Project Plan SP 2012-024

Rangelands restoration: reintroduction of native mammals to Matuwa (Lorna Glen)

Animal Science

Project Core Team

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Approved and active

Document endorsements and approvals as of Feb. 26, 2020, 12:33 p.m.

Project Team	granted
Program Leader	granted
Directorate	granted
Biometrician	required
Herbarium Curator	not required
Animal Ethics Committee	not required

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Biodiversity and Conservation Science Program

Animal Science

Departmental Service

Service 6: Conserving Habitats, Species and Communities

Project Staff

Role	Person	Time allocation (FTE)
Supervising Scientist	Cheryl Lohr	0.0
Research Scientist	Keith Morris	None
Technical Officer	Mark Blythman	0.8

Related Science Projects

6.1 Barrow Island Threatened and Priority Fauna Species Translocation Program (in Prep) 6.2 Developing sustainable management systems for the conservation of biodiversity at the landscape scale in the Gibson Desert and Gascoyne Bioregions. (#2003/004) 6.3 The role of soil disturbance by native fauna in the restoration of Western Australia's rangelands'. SPP# TBA

Proposed period of the project

Jan. 1, 2007 – June 30, 2023

Relevance and Outcomes

Background

Lorna Glen, 244 000 ha, is located 1100 kilometres north east of Perth, in the rangelands of Western Australia. It lies across the boundary of the Gascoyne and Murchison IBRA regions. It was established as a pastoral lease in the 1930s, and stocked at various times with sheep and cattle, until 2000 when it was purchased by the Western Australian Government for addition to the conservation estate. Earaheedy, the pastoral lease to the north east of Lorna Glen was also purchased by the Western Australian Government, in 1999. Both areas are currently Unallocated Crown Land and managed by the Department of Environment and Conservation (DEC) in partnership with the traditional owners. The area now comprising Lorna Glen 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). Mammal translocations to Lorna Glen are part of the first integrated ecological restoration of a rangeland property in Western Australia. Potentially Lorna Glen could support one of the most diverse mammal assemblages in arid Australia, and contribute significantly to the long-term conservation of several threatened species. 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. During the process of translocation, and once populations are established, there is considerable potential for students and other researchers to study arid zone mammal biology and ecology and related issues. Mammal fauna A biological survey targeting small vertebrates was commenced on Lorna Glen in June 2003 (Cowan 2004), the aim of which was to determine the diversity and relative abundance of small mammals and reptiles on Lorna Glen, and to relate this to the optimum feral cat baiting period. A list of historic mammal records for the area within 200 kilometres of Lorna Glen has also been compiled, and a sub-fossil survey of Lorna Glen and parts of Earaheedy was undertaken in August 2006, to provide an insight into the mammal fauna of the area just prior to European settlement, (Baynes 2006). At least 36 species of non-volant mammal species occur, or once occurred, on Lorna Glen. (Baynes 2006, Morris et al. 2007, Cowan 2004). Of these 13 (three species of native rodent, six species of small dasyurid, two large macropods and the echidna) (36%) are still extant, 6 (17%) possibly still occur, but have not been recorded during recent biological surveys. Another 17 species of non-volant mammals probably occurred on Lorna Glen in historic times and of these 12 (33%) species are locally extinct, and 5 (14%) species are totally extinct (mainly medium-sized mammals). Introduced fauna control and fire management. Domestic cattle were removed from Lorna Glen after it was acquired by the WA Government in 2000. All artificial watering points (bores, dams) were closed off soon after. Cattle from adjacent pastoral leases did periodically wander into the property. However the completion of a cattle proof boundary fence around Lorna Glen in 2011 has now stopped this. The fence and culling program have also significantly reduced the numbers of feral camels on Lorna Glen. Feral goats are occasionally recorded in the north of Lorna Glen. Regular aerial and ground monitoring of camels, cattle and goats are undertaken to assess the effectiveness of management, and direct ongoing control programs. Rabbits occur on Lorna Glen at low densities and no control has been undertaken to date. Feral cat baiting has been undertaken since July 2003, and this has been successful at significantly reducing fox and feral cat abundance. Between 2003 – 2006 feral cats had been reduced from about 30 cats per 100 km to less than 5-10 cats per 100 km. Baiting was extended to 5km beyond the boundary of the property in 2011 to increase the baited buffer and provide better management of predators on the property. Aerial baiting and strategic trapping at Lorna Glen has maintained feral cat activity at approximately 7-11 cats per 100km for much of the subsequent period (a reduction of approximately 75% over pre control levels). Foxes are rarely detected. Wild dogs are also present and are controlled to some extent by the cat baiting program; A fire management plan has been prepared for Lorna Glen / Earaheedy (Muller 2006) and prescribes a series of strategically placed small patch burns aimed at reducing the spread of wildfires and promoting a range of age class vegetation which protect physical and cultural assets, as well as promoting biodiversity and protecting translocation and research sites in the future. This has been in practice since 2006. Mammal translocation program All species listed as locally extinct at Lorna Glen occur elsewhere in WA and could be reintroduced. It is proposed that 12 species be reintroduced to Lorna Glen over a ten to twelve year period (2007 – 2019), with one to two species being reintroduced in most years. The source of founders and the timing of reintroductions is dependent on the availability and