Woylie Conservation and Research Project: Progress Report 2010–2013

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Department of Parks and Wildlife

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State Natural Resource Management

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Cover image: Juvenile woylie in the hand, photo by Sabrina Trocini

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The principal collaborating organizations have included, Warren Catchments Council, Murdoch University, Perth Zoo, Australian Wildlife Conservancy, South Australian Government Department of Environment and Heritage, University of Western Australia, Kanyana Wildlife Rehabilitation Centre, Whiteman Park, and University of Adelaide. Wildlife rehabilitators have looked after orphaned young including Leslie Harrison and Maroo Wildlife Refuge. This project has also been conducted with extensive collaboration and support from within the agency, including staff from Science and Conservation Division and Regional and Fire Management Services Division (for example Southwest, Swan, Warren, and Wheatbelt Regions), and with general support from the Woylie Recovery Team.

This work has been covered by numerous animal ethics approvals including but not limited to DPaW approvals 2006/08, 2009/52, 2012/57; 2010/36; 2012/27; 2009/36, 2012/42 and the associated requisite permits including the Animal Welfare Act (2002) permit (Licence U10/2012-2015), Wildlife Conservation Act (1950) Regulation 17 (SC001303), and Poisons Act (1964) permit (7811). The DPaW Science Project Proposal Approval for this program is SPP 2007-002.

Summary

The woylie or brush-tailed bettong (*Bettongia penicillata*) is critically endangered having declined by 90% in seven years (1999–2006) from a peak of about 200,000 individuals. This is a progress report summarising the management and research activities associated with woylie conservation in the Upper Warren region in southwest Western Australia, where the largest woylie populations remain. This work was principally funded by Western Australian Natural Resource Management Programs (BCI and WANRM), a Caring for Our Country federal grant (CFOC), the Western Australian Government Department of Parks and Wildlife (DPaW, formerly DEC), Perth Zoo, South West Catchments Council, Wildlife Conservation Action, Australian Academy of Science, South Coast NRM and the Environment Division of the United Nations Association of Australia (WA) Incorporated. Collaborations and partnerships with other organisations have been critical to the successes of these endeavours. These have included Warren Catchments Council, Murdoch University, Perth Zoo, Australian Wildlife Conservancy, South Australian Government Department of Environment and Heritage, University of Western Australia, Kanyana Wildlife Rehabilitation Centre, Whiteman Park, and University of Adelaide. Wildlife rehabilitators have looked after orphaned young including Leslie Harrison and Maroo Wildlife Refuge.

This report provides an update from earlier progress reports (DEC 2008a; Wayne *et al.* 2011), documenting the Woylie Conservation Research Project’s (WCRP) major priorities and activities in relation to woylie conservation based in the Upper Warren region, 2010–2013. It provides an outline of the activities and preliminary results only. More comprehensive analyses and consideration of the results will be forthcoming, and published as appropriate across a range of media including scientific papers, management documents and communiqués with the public and community groups. The material presented here should therefore be considered as preliminary and indicative only and potentially subject to change in response to further validation and development.

Organised into two chapters, the first provides background regarding the species and woylie conservation and research activities since 2006. It provides a contextual overview including outlines for the externally funded WANRM and CFoC funded projects. The second chapter, the main focus of the report, provides an account on the following;

I. Introduced predator control and monitoring
II. Perup Sanctuary—establishment and progress of a woylie insurance population
III. Woylie conservation—translocations, monitoring and research
IV. Community participation and education, and
V. Evaluation of woylie conservation actions

I) Introduced predator control and monitoring

Government agencies responsible for natural resource management and conservation began fox-baiting programs in the Perup in 1977. Since then it has been progressively improved and expanded to include most of the DPaW-managed estate within the Upper Warren region, being distributed by a combination of aircraft and ground vehicles. The current frequency of fox baiting ranges from every three months for most of the region, to monthly for a core area within a 10 km radius of the Perup Sanctuary, to weekly for a core area of Yendicup within this, where woylies were translocated to in July 2013.

Landholders in the Upper Warren region were canvassed to promote interest in local native wildlife and in introduced vertebrate pest control. Project coordinators engaged with 34 landholders occupying in excess of 16,000 ha in the course of seeking support in a range of project-related activities. Information and training sessions were provided. Many landholders participated in several predator control activities on their freehold land, in coordination with predator control efforts on adjacent DPaW-managed land, either directly or by providing access for professional contractors to undertake the work.

Monitoring of introduced foxes and cats across the Upper Warren region, using arrays of sand pads, indicate that fox activity has increased substantially since 2006 and differs significantly between sites. Cat activity has been less variable over space and time and not related to fox activity. These results have important implications for the conservation and recovery of the woylie and other native species.

Improving the quantification of introduced predator activity

Introduced predator survey methods (sand pads and remote sensor cameras) were compared in the Upper Warren region in March 2012. Significant differences in the detection of target and native fauna was found between the two different camera models tested. The detection rates from the Reconyx camera model were roughly comparable to those on the sand pads or greater based on preliminary comparisons and within the constraints of the trial design. Some of the relative advantages of the cameras are discussed. Cameras also proved themselves a useful validation and training tool for species identification from prints on the sand pads.

Set up trials for remote sensor cameras conducted in July–August 2012 demonstrated that locating the cameras next to forest tracks detected significantly more foxes and cats than off-track. There was no significant difference in the detection rates between cameras using no attractants versus those using a smell (tuna oil) or sound (bird tweeter). This provided the basis for developing introduced predator monitoring protocols using remote sensor cameras in southern jarrah forest habitat.

A pilot trial of hair traps for DNA mark recapture of foxes and cats was conducted in August 2012. Based on the results, hair traps were not subsequently deployed as an introduced predator monitoring method as part of this project.

