- Similarly, continued searches for signs, track counting, trapping and the camera trap grid (Table 5.) in the bandicoot release area around No. 9 well, continues to provide ample evidence of a healthy ongoing bilby population in this area (Fig. 4).

- Trapping for bandicoots in August 2016 captured two sub-adult male bilbies south west of No. 9 well which were microchipped, and were a valuable opportunity to engage with the Martu women rangers.
- The Women Rangers Program continued several sessions of 2 ha plot track monitoring on Matuwa in 2016 (in addition to similar plots on Jundee). These activities also showed up bilby activity on four of the twelve plots and found additional bilby sign at four other locations, as far west as the boundary with Milrose Station.
- Track dragging and monitoring looking for bandicoot signs, also found bilby in the sandplain to the west of the Granite Peak road.
- Work to widen and realign parts of the Granite Peak road that was initiated in May 2016 by the Wiluna Shire, also highlighted fresh bilby sign in this area, south of where the bilby team, were carrying out their scat and digging surveys.

These records contribute to an understanding of bilby occurrence throughout the sandplain habitat which appears quite extensive. There continues to be a persistent presence in the area south of the enclosure, indicated by regular and consistent signs from Possum Lake, north to at least the Lorna Glen road, and westward, well past the Granite Peak road. To the south and east of Possum Lake, beyond No. 9 Well and Christmas Creek Well, bilbies appear to be regularly using both mulga woodland (Sherwood land system), and the spinifex sandplain (Bullimore land system) as far south as the Matuwa boundary. (Fig 4.)

Horseback surveys in 2015 (Burrows et al, 2015b), provided an estimated bilby population in a ~30,000ha area (four surveyed cells), of ~312 (234-390) individuals. Even if the lower density was extrapolated across the ~ 106,000ha of suitable habitat identified (Burrows et al, 2015b), then the Matuwa population could potentially be ~ 800+ bilbies.

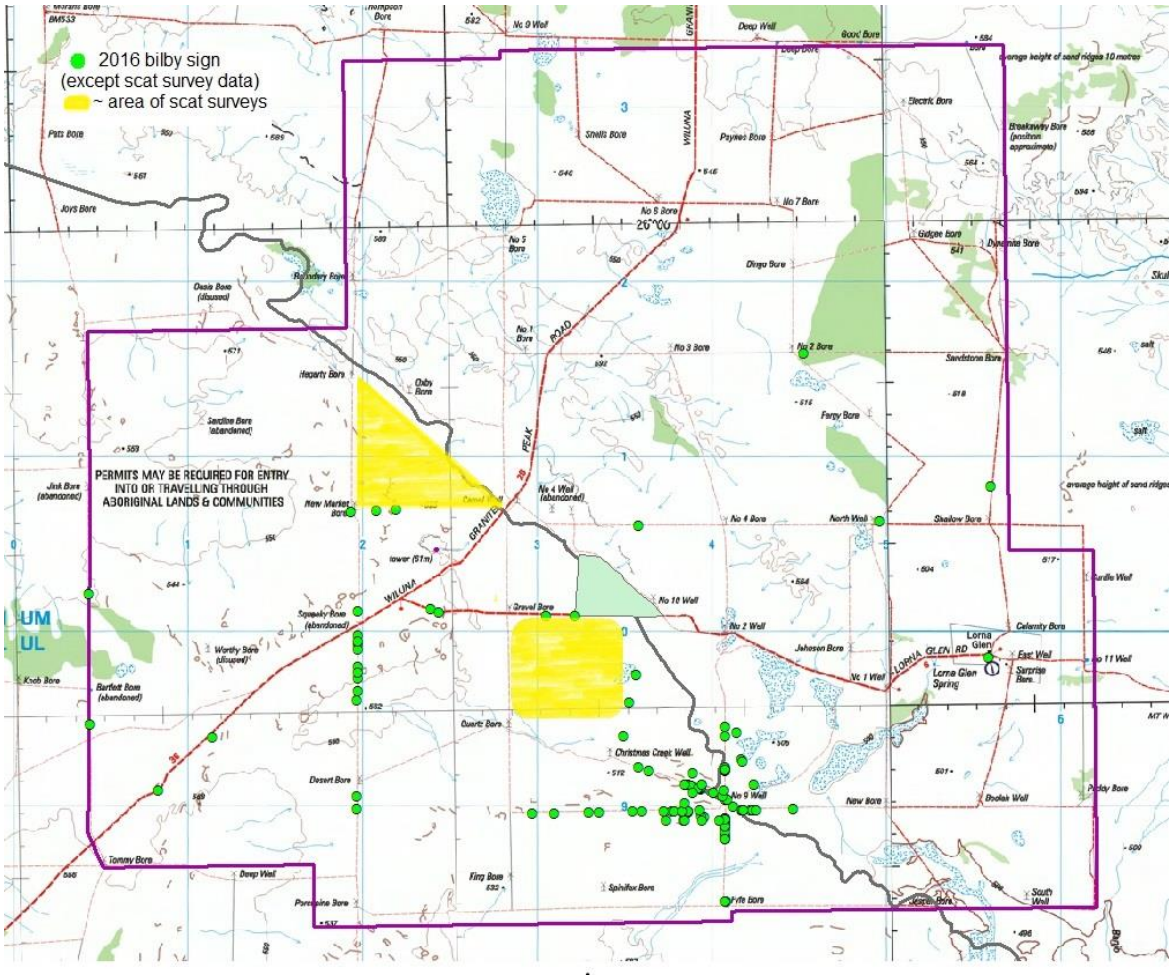
In 2015, the population density estimation technique developed for use, for bilbies in the Pilbara (Dziminski and Carpenter, 2014), using a combination of Distance analysis of scat transects and DNA identification of individuals from these scat samples, was further tested over a part of the spinifex sandplain in the above described area at Matuwa. Preliminary results indicate 23 individuals were detected from 215 scats collected from 66.3 km of transects across an approximately 4 000 ha area. (Parks and Wildlife, 2016)

If densities are similar throughout the sandplain habitat, then based on the above density, and estimated 'suitable habitat' used by Burrows *et al*. (2015), the estimated size of the bilby population on Matuwa could be ~600+ individuals. An assessment of bilbies in the other land systems that make up a further 138,000ha of Matuwa would be useful to obtain a more accurate estimate of population size for all of Matuwa).
Additional surveys of the same site, south of the enclosure, and a new area east of Granite Peak road were undertaken in 2016, and are still being analysed. Further bilby surveys using this technique are planned for 2017.

Table 5. Bilby records on camera traps in 2016.

	No. of trap stations	No. nights	No. of traps with bilby	No. bilby records	% trap stations with bilby	bilbies per trap night
BC grid	42	267	10	45	23.8	0.4
Cat cameras	50	74	7	7	14	0.19

Figure 4. Locations of bilby sign recorded during 2016.