status of suitable populations, which could include extant wild, stable translocated, and fenced breeding populations. A number of species (bilby, boodie, mala, western barred bandicoot, Shark Bay mouse, pale field rat, numbat and chuditch) may need to be bred in captivity, either at DEC facilities (Peron or RTD), or at Perth Zoo. The first translocation (bilby) occurred in August 2007, followed by brush tailed possum and mala in 2008. As an adaptive management response to the failure of some of these translocations, a feral predator free, fenced exclosure of 1100ha was constructed in 2009/10. It's aim is to facilitate a modification of translocation strategy for some species where various hypotheses proposing an acclimatisation period, and/or release of F2 generations to improve success, will be tested. Releases of boodie and golden bandicoot into the 'exclosure' occurred in 2010, and their populations have rapidly increased in the absence of feral predators. An expansion is proposed to provide sufficient size to accommodate larger populations of some species for a longer period. A generic set of guidelines has been developed at the start of the project to broadly plan the translocation of each species. However these have and will, be modified to suit the species' specific ecology, life history, behaviour, predator awareness and ability of the source population to support removal of animals. Literature review: Reviews of translocation outcomes across the world over the last 20 years (Short et al. 1992; Griffith et al 1996; Fisher and Lindenmayer, 2000; Short, 2009; Sheean, et al 2012; Perez et.al. 2012) indicate that a significant proportion, have resulted in failure, and there is often uncertainty as to the cause or causes of this. This lack of success, and inability to identify important causes of failure (or success) is usually attributed to deficiencies in one of 2 areas; 1) a lack of strategic design in the planning of the translocation programs with a paucity of testable hypotheses and a failure to clearly identify criteria for success (Armstrong and Seddon, 2007; Seddon et al. 2007;); and/or 2) a failure to adequately monitor and measure success criteria, which may be due to one or a combination of either, a) the difficulties associated with trying to collect and statistically analyse data from small, cryptic, and elusive populations, and b) a failure to adequately commit resources to continue long term monitoring of the reintroduced population (often monitoring is severely curtailed or ceased after a relatively short period (1-3 yrs). 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). 1) There has always been an inherent tension in the dichotomy that exists between the 2 purposes of threatened species management and reintroduction science. Achieving management goals necessitates selecting, what is believed to be the best techniques and 'treatments' that will provide the greatest likelihood of achieving successful conservation goals (i.e. long term establishment and persistence of the reintroduced population) drawing on all sources of prior knowledge and experience. The goal of research (prioritising the scientific method that uses a control and 'treatment' hypothesis testing, experimental design, in order to maximise learning and identification of the critical variables that produce success or failure), risks 'wilfully sacrificing' very valuable individuals of a threatened species in the process of pursuing (frequentist) statistical rigour. Scientific, conservation and ethical considerations, demand finding a balance between these competing needs. Clear development of success criteria and testable hypotheses, inclusion of adaptive management feedback processes, and Bayesian and modelling approaches to design and evaluation of projects can help to find this balance (Ewan et.al. 2004; Sheean et.al. 2012). 2) Failure of monitoring and analysis. a. New techniques such as non-invasive genetic sampling and analysis, GPS satellite and RFID telemetry, IR camera trapping, are providing promising possibilities for additional tools which can assist in sampling elusive and rare species (Janecka et. al, 2011; Sugimoto et.al, 2012; Meek et.al, 2012; Roon et.al, 2005; Dyo et.al, 2009; Thomas et.al. 2011). In addition, recent work using non-parametric statistics such as Bayesian inference, Monte Carlo analysis and modelling approaches, are now providing tools that can more usefully analyse the type of limited data sets that are usually obtainable from the rare, small and elusive populations commonly produced in conservation and reintroduction biology. These new approaches can incorporate the wealth of previous and related experiments or specialist 'experience' (expert knowledge) that often informs the design of the translocation protocols/experiment, into models which are then interrogated and refined with each new set of data that becomes available. (Wade, 2000; Gotelli and Ellison, 2004; Ewen et al, 2012) b. Failure to commit sufficient resources to continue monitoring at appropriate intensity and long term ecologically significant time frames, is often a political and economic issue that needs to be addressed at the start of any program, but it has been identified again and again (Armstrong and Seddon, 2007; Sheean et.al. 2012) as a significant factor that contributes to failure of a translocation program on both fronts (Management and Research); i. Insufficient or inappropriate monitoring prevents early identification of changing parameters, which would alert the manager/researcher to declines in a timely fashion. This deficiency precludes any opportunity for active intervention that could reverse the decline and prevent extinction and failure of the translocation itself (monitoring as an essential part of adaptive management). ii. Inadequate monitoring results in an inability to learn anything useful (even in hindsight) regarding the critical variables that lead to the failure (or success) of the translocation, due to a lack of information and insufficient data collection during the critical period (monitoring to provide data for scientific analysis and ecological understanding).