Two replicate trials were conducted in the Upper Warren region (September 2012–March 2013) to quantify the density of introduced predators and calibrate the results from survey methods (sand pads and remote sensor cameras). A coordinated targeted removal of introduced predators by professionals on DPaW-managed lands and professionals and landholders on adjacent private properties resulted in trapping or shooting of 9 foxes and 3 cats. Within the core surveillance zone (3 km radius, 2,800 ha) at Balban at least 5–6 different adult cats, 2 kittens and 7 fox individuals were identified. At Boyicup at least 6–7 different adult cats, 3 kittens, and 4 fox individuals were identified. Future analyses will derive predator density estimates and investigate the accuracy and precision of camera and sand pad survey methods used to monitor introduced predators.

The analysis of contents of the gastro-intestinal tracts of 15 foxes and six cats from the native forests and adjacent agricultural lands in and around the Balban and Boyicup areas of the Tone-Perup ‘A’ class Nature Reserve indicate that stock and introduced rodents associated with the agricultural areas represent a significant proportion of their diets. Native animals (koomal (or common brushtail possum *Trichosurus vulpecula hypoleucus*), birds, frogs, reptiles and invertebrates) also constitute a significant proportion of the diet. The parasites found in these cats (*Toxocara cati, Taenia taeniaeformis, Spirometra erinaceieuropaei, Oncicola canis and Cyathospirura dasyuridis*) are known to be potential issues to humans, stock, wildlife and their hosts but their significance in the Upper Warren region remains to be determined. Analyses of samples from these foxes and cats are ongoing as part of larger collaborative projects with experts at Murdoch University.

II) Perup Sanctuary

The Perup Sanctuary was constructed January–September 2010 based on a design to maximise the ongoing prospects of maintaining the predator-free status of the facility and to minimise the ongoing costs of maintenance and repair. All emus and chuditch, most western grey kangaroos and western brush wallabies and 43 koomal were removed September–October 2010. The sanctuary was confirmed free of foxes and cats in October 2010. Monitoring for predator incursion using a range of methods remains ongoing, as does the monitoring and management of rabbits, weeds and indicators of forest health such as wandoo decline and dieback. Planned guidelines for the management of the Perup Sanctuary will also include fire.

Surveys including vegetation plots, pitfall traps, cage traps, spotlighting, nest boxes and remote sensor cameras indicate that at least 13 mammal, 66 bird species, 19 reptile, 10 frog species and 164 vascular plant species are found in and immediately adjacent to Perup Sanctuary. The sanctuary provides refuge for many of these species that are also vulnerable to introduced predators. Ongoing monitoring inside Perup Sanctuary, in conjunction with monitoring at comparative sites on the outside, will help to understand what other effects a predator-free enclosure may have on the plants, animals and ecosystems within. Significant differences exist in the plant and animal assemblages found in various different parts of the landscape/habitat types within the sanctuary.

III) Woylie conservation

Woylie translocations

A total of 41 (21 males, 20 females), 8 (4 males, 4 females) and 5 woylies (2 males, 3 females) were sourced from across the Upper Warren region and translocated to Perup Sanctuary, Native Animal Rescue facility (Malaga) and Perth Zoo captive colony, respectively, in November–December 2010. The survivorship of the woylies in the Perup Sanctuary in the first 12 months post translocation was substantially greater than comparable woylies in the wild populations of the Upper Warren region. Predation by foxes and cats were associated with most of the mortalities outside of the Perup Sanctuary, whereas no predation was observed inside the sanctuary.

A total of 87 woylies (51 males, 36 females) were translocated from Perup Sanctuary to nearby Yendicup in July 2013. The translocation area has been subject to weekly ground-based fox baiting since a week before the release of woylies into the area and will continue for at least 2–3 months. Monitoring using 50 remote sensor cameras within a 3 km radius of the centre of the release site remains ongoing. Follow up monitoring by trapping is planned at 3 and 9 months post release and at least annually thereafter.

A total of 36 woylies (23 males, 13 females) were translocated from Dryandra to Perup Sanctuary in July 2013. Monitoring in the sanctuary using remote sensor cameras and trapping will be ongoing. Lower than expected trapping rates at Dryandra merit revising abundance estimates for this important natural woylie population.

The first five independent offspring (3 males and 2 females) from the last remaining 6 woylies from Tutanning, being held at Kanyana Wildlife Rehabilitation Centre, were released into the Perup Sanctuary; two on 20th August 2013, 3 on 24th October 2013. Remote sensor cameras and trapping (October 2013 and March–April 2014) will continue to monitor their progress in Perup Sanctuary.

Woylie monitoring

Long-term and extensive monitoring of medium-sized native mammals in the Upper Warren region, using small cage traps, provides an unrivalled resource to conservation managers and researchers. Having declined by 95%, woylie numbers have remained low but relatively stable at the regional scale since 2005. Subregional patterns are also evident, including no signs of recovery in central Perup – including woylies remaining undetectable in Yackelup since 2005, potentially the beginnings of a modest recovery in southern Perup, later and more subdued declines and some recovery in northern Perup, and in Greater Kingston, where the declines first began, the first and only substantial recovery to date has not been sustained having undergone a secondary decline to new record lows. The monitoring provides some of the strongest evidence available for and against the possible causes of the woylie decline and limiters of recovery and represents an excellent resource to inform wildlife conservation managers in a timely manner of population changes and potential issues, and provides insights into the biology and ecology of several native mammal species.