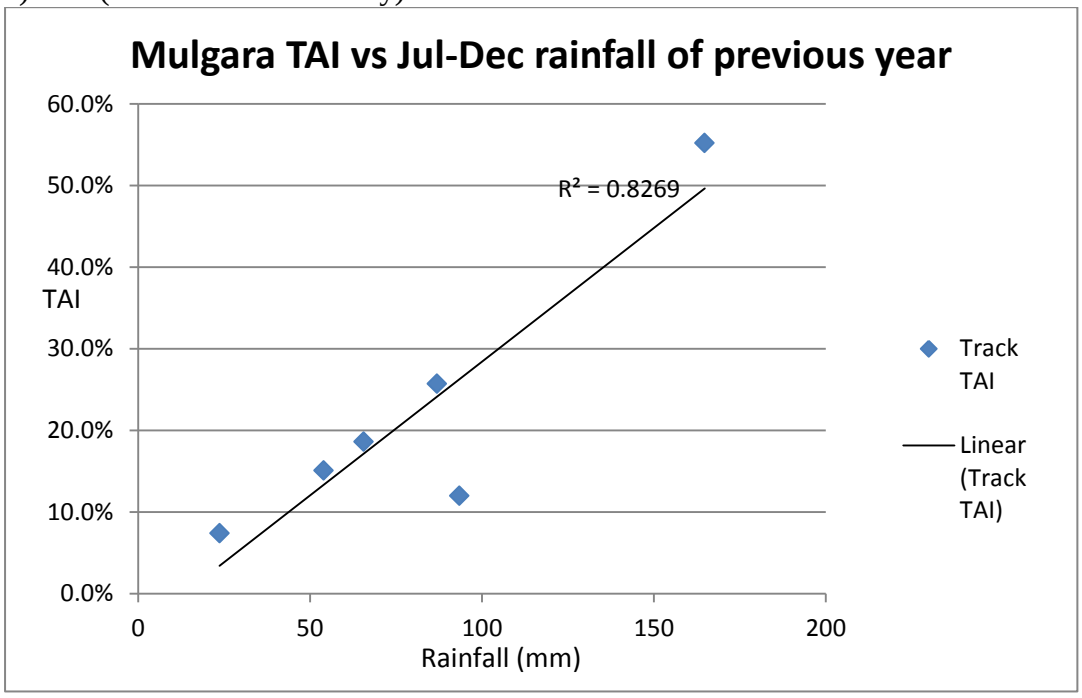
4.2.3 Mulgara

In 2016, mulgara were only captured during the standard annual enclosure trap monitoring. The four mulgara trap grids (two inside and two outside the enclosure) were not opened in 2016. Trap success rate inside the enclosure was 4.9%, equal to the lowest recorded for this time of year (compared to 4.9% in 2014 and 12.5% in 2015).

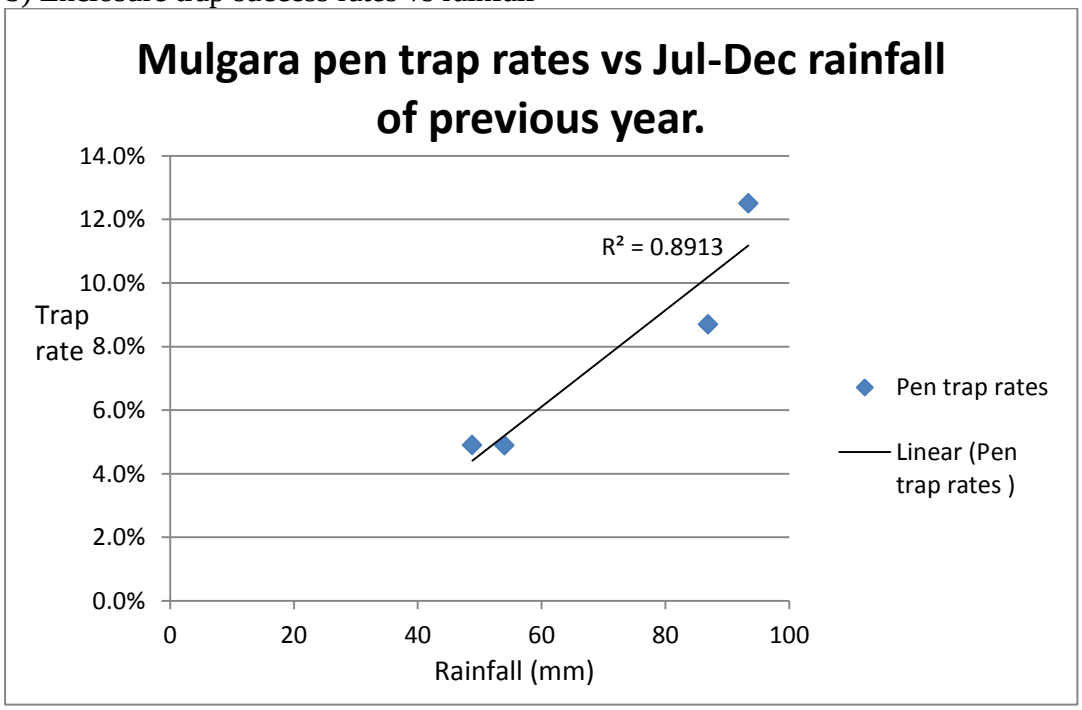
Mulgara numbers do not initially appear to be correlated with annual rainfall totals, or total rainfall for the immediate 12 months prior to trapping. [Rainfall in the previous 12 months to April 2016 trapping (April 2015-March 2016) was 246mm, whereas it was less than that (213mm) prior to April 2015, and much higher (420mm) prior to April 2014]. However, a significant positive correlation does appear to be present (Fig 5.) between the rainfall in the period July-December of the previous calendar year (54mm, 93.4mm and 48.8mm prior to April trapping in 2014, 2015 and 2016 respectively). This time frame corresponds to the mulgara breeding season and early independence of young at Matuwa (pouch development begins in July, PY start to appear in August, most females have PY by September and well furred young, out of pouch but still with the mother, have been recorded in early November). Consequently, the amount and effectiveness of rainfall over the previous breeding season seems to have the greatest influence on capture rates and activity in the next year than does the total rainfall for the previous year.

In 2016, monitoring of cat bait response was shifted from a track based count to a camera based system. Mulgara appear not to be easily detected by the camera stations, and so Track Activity Index (TAI) for mulgara are no longer available and there is no viable Camera Activity Index (CAI) (Burrows *et al.* 2015) replacement. However, plans to incorporate the cat bait camera monitoring into a wider fauna monitoring network of cameras include the lowering of the camera height in hopes of increasing capture of smaller animals, so this may help to increase identification of mulgara by this method in the future.