Aims

1. To restore ecosystem health and function to the arid rangeland at the Proposed Lorna Glen Conservation Park, through reduction of impacts of feral / introduced animals and restoration of ecosystem services provided by reintroduced and extant native species.

2. To trial and improve the success of translocation techniques and strategies for CWR fauna in the arid rangelands. Utilizing experimental hypothesis testing where possible, but given the constraints of threatened species conservation, where an experimental approach may not be acceptable or practical, then using modelling approaches to better understand factors affecting success, and maximising effectiveness of evaluation and learning through ensuring translocations are carried out in an active/passive adaptive management framework.

2.1. This may include; disease risk analysis, genetic analysis, behavioural assessment [+/- behavioural modification], habitat quality analysis, PVA analysis, novel predator management techniques.

3. To develop and improve new monitoring and survey technologies, to improve efficiency and effectiveness of protocols for sample collection and data analysis, and monitoring immediate, medium and long term fate of translocations of these species in the arid rangelands environment.

3.1. This may include use of; standard cage trapping and individual animal measurement and health analysis, GPS telemetry, RFID reader station technologies, remote IR camera occupancy and presence/absence surveys, DNA analysis.

4. To develop and utilise methods of measuring and monitoring ecosystem function and habitat quality in the arid rangelands.

4.1. This may include; vegetation cover, structure, connectivity and composition, utilizing line transects and canopy software to calculate % cover and spatial analysis; assessment of productivity using soil nutrient analysis.

Expected outcome

a) Improved health and function of this arid ecosystem.
b) Improved security of several threatened fauna species and contributions to improvement of overall conservation status.
c) Improved translocation techniques that will be transferable to other translocation programs within DEC and other Government and NGO's, and assist in increasing likelihood of success in future programs.
d) Increased knowledge of species requirements, interactions and contributions to ecosystem functions in arid environments.

Knowledge transfer

a) Internal and external wildlife conservation managers
b) Community and industry conservation organisations.
c) Other researchers/students (e.g. University and independent research institutes)
d) Internal DEC Science Information Sheets,
e) Peer reviewed publications, and conference papers/posters.
f) Contributions to other documents/processes eg. DEC Long term Translocation prioritisation strategy, revision of DEC guideline No. 29, on translocations, and relevant SOP's.