Monitoring in the Perup Sanctuary by trapping has shown that at least 83% of the 41 original founders released by December 2010 were still alive in 2013. In April 2013, the trapping results conservatively indicate that the population had increased to more than 300. All adult female woylies captured have been breeding, some being sexually mature as small as 620 g. One female has been repeatedly observed with twin pouch young, which is extremely rare. While woylie numbers have grown strongly in the Perup Sanctuary, the capture rates of wild woylies at comparative sites in the Upper Warren region have remained very low.

Many collaborative activities have been linked with the on-ground woylie conservation actions in the Perup Sanctuary and Upper Warren region more broadly. The vast majority of these collaborations have been through student projects and experts at Murdoch University and Perth Zoo. Much of this work is focused on delivering a better understanding of the nature of the woylie declines, the possible causal factors of these declines and the ecology and biology of the woylie relevant to its conservation and in some cases native wildlife more broadly. A very brief outline of these activities and progress is reported here including; strategic planning and management of the possible role of disease in the recent woylie declines, woylie health and disease monitoring, pathology, trypanosomes, Toxoplasma, other parasite investigations, bacteria, viruses, genetics and population modelling, food resources and woylie diet, and ecological factors associated with the distribution and abundance of woylies.

IV) Community participation and education

Volunteer involvement has been a substantial and critical component to the successes of this project. The CFOC funded components of this project alone involved 159 individuals contributing an average 6.2 days each and a total of 984 days and 9889 volunteer hours, worth at least $250,000 of labour. These calculations do not include the involvement of Bush Cadets, primary and secondary school student experiences, landholder involvement in vertebrate pest animal control or volunteers assisting at public information display booths at events like local shows and festivals. Benefits to volunteers included being provided information regarding the conservation and management of woylies and other wildlife, they received training and inductions relevant to the tasks being undertaken, work experience with wildlife and research professionals, and they experienced and contributed to a diversity of activities including sand pad monitoring, spotlighting, trapping, woylie health and radiotelemetry monitoring, woylie translocations, baseline vegetation and small vertebrate surveys and data management.

A large amount of information material has been produced regarding woylie and wildlife conservation and recovery efforts. This includes scientific papers and reports, oral and poster presentations, popular articles, information brochures, web material, videos, newsletters, letters and information packs and interpretation panels along a ‘Woylie Walk’ trail at Perup: Nature’s Guesthouse. Over 187 articles relating to the woylie and this project have appeared in the public media including newspapers, radio, television and other print media.

The woylie and wildlife conservation issues and recovery efforts have been communicated to a broad spectrum of the public and community groups. Forums have included volunteer, student and work experience programs, visits to the facilities at ‘Perup: Nature’s Guesthouse’ and the development of an interpretation trail, the ‘Woylie Walk’ that links these facilities with the Perup Sanctuary. Audiences and participants have included school-aged children (for example Bush Rangers, Junior Landcare Group, class incursions/excursions), university students, volunteers of all ages from around Australia and internationally, local landholders and tourists.

A feasibility study, which was a component of the Caring for Our Country woylie conservation project, was conducted by a group of students from the third year Ecotourism unit at Murdoch University. They produced a document, ‘Strategic Destination Management Plan 2012–2016 — Perup: Nature’s Guesthouse’, which provided recommendations of strategies to address financial viability, marketing, facilities and services, education and interpretation and the introduction of further tourism activities. This paper is being reviewed internally by DPaW as part of the development of a business management plan for the Perup facilities.

V) Evaluation of woylie conservation actions

Perup Sanctuary

The Perup Sanctuary infrastructure has effectively excluded introduced predators since it was completed in October 2010. Storm damage from strong winds and rain has been minimal because of the design and construction. While ongoing maintenance is required, the initial investment is expected to be more cost effective in the longer run and provide greater security to the investment in the woylie insurance population. Best practice, informed by the best available information, was used to select candidates to establish the woylie colony in the Perup Sanctuary with the greatest available genetic diversity from the populations in the Upper Warren region. More recently, genetic augmentation from Dryandra stock and offspring from the last surviving animals from Tutanning will help make the Perup Sanctuary insurance colony representative of the genetic diversity across the species. The survivorship of the founders in the Perup Sanctuary has been excellent (at least 83% confirmed alive in 2013, only one confirmed death), all females are breeding and the population growth has been at it maximum potential, resulting in about a 1,000% increase from its original founder colony of 41 to about 400 individuals in mid-late 2013. The Perup Sanctuary is also delivering a conservation benefit to other vulnerable and threatened native species. Adequate monitoring has been and will continue to be an essential aspect of the ongoing management of the biodiversity assets in the Perup Sanctuary.

Fox control regimes in the Upper Warren region

In addition to the quarterly aerial and ground baiting regime applied to most of the DPaW-managed lands in the Upper Warren region, monthly ground baiting for foxes has been applied to a core area of Perup (~14,500 ha) as part of this project since October 2010. While monitoring has indicated that fox activity has substantially increased regionally since 2006, it is currently unclear as to whether the monthly baiting program has reduced fox densities. A preliminary look at the trends in woylie and chuditch capture rates are consistent with the monthly baiting in the core Perup area potentially resulting in a relative increase in abundances, however further testing is need to determine whether this is in fact the case.

Woylie species overview

The woylie is *Critically Endangered* having undergone 90% decline in the seven years from 1999. The remaining natural populations in the Upper Warren region and Dryandra remain critically important. The risk of local extinction of small populations remains high and likely for at least some of these without increased effective management. Priorities include maintaining the insurance population at Perup Sanctuary, verifying the status of the Dryandra population and undertaking translocations within a scientific framework to augment existing populations, possibly establish other insurance populations and stimulate recoveries in the wild. Confirming the causes of the decline and factors limiting recovery fundamentally remains the most effective and assured way of delivering the best possible conservation outcome for the species.