Figure 5. Mulgara numbers and rainfall at Lorna Glen.
a) TAI (available to 2015 only) vs rainfall



b) Enclosure trap success rates vs rainfall



4.2.4 Golden bandicoot wild release monitoring

Monitoring of the 2015 wild released golden bandicoots occurred from March to November 2016. This involved, a permanent camera trap grid over the eight month period, plus track monitoring and trapping on three occasions (March, May and August). The track monitoring was hampered by rainfall in March and May, and provided limited information on more widespread bandicoot presence. March monitoring indicated that good numbers had survived the 2016/17 summer and persisted in and around the release site (particularly site B) by six months post release. Tracks confirmed they had continued to breed and young animals were present in the population. Although track count numbers in May had decreased from March, the recovery of a new recruit and more small tracks were encouraging signs. By August/September however, no bandicoots were trapped and few signs observed. Continued predation by feral cats may have been responsible for this apparent decline, despite a reduction in cat activity across Matuwa of approximately 40% (of an already low density cat population) after cat baiting in July. Despite this, the continued presence of at least some individuals (tracks and photos) in and around the release sites as late as October 2016 (13 months post release), tracks observed up to 20km from the release site, and radio-tracking evidence of individuals dispersing as much as 12 km and returning, are all positive signs that suggest at least part of the reduction in animals at the release sites may be due to dispersal. It may be that the golden bandicoot population will behave similarly to bilbies and gradually develop a low density and transient presence across the available habitat which will be difficult to monitor and quantify.

4.2.4.1 Trapping

Trapping (Table 6.) around the bandicoot release sites in March was limited, but one adult breeding female was recaptured. In May bandicoots were still resident at or nearby the release locations, but the August/September trapping failed to capture any individuals, despite fresh tracks very near some traps at, and south of, release site B.

Table 6. Trap results bandicoot release site 2016

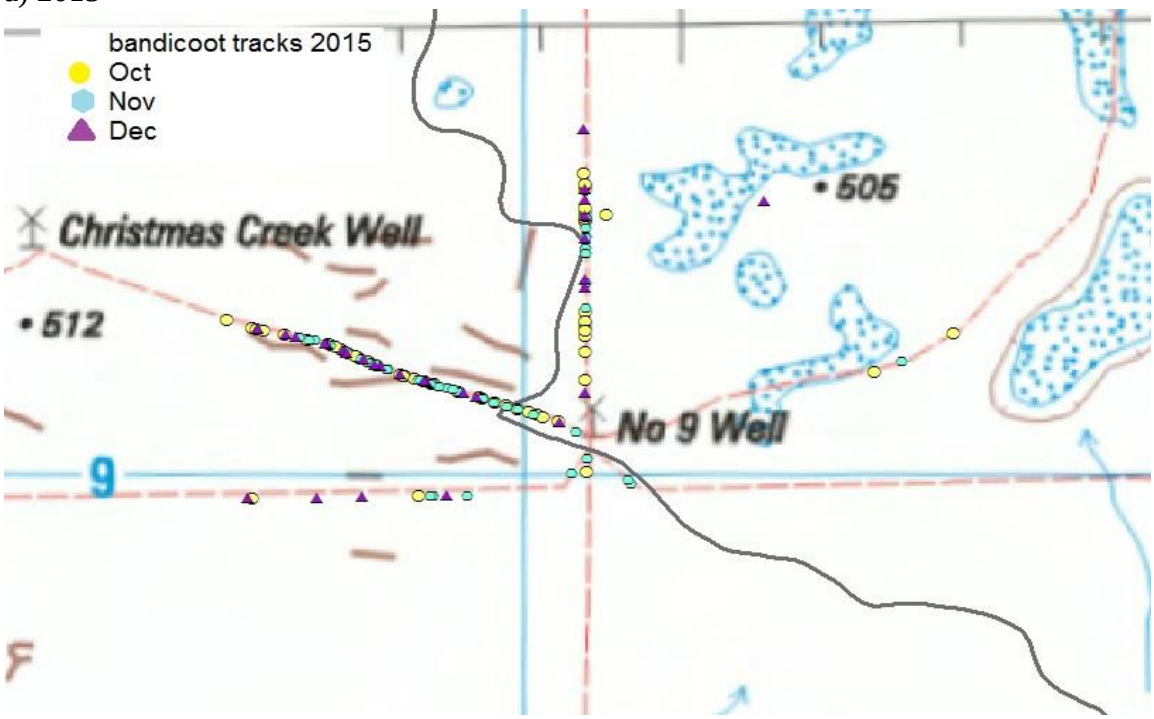
Location	Trap nights	No. captures	Capture rate	No. individuals	No. new individuals	% females reproductive
Site B plus (March)	72	2	2.8%	1(0:1)	0	100
Site A (May)	180	0	0			
Site B plus (May)	228	5	2.2%	3(2:1)	1	0
Site A (Aug)	180	0	0			
Site B plus (Aug)	498	0	0			

4.1.3.1 Track surveys and cat trapping

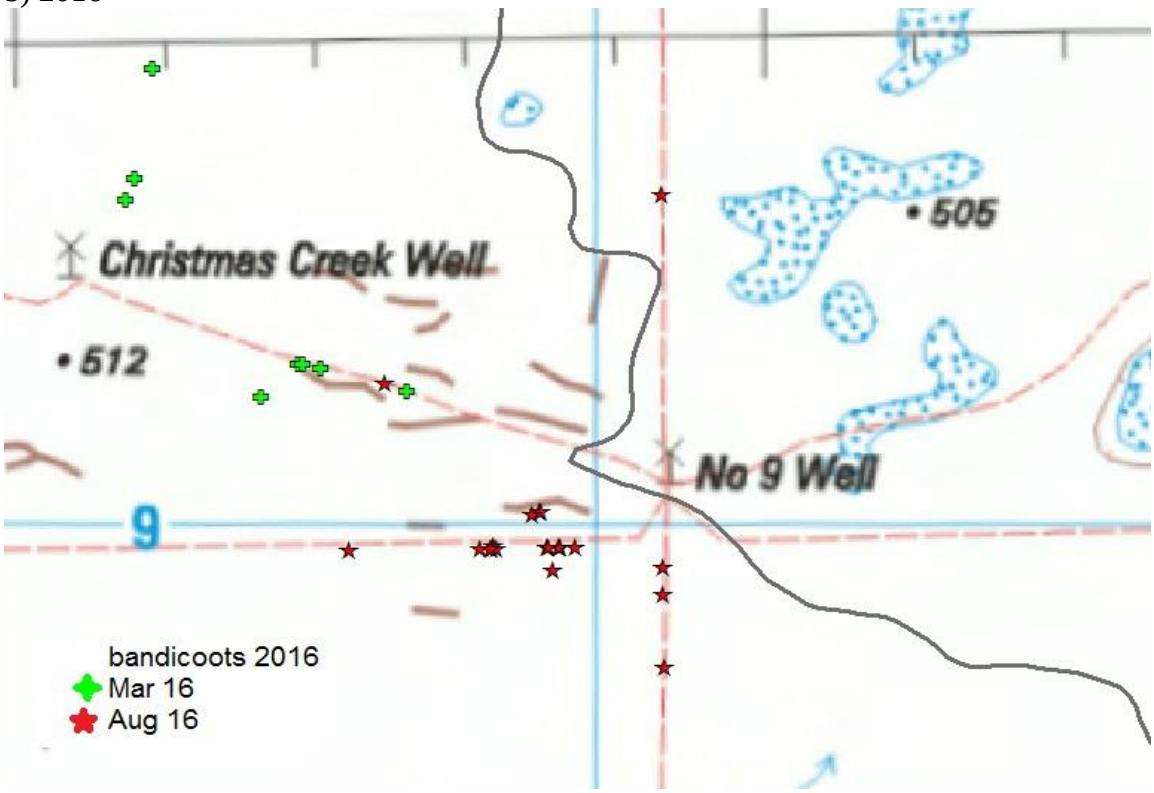
Several days of intensive track monitoring for both feral cats and dingoes and native fauna were conducted on the release site tracks ('Wagon wheel') during each monitoring session, whilst trapping for cats. The number and distribution of bandicoot tracks gradually reduced over that time frame.