Tasks and Milestones

Major Tasks
Milestones
Outputs
1.Feral Predator Control
1. Fox and feral cat initial control (trapping, baiting, shooting) (2004).
1. Reduction of feral cat and fox numbers and easing of terrestrial predation pressure within the reserve.
2. Feral herbivore control
1. Removal of cattle (2012)
2. Removal of large feral herbivores (camels, horses, donkeys) (2012)
3. Construction of large herbivore fence around entire reserve. (2011)
1. Removal and exclusion of large herbivores from the reserve and significant reduction of grazing pressure and structural damage on the ecosystems.
3. Feral predator proof fenced enclosure constructed (+ expansion)
1. Consult with Traditional owners and obtain permits for clearing and construction (2009).
2. Construction of fence (2010).
1. Establishment of a protected and secure population of several highly predator-sensitive species in the arid rangelands.
4. Fire management plan developed
1. Fire Management plan implemented.
1. Protection of valuable, infrastructure, habitat and populations of reintroduced species.
5.Reintoduction of various spp
1. Reintroduction of various species into feral predator protected exclosure (2010-)
2. Reintroduction of species into wider reserve area (outside feral predator exclosure) (2007-)
1. Translocation Proposals and AEC's prepared for each species.
2. Annual reports on fauna translocations
3. Technical reports and/or Scientific papers on new translocation strategies/techniques.
6. Monitor establishment, persistence and dispersal, of reintroduced fauna in this landscape, and document change in presence and functioning of ecosystem services.
1. Confirmation of establishment and persistence of healthy, self-sustaining populations of reintroduced fauna on the reserve.

2. Collection of critical population and ecosystem parameters that will be used as criteria to inform and direct ongoing management actions.
3. Document first appearance and occupancy of species in new locations across reserve.
4. Documentation of effects of presence of reintroduced species on ecosystem services and health (E.g. effects of digging on soil structure, nutrients, water dynamics, seed dispersal and floristics; effects of grazing and browsing on vegetation).
1. Establishment of monitoring protocols.
2. Data base development
3. Annual progress reports.
4. Publication of Technical and Scientific papers on Translocations, and species ecology at this site.
5. Protocols for future translocations.
6. Development of PVA's for various spp.
7. Development of knowledge regarding impacts of species' reintroductions on ecosystem services.
7.Investigate
1. Murdoch – PhD study looking at effects of disease/parasites and source populations on success of translocations (2010-13).
2. Possible additional investigations into potential of behavioural modification/training and effects on translocation success.
3. Possible additional investigations into feasibility of novel strategies to increase success of translocations (e.g. use of guardian spp).
4. Possible additional investigations into effects of habitat quality/characteristics (3 dimensional physical structure and spatial distribution of resources and refuges, as well as species structure), on translocation success.
1. PhD Thesis
2. Journal publication
3. Publication of Technical and Scientific papers on Translocations
8. Link with other stakeholders for additional research/management and engagement opportunities.
1. UWA – Honours study on effects of different levels of predator control on mulgara (2012).
2. UWA - PhD study looking at effects of individual behavior on translocation success (2013).
3. Additional studies on mesopredator interactions and effects of management activities on these relationships (2013-).
4. Possible additional investigations into effects of mesopredator interactions on translocation success.
1. Various Theses and possible journal publications.
9. Communicate outcomes of reintroductions and associated research.
1. Annual and regular verbal and written reporting.
2. Communication in internal and scientific literature
1. Dissemination of knowledge and experience gained to the wider conservation management and research communities.
2. Provide direct guidance and advice to DEC regional conservation management activities for this reserve and other rangeland ecosystem and translocation programs.
3. Information sheets and interaction with volunteer and tourist communities.

