GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Twelve years of rangelands restoration: reintroduction of native mammals to Matuwa (ex-Lorna Glen pastoral lease): SPP 2012-024

Version: Approved by:

Last Updated: day month year

Custodian: Review date:

Version number	Date approved DD/MM/YYYY	Approved by	Brief Description
1.1			

Twelve years of rangelands restoration: reintroduction of native mammals to Matuwa (ex-Lorna Glen pastoral lease): SPP 2012-024

Cheryl Lohr

October 2019

GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Department of Biodiversity, Conservation and Attractions
Locked Bag 104
Bentley Delivery Centre WA 6983
Phone: (08) 9219 9000
Fax: (08) 9334 0498

www.dbca.wa.gov.au

This report was prepared by Cheryl Lohr

Questions regarding the use of this material should be directed to:
Dr Cheryl Lohr
DBCA Biodiversity and Conservation Science
Department of Biodiversity, Conservation and Attractions
Locked Bag 104
Bentley Delivery Centre WA 6983
Phone: (08) 04055750
Email: Cheryl.lohr@dbca.wa.gov.au

The recommended reference for this publication is:
Lohr, C., 2019, *Twelve years of rangelands restoration: reintroduction of native mammals to Matuwa (ex-Lorna Glen pastoral lease): SPP 2012-024*, Department of Biodiversity, Conservation and Attractions, Perth.

This document is available in alternative formats on request.

Contents

Acknowledgments

I would like to acknowledge the traditional owners of Matuwa (ex-Lorna Glen) and Kurrara Kurrara (ex-Earaheedy), the Wiluna Martu people, and Tarlka Matuwa Piarky Aboriginal Corporation (RNTBC) for allowing access to the Indigenous Protected Area (IPA) during this research.

I would also like to acknowledge the staff from the DBCA Goldfields Region and previous researchers, technical staff, and volunteers involved in 2012-024, especially, Colleen Sims, Judy Dunlop, Neil Burrows, Tamra Chapman, Mark Blythman, and Keith Morris.

1 Background

Matuwa (ex-Lorna Glen pastoral lease) is located 1100 kilometres north east of Perth, in the rangelands of Western Australia, and lies across the boundary of the Gascoyne and Murchison IBRA regions. It was established as a pastoral lease in the 1930s, and stocked with sheep and cattle, until 2000 when it was purchased by the Western Australian Government for addition to the conservation estate. Kurrara Kurrara (ex-Earaheedy), the pastoral lease to the north east of Lorna Glen was also purchased in 1999. The land was managed by the Department of Biodiversity, Conservation and Attractions (DBCA, and its predecessors), Goldfields Region and DBCA Biodiversity Conservation Science Animal Science Program after the purchase with informal joint-management agreements with the Wiluna Martu and TMPAC. In 2015, both areas became a part of the Matuwa Kurrara Kurrara exclusive possession Indigenous Protected Area (MKK IPA), held in trust by Tarlka Matuwa Piarku Aboriginal Corporation (TMPAC) for the Martu people (Tran & Langford, 2015). DBCA and TMPAC are currently in the process of formalising a joint-management agreement for the management of Matuwa Kurrara Kurrara.

Matuwa once supported a diverse faunal assemblage with at least 36 species of non-volant mammals (Baynes, 2006; Cowan, 2004). Threats particularly introduced predators contributed to massive declines in native mammals in arid regions (Burbidge & McKenzie, 1989). Of the 36-species noted above, 13 species (three Muridae, six Dasyuridae, two Macropodidae and the echidna, *Tachyglossus aculeatus*) are still extant, 6 species possibly still occur, but have not been recorded during recent biological surveys, 12 species are locally extinct, and 5 species are totally extinct (Morris, et al., 2007).

In 2000, the overall aim for Matuwa Kurrara Kurrara was to restore the rangeland environment. Two science projects were initiated: ‘Project Rangelands Restoration … managing fire and introduced predators’ (SPP 2003-004) and this project ‘Rangeland restoration … reintroduction of native mammals’ (SPP 2012-024). These projects worked alongside the activities of the DBCA Goldfields Regional staff to manage the infrastructure and natural environment of Matuwa Kurrara Kurrara.

In summary, several threat mitigation activities were implemented prior to this project (2012-024) being initiated. Domestic cattle were removed and all artificial watering points (bores, dams) on Matuwa and Kurrara Kurrara were closed off in 2000. Feral cat (*Felis catus*) baiting was initiated at Matuwa in July 2003. Between 2003 – 2006 feral cats were reduced from about 30 cats per 100 km to less than 5-10 cats per 100 km (Algar, et al., 2013). A threshold of 10 cats/km of driving transect was defined as an acceptable density of cats during native fauna translocations. In 2011 baiting was extended to 5km beyond the southern and western boundaries of Matuwa to create a buffer around the property. After 2006, annual predator monitoring was primarily conducted by Neil Burrows (SPP 2003-004) (Burrows & Liddelow, 2012; Burrows & Liddelow, 2013). A fire management plan which prescribes a series of strategically placed small patch burns for Matuwa Kurrara Kurrara was implemented in 2006 and maintained by the Goldfields Region (Muller, 2006). An electric boundary fence was installed around the perimeter of Matuwa in 2011 and in combination with aerial and ground control operations for feral herbivores, reduced the abundance of camels, cattle, and goats on the property. Additionally, small vertebrate fauna surveys occurred over 16 trapping sessions between 2002 and 2010 (Champan & Burrows, 2015) and 24 permanent biological survey sites were established in late 2002 with four seasonal surveys over the subsequent year (Cowan, 2004; Cowan, et al., 2003).The remainder of this report only discusses the activities of this project (SPP 2012-024).

With threat mitigation activities in place, this project (SPP 2012-024) aimed to reintroduce 12 species of mammals to Matuwa over a ten to twelve-year period (2007 – 2019) (Morris, et al., 2007). In August 2007, the first mammal reintroduction occurred on Matuwa with the release of 40 bilbies (*Macrotis lagotis*) (Table 1). In 2008 eight brush-tailed possums (*Trichosurus vulpecula*) and 15 mala (*Lagorchestes hirsutus*) were reintroduced. Within two months of release 14 bilbies had died through predation or a lack of food or shelter (Morris, 2007). Similarly, several possums died due to dehydration or starvation (Morris & Dunlop, 2009), and a large proportion of mala were lost to cat predation (Miller, et al., 2010). The 2007/08 releases took place during the drier months of the year, after two years of below average rainfall (Morris & Dunlop, 2009). Anecdotally, the vegetation was dry with little herbage and few observable flowers or seeds to provide food. A strategic ground-baiting program using ERADICAT® and cat-trapping program using elevated leg-hold traps was implemented at the translocation sites, which removed additional cats, and reduced observed cat predation on bilbies (Morris & Dunlop, 2008; Morris & Dunlop, 2009).