Figure 6. Dispersal of bandicoot tracks post release

a) 2015



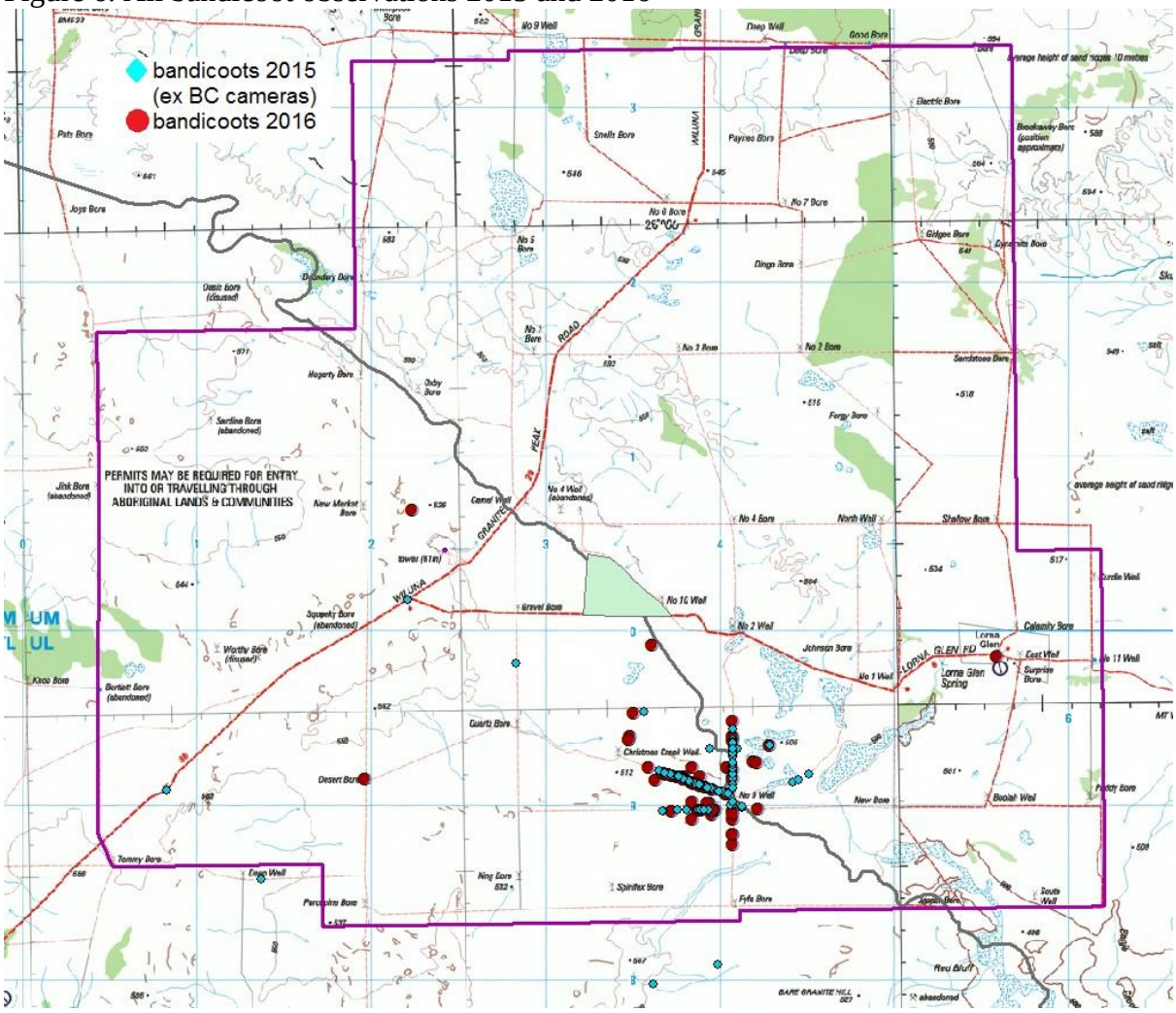
b) 2016



4.1.3.2 Camera grid

The grid of 42 Reconyx PC900 cameras used to monitor the translocation in 2015, was redeployed in March and were in operation until early December 2016 (11,200 camera trap nights). As with the above monitoring, numbers of bandicoot records decreased over time. The last photos, however, were recorded as late as 21/10/2016. These were in the area where tracks were seen whilst trapping in early September.

Figure 6. All bandicoot observations 2015 and 2016



The Translocation Proposal for the 2015 'wild' release of golden bandicoots outside the enclosure included the following criteria for success;

Criteria for success of the translocation in the short term (0-6mths)

- *Survival of at least 50% of the released population (as measured by radiocollared individuals) for two months.*

- *Continued presence of individuals at the release location (or alternate locations that animals may move to) for 6 months (as measured by trapping and other signs [tracks/diggings/camera encounters].*
- *No more than 15% loss before stabilisation or increasing body weights of the majority (>50%) of released individuals within 8 weeks of release.*

Criteria for success in the medium / long term (7 months – 3 years):

- *Continued persistence of presence of released individuals at/near release site.*
- *Evidence of breeding of individuals*
- *Evidence of survival and recruitment of new F1 and subsequent generations at/near release sites*
- *Dispersal of individuals to nearby appropriate habitat (tracks/signs)*
- *Increased occurrence of records of bandicoots across Lorna Glen.*

Criteria for failure/ triggers for action:

- *Greater than 70% predation of released/collared individuals (**any** feral predation events within the first 2-3 months (collar life) will trigger immediate action to kill/remove the predator – including trapping/baiting/shooting)*
- *Sustained (>4 weeks), significant (>15%) body weight loss and continuing decline, in >50% of individuals will trigger either supplementary feeding or recapture of remaining individual and return to enclosure, depending on the assessed causes and associated environmental conditions.*
- *Lack of evidence of breeding within the population*
- *No recruitment over a 18 month period*
- *Lack of evidence of animal activity (tracks/diggings/camera encounters)*

The translocation met or exceeded all of the short term success criteria in the first six months. The monitoring in the first three months was sufficient to trigger a rapid and successful response to wild dog predation and keep the predation pressure low (Sims 2015). The early intensive predator management was demonstrated to provide significantly improved survival past that previously achieved for bandicoots or boodie wild releases at Matuwa. However, after cessation of the intensive predator control, signs of bandicoots have reduced, and it is uncertain at this stage whether the medium to long term success criteria will be met.