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Study design

Methodology

This Project encompasses a large scope of extremely varied, smaller investigations and programs over a long period of time, which will include some with an experimental structure, and genetic analyses, but most will be more survey or reconnaissance oriented. As such, it is not possible to detail all the specific methodology and appropriate statistical analyses which will be developed and utilised for each individual stage/component. The specific structure of survey/study design and analysis will often depend on the responses of the translocated species and the results of previous surveys and project components. The Project will develop over time and the knowledge and application of suitable methodologies and statistical analyses will also develop and change, in response to both direct results/outcomes of earlier stages of this Project, and to broader improvements in the general theory and application of reintroduction biology and ecological statistics. This is the basis of utilizing an adaptive management style approach.

Details relating to some specific project components are shown below;

TRANSLOCATIONS

A generic set of guidelines was developed at the start of the project to broadly plan the translocation of each species. Translocation Proposals approved by the Director of Nature Conservation have also been prepared.

The generic starting guidelines included:

- Translocations for each species to occur over two years (assuming translocation in first year is successful) i.e. initial release in year 1 followed by restocking in year 2.
- Translocations to occur in May and August.
- At least 40 founders per year (20 males, 20 females) will be translocated, at the same time.
- At least 20 of these to be intensively monitored via radio tracking.
- Monitoring would include an initial intensive eight week period immediately after release, followed by two week monitoring periods of radio-tagged animals every 6-8 weeks for at least the next 1-2 years after each release.
- Additional monitoring of non-radio-tagged animals through trapping would occur at least every 6 months after this time and be restricted to cooler months between March/April and September/October each year.
- Releases will be “hard” releases where possible, but some releases may involve a two stage process whereby a ‘soft release’ or predator-free acclimatisation pen is used to allow species to adjust to new habitats and food sources, and increase population size prior to a second stage release into the wider property.
- Source populations will also be monitored.

NB: However these have and will, be modified to suit the species’ specific ecology, life history, behaviour, predator awareness and ability of the source population to support removal of animals.

Reintroductions of locally extinct threatened mammal fauna (Bettongia lesueur, Isoodon auratus barrowensis, Macrotis lagotis, Trichosuris vulpecula, Lagorchestes hirsutus, Pseudomys fieldi,) 2007 to 2011/2012 and future (Phascogale calura, Dasyurus geoffroii, Perameles bougainville, Sminthopsis psammophila, Myrmecobius fasciatus, Petrogale lateralis, Rattus tunneyi) will utilise the following approach:

- Using proven techniques (considering factors such as, disease, genetics, small population dynamics, animal behaviour, habitat quality, predator management), and improving techniques of reintroduction for specific species in this habitat through an active adaptive management approach.
- Monitoring the different phases of reintroductions, i.e. 1) short term [1-6mths] (early survival and dispersal); 2) medium [6mths – 2 yrs] (recruitment, population increase and dispersal), and 3) long term [2 – 20yrs] (continued population increase and dispersal, population stabilisation, establishment and persistence).
- Use of current well-proven monitoring techniques (radio-telemetry, cage trapping, spotlight monitoring, monitoring tracks and signs, habitat analysis), in combination with trialling and assessing appropriateness of new and emerging technologies that may prove better suited for rare, elusive and cryptic species. This may include; satellite telemetry, camera trapping, RFID ‘trapping’, individual identification and movement, and population demographics from non-invasive genetic analysis [hair/scat]; remote sensing technology [LIDAR].

o Statistical analysis will involve appropriate use of packages and approaches suitable to the type of data able to be collected. Some data sampling will be of the capture-mark-recapture format, and will be able to be analysed using traditional parametric ANOVA techniques. Data that is not able to be collected in a CMR framework to provide abundance measures, will still be able to provide information on other species parameters such as population demographics, activity indices, presence/absence and occupancy. Much of the data collected during the monitoring of translocations will reflect the characteristics of complex and variable ecological processes, adaptive management practices, small populations, and rare or elusive threatened fauna species which may violate the assumptions integral to application of the parametric analysis (random, independent sampling, and known distribution), and likely will require use of alternate approaches (Bayesian inference, Monte Carlo analysis).

o Appropriate software packages for statistical analysis will include; programs ‘MARK’, ‘R’, ‘Presence’

o Use of adaptive sampling designs which suit the population characteristics of the species and the ecosystem (e.g. Adaptive cluster sampling, two-stage or stratified sampling are generally more suited to different types, sparse, clustered, rare and/or elusive populations, than traditional random sampling techniques)

o Spatial analysis software for GIS mapping, triangulation and home range analysis (eg. ArcGIS, Ranges8, LocateIII, oziexplorer)

o Data management software used will include Access, CameraBase, and Cybertracker.