Other medium-sized mammals in the Upper Warren region

The Upper Warren region has long been recognised as one of the most important fauna conservation areas in southwest Western Australia. At least five mammal species (wambenger, dunnart, quenda, woylie, ngwayir) have declined substantially (75%–100%) within the last 20 years in the Upper Warren region. Koomal and chuditch have increased substantially (300–500%) since 2004. Population changes in these and other species, such as the numbat, require further investigation.

Future planning and priorities

A brief review is provided of the activities that will continue now that current external funding sources have concluded, what will not continue without securing new resources, opportunities for building on the achievements to date, and what management and research priorities there may be for the future. Top priorities include;

- The establishment and maintenance of insurance populations to conserve the extant genetics of species particularly at risk, including the woylie and ngwayir
- Effective management and monitoring of introduced predators in priority fauna conservation areas
- Adequate monitoring of woylies, other vulnerable and threatened native fauna and key covariates including animal resources, predators and disease, animal health, habitat and disturbance factors
- Completion of a woylie population management and translocation strategy
- Better quantify the population changes in sympatric species (for example wambenger, quenda, ngwayir, woylies, chuditch, koomal) and better understand what might be driving these changes across the southwest

- Incorporate scientific and experimental elements into management, conservation and recovery actions that directly help to inform effective management and help elucidate the causes of the recent population changes (for example effective active adaptive management)
- Synthesise and critically review the evidence to what extent predators and disease may be involved in the declines (and limitation to recovery) at key woylie populations

CHAPTER 1: OVERVIEW OF THE WOYLIE SITUATION AND EXTERNALLY FUNDED CONSERVATION PROJECTS

1 Background

1.1 Woylie decline overview

The woylie or brush-tailed bettong (*Bettongia penicillata*) is critically endangered having declined by 90% in seven years (1999–2006) from a peak of about 200,000 individuals (Wayne *et al.* 2013a). The declines have been substantial, rapid and unexpected. All four of the last remaining natural populations have been affected, one of which (Tutanning) is now considered extinct. The largest natural woylie populations (Perup and Kingston) are found in the Upper Warren region, east of Manjimup, and constituted about 85% of the species in 1999 but declined by 95% between 2002 and 2008 (Wayne *et al.* 2013a). The only other natural woylie population, at Dryandra woodland northwest of Narrogin, declined by 92% between 1999 and 2006. Albeit more subdued, the declines continue in some areas and so far there has been no sustained substantial recovery. The evidence to date indicates that the declines have been primarily driven by the predation by introduced predators of woylies thought to have become more vulnerable by some other factor, most probably disease (DEC 2008a, Wayne *et al.* 2011, 2013b).

1.2 Woylie conservation and research

The woylie conservation research project (WCRP) was established in 2006 and is a collaborative effort to identify the cause(s) of the declines, identify the management required to reverse these declines and to develop adequate mammal monitoring protocols that will enable future changes in population abundances to be quantified and explained (DEC 2008a). While the principal source of funds for the woylie conservation actions and research has remained the Department of Parks and Wildlife (DPaW; formerly Department of Environment and Conservation, DEC), other substantial contributions have been critical. Originally partially funded by the WA Biodiversity Conservation Initiative (BCI) ‘Saving Our Species’ program ($300,000 in 2006/07), other significant sources directly related to the project have included Western Australian Natural Resource Management (WANRM; $750,000 in 2009–2013), the Australian Government ‘Caring for Our Country’ program (CFOC; $408,500 in 2010–2013), Perth Zoo ($61,000 2008/09), South West Catchments Council ($12,000 in 2012–13), Wildlife Conservation Action (WCA; $10,500 in 2008–2010), South Coast NRM ($7,600 in 2008) and the Environment Division of the United Nations Association of Australia (WA) Incorporated ($3,500 in 2008). More than 350 volunteers have also contributed more than 16,000 hours (i.e. equivalent to >$400,000 value). Around $800,000 in kind and material costs have come from external partners such as Murdoch University, Perth Zoo, the wildlife disease project supported by the Australian Research Council ("The nature, diversity and potential impact of infectious agents in Western Australian threatened mammals", a MU and DEC collaboration), and other universities and institutions since 2006. There have been other funding sources for associated projects led by key collaborators and students including the Australian Academy of Sciences, and World Wildlife Fund (WWF), among others.

The principal collaborating organizations have included, Warren Catchments Council, Murdoch University, Perth Zoo, Australian Wildlife Conservancy, South Australian Government Department of Environment and Heritage, University of Western Australia, and University of Adelaide. The WCRP also became a collaborating partner with four other DPaW research projects (in association with the Invasive Animals CRC; 2006–2010) investigating the effectiveness of broadscale fox control and mesopredator release, principally of feral cats (Morris *et al.* in prep).

In response to the increased risks of extinction, an emergency conservation action program to establish an insurance population was initiated in 2009. Construction of the Perup Sanctuary (423 ha enclosure in part of Tone-Perup 'A' class Nature Reserve) was completed by September 2010. Having been confirmed free of terrestrial predators, 41 carefully selected woylies, representative of the genetic diversity across the Upper Warren region, were introduced to the Perup Sanctuary between October and December 2010. The total cost for this work was $1.5 million (2009–2011, including $0.5 million from WA NRM), plus at least a further $250,000 (2011-2013 from WA NRM) for further capital works.

The Caring for Our Country (CFOC) federal program funded a project led by Warren Catchments Council (WCC) entitled, 'Using well managed native habitat to rescue woylies from the brink of extinction' (November 2010–July 2013). The project was designed to securely manage native habitat to aid woylie survival, by removing predators adjoining the Perup Sanctuary; managing the integrity of the Sanctuary; monitoring the health and condition of the woylie to help determine the cause of population declines and to increase public awareness/participation.