4.2.5 Bird monitoring

4.2.5.1 Wedge-tailed eagle ecology.

The satellite tagging project by Simon Cherriman is now part of a formal PhD program. Two new wedge tailed eagle fledglings were satellite tagged in spring and early summer 2016, one from the nest inside the enclosure and one from a nest outside. The fledgling from inside the enclosure (tagged on 21 October, and fledged on 16 November) was found dead on 12 December, with a post mortem showing no clear cause of death. The second fledgling, tagged on 12 December, is still alive as of 5 February 2017. There is still one adult, and one 4 y.o. tagged bird making a total of three birds (out of six originally satellite tagged) still providing information on eagle ecology and movement. Work in 2016 also involved educational activities with the Wiluna School children visiting and taking part in some eagle nest monitoring.

Part of this study will compare survival of juveniles in the arid zone vs the south-west. Data from tagged, banded and unbanded birds at Matuwa over five years seem to point to very low survival, consistent with previously published research. It appears that 2016 in particular, was a poor year at Matuwa, with only three of 35 breeding pairs producing a chick, compared to five in each of the previous two years (Cherriman, *pers. comms,*). Rainfall data reflects this (see Appendix 2.), indicating that the late summer/autumn/early winter rains were generally better in 2014/15, and there was free standing water and breeding waterfowl at Lyndsey Gordon Lagoon well into the middle of 2014, when rainfall was otherwise low.

4.2.5.2 Malleefowl and bush stone curlew observations.

Malleefowl have been recorded by Parks and Wildlife staff at Matuwa as early as 2003, when two birds were seen, and then again in 2007 when tracks were sighted during a bilby release. More recently on 17 April 2014, a single malleefowl was sighted and subsequently photographed. Since then opportunistic searches resulted in scattered observations of tracks and in late 2015 a bird was photographed by a motion camera. In 2016, fresh malleefowl tracks and individuals were being seen regularly and by late 2016 an active breeding mound was located. Cameras were deployed at the mound and the courtship displays of the pair were recorded. They continue to be monitored.

Bush-stone curlews which have only recently been delisted were a focus for targeted surveys. There have been anecdotal reports of curlews occurring on Matuwa by Parks and Wildlife staff in the past, but no specific locations had been identified. In 2015 several curlews were photographed by remote cameras that had been put out as part of a cat monitoring program. This was a little unexpected as one of the sites had been extensively burnt recently. Targeted searches of the sites to determine where the curlews may have found refuge after the fires identified a few small patches of unburnt mulga vegetation where the curlews were found. In 2016, targeted surveys were carried out to find more groups closer to the homestead. This resulted in one group of around five birds being located in a site that they were not previously known to occur.

5 Feral control and monitoring

5.1 Aerial cat baiting

The annual aerial cat baiting occurred from 18-19 July, 2016. The bait density achieved was approximately 40 baits/km^2 (below the prescribed 50 baits/km^2), due to the use of the higher speed twin engine aircraft, and difficulties with the bombardier getting sufficient baits loaded into the baiting carousel. No rainfall was recorded in the 20 days after the baiting, but there was some rain prior to the baiting, and warmer temps than preferred for the period, resulted in less than ideal conditions for bait effectiveness (Burrows *et al.* 2016). It is worth noting that the trend in temperatures over the last 12 years has been for higher minimum monthly averages (Appendix 2.), and this may have some impact on reducing the frequency of ideal cold conditions at bait time in the future.

5.1.1 1080 baiting effectiveness.

Following on from the comparative trial of CAI (Camera Activity Index) and TAI (Track Activity Index in 2015 (Burrows *et al.* 2015), CAI alone was used to monitor effectiveness of baiting in 2016. Camera monitoring occurred from 3 June to 17August and CAIs were calculated for 45 nights pre-bait and 20 nights post-bait. The pre-bait CAI = 3.4 was reduced 38% to CAI = 2.1 post bait (based on the 2015 comparison, these figures equate to ~ TAI's of 10 and 6.1). This pre-bait figure had increased since post bait 2015, but had not returned to the same level of pre-bait 2015 (CAI = 7.0). This suggests only a modest effect of baiting on cat numbers, however this was not surprising given the low CAI prior to baiting (Burrows *et al.* 2016). Burrows *et al.* (2016) state that dog numbers are not accurately measured by the camera array configuration, but that the monitoring suggests an increase in post bait activity and a generally high density of wild dogs/dingoes on Matuwa.

5.2 Ground baiting for cats and wild dogs

Hand baiting for both feral cats and wild dogs occurred on selected roads around threatened fauna release sites and recorded locations several times in 2016 (March, September and December). Both our recent dog baiting work on Matuwa in 2015/16 and monitoring of dog bait trials in nearby regions (Kirkalocka Station) (T. Kreplins *pers. comm*.) suggest that baiting may not be very effective for adult dogs and may only be useful in targeting breeding bitches and pups. Bait suspension devices (BSDs) (following the Departmental 'Feral Cat Baiting Prescription' and Algar and Brazell, 2008) were established at 1km intervals around the enclosure to hang baits off the ground, targeting cats and dogs patrolling the fence and reducing risk of non-target (bandicoot, bilby, mulgara) uptake.

5.3 Cat trapping

Trapping to try to remove cats in the bandicoot release area around No.9 Well, continued opportunistically when qualified staff were on site in 2016 (Mar, May, August/September). However, it was hampered by rain on several occasions, and only one cat was successfully trapped and removed, although there were tracks of 3-4 cats evident at most times, and regular records on cameras.

5.4 Rabbits

No specific rabbit monitoring or management occurred in 2016, although spread of myxomatosis was facilitated by the release of a diseased rabbit into the enclosure.

6 Translocations

6.1 Golden bandicoots 'wild' release.

Although the possibility of supplementary translocations for golden bandicoots, were considered for spring 2016, none occurred due to low capture rates in the enclosure in May.

7 Environmental conditions / Abiotic factors

7.1 Rainfall/temperature/seasons/resources

Rainfall of 209 mm was recorded in 2016, below the average long term mean of 263mm, and median of 243mm [Appendix 2.]). In particular the rainfall for the July – December period was only 44.2mm. This follows another below average 215 mm of rain for 2015 (48.8mm for July - December). If these low rainfall figures for 2016 are followed by more below average rainfall in 2017, capture rates of native fauna such as mulgara may again be reduced, but it may improve potential effectiveness of the July aerial bait if other small mammal numbers also stay low (Christensen *et al*. 2013).