Translocation methodological approach.

1) Passive Adaptive Management (AM) – using expert knowledge and experience of target and related species, and other translocation practices to select and apply the techniques, which are expected to provide the highest probability of success for each species. Subsequent monitoring of clearly identified criteria of success, and based on analyses of these results, then inform decisions to continue with first strategy or modify techniques to increase the likelihood of success in future (Bayesian analysis and modelling).

2) Active AM – Test specific hypotheses during translocation process in an experimental fashion. For example:

i) H1. Parasite load reduces survival of individuals during and after translocation into a feral predator-free environment. (collect samples of ecto-parasites and blood born parasites, at time of translocation and subsequently at regular intervals post-release, to determine if subsequent survival, individual health and reproductive performance is influenced by initial parasite loads and treatment or non-treatment (control) of individuals to reduce parasite loads at time of translocation)?

ii) H2. Complete removal of feral predation threats through release into feral predator proof exclosure, will provide maximum survival, reproduction, recruitment and population growth?

Species monitoring programs

1) Reintroductions (e.g. bilby, brushtail possum, mala) directly translocated into wider LG area under aerial predator baiting regimes.

- Short term survival monitored using radio or satellite telemetry carried out on > 50% of original release animals.
- Medium term survival, reproduction and recruitment, individual condition and habitat use monitored using telemetry, standard systematic transect trapping within release area, and reproductive and morphometric measurements taken of individuals.
- Long term monitoring to track population establishment and dispersal, involving
  - o standardized track based surveys of signs (bilby, possum, golden bandicoot, boodie)
  - o horse back based transect surveys of bilby activity and sign (burrows, diggings, tracks) off main vehicle track system in standard quadrat areas.
  - o Monitoring of release sites and potential habitats for signs of habitation (possum scats, claw marks around potential refuge habitat locations), and follow up with camera and cage trapping to determine population size, demographics and trends (multi-stage sampling).
  - o Opportunistic records of signs across property, collected by all operations personnel during works.
  - o Non-invasive genetic sampling (population sizes, demographics, distribution)
- Many of these techniques will be unlikely to be able to provide strict abundance estimates, but can, with additional validation trials, give valuable population indices, and provide useful spatial and temporal trends in presence/absence and occupancy across locations and habitats.

2) Reintroductions (boodie, golden bandicoot, Shark Bay mouse, mala) translocated into predator free enclosure.

- Short term survival monitored using radio or satellite telemetry carried out on a pptn of original release animals.
- Medium term survival, reproduction, recruitment, individual condition,
  - o radio and satellite telemetry to investigate home range sizes and habitat use (comparisons between sex and source populations).
  - o standard systematic transect trapping, and CMR to provide abundance estimates
  - o Haematological sampling and genetic analysis to investigate influence of disease/parasites on survival and reproduction.
- Long term monitoring to track population establishment and persistence, and adaptation to new environment, involving;
  - o Systematic trapping and CMR study providing abundance trends over time and investigation of density-dependence (or independence) on population demographics and parameters.
  - o Genetic analysis to investigate hybridisation of different source populations in boodies.
  - o Morphometric sampling of individuals to investigate apparent release of 'island effect' on size in golden bandicoots.

Other species monitoring programs will be developed using similar techniques and approaches, and tailored to suit the specific behaviour, ecology, population size and habitat selection.

Habitat/Ecosystem monitoring programs.