As an adaptive management response to the failure of these translocations, an 1100 ha feral predator-free, fenced enclosure was constructed in 2009/10 (Bode, et al., 2012) at an approximate price of $250,000 (N. Wessels pers comm). The construction of the 15 km fence was completed in November 2009. The fence was constructed in a triangle, west of well #10. The top two wires of the fence are electrified and a 30cm skirt is buried underground (Miller, et al., 2010). Within the enclosure, cats were eradicated using a combination of 1080 baits and trapping. Rabbits inhabiting unused boodie warrens were reduced using one shot oats, and varanids were reduced via noosing and trapping. Kangaroos within the enclosure were culled. In 2014, a third electrified wire half-way up the outside of the fence was installed in response to three feral cat incursions.

The purpose of the enclosure was to provide a refuge for translocated animals where they could acclimatise to the arid environment, and/or provide a population of locally adapted F2 generation individuals that may then be successfully translocated to the open landscape. Releases of boodies (*Bettongia lesueur*) and golden bandicoots (*Isoodon auratus*) into the predator-free enclosure occurred in 2010, and their populations have rapidly increased in the absence of feral predators (Table 1).

Table 1: List of species proposed for translocation to Matuwa (Morris, et al., 2007) and the status of the translocation (Miller, et al., 2010; Sims, et al., 2015).

Species proposed for reintroduction	**Proposed date**	**Status of reintroduction**			
Source		**Number animals**	**Location**	**Date**	**Outcome**
Bilby, *Macrotis lagotis*	Aug 2007	46	Open landscape	Aug 2007	Successful
RTD, PCBC, Thistle Island SA		60	Open landscape	Aug 2008	Successful
		24	Open landscape	Aug 2009	Successful
Brushtail Possum, *Trichosurus vulpecula*	May 2008	8	Open landscape	Aug 2007	Successful
RTD, Boyagin, Mt Caroline, Karakamia		63	Open landscape	May 2008	Successful
		24	Open landscape	July 2009	Successful
Boodie, *Bettongia lesueur*	Aug 2008	86	Predator-free pen	Jan 2010	Successful
RTD, Barrow Island		27	Open landscape	Oct 2010	Failed
Mala, *Lagorchestes hirsutus*	May 2009	29	Open landscape	Aug 2008	Failed
PCBC, Trimouille Island		34	Predator-free pen	June 2011	Successful
		12	Predator-free pen	April 2012	Successful
		22	Predator-free pen	August 2013	Successful
Golden Bandicoot, *Isoodon auratus*	Aug 2009	160	Predator-free pen	Jan 2010	Successful
Barrow Island		93	Open landscape	Sept 2015	Unknown
Shark Bay Mouse, *Pseudomys fieldi*	May 2011	37	Predator-free pen	June 2011	Failed
		51	Predator-free pen	April 2012	Failed
Western Barred Bandicoot, *Perameles bougainville*	May 2010	Did not occur			
Black-footed Rock-wallaby, *Petrogale lateralis*	Aug 2010	Did not occur			
Pale Field Rat, *Rattus tunneyi*	Aug 2011	Did not occur			
Red-tailed Phascogale, *Phascogale calura*	May 2012	Did not occur			
Numbat, *Myrmecobius fasciatus*	Aug 2012	Did not occur			
Chuditch, *Dasyurus geoffroii*	May 2013	Did not occur			

Return to Dryandra captive breeding program (RTD); Peron Captive Breeding Centre (PCBC)

An expansion of the predator-free enclosure to provide a larger refuge that may accommodate larger populations of some species for a longer period has been proposed. Building the additional enclosure has been postponed until DBCA and TMPAC have finalised a joint-management agreement.

Reviews of translocation outcomes across the world over the last 20 years (Short, et al., 1992; Griffiths, et al., 1996; Fischer & Lindenmayer, 2000; Sheean, et al., 2012; Perez, et al., 2012; Morris, et al., 2015) indicate that a significant proportion, have resulted in failure, and there is often uncertainty as to the cause or causes of these failures. This lack of success, and inability to identify important causes of failure is usually attributed to a lack of strategic design in the planning of the translocation programs with a paucity of testable hypotheses and a failure to clearly identify quantitative criteria for success (Seddon, et al., 2007; Armstrong & Seddon, 2007), and/or a failure to adequately monitor and measure success criteria. Early survival and recruitment of the translocated population has often been monitored, but this has not extended through the full establishment and persistence phases. The faltering of these phases and concurrent reversal in population trends, leading to decline and extinction then goes unrecorded. At some later date, a revisit to the site fails to locate any individuals, and the dearth of data makes it impossible to determine what has ‘gone wrong’ in the interim (Seddon, et al., 2007). Failure to adequately monitor translocated populations may be due to the difficulties associated with collecting and statistically analysing data from small, cryptic, and elusive populations, and/or a failure to adequately commit resources to continue long term monitoring. This project set out to reintroduce several mammal species to Matuwa and to subsequently monitor the establishment of each species for several years.

2 Translocations of species to Matuwa

2.1 Bilby

130 bilbies were released at Matuwa from the Peron Captive Breeding Centre (PCBC), Return to Dryandra (RTD) captive breeding facility, and Thistle Island, South Australia. The bilbies were originally released in August 2007 along the Christmas Creek Well track (-26.2746; 121.3713) into deep loamy sands with moderately spaced and sized spinifex clumps, and a diversity of overstory species. Several bilbies released in 2007 were fitted with radio-transmitters. Unfortunately, 69% of the bilbies soon died. The highest cause of mortality was cat predation (40%) followed by unknown causes (27%), starvation (20%) and raptor take (13%) (Morris, 2007; Morris & Dunlop, 2008). In September 2007, five animals were moved to a site on the Lorna land system, north-east of North Well (-26.1304; 121.5079), where they had greater survival rates (Morris & Dunlop, 2008). Between 2007 and early 2009 130 bilbies were released and it was predicted 44.2% of individuals successfully established in the short term (<1 year) (Morris & Dunlop, 2009).