Output from the WCRP has included, three scientific workshops, more than 20 papers published in scientific journals, more than 31 reports including two major progress summaries (DEC 2008*a*, Wayne *et al.* 2011), more than 50 presentations at national and international scientific conferences, more than 50 presentations at other forums (for example university lectures, seminars to scientific, public and interest groups, etc), 6 popular articles (for example *LANDSCOPE*), 3 fact sheets, a website, a YouTube video and a video training manual. (see Appendix A). Many more products will also be forthcoming including scientific papers currently in press, in review, submitted or in preparation. There have been 31 student projects associated with the WCRP, of which 16 are PhDs, one research Masters and eight are Honours theses. Twelve student projects are current (see Appendix B). More than 187 media articles have also been published since 2006 (see Appendix C).

While the WCRP has had an increasing focus on the woylie populations in the Upper Warren region, earlier work within the program (for example Population Comparison Study) also examined some aspects of other woylie populations, particularly Karakamia Wildlife Sanctuary in collaboration with AWC and to a lesser extent Batalling and Dryandra in collaboration with departmental colleagues working in these areas. Work continues in the other woylie populations under other research and monitoring programs, with which there is frequent communication and collaboration where appropriate.

1.3 National Recovery Team and Plan for the woylie

The Woylie Recovery Team was re-established in October 2008 and the National Recovery Plan for the woylie was formalized in 2012 (Yeatman and Groom 2012). The long-term objectives of the plan are to maintain first, then increase the current distribution and abundance by reducing the impacts of processes that are causing species decline and by establishing new wild populations in suitable habitat within the species former range.

Recovery actions within the recovery plan

1) Verify the causes of the decline and suppression of recovery and implement remedial action to address these.

2) Minimise predation by introduced foxes and cats at priority sites.

3) Maintain or improve the health, genetic diversity, relative value and viability of wild populations.

4) Maintain genetic diversity of the insurance captive populations at least at 2012 levels.

5) Maintain captive population sizes sufficient to act as source populations for future translocations.

6) Undertake targeted translocations as re-introductions (and as introductions where necessary) to achieve an enhanced conservation status for the species.

7) Inform and educate the community about, and involve the community in, the recovery actions required to conserve the woylie.

The activities and priorities of the WCRP are directly aligned to meeting the objectives and recovery actions outlined in the National Recovery Plan for the woylie.

2 Report scope

This report focuses on the progress achieved since the construction of Perup Sanctuary in late 2010 through to August 2013 at the completion of the translocation of woylies from Dryandra and Tutanning (now extinct in the wild) populations into the Perup Sanctuary. It builds on the work done previously and reported elsewhere (e.g. DEC 2008a, Wayne *et al.* 2011). In particular we report here on the activities principally funded by WANRM, CFOC and DPaW, which were integrated and complementary programs, the total value of which is much greater than the sum of the parts. An outline of the externally funded projects is provided. Then the structure of the report reflects the program's major priorities and activities in relation to woylie conservation based in the Upper Warren region, 2010–2013;

1. Introduced predator control and monitoring
2. Perup Sanctuary
3. Woylie conservation—translocations, monitoring and research
4. Community participation and education, and
5. Evaluation of woylie conservation actions

This is a progress report, outlining the activities and the preliminary results from recent work as part of the WCRP. More comprehensive analysis and consideration of the results will be forthcoming, and published as appropriate across a range of media including scientific papers, management documents and communiqués with the public and community groups by way of popular articles, fact sheets, news articles, talks and the like. The material presented here should therefore be considered as preliminary and indicative only and potentially subject to change in response to further validation and more thorough scrutiny.

3 Project outlines for externally funded programs

Three externally funded projects are summarised here before reporting on the combined achievements across the woylie conservation programs;

a) Emergency conservation action for the woylie (WANRM)
b) Targeted major recovery actions for the critically endangered woylie (WANRM)
c) Using well managed native habitat to rescue woylies from the brink of extinction (CFOC)

3.1 WA State NRM Project I: summary and aims

The project, 'Emergency conservation action for the woylie' was jointly funded by WANRM, DEC (now DPaW), and Perth Zoo, in collaboration with others. Announced in July 2009, the project operated December 2009 to December 2010. The principal purpose of the project was to establish a woylie insurance population by the construction of the Perup Sanctuary and support efforts to determine the causes of the recent woylie decline and factors limiting recovery.

Project objectives

- Establish a wild *in situ* insurance population within a predator-free enclosure.
- Demonstrate the effectiveness of the enclosure to facilitate and secure a robust woylie recovery
- Monitor population status/changes in the wild woylie populations inside and outside the enclosure
- Demonstrate the role of predators in limiting the recovery of woylie populations
- Support investigations into the role of disease in woylie decline and recovery
- Comparatively monitor other effects of the enclosure treatment (for example soil, flora and fauna)
- DEC will cooperate with AWC, Perth Zoo and others in the establishment of the secure Perup woylie population.

Project outcomes

- Construction of secure enclosure – 8 km fencing
- Remove introduced predators from within the enclosure
- Source and stock the enclosure with >40 woylies to establish a robust and healthy insurance population
- Demonstrate an increase in woylies within a predator-free environment.