7.2 Temperatures

Temperature records for Wiluna indicate that 2016 had relatively cooler monthly maximums compared to recent years, with relatively few months greater than the long term averages. Minimum temperatures, however, were still higher than long term averages for 75% of the months. This is more in line with recent trends where 75% of both minimum and maximum monthly temperatures over the last 12 years have been greater than the long term averages (~ 25% of the monthly averages were in the top 10% of all records) (Appendix 2.)

8 Engagement/planning/joint management with Martu

In early 2016 science staff attended meetings with the MKK IPA management committee and CNDTS, where the women expressed a desire to be more involved in fauna monitoring and management activities with Parks and Wildlife on Matuwa. The coordination of timing and logistics between science field trips and Martu Women ranger's activities is difficult, and we were not able to coordinate activities around the pen monitoring in May. However, several women carrying out the Southgate 2 ha fauna plot monitoring program (Southgate, 2013), with J Courtney and CDNTS, during August/September were able to be involved with the trapping program for reintroduced bandicoots. This enabled the ladies to see and handle fauna such as desert mice, mulgara and bilbies. Mulgara captures and release were invaluable in improving the women's skills in identifying and interpreting tracks they were observing in their monitoring plots. The unexpected capture of two bilbies, gave the women a profound and powerful experience of being able to see and touch a live bilby, for which they had heard the traditional stories, but had never seen, or remembered only from very early childhood.

As mentioned above, the plot monitoring activities of the Martu women rangers on Matuwa is making a valuable contribution to identifying occurrence and dispersal of bilbies and bandicoots across the property, as well as the recording of feral predator presence.

9 Future directions 2017/18 onwards

9.1 Increased engagement with Traditional Owners

It is expected that there will be increased engagement of the Martu and Indigenous Area Management group in all areas of future management at Matuwa and this will develop over time, but are likely to include involvement in different aspects of monitoring native fauna and feral management activities. The Martu women, in particular are keen to become more involved in fauna programs, and some potential areas are listed below. However, successful engagement and useful results for both Martu and Parks and Wildlife will depend on a key liaison/coordinator role that can work closely with interested and enthusiastic Martu ladies and Parks and Wildlife staff. And who has the background to translate the science and conservation requirements, and can help Martu people develop their skills in these areas.

- Track monitoring native and feral fauna – continuation and possible expansion of the 2 ha plot system (including bandicoot tracks)?
- Camera station surveys?
- Possum surveys?
- Spotlight monitoring pen fauna?
- Involvement with future translocations – monitoring sign?
- Feral predator monitoring and control - cat/wild dog trapping?
- Enclosure expansion – approvals, funding sources and construction?

9.2 Monitoring

9.2.1 Bilby, possum and golden bandicoot monitoring

The previous camera grid over the 2015 golden bandicoot release sites (near No. 9 Well) will be run for at least six weeks in early 2017. The results of this survey and track surveys, will determine if it will continue for longer and if any trapping will be targeted in the area.

Expansion of camera monitoring on roads is planned in 2017, to identify occurrence and dispersal of bilby and bandicoots across the wider Matuwa landscape. Initial focus will be ~35 locations distributed across the SW half of the property (Eastern Murchison IBRA region) in the Bullimore sandplain and will be deployed for ~ three months in the first half of the year. A similar number of camera trap locations will be deployed in the NE half for a similar time frame, later in the year.

Possum trapping at all previously known population locations will be carried out in 2017. If a suitable student can be found, the home range movements and habitat use will be studied.

The 12 x 2 ha plots that have been monitored in spring for the last two years by the Martu women rangers, may not occur this year if the Women's program does not continue. If this is the case, it may be possible to visit these sites ourselves at least once to fill the gap.

9.2.2 Predator monitoring

Pre and post-bait monitoring of cat activity using the IR cameras to obtain a CAI, on the old TAI transects will be continued in 2017.

9.2.3 Mulgara monitoring

There are no plans to run the mulgara trapping grids in 2017. The TAI data for mulgara from predator monitoring transects were a good mirror of trapping data, however the CAI which has now replaced this, did not appear to have a high detection rate for mulgara. Changes to the height of camera stations in 2017 may improve this capacity.

9.2.4 Enclosure monitoring

The enclosure trapping will continue annually, and vehicle spotlight monitoring for mala and other species, when possible. A better recording system for the cat camera images will be used to help inform where mala and possums are hanging out in the enclosure. We will continue to try and search for PIT tags under raptor nests/roosts in and around the enclosure at least once a year.

9.3 Translocations

9.3.1 Golden bandicoot wild supplementation

Supplementary wild releases of bandicoots at Matuwa may occur in 2017/18, if there is sufficient evidence of animals persisting from the 2015 release, and if enclosure monitoring indicates sufficient recovery of this population.

9.3.2 Red tailed phascogales

Plans being made for a potential release of red-tailed phascogales onto Lorna Glen in early 2018 are dependent of results from further research into their susceptibility to the *Eradicat* ® bait. The proposal will be for a comparative release of animals at two locations, one being inside the feral-free enclosure and another at a suitable site outside this area. The reintroduction will be dependent on suitable source site populations being identified and surveyed at the time.

9.3.3 Boodies to wild

A translocation of boodies from the enclosure to wild sites on Matuwa (most likely warren systems west of the homestead) is planned for 2018, if suitable predator control can be achieved. Information obtained from the research conducted within the enclosure in 2017 will inform design, and the translocation may occur in collaboration with researchers and animals from Arid Recovery Project, South Australia.

9.3.4 Genetic supplementation of possums

In response to the work done on genetics and PVA in 2016, plans are to move some individuals between sub populations during the trapping in 2017 in order to improve gene flow.

If planned research into resource use can identify whether sufficient suitable habitat is available, then a small number of new individuals will be translocated into Matuwa from other suitable source sites, to improve gene diversity and long term viability.

9.3.5 Genetic supplementation of enclosure populations

Genetic supplementation of the bandicoot population inside the enclosure has been recommended by Ottewell *et al*. (2014) and 2018 would be a suitable time for this to occur (5-10 years after the initial translocation). Boodies and mala should be supplemented in a similar time frame. Similarly, another Shark Bay mouse translocation could be undertaken in 2019/20 and coordinated with monitoring the North West Island population in the Montebello group.

9.3.6 Malleefowl

Given the recent increase in malleefowl sightings and location of a nesting mound, there has been some discussion around the possibility of assisting recovery of this species on Matuwa by collecting newly hatched chicks from the mound (if the pair are productive) and transferring them to the enclosure. This would give them some protection from introduced predators during their early growth stage. Once they are more mature, birds may stay as resident within the enclosure or disperse out into the wider property at an age when they will be more resistant to predation.

9.4 Research

9.4.1 Boodies

A student will be carrying out studies on home range, and warren and habitat use of boodies within the enclosure in 2017, with the aim of providing information to help inform the planned translocation in 2018. If another student can be found, then diet and genetics of these animals will also be assessed.