Interestingly, the source of bilbies seemed to have some influence over the most likely cause of mortality. No bilbies from RTD appeared to suffer starvation, whereas some captive bred PCBC animals and Thistle Island animals did suffer from a lack of resources. In contrast, fewer Thistle Island animals were lost to predation than captive bred animals from either PCBC or RTD (Miller, et al., 2010).

Bilby survey records were collated in 2014, and it was estimated the total population of bilbies at Matuwa was over 200 individuals (King & Burrows, 2012; Sims, et al., 2015; Burrows, et al., 2012). Further bilby scat surveys conducted in May 2016, detected 23 individuals in 4000ha (Sims, et al., 2017) and additional opportunistic records collected via camera-traps, cat track-counts, 2ha Martu track plots, and trapping revealed bilbies had dispersed across the Matuwa landscape and into neighbouring cattle stations. If the lowest bilby density values collected were extrapolated across the ~ 106,000ha of suitable habitat (Burrows et al, 2015b), then the Matuwa population could potentially be 600-800 bilbies (Sims, et al., 2017; Burrows, et al., 2015). The continued presence of bilbies after ten years suggests a healthy population with regular new recruits has established and the translocation was a success.

A study of relic (2-4 year old) bilby burrows near Pink Lake (-26.0811; 121.4536) found they could potentially provide more suitable habitats for the establishment and productivity of other species by moderating microclimates, accumulating nutrients and soil moisture, and ameliorating the potentially detrimental effects of bio-available aluminium (Chapman, 2013).

2.2 Brushtail possum

In the arid zone, possums have been recorded in Eucalypt woodlands with hollow bearing trees breakaways and rock piles, in boodie warrens and in caves (Morris, et al., 2008). On the 15th of August 2007, eight brushtail possums were released in

Eucalyptus camaldulensis woodland near the Matuwa #2 well (-26.1992; 121.4066). Seven of the possums were fitted with radio-collars. Zero mortalities despite movements of up to 8km from the release site were recorded in the remainder of 2007 (Morris, 2007; Morris & Dunlop, 2008). Between 9-16th May 2008, another 63 possums were released at #2 well site (-26.207; 121.408), Possum lake (-26.230; 121.350), Lorna Glen Spring (-26.236; 121.5333), south of #1 well (-26.2576; 121.4975), and at East well (-26.225; 121.570). Twenty-three of these possums were fitted with radio-transmitters, of which 5 (21%) died within a month. The likely cause of death was dehydration and starvation (Morris & Dunlop, 2008). Some unwell possums were recaptured and moved from #2 well site to the Lorna Glen homestead (-26.2232; 121.5568) which has greater water and food resources. The possums were sourced from Dryandra National Park, nearby Boyagin Nature Reserve, Mt Caroline and Karakamia Sanctuary and failure to adapt from the wheatbelt or mediterranean Perth Hills environment to an arid environment may have been the ultimate cause of death for many animals.

Surveys for brushtail possums were conducted in 2012 and 2014 using cage traps, baited camera-traps, and observations of scats and scratches on trees. Over 26 individuals were observed at the Lorna Glen Homestead, Lorna Glen Spring, wells 1, 2, and 10, and Possum Lake. There are a number of possums that appear to be resident within the predator-free enclosure (Sims, et al., 2015).

The last extensive possum monitoring session undertaken in 2015 identified several melanistic possums, young animals appearing in several ‘gilgai’ areas and at least one young male possum was present around the No. 9 well area. However, there is still little indication that possum populations have spread or persisted outside the *Eucalyptus camaldulensis* dominated drainage systems. The occasional record in Acacia woodland and Triodia dominated sandplain may be dispersing or displaced males, and although they may survive for significant time periods, are not likely to be viable parts of the breeding population. Consequently, it appears that the effective population size is probably smaller than the founder population, and the sub-populations (LG homestead/East well/LG soak; No.1 Well; No.2 Well; No.10 Well/Possum Lake Rd) may be isolated from each other (Sims, et al., 2017).

Tissue samples (n=33) collected between 2012 and 2016 were analysed to assess the genetic status of the Matuwa population and compare these to the other populations (Semple, et al., Unpublished). Results indicate that mixing several source populations produced a better genetic profile with lower levels of inbreeding and higher heterozygosity than the source populations. 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 10-15 years without further management (Semple, et al., Unpublished).

2.3 Boodie

The boodies translocated to Matuwa were sourced from Barrow Island in January 2010, with trapping effort focused on or near the construction footprint of the proposed gas processing plant (DEC, 2010; Miller, et al., 2010). A quarantine-compliant helicopter was chartered to transport animals from Barrow Island to Karratha. Animals flown to Karratha were transferred subsequently by fixed wing aircraft to Matuwa. Supplementary feed and water were provided in the enclosure due to harsh summer conditions. Twenty-five of the 86 boodies released at Matuwa were fitted with a mortality sensing radio-collar to allow monitoring of survivorship and movements over the first three months after release. Sixteen boodies died within a few months, most likely from exposure because of failure to enter a warren system on release. A higher proportion of captive bred animals died (25%; 5 of 20) compared to the wild caught animals (13.6%; 9 of 66) (Miller, et al., 2010).

By August 2011 there was an estimated 208 (165-251) boodies inside the enclosure, which climbed to 499 (350-648) in October 2013 before fluctuating from 360 (288-432) in October 2014 to 452 (352-525) boodies in May 2016 (Department of Parks and Wildlife, 2015; Department of Parks and Wildlife, 2014; Department of Parks and Wildlife, 2016; DEC, 2012). Initially, boodies selected calcrete habitat within the predator-free pen before gradually dispersing into the sand plain habitat. In 2012, only 15.46% of boodie captures were in spinifex habitat, this increased to 19.48% in 2013 and 26.90% in 2014 (Sims, et al., 2015).

A trial release of 27 animals into the ‘greater Lorna Glen area’ in Oct 2010 failed with wild dog predation accounting for 8/16 known mortalities of collared animals within 2 weeks of release. This triggered a management response to trap and return surviving animals to the enclosure. Only four animals were recaptured and returned, and the remainder presumed dead. No further sign has been recorded at these sites (Sims, et al., 2015).