- Establishment of a secure insurance population that is genetically healthy and adequately representative of the wild Perup population that is at risk of local extinction

Project milestones

- Preparatory administration and site works / site survey, environmental checks, tenders, construction and management plan, ground works (track upgrades, fence alignment clearing, drainage, hygiene plan), etc
- Infrastructure establishment—fence construction, monitoring infrastructure—sand pads and trapping grids/transects
- Removal of foxes and cats; relocation of chuditch, western grey kangaroos, western brush wallabies, and emus.
- Stock with woylies sourced from throughout Perup, minimum of 40 founders (>20 of each gender)
- Predator management—fence patrols and maintenance, routine predator monitoring and predator removal if required
- Woylie monitoring—comparative survivorship responses (radio telemetry) and population responses (quarterly trapping)

Monitoring and evaluation milestones

- Comparative predator and woylie/wildlife monitoring inside the enclosure (initially quarterly), biannually at key monitoring sites in the Upper Warren region (Keninup, Warrup) and at least annually at other monitoring sites (Balban, Yendicup, Moopinup, Yackelup, Camelar, Boyicup, and Winnejup)
- Woylie monitoring in the first 12 months to include comparative survivorship responses using radio telemetry of at least 20 woylies inside and outside the enclosure. Causes of death to be investigated using forensics and pathology
- Routine health checks and disease sampling (blood, faeces, ectoparasites) and clinical investigations as required
- Learning opportunities exist including vegetation (floristics, structure and DRF), fungi and litter responses to changing woylie densities (for example internal reference exclosures), and monitoring responses of other fauna (for example possums, wambenger, wedgetail eagles, etc)
- Consider value of the enclosure for achieving other conservation objectives, for example re-introduction of dalgyte and boodie, education, etc

3.2 WA State NRM Project II: summary and aims

The project, 'Targeted major recovery actions for the critically endangered woylie' was designed to build on and enhance the 2009–2011 State NRM investments in woylie recovery (principally the establishment of the Perup Sanctuary) and address key priorities identified in the National Recovery Plan for the Woylie

(Yeatman and Groom 2012). Project partners included DPaW (formerly DEC), Warren Catchments Council (WCC), Murdoch University, Department of Agriculture and Food (DAFWA), and Native Animal Rescue (NAR). This project ran between October 2011 and March 2013.

Project objectives

1) Reduce predation by foxes and cats in priority woylie populations
- increase fox-baiting frequency at already identified critical population sites
- implement increased feral cat control at above sites
- demonstrate effectiveness of increased efforts for adoption under DEC and neighbour ongoing fox and feral cat control programs

2) Increase the captive breeding capacity and better manage insurance populations to be self-sustaining
- manage a genetically robust captive population at participating ZAA facilities including Perth Zoo
- manage and monitor the woylie population within the 423 ha Perup Sanctuary (PS) established in 2010 with NRM funds

i.e. substantially deliver on the woylie recovery plan objective—begin the restoration of declined populations.

Project activities

- Upgrade the high-value captive insurance population and improved facilities for threatened species at Perth Zoo
- Final enhancement of the Perup Sanctuary (PS) facilities partly funded by State NRM, including additional electrical fencing to increase the security of the woylie population within and maintaining the predator-free status of the sanctuary
- Significantly reduced predation pressure by foxes and cats on already identified highest priority wild woylie populations to facilitate their recovery and that of other co-occurring threatened and conservation dependent species (for example wambenger or brush-tailed phascogale, ngwayir or western ringtail, numbat, quenda, chuditch).
- Demonstration of the effectiveness of increased predator control on reducing predators and increasing woylies for adoption in DEC and others continuing baiting/control programs
- Significantly increased numbers of woylies in key targeted populations and greatly enhanced capacity for captive breeding
- A communication program including frequent media releases and engagement with local communities to increase awareness and encourage participation in biodiversity conservation and threatened species recovery

3.3 CFOC Project summary and aims

The project, 'Using well managed native habitat to rescue woylies from the brink of extinction' was led by the Warren Catchments Council (WCC) in partnership with DPaW (formerly DEC), Perth Zoo and Friends of Perup. The project formally began on 17 November 2010 and on-ground activities were completed by 31 July 2013.

Project description

This project was designed to aid the survival of the woylie by removing predators that reside on the land within and adjoining the Perup Sanctuary; managing the integrity of the sanctuary; monitoring the health and condition of the woylies to help determine the cause of population decline; and by raising the public awareness of the issues faced by the endangered woylie and increasing active participation in integral activities.

Project targets

- To increase by 400 hectares by June 2013 the area of native habitat and vegetation that is managed to reduce critical threats to biodiversity and enhance the condition, connectivity and resilience of habitats and landscapes.
- Reduce the impact of vertebrate pest animals to maintain or improve biodiversity, aquatic ecosystem, World Heritage and sustainable practices outcomes.
  i) Perup Sanctuary—this will allow regeneration and recovery of at least 400 hectares of native habitat that supports critically endangered, endangered and threatened species and communities.
  ii) At least 5 private land managers (> 100 ha) adjacent to and/or near to the Tone-Perup Nature Reserve
- To increase the recruitment and retention of 200 volunteers in community groups involved in managing natural resources, over the next three years, in particular 50 youth.

Project activities

1a) Control Introduced Vertebrate Pests

- Develop and implement a plan for controlling introduced vertebrate pests within the 400 ha Perup Sanctuary.
- Engage with all local landholders adjoining the Perup Sanctuary to reduce the impact of introduced vertebrate pests using an integrated approach.

- Secure at least 5 landholders to agree to participate in introduced vertebrate pest control and continue their involvement.
- Develop and implement a plan for controlling introduced vertebrate pests control on private properties surrounding Perup Sanctuary.
- Monitor introduced vertebrate pests in and around Perup Sanctuary and conduct follow-up control as necessary.

1b) Manage native habitat

- Initiate and complete a baseline survey of Perup Sanctuary's fauna and vegetation.
- Report on baseline survey data of Perup Sanctuary's fauna and vegetation.
- Evaluate the change in condition of the fauna and vegetation of Perup Sanctuary compared with the baseline survey.