9.4.2 Possums

We are currently searching for an interested student to assist with some studies into diet, habitat and hollow use, and home range analysis of possums, in order to try and determine what is limiting the size and distribution of the possum population. The aim is to find management solutions that can improve the long term viability of the population.

Other research needed over the next couple of years to assist in future management include;

- Trial different nest box designs in Matuwa with the view of possibly improving/extending suitable habitat by providing additional nest sites for possums.

- Identifying suitable source for additional brush tail possum genetic supplementation (‘genetic rescue’) from outside Matuwa (Perup, Dryandra, other wheatbelt populations, Barrow Is, Midwest, Pilbara?)
- Identify other *E. camaldulensis* habitat on/nearby Matuwa (Kurrara Kurrara, Wongawol [Skull soak drainage line?], Milrose? Granite Peak?) which might extend the meta population.

10 Acknowledgements

Many people have made significant contributions to the fauna reconstruction component of the Rangelands Restoration project. In addition to the Parks and Wildlife staff and volunteers helping directly with the fauna research and monitoring work, there are many others who have contributed a great deal of effort over the years, and without whom, the project would be difficult to sustain. The dedicated staff and volunteer caretakers at Lorna Glen make our stays at the homestead comfortable, and also assisted with daily monitoring and management. The contributions and dedication of Goldfields Regional staff in carrying out many of the crucial management activities in maintaining the Matuwa property is appreciated. In particular Ian Kealley, Tjokke Pieterse, Jennifer Jackson, Vanessa Jackson, Ryan Butler and many other staff who make up the work teams responsible for management of the property with the Martu traditional owners. Surrounding neighbours, particularly Rex and Norma Ward at Milrose station, have been an important sources of connection and community for those living and working at Matuwa, and their practical assistance and support is greatly appreciated. The Western Shield annual aerial cat baiting program delivery and bait production program has always been professionally provided by Rob Brazell and his crew from the Harvey bait factory. We are grateful to the Martu traditional owners who have readily contributed their time, knowledge and skills to assisting with various aspects of the project, and continue to allow us to work on their lands in the pursuit of our shared goal of restoring the ecosystem to good health and 'looking after country'. This Project is funded by Department of Parks and Wildlife, Science and Conservation Division, Goldfields Region and the Gorgon Gas Project – fauna translocation offset fund.

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12 Appendix 1. 2016 Field Trips.

Dates	No. Field Days	Personnel	Activities	Approximate Total working day equivalents
10-17 Mar	8	5 – C. Sims, M Blythman, J Eliot (v), G Eliot (V), J Miller (V).	• Monitor GB release sites (place BC camera grid; trap release site; track count; cat trap at release site; dingo bait) • Use of metal detectors to find and ID PITs of pen spp eaten by WTEs • Collect and clean skeletal reference collection	40
26 Apr-11 May	16	5 – C. Sims, M Blythman, J Miller (V), Zigourney Neilsen (V), Carly Littleford (V).	• Annual pen trap • GB release monitoring (check and reset BC camera grid; trap release sites; track counts; cat trap at release sites; dingo bait) • Spotlight pen	80
8 – 15 May	8	3 – M. Dziminski, F. Carpenter, F Morris (V)	• Bilby scat surveys	24
19-26 July	7	3 – M Blythman, J Miller (V), L Semple (S)	• 1080 aerial cat baits • Check and reset BC camera grid • Hand bait GB release site • Trap, search and spotlight for possums (for Masters DNA/PVA) • Use of metal detectors to find and ID PITs of pen spp eaten by WTEs	21
1-5 Jun	5	3 – N Burrows, G Liddelow, V Jackson, E Thoomes (V)	• Pre –bait CAI camera deployment	20
15-19 Aug	5	3 – N Burrows, G Liddelow, V Jackson, E	• Post –bait CAI camera collection	20

		Thoomes (V)		
22 Aug – 1 Sept	11	4 – C Sims, M Blythman, L Zhang, S McPherson (V)	• GB release monitoring (trap release sites; track counts; cat trap at release sites; cat and dingo bait) • Spotlight pen • Set cat bait gantries around pen. • Martu women rangers engagement.	44
28 Nov – 5 Dec	8	3 – M Blythman, P Chia (V), A Stricker (S)	• Collect BC cameras • Spotlight pen • Investigate sandalwood nut eating for FPC Jon Brand • Hand bait dingoes. • Reset cat bait gantries around pen.	24
Totals	68	20		273

13 Appendix 2. Climate data Wiluna and Lorna Glen

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
All years	**38**	**36.6**	**34**	**29.2**	**23.8**	**19.9**	**19.4**	**21.9**	**26.3**	**30.4**	**34.**	**36.9**
2005	39.4	40.4	36	32.8	26.9	20	20.2	22.2	26.3	30.6	35.3	37.4
2006	33.8	32.6	33.1	25.7	24.4	21.3	20	27	28.6	33.3	36.5	36.1
2007	36.6	41.7	32.8	30.3	24.3	20.3	22.3	24.3	28.6	32.4	35.7	35.5
2008	41.7	35	35.7	30.4	27.6	21.4	21	21.3	27.1	30.9	30.3	37
2009	40.6	37.7	34.5	29.7	23.7	20.1	19.8	25.2	25.8	33.8	34.2	38.1
2010	41.2	40.1	35	32.1	25.1	19.9	18.9	22.4	24	30.2	34.5	36.7
2011	39.7	35.3	29.2	30	22.7	21.3	20.8	24.2	26.4	30.2	32.6	35.3
2012	34.9	36.4	30.8	29.9	25.1	20.9	20.3	25.2	28.2	33.7	34.4	37.2
2013	39.6	37.8	33.6	33.1	24.6	18	20.4	25.5	26.3	33.3	36.5	37
2014	38.5	35	35.8	30.7	24.2	19.7	20.5	25.6	30.1	33.9	34.7	39.2
2015	40.2	40	30.1	26.4	22.3	22.6	20.8	23.7	27.6	35.3	36	39.4
2016	37.7	37	34.6	30.6	26.2	19.8	18.6	21.5	24.8	30.4	35.1	38.1

Wiluna Max Monthly Temps: Long term mean, and annual monthly Max 2005-2016. 39.4 = hotter than all year mean; 33.8 = 10%ile; 41.7 = 90%ile

2005-2016 - 106/144 months (74%) hotter than all year mean; 34/144 (24%) in 90%ile of all records
2016 – 6/12 (50%) hotter than all year mean; 1/12 (8%) in 90%ile of all records