In 2013/14, the effect of warren digging by boodies on soils and vegetation (Ward, 2012) was investigated. Soil rock content, hydraulic conductivity, mineral nitrogen, phosphorus, potassium and sulfur were significantly higher for soils on the active part of the boodie warren than on the relic part of the warren. Cotton bush (*Ptilotus obovatus*) shrubs were similar in size for the areas compared, but those growing on the active part of the warren had significantly more living tissue, greater leaf biomass and larger leaves, with higher moisture and nutrient content. The results suggest that boodies can contribute positively to habitat restoration at Matuwa (Chapman, 2015). Another study showed that boodies move, scatter hoard and cache sandalwood seeds (*Santalum spicatum*) near potential host plants and have the potential to improve seed germination and recruitment of sandalwood trees (Chapman, 2015).

In 2014, research into the genetic consequeces of mixing two isolated, island populations of boodies at Matuwa was completed using mitochondrial DNA and microsatellite analysis (Thavornkanlapachai, et al., 2019). While the founders had high levels of genetic divergence, the analysis found evidence of reciprocal interbreeding with asymmetrical introgression in the form of a bias towards crosses between males from the smaller-sized Barrow Island source populations and females from the larger Bernier and Dorre Island (RTD captive bred) source population. There is no evidence that the interbreeding has resulted in any loss to reproductive capacity or survivorship (Thavornkanlapachai, et al., 2019).

In 2017 and 2018 an Honours student used capture-recapture and a combination of GPS and radio-tracking techniques to study the social organisation and warren use by boodies in the predator-free pen at Matuwa.

2.4 Mala

Twenty-nine mala were released into long unburnt spinifex at Possum Lake (-26.230; 121.350) from the PCBC between the 16th and 18th August 2008 (Miller, et al., 2010). The ephemeral lake system provides a good variety of vegetation types, including those which are used by mala (Pearson, 1989). However most, if not all, had died by December 2008 (Morris & Dunlop, 2009). Sixteen of these animals were fitted with mortality sensing radio-collars with a 12-month battery life. The highest cause of mortality for mala was cat predation with 55% of animals taken within 10 weeks. These predation events were consecutive, with one or two animals being killed per night. Cats were observed to be excess killing and caching animals and returning the following night to consume the carcass. An additional 13% were lost to raptor predation, highlighting the naivete of this species (Morris & Dunlop, 2009). The last radio-collared animal died 17/11/08, however mala tracks continued to be sighted in the area (June 2009) during dragged track counts.

Although the cause of death for many of the mala was predation, it is likely other factors contributed to their deaths and that these animals were not well suited for hard release. These animals were kept in intensive captive breeding facilities, associated human activity with being fed and were not used to foraging for themselves. They had no knowledge of cats as predators (Morris & Dunlop, 2009). In response to the raptor predation events, Simon Cherriman from iNSiGHT Ornithology was contracted to conduct wedgetail eagle nest survey and dietary analysis.

Further translocations of mala from Trimouille Island and Dryandra, to the Matuwa enclosure, occurred in 2011/12. Radiotelemetry provided some information on early survival and movements. Targeted trapping and spotlight monitoring of radio-tagged animals have indicated long-term survival of individuals in the enclosure, with good body condition and breeding activity (DEC, 2012; Sims, et al., 2015). Unfortunately, trapping mala in the presence of boodies must be done via hand-netting and hence we do not have sufficient data to estimate the abundance of mala inside the enclosure. Similarly, spotlighting in dense spinifex grassland rarely provides sufficient data for abundance estimation via DISTANCE analysis.

2.5 Golden bandicoot

The golden bandicoots translocated to Matuwa were sourced from Barrow Island, with trapping effort focused on or near the construction footprint of the proposed gas processing plant (DEC, 2010). None of the 160 bandicoots released at Matuwa in 2009 were fitted with radio-collars (Table 1). Only two golden bandicoots are known to have died, both from heat stress during the release period when temperatures at Matuwa were averaging 40 - 45°C. Subsequent, trap-based monitoring found their overall condition remained high after release with over 85% of females have 1-2 pouch young present. By August 2011 there was an estimated 166 (132-200) golden bandicoots inside the enclosure (DEC, 2012), which increased to 400 (117-681) in October 2013 and 394 (223-565) bandicoots in October 2014. In May 2016 there were only an estimated 90 (70-110) bandicoots in the predator-free pen after 93 bandicoots were translocated to the open landscape (Department of Parks and Wildlife, 2015; Department of Parks and Wildlife, 2014; Department of Parks and Wildlife, 2016).

Throughout 2011 and 2012, regular reports of bandicoots outside the enclosure have been made, including animals immediately outside the enclosure and individuals recorded more than 8 km away (DEC, 2012). These individuals have dispersed naturally from the enclosure as young bandicoots are small enough to pass through the mesh of the fence. A trial release of 49 golden bandicoots into *Triodia basedowii* habitat near Possum Lake occurred in May 2012. Unfortunately, the translocation was not successful as 77% of the 19 radio-tracked bandicoots died due to feral predation (DEC, 2012). 2012 was a year when feral cat activity appeared to triple during the autumn months when cats typically disperse to new areas (Algar, et al., 2013).

In 2015 a second translocation of 93 golden bandicoots from the predator-free enclosure to the open landscape occurred, with stricter guidelines incorporated into the translocation proposal. 24 of these animals were fitted with mortality sensing radio-collars to provide 12 weeks post release bandicoot survival data. Feral cats were controlled through annual aerial ERADICAT® baiting and leg-hold trapping which removed an additional 13 cats from the translocation site. Dingoes were identified as the predator responsible for 4 of the 9 mortalities in the first 3 weeks post release and a concerted effort to lay 1080 dog baits and rabbit baiting (secondary baiting) resulted in a reduction of observed dingo track activity (Sims, 2015).

Between March and November 2016, 42 camera-traps were installed at the translocation site and used in conjunction with track monitoring and three trapping sessions to monitor the success of the bandicoot translocation. The continued presence of bandicoots at the release sites in October 2016, tracks observed up to 20km from the release site, and radio-tracking evidence of individuals dispersing as much as 12 km and returning suggested that bandicoots had established a population. Declines in activity indices over time suggest bandicoots will develop a low density and transient presence across the available habitat which will be difficult to monitor and quantify. The short-term success criteria for the translocation were met but due to declining activity indices it is uncertain whether the medium to long term success criteria will be met.