1c) Control of WoNS and invasive weeds

- Eradicate blackberry and bridal creeper and control other invasive weeds within the sanctuary.

1d) Translocation

- Negotiate to source woylies and facilitate their translocation to Perup Sanctuary.

1e) Monitoring woylie health and population

- Monitor the health and population of Woylies.

2a) Information

- Prepare, publish and distribute information material for use by schools, visitors, volunteers.

2b) Signage

- Design and erect interpretive signs at Perup Sanctuary.

2c) Volunteers

- Engage and train at least 200 volunteers to assist in project, 50 of who are youth (under 35 years).

2d) Feasibility Study

- Investigate the feasibility of ecotourism to offset future running costs of Perup Sanctuary.

CHAPTER 2:

WOYLIE CONSERVATION ACTIVITIES

4 Introduced Predators

4.1 Introduction

The introduced European red fox (*Vulpes vulpes*) and feral cat (*Felis catus*) have been linked to the extinction and reduction in the abundance and distribution of many species of Australian native fauna and remain common key threats to their ongoing conservation, particularly for species under 5.5 kg (e.g. Burbidge and McKenzie 1989; Short *et al.* 2005; Denny and Dickman 2010). Fox control, under programs such as *Western Shield*, has been successful in southwest Western Australia with the use of meat baits impregnated with 1080 (sodium monofluoroacetate)—a lethal poison to introduced species to which native fauna have varying degrees of a natural coevolved resistance (e.g. King *et al.* 1978, 1981, 1989; Orell 2004; Wyre 2004). The control of cats can be achieved but can be problematic over larger spatial and temporal scales and may be influenced by the environmental context (e.g. Burrows *et al.* 2003; Nogales *et al.* 2004). Monitoring introduced predators that adequately measure abundance or density is also challenging (e.g. Forsyth *et al.*2005; Denny and Dickman 2010). Nonetheless, substantial fauna recoveries have been achieved from introduced predator control in Australia (e.g. Orell 2004; Wyre 2004; Wheeler and Priddel 2009; Kinnear *et al.* 2010).

Control, monitoring, improving the survey methodology and understanding the role of introduced predators in the decline and limiting the recovery of woylies were all major objectives of the Woylie Conservation and Research Project. This section provides an overview of these activities within the Upper Warren region.

4.2 Control—DPaW

Summary: Government agencies responsible for natural resource management and conservation began fox-baiting programs in the Perup in 1977. Since then it has been progressively improved and expanded to include most of the DPaW-managed estate within the Upper Warren region, being distributed by a combination of aircraft and ground vehicles. The current frequency of fox baiting ranges from every three months for most of the region, to monthly for a core area within a 10 km radius of the Perup Sanctuary, to weekly for a core area of Yendicup within this, where woylies were translocated to in July 2013.

4.2.1 Aerial and ground baiting activities

Researchers in the Forests Department began fox-baiting in some areas of Perup in 1977 but was somewhat variable in space, time (generally 1–2 year intervals) and bait medium (Burrows and Christensen 2002; G. Liddelow pers. comm.). Broad-scale aerial baiting began in 1990. Single baiting events (once per year) of 5 baits km^{-2} were undertaken in 1990, 1992 and 1994. Two baiting events per year were carried out in the intervening years and from 1995 to 1996 (Burrows and Christensen 2002). Also during the early 1990s the Department of Conservation and Land Management (CALM, now DPaW), assisted by the Department of Agriculture, undertook ground baiting within parts of the 'Perup' area to support adjoining farmers fox baiting efforts. Native fauna populations in the area had a positive response from implementation of fox control, so in 1992 the ground baiting of CALM-managed lands increased to other strategic areas in the Upper Warren region. Up to four ground-baiting events per year were undertaken, with an emphasis during spring and autumn (I. Wilson pers. obs.). With the implementation of the *Western Shield* program in late 1996, a large proportion of the Upper Warren region began to be aerially baited four times per year. This was supported by ground baiting around boundaries (Figure 1). The interval between aerial baiting events in the Manjimup aerial baiting cell (Figure 2) has become more consistent within (i.e. small SE bars) and between years since 2009, after resolving some contract issues with the aerial distribution of baits.