- Examining the role of reintroduced mammals on soil health and plant productivity and to determine their contribution to ecosystem restoration.

o Characterising digging morphology and soil displacement using physical and photogrammetric models to provide details of size and shape of burrows and diggings of various spp. Estimated volume displaced will be extrapolated to calculate tonnes/ha excavated and comparisons between spp and habitats. Stats: multi-way ANOVAS, multivariate modeling, canonical plots and surface profiling.
o Use of 'button' recording devices to measure microclimate characteristics of diggings, such as temperature, humidity and wind speed, and comparing to nearby undisturbed ground. Stats: paired comparisons, repeated measures ANOVA, discriminant analysis
o Comparisons of soil penetration, chemistry and moisture between diggings, spoil and undisturbed ground using a soil penetrometer and laboratory analysis. Stats: repeated measures ANOVA, discriminant analysis.
o Spatial analysis of morphology, entries, trails, links and diggings on a boodie warren. Stats: spatial pattern analysis of proximity of digging to entries / warren; Indices of clustering, correlograms, point polygon analysis and point line analysis.
o Comparison on soil chemistry, rock content, moisture, infiltration and plant biomass and chemistry for cotton bush on and off boodie warren. Stats: paired comparisons, discriminant analysis.
o Comparison of invertebrate fauna trapped in bilby diggings and on undisturbed soil. Stats: species accumulation curves, comparison of diversity indices between the two treatments (Beta diversity).
o Radio tracking of sandalwood nuts to determine if caching occurs. If so, patterns of dispersal and information about caches will be collected e.g. number of nuts in cache, seedlings produced, soil parameters, proximity to adult sandalwood. Stats: frequency analysis of dispersal distances. Spatial analysis of cache sites in relation to other plants / habitat parameters.
o Comparison of soil and plant parameters for sandalwood trees visited (as indicated by trails) and not visited by fauna (outside the enclosure) and their hosts. Paired comparisons.
o Testing of techniques to measure soil erosion resulting from digging fauna in comparison with undisturbed soil. This would involve particle analysis of photographs of sticky traps used to capture airborne soil. Stats: Analysis of variance.
o Testing of photographic and laser mapping techniques to monitor changes in the morphology of diggings, warrens and spoil mounds over time. Stats: Repeated measures ANOVA.

- Habitat quality analysis at release sites and effect on success of translocations. Stats: Multi-variate ANOVA

o Measurement of patch size, % cover and connectivity of refugia (available software analysis of photographic imaging) – 'Canopy' and connectivity analysis software programs (eg Fragstat, Spring). Stats: ANOVA
o Analysis of soil chemistry (P, N, K), as a measure of soil quality and habitat productivity. Stats: ANOVA
o Habitat productivity (vegetative biomass, randomly selected 50m line transect measures, similar to those used for fire fuel load assessments).
o comparisons of mean vegetation cover, connectivity and height between habitat locations and potential release sites
o Invertebrate food analysis

- Effects of predator controls and climatic variability on highly responsive indicator fauna spp (eg native rodents, mulgara) –

o Mulgara - assessing comparative population size (using program MARK), condition, demographics and habitat use in different predator management regimes and temporal variations (using eliot trapping, morphometric and reproductive measurements, single-stage radiotransmitters to compare home ranges (kernels) between locations and treatments, using Locate2 and Ranges8. Stats: one way and two-way ANOVA, repeated measure ANOVA, multivariate principal component analysis.
o Comparison of track activity indices between different feral control treatments.

- Assessment of meso-predator interactions and activity between different feral control treatments. This will be run by a PhD candidate and starting in 2013/14.

Biometrician's Endorsement

required

Data management

No. specimens

None planned, but if questions arise regarding identification of species or subspecies, then voucher specimens (whole and/or tissue) will be collected in an effort to determine taxonomy or confirm identity of new species collected.

Herbarium Curator's Endorsement

not required

Animal Ethics Committee's Endorsement

not required

Data management

Development of Excel and MS Access data bases. Appropriate photographic databases being investigated include 'CameraBase'. Data will be stored on laptop computer, with backups on Woodvale server and external hard drives, monthly.

Budget

Consolidated Funds

Source	Year 1	Year 2	Year 3
FTE Scientist			
FTE Technical			
Equipment			
Vehicle			
Travel			
Other			
Total			

External Funds

Source	Year 1	Year 2	Year 3
Salaries, Wages, OVertime			
Overheads			
Equipment			
Vehicle			
Travel			
Other			
Total			