A genetic assessment of the golden bandicoots translocated from Barrow Island to Hermite Island, Doole Island and Lorna Glen was undertaken. There was no significant loss of genetic diversity or increase in inbreeding or relatedness among wild born individuals, two years post release. However, population viability analysis (PVA) predicts that the translocated populations are susceptible to genetic loss over time and recommends ongoing population augmentation after 5-10 years (Ottewell, et al., 2014).

A small study of home range and refuge selection by golden bandicoots within the enclosure was conducted in 2015. Twenty animals were radio-collared in the main habitat types (Bullimore sand plain and mulga woodland on gravel covered clay/loams) within the enclosure. Bandicoots were tracked to a minimum of 10 daytime refuges for 14 of the 20 animals. Night-time tracking recorded triangulations for each individual to calculate locations with 20-30 'fixes' obtained for each. The data suggests that although bandicoots are foraging in both the spinifex and mulga woodland habitats, they can travel significant distances in a single night (1-3km), with many returning to refugia in the spinifex sand plain during the day (Sims, et al., 2015).

2.6 Shark Bay mouse

In June 2011 37 Shark Bay mice (*Pseudomys fieldi*) were translocated from Northwest Island to the Matuwa enclosure, with another 51 translocated in April 2012 (DEC, 2012). Radio-telemetry and trapping revealed Shark Bay mice released in 2012 survived for 4-6 months, but long-term survival was unlikely, with evidence of predation by mulgara (*Dasycercus blythi*) and other native predators (barn owls, varanids, and snakes) resident within the enclosure (Sims, et al., 2017).

2.7 Adaptive management issues

There was a feral cat incursion into the predator-free pen in August 2011. The cat was removed within one week (Burrows & Liddelow, 2013). Two more cat incursions occurred in 2014 (Sims, et al., 2015). The cats were detected via camera-traps installed along driving tracks at 1km intervals and monitored weekly by volunteer homestead caretakers. Post-mortem examination of these cats revealed empty stomachs, and along with movement information gathered from the camera stations, indicated that the cats were more concerned with finding a way back out of the pen to their familiar home ranges, than gorging on the abundant prey within the enclosure. Additional electrified wires were added to the fence and a rapid response protocol for cat incursions was put in place. There have been no further cat incursions since August 2014 (Sims, et al., 2017).

Above average rainfall in 2011 resulted in several fence washouts. Goldfields Region staff have since modified the berms to allow better drainage. From 2011-2014, above average rainfall also resulted in an increase in native fauna prey, and an increase in dingoes and feral cats. This was reflected in sustained high cat track activity indices and less effective feral cat baiting as determined by using camera-traps and track counts (Burrows, et al., 2011; Burrows & Liddelow, 2011; Burrows & Liddelow, 2012; Burrows & Liddelow, 2012; Burrows & Liddelow, 2013; Burrows & Liddelow, 2013; Burrows & Ward, 2012).

Hand baiting for both feral cats and wild dogs occurred on selected roads around threatened fauna release sites and recorded locations in March, September and December 2016. Recent dog baiting work in the Goldfields Region suggests 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) (Algar & 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.

3 Other research

3.1 Non-toxic bait trials

Non-toxic baiting trials were conducted within the predator-free enclosure during May 2010 to examine the frequency and quantity of bait uptake by non-target species (Miller, et al., 2010). Three transects, each with 8 sand pads, were established in the enclosure. One bait (15g dry weight) was placed on each sand pad for five consecutive nights. Some pads were closed for various reasons, leaving a total 110 baits being laid. In total there were 118 visits to the baited sand pads. Of the 28 baits that were taken, bandicoots took 14, boodies took 11, birds took 2 and a possum took 1 bait. 42% of bandicoot visits to a baited sand pad resulted in the bait being taken, whereas only 15% of boodie visits resulted in a bait being taken. Baits that were taken may not have been consumed. Boodies for example, were observed trying to bury baits.

Boodies have a high tolerance to sodium monofluoroacetate (1080 poison) with an LD_{50} of 15 mg/kg of 1080 (King, et al., 1981; Twigg & King, 1991; McIlroy, 1982). ERADICAT® baits contain 4.5mg of 1080. Therefore, an average sized boodie (1kg) would need to eat at least 3 ERADICAT® baits to have a 50% chance of being killed, which in combination with the relatively low probability of a bait encounter resulting in bait take, suggests they are at minimal risk during fox, cat, and rabbit control programs. *Isoodon auratus* has an LD_{50} to 1080 of 9 mg/kg (Twigg & King, 1991; Twigg, et al., 1990), suggesting that average sized animals (260-650g) may succumb to 1080 poisoning if they consume 0.5-1.3 ERADICAT® baits, which in combination with the relatively high probability of bait take suggests that golden bandicoots may be at risk from 1080 baiting programs.

3.2 Mulgara research

In 2012, an Honours student used capture-recapture and radio-tracking techniques to determine if feral cats were having an effect on the population size, mophometrics and movement patterns of the mulgara (*Dasycercus blythi*) (Read, 2012). Trapping grids were set inside and outside the predator-free pen at Matuwa and 19 mulgaras were radio-tracked. There was no significant difference in population numbers, morphometrics and home ranges of *D. blythi* inside and outside the pen (Read, 2012); but the density of feral cats immediately outside the pen was not determined.

3.3 Bird monitoring

Landscape level bird monitoring and banding began at Matuwa in 2003 under Neil Hamilton's Australian Bird and Bat Banding Scheme, ACT (ABBBS) license and project (Bell, et al., 2015; Coate, 2010). To date, 154 bird species have been detected at Matuwa.

Bird banding associated with this project began in 2013 with 3 dedicated bird banding trips lasting 10 days each and an additional 1300 birds from 53 species banded. This work is being continued under Neil Hamilton's direction as volunteer work in association with Bird Life Australia and a network of other volunteers.

3.4 Wedgetail eagle diet

In March 2016, the team trialled the use of high-quality metal detectors in locating and identifying fauna microchips in and underneath the nests of aerial predators. A total of 20 microchips were located from both current and old wedge-tailed eagle nests and a barn owl roost within and nearby the enclosure (Blythman, et al., 2017). Undamaged microchips could be connected to mammals in the pen. Most microchips were from golden bandicoots (15) with only one mala and four boodies recorded.