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
All years	**22.9**	**22.1**	**19.6**	**15.1**	**10**	**6.7**	**5.5**	**6.8**	**9.9**	**13.9**	**17.9**	**21.1**
2005	22.6	24.1	22.6	18.5	13.8	6.5	5.5	6.7	10.5	14	18.9	20.5
2006	22.2	20.6	19.0	12.8	8.9	4.5	3.5	8.8	12.4	16.4	20	19.3
2007	19.9	24.9	18.1	16.3	9.7	5.4	7	6.6	9.5	14.8	16.4	17
2008	21.4	20.5	20.2	15.3	11	7.1	6.2	5	10.6	16.1	16	20.9
2009	25.3	23.0	18.8	15.9	8.8	8.1	7.6	7.7	8.9	14.9	18.4	23.1
2010	24.8	25.6	21.3	18	10.7	8.7	3.8	6.9	8.3	16.3	19.1	21.5
2011	26	23	18.5	16.6	10.2	6.6	7.9	9.3	9.6	16.1	17.9	21
2012	24.1	20.7	16	14.4	9.7	6.2	4.1	8.1	10.9	17.2	18.2	22.9
2013	23.6	23.9	20.3	16.9	11.7	7.7	6.7	7.4	10.6	14.6	20.5	22.5
2014	24.4	21.8	21.6	15.8	11.1	4.9	4.7	7.5	13.3	16	18.8	22.6
2015	24.7	25.2	19.5	19.4			6.6	7.3	10.3			
2016	23.4	20.7	21.4	16.5	11.5	7.5	6.1	7.3	8.6	13.8	19.5	22.9

Wiluna Min Monthly Temps: Long term mean, and annual monthly Max 2005-2016. 24.1 = hotter than all year mean; 33.8 = 10%ile; 41.7 = 90%ile
2005-2016 - 90/144 months (62%) hotter than all year mean; 33/144 (23%) in 90%ile of all records
2016 – 9/12 (75%) hotter than all year mean; 3/12 (25%) in 90%ile of all records

Lorna Glen Station No. 013005

Summary rainfall statistics for all years (since 1939).

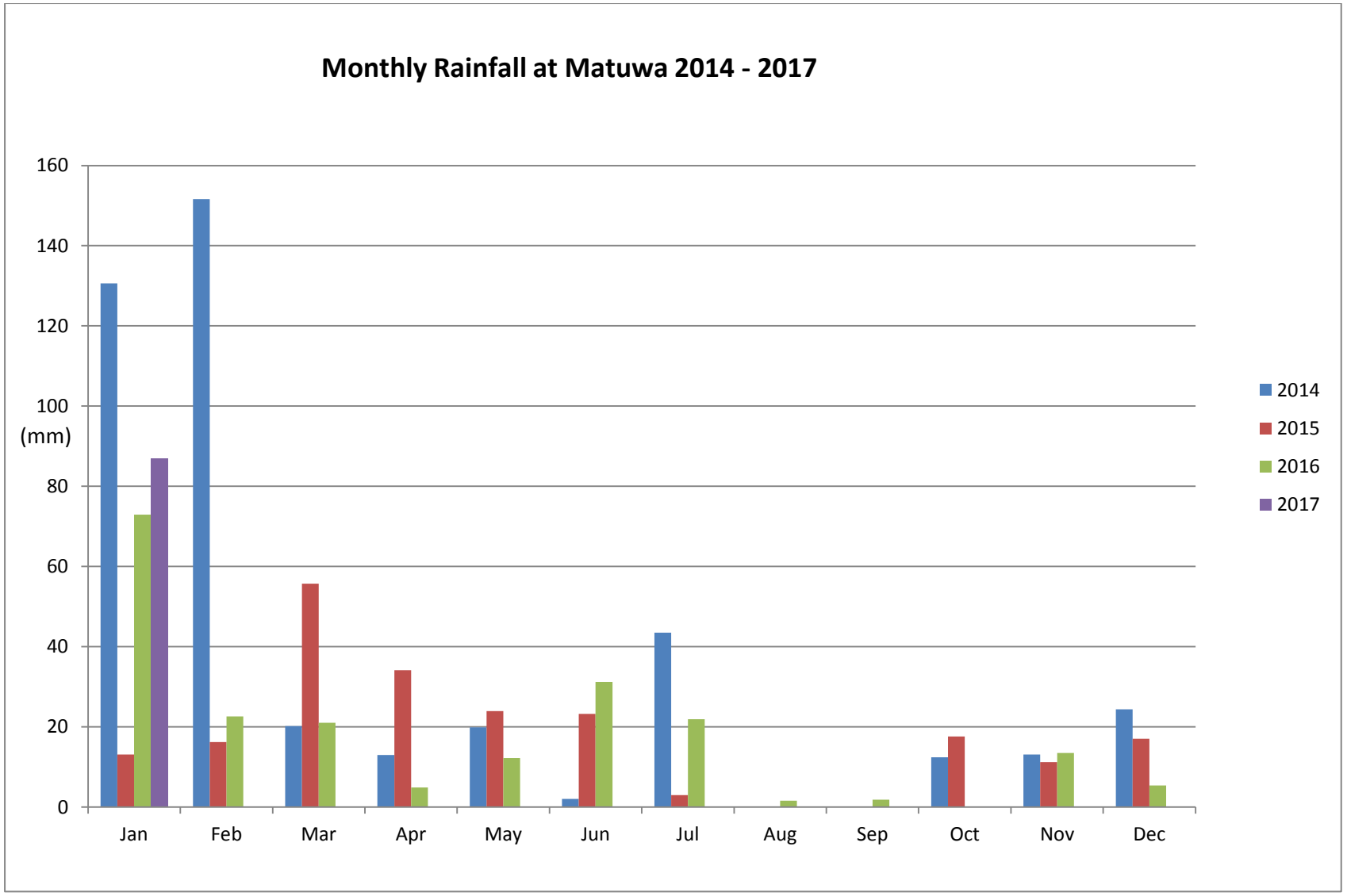
Information about climate statistics

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	39.0	47.2	37.7	24.9	21.0	17.9	14.3	7.9	3.7	7.5	13.8	26.2	263.1
Lowest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	86.4
5th %ile	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.9
10th %ile	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	117.4
Median	18.0	23.4	20.2	15.7	12.2	9.1	6.1	2.5	0.0	1.8	6.4	20.5	243.1
90th %ile	130.0	128.7	95.9	65.5	58.0	47.7	40.4	27.0	15.1	19.2	36.6	60.0	463.0
95th %ile	137.0	154.9	137.8	77.7	71.9	71.1	46.2	38.2	19.4	30.9	54.3	74.1	582.1
Highest	281.4	256.5	251.0	163.4	112.1	110.5	74.4	59.0	29.2	67.8	104.0	130.6	706.0

Mean =263mm
Median = 243mm
Lowest 10% = 117mm

Annual Rainfall at BOM homestead station and average of other rain gauges on Matuwa.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Hmstd Annual rainfall (mm)	--	--	338	122	634	*297*	259	168	236	394	*250+?*	262	431	215	*209*
Mean of other gauges								125	173	300	197	220	279	188	


Monthly Rainfall at Matuwa 2014 - 2017
160
140
120
100
(mm)
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2014
2015
2016
2017