Simon Cherriman from iNSiGHT Ornithology continued research into the diet, breeding and movements of the wedge-tailed eagle at Matuwa using nest surveys, banding chicks and attaching solar-powered GPS/Satellite Platform Transmitter Terminals to some birds (Cherriman, 2012; Cherriman, 2012; Cherriman, 2013; Cherriman, 2013). Seventy-nine wedge-tailed eagle nests (92% of nests in *Acacia pruinocarpa* trees) within 29 breeding territories had been found and mapped as of 2013/14. Most eagle territories (~20-50 km^2) occur in rockier mulga shrublands with no nests in broad areas of sandplain/spinifex habitat (Cherriman, 2013). Data collected over five years suggests eagles have very low survival rates and low reproductive success (only 38% of pairs laid eggs) particularly during years with below average rainfall. Analysis of 987 prey fragments and 80 regurgitated pellets yielded 231 individual prey items. The most frequently eaten prey animals were larger macropods, emu (*Dromaius novaehollandiae*) chicks, Australian bustards (*Ardeotis australis*) and large varanids. Reintroduced medium-sized mammals such as boodies, golden bandicoots and bilbies were rare, with only one pair of birds hunting in the predator-free pen (Cherriman, 2013).

The wedge-tail eagle satellite tagging project by Simon Cherriman is now part of a formal PhD program. As of August 2017 six Matuwa wedge-tail eagle fledglings have been tracked: two currently carry transmitters, one has dispersed to the Great Sandy Desert; two died shortly after fledging; one died 11 months after fledging 250km north of Matuwa and the sixth shed the transmitter (transmitter harness uses a weak link to prevent need for recapture) after 4 years of tracking (S. Cherriman pers comm). Additionally, 12 juvenile and 4 adult birds have been banded under Neil Hamilton's ABBS license and project.

3.5 Malleefowl management

Malleefowl were recorded by DBCA 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. In late 2016 an active breeding mound was located. Cameras were deployed at the mound and the courtship displays were recorded (Sims, et al., 2017). Sufficient data were collected to allow the team to predict when malleefowl chicks would hatch, which allowed us to catch one chick and translocate it into the predator-free pen in January 2018. The chick could not be banded or tracked due to its size and has not been seen since translocation.

3.6 Mesopredator interactions

A PhD project examining the interaction of feral cats and dingoes at Matuwa finished in 2016. Using GPS radio-collars and camera-traps this study demonstrated that dingoes exhibited a strong association for mulga (*Acacia anuera*) woodlands, while feral cats used all habitat with a slight increase in selection for Triodia grassland habitats. These results suggest that dingoes are unlikely to significantly influence feral cat space use, that there is no strong evidence for dingo suppression of feral cats at Matuwa, and that targeted control of feral cats will likely impact dingoes. This study has also shown that dingoes at Matuwa are 90-98% pure with little, or no, interbreeding with domestic dogs (Wysong, 2016).

3.7 Rabbit monitoring

Trials to find a suitable method to control and or monitor trends in rabbit populations began at Matuwa in early 2014. 20km spotlight transects were found to be unsuitable for estimating abundance due to low detectability inside and outside the feral proof enclosure, so dung pellet count transects were established. These consist of a two kilometre transect inside and outside of the enclosure with pellets counted at 100m intervals. Unfortunately, the rabbit monitoring was not continued beyond the trial.

Several rabbit control methods were trialled inside the enclosure including shooting and trapping but both appear to be unsuitable for complete eradication of rabbits. 13 rabbits were collected to determine the presence of disease antibodies; however, these samples are still waiting to be analysed (Sims, et al., 2015). The spread of myxomatosis was facilitated by the release of a diseased rabbit into the enclosure in 2016 (Sims, et al., 2017).

4 Recommendations

Several lessons have been learned during this project. The primary recommendations are listed below.

- Translocations to the arid zone should be planned for the beginning of the wet season when the area is most productive for vegetation and invertebrates. At Matuwa the wet season typically starts in November. Translocation plans should be aborted if rainfall does not occur.
- Supplementary feeding and/or soft release approaches should be considered.
- Animals should be released at dawn into shelters or warrens for protection from the elements.
- Founder animals should be sourced from wild populations in nearby climatically, geographically, and environmentally similar areas over captive bred animals.
- Intensive control of introduced predators should be implemented at all translocation sites, until the new population is established.

5 References

5.1 Published articles associated with 2012-024

Journal articles

Blythman, M., Cims, C., & Eliot, G. (2017). Wedgie gold: using metal detectors to recover PIT tags under areas used by wedge-tailed eagles and barn owls. *Australian Mammalogy*, DOI: 10.1071/AM17021.

Bode, M., Brennan, K.E.C., Morris, K., Burrows, N. and Hague, N. (2012). Choosing cost effective locations for conservation fences in the local landscape. *Wildlife Research,* 39, 192-201.

Burrows, N., Dunlop, J. and Burrows, S. (2012). Searching for signs of bilby (*Macrotis lagotis*) in central Western Australia using observers on horseback. Journal of the Royal Society of W.A., 95, 167-170.

Chapman, T. (2013). Relic bilby (Macrotis lagotis) refuge burrows: assessment of potential contribution to a rangeland restoration program. *The Rangeland Journal, 35*, 167-180.

Chapman, T. (2015). Comparison of soils and plants on the active and relic parts of a recolonised burrowing bettong (*Bettongia lesueur*) warren. *Pacific Conservation Biology, 21*, 298-306.

Chapman, T. (2015). Reintroduced burrowing bettongs (Bettongia lesueur) scatter hoard sandalwood (*Santalum spicatum*) seed. *Australian Journal of Zoology, 63*, 76-79.

Ottewell, K., Dunlop, J., Thomas, N., Morris, K., Coates, D., & Byrne, M. (2014). Evaluating success of translocations in maintaining genetic diversity in a threatened mammal. *Biological Conservation, 17*, 209-219.

Thavornkanlapachai, R., Mills, H., Ottewell, K., Dunlop, J., Sims, C., Morris, K., Donaldson, F., and Kennington, W.J. (2019). Mixing genetically and morphologically distinct populations in translocations: Asymmetrical introgression in a newly established population of the boodie (*Bettongia lesueur*). **Genes**, *10*: 729.

Landscope articles

Dunlop, J., & Morris, K. (2009). Into the wild: restoring rangelands fauna. **Landscope***, 24*, 52-58.

Hamilton, N., Onus, M., Forrest, K. (2010) Fighting back: mulgaras return. **Landscope***, 26*, 6-8.

King, R. and Burrows, N. (2012). The great bilby muster. ***Landscope****, 27*, 6-8.

King, R. (2018). Monitoring Matuwa and Kurrara Kurrara: a labour of love. **Landscope**, *33*, 48-52.

Theses and unpublished manuscripts

Read, M. (2012). *The population size, morphometrics and movement patterns of the brush-tailed mulgara (Dasycercus blythi): is predation by feral cats (Felis catus) having an effect?* Perth, Western Australia: University of Western Australia.

Semple, L., Ottewell, K., Sims, C., Simianer, H., & Byrne, M. (Unpublished). Genetic viability of a reintroduced population of south-western brushtail possum (*Trichosurus vulpecula hypoleucus*), Western Australia. 30.

Wysong, M. (2016). *Predator ecology in the arid rangelands of Western Australia: Spatial interactions and resource competition between an apex predator, the dingo Canis dingo, and an introduced mesopredator, the feral cat Felis catus.* Perth, Western Australia: University of Western Australia.

5.2 Internal reports

Burrows, N., Hearle, G., Woods, T., Liddelow, G. (2011) *Lorna Glen introduced predator monitoring: 22-26 July 2011, post-bait data summary.* Department of Environment and Conservation, Kensington, WA.

Burrows, N., Liddelow, G. (2011) *Lorna Glen introduced predator monitoring: data summary, 23-27 June 2011.* Department of Environment and Conservation, Kensington, WA.

Burrows, N., Liddelow, G. (2012) *Aerial baiting to control introduced predators on Lorna Glen, winter 2012.* Department of Environment and Conservation, Kensington, WA.

Burrows, N., Liddelow, G. (2012) *Lorna Glen introduced predator monitoring: pre-bait survey 28 June-2 July 2012.* Department of Environment and Conservation, Kensington, WA.

Burrows, N., Liddelow, G. (2013) *Breach of the Lorna Glen fauna refuge compound by a feral cat: chronology and lessons learnt.* Department of Parks and Wildlife, Kensington, WA.

Burrows, N., Liddelow, G. (2013) *Lorna Glen introduced predator and mulgara monitoring: pre-bait survey 8 June-11 June 2013.* Department of Environment and Conservation, Kensington, WA.

Burrows, N., Liddelow, G. (2013) *Lorna Glen introduced predator control: post-bait survey report 7-10 August 2013.* Department of Parks and Wildlife, Kensington, WA.

Burrows, N., Ward, B. (2012) *Lorna Glen introduced predator monitoring, 27-31 January 2012.* Department of Environment and Conservation, Kensington, WA.

Burrows, N., Foster, C., Gilbert, C., Gray, D., Rowbotham, E., Smith, S., . . . Thoomes, E. (2015). *Monitoring bilby (Macrotis lagostis) at Matuwa (Lorna Glen) using observers on horseback.* Perth, Western Australia: Western Australia Department of Parks and Wildlife.

Cherriman, S. (2012). *Breeding of the wedge-tailed eagle Aquila audax during 2012 at Lorna Glen Conservation Reserve, Western Australia.* Parkerville, Western Australia: iNSiGHT Ornithology.

Cherriman, S. (2012). *Diet and status of the wedge-tailed eagle Aquila audax at Lorna Glen Conservation Reserve, Western Australia.* Parkerville, Western Australia: iNSiGHT Ornithology.

Cherriman, S. (2013). *Diet, nest sites and breeding success of the wedge-tailed eagle Aquila audax, during 2012 at Lorna Glen Conservation Reserve, Western Australia.* Parkerville, Western Australia: iNSiGHT Ornithology.

Cherriman, S. (2013). *Nest sites, breeding, satellite telemetry and diet of the wedge-tailed eagle Aquila audax at Lorna Glen, Western Australia.* Parkerville, Western Australia: iNSight Ornithology.

DEC. (2010). *Gorgon Gas Development: Threatened and priority species translocation and reintroduction program, annual report 2009/2010.* Perth, Western Australia: Western Australia Department of Environment and Conservation.

DEC. (2012). *Gorgon gas development, threatened and priority species translocation and reintroduction program: Annual report 2011/2012.* Perth, Western Australia: Western Australia Department of Environment and Conservation.

Department of Parks and Wildlife. (2014). *Barrow Island threatened and priotity species translocation and reintroduction program annual report to CALM Act Minister, Barrow Island Act Minister and Gorgon Joint Venturers 2013/2014.* Perth, Western Australia: Western Australia Department of Parks and Wildlife.

Department of Parks and Wildlife. (2015). *Barrow Island threatened and priority species translocation and reintroduction program annual report to CALM Act Minister, Barrow Island Act Minister and Gorgon Joint Venturers 2014/2015.* Perth, Western Australia: Western Australia Department of Parks and WIldlife.

Department of Parks and Wildlife. (2016). *Barrow Island threatened and priority species translocation and reintroduction program annual report to CALM Act Minister, Barrow Island Act Minister and Gorgon Joint Venturers 2015/2016.* Perth, Western Australia: Western Australia Department of Parks and Wildlife.

Miller, E., Dunlop, J., & Morris, K. (2010). *Rangelands restoration: Fauna recovery at Lorna Glen Western Australia. Progress report August 2008-June 2010.* Perth, Western Australia: Western Australia Department of Environment and Conservation.

Morris, K. (2007). *Lorna Glen fauna reintroduction.* Perth, Western Australia: Unpublished Western Australia Department of Conservation and Land Management.

Morris, K. (2007). *Lorna Glen fauna reintroductions: Summary of progress 30 September 2007.* Perth, Western Australia: Western Australia Department of Conservation and Environment.

Morris, K., & Dunlop, J. (2008). *Fauna reconstruction at Lorna Glen - Reintroduction of ninu and wayurta.* Perth, Western Australia: Western Australia Department of Environment and Conservation.

Morris, K., & Dunlop, J. (2009). *A strategy to improve the survivorship of translocated mammals at Lorna Glen.* Perth, Western Australia: Western Australia Department of Environment and Conservation.

Morris, K., N, T., Johnson, B., Orell, P., & Brennan, K. (2008). *A report on the selection of release sites for bilbies (Macrotis lagotis) and brushtail possums (Trichosurus vulpecula) at Lorna Glen.* Perth, Western Australia: Western Australia Department of Environment and Conservation.

Morris, K., Orell, P., Cowan, M., & Broun, G. (2007). *Reconstructing the mammal fauna of Lorna Glen in the rangelands of Western Australia, 2006-2016.* Perth, Western Australia: Western Australia Department of Environment and Conservation.

Sims, C. (2015). *Preliminary report on wild release of golden bandicoots into Matuwa 2015.* Perth, Western Australia: Western Australia Department of Parks and WIldlife.

Sims, C., Morris, K., & Blythman, M. (2012). *Rangelands Restoration - Lorna Glen fauna activities, summary, February 2012.* Perth, Western Australia: Unpublished report, Western Australia Department of Environment and Conservation.

Sims, C., Morris, K., & Blythman, M. (2015). *Rangelands Restoration: Fauna recovery at Matuwa (Lorna Glen), Western Australia Progress Report 2014.* Perth, Western Australia: Western Australia Department of Parks and Wildlife.

Sims, C., Morris, K., & Blythman, M. (2017). *Rangelands Restoration: Fauna recovery at Matuwa (Lorna Glen), Western Australia Annua report 2016.* Perth, Western Australia: Western Australia Department of Parks and Wildlife.

5.3 Other References

Algar, D., & Brazell, R. (2008). A bait-suspension device for the control of feral cats. *Wildlife Research, 35*, 471-476.

Algar, D., Onus, M., & Hamilton, N. (2013). Feral cat control as part of Rangelands Restoration at Lorna Glen (Matuwa), Western Australia: the first seven years. *Conservation Science Western Australia, 8*, 367-381.

Armstrong, D., & Seddon, P. (2007). Directions in reintroduction biology. *Trends in Ecology and Evolution, 23*, 20-25.

Baynes, A. (2006). *Preliminary assessment of the original mammal fauna of Lorna Glen station.* Perth, Western Australia: Western Australia Department of Environment and Conservation.

Bell, D., Agar, P., Luyer, R., & Loneragan, W. (2015). Winter bird assemblages at Lorna Glen (Matuwa) and Earaheedy (Kurrara Kurrara) conservation reserves. *Western Australian Journal of Ornithology, 7*, 1-14.

Burbidge, A., & McKenzie, N. (1989). Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation, 50*, 143-198.

Chapman, T., & Burrows, N. (2015). Lorna Glen (Matuwa) small vertebrate fauna monitoring program 2002 - 2010 – preliminary analysis and review. Perth: Western Australia Department of Parks and Wildlife.

Coate, K. (2010). An annotated checklist of birds from Lorna Glen (Matuwa): A proposed conservation park on the boundary of the Murchison and Gascoyne regions of Western Australia. *The Western Australian Naturalist, 27*, 127-149.

Cowan, M., Kenneally, K., Edinger, D>, How, R., & Coate, K. (2003). *Prospecting, pastoralism and preservation – conserving the wildlife of Lorna Glen*. Perth, Western Australia: LANDSCOPE Expeditions, the Department of Conservation and Land Management, and The University of Western Australia.

Cowan, M. (2004). *Preliminary analysis of fauna sampling for CALM's feral cat research program at Lorna Glen.* Perth, Western Australia: Western Australia Department of Conservation and Land Management.

Fischer, J., & Lindenmayer, D. (2000). An assessment of the published results of animal relocations. *Biological Conservation, 96*, 1-11.

Griffiths, H., Davison, A., & Birks, J. (1996). Species reintroductions. *Conservation Biology, 10*, 923.

King, D., Oliver, A., & Mead, R. (1981). *Bettongia* and fluroacetate: a role for 1080 in fauna management. *Australian Wildlife Research, 8*, 529-536.

McIlroy, J. (1982). The sensitivity of Australian animals to 1080 poison III. Marsupial and eutherian herbivores. *Australian Wildlife Research, 9*, 487-503.

Morris, K., Page, M., Kay, R., Renwick, J., Desmond, A., Comer, S., . . . Sims, C. (2015). Forty years of faunal translocations in Western Australia: lessons learned. In D. Armstrong, M. Hayward, D. Moro, & P. Seddon (Eds.), *Advances in reintroduction biology of Australian and New Zealand fauna* (pp. 217-235). Melbourne: CSIRO Publishing.

Muller, C. (2006). *Fire management plan - Lorna Glen / Earaheedy.* Perth, Western Australia: Western Australia Department of Environment and Conservation.

Pearson, D. (1989). The diet of the rufous hare-wallaby (Marsupalia: Macropodidae) in the Tanami Desert. *Australian Wildlife Research, 16*, 527-535.

Perez, I., Anadon, J., Diaz, M., Nicola, G., Tella, J., & Gimenez, A. (2012). What is wrong with current translocations? A review and a decision-making proposal. *Frontiers in Ecology and the Environment, 10*, 494-501.

Seddon, P., Armstrong, D., & Maloney, R. (2007). Developing the science of reintroduction biology. *Conservation Biology, 21*, 303-312.

Sheean, V., Manning, A., & Lindenmayer, D. (2012). An assessment of scientific approaches towards species relocation in Australia. *Austral Ecology, 37*, 204-215.

Short, J., Bradshaw, S., Giles, J., Prince, R., & Wilson, G. (1992). Reintroduction of macropods (Marsupalia: Macropodoidea) in Australia - a review. *Biological Conservation, 62*, 189-204.

Tran, T., Langford, L. (2015). Negotiating the shared management of Matuwa and Kurrara Kurrara. Canberra: Australian Institute of Aboriginal and Torres Strait Islander Studies.

Twigg, L., & King, D. (1991). The impact of fluoroacetate-bearing vegetation on native Australian fauna: A review. *Oikos, 61*, 412-430.

Twigg, L., King, D., & Mead, R. (1990). Tolerance to fluoroacetate of populations of *Isoodon* and *Macrotis* and its implications for fauna management. In J. Seebeck, P. Brown, R. Wallis, & C. Kemper (Eds.), *Bandicoots and bilbies* (pp. 185-192). Sydney: Surrey Beatty and Sons.