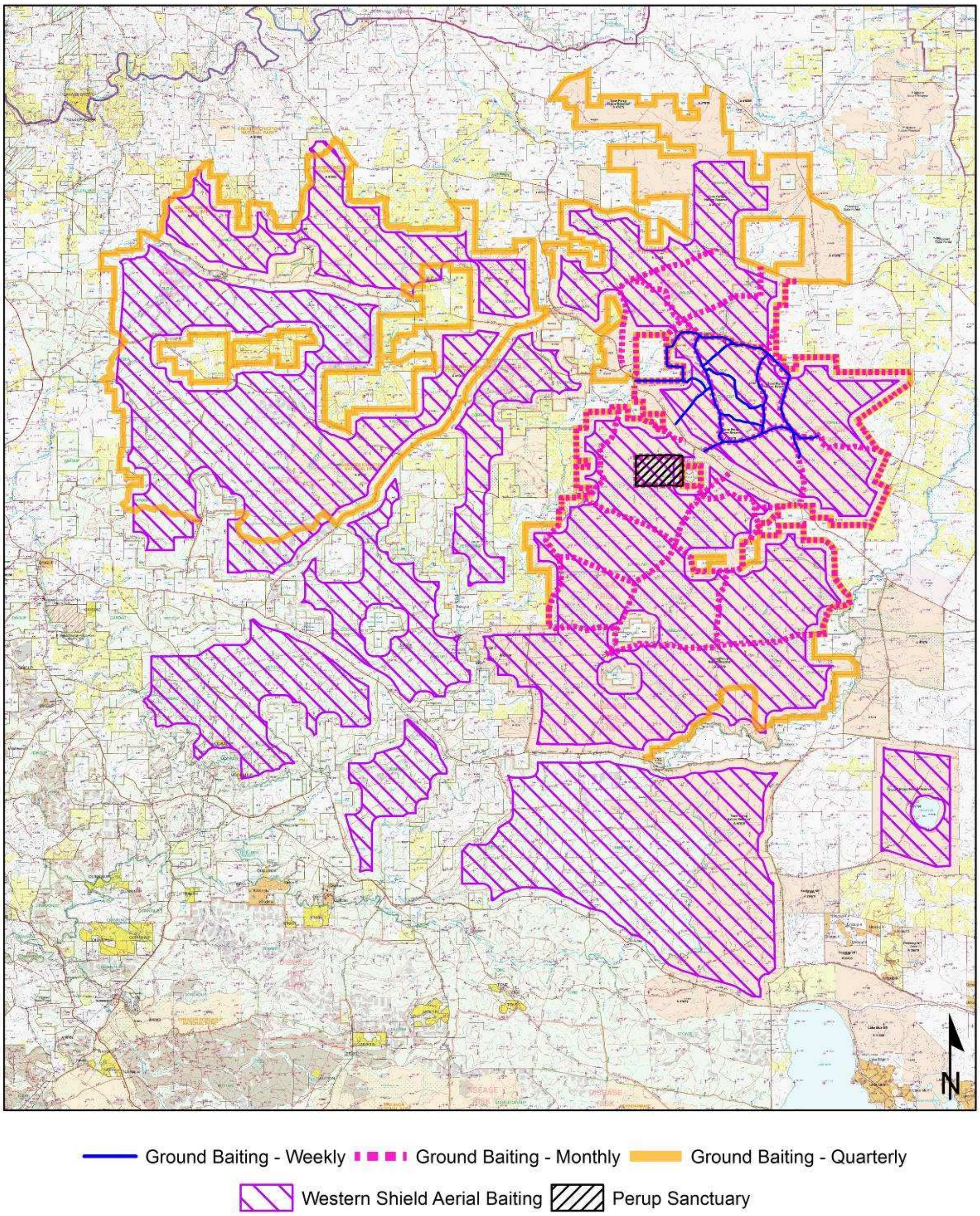


Figure 1. Map of the Upper Warren region showing the fox baiting activities including 1) the quarterly aerial baiting and associated perimeter ground baiting, 2) monthly ground baiting within the Perup core area since October 2010, and 3) the weekly ground baiting in and around the woylie translocation in Yendicup forest block (July–October 2013).

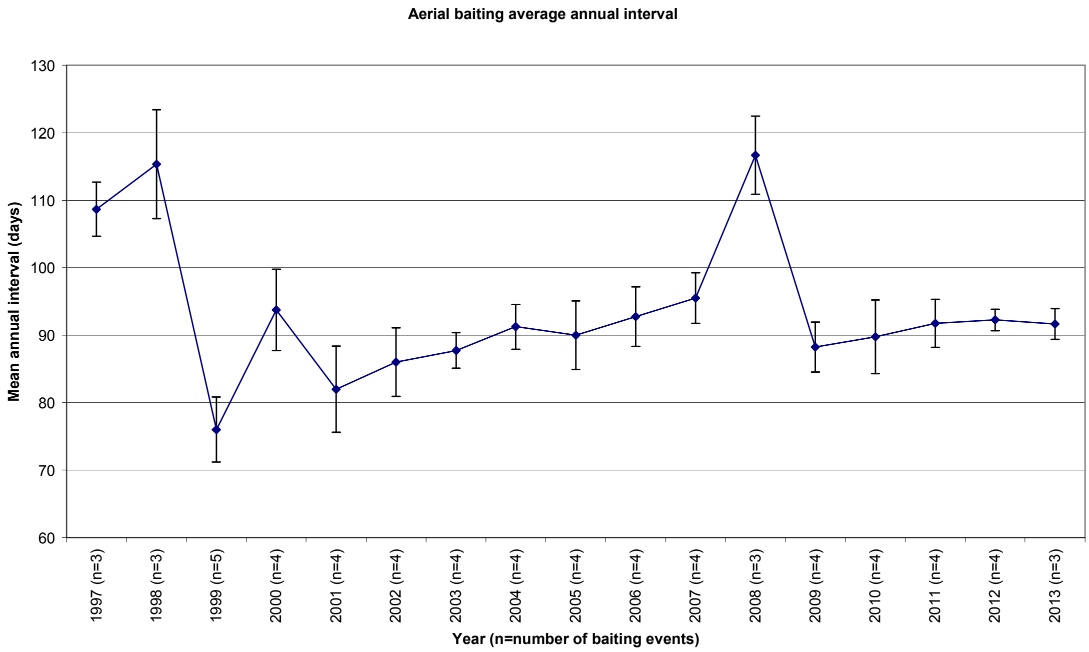


Figure 2. Average interval per year for aerial fox-baiting for the Manjimup flight cell, November 1996 to August 2013.

4.2.2 Recent additional core baiting activities

As part of the added protection of the insurance population of woylies within the Perup Sanctuary, a monthly baiting regime along tracks within a 10 km buffer has been undertaken on DPaW-managed lands (c. 14,500 ha) since October 2010. To support the relocation of woylies from the sanctuary into an adjoining area of forest in Yendicup (see section 6.2.2), a weekly supplementary ground-baiting regime for three months (July–October 2013) was conducted. All open tracks within 3 km of the nominated release site were targeted for ground baiting (Figure 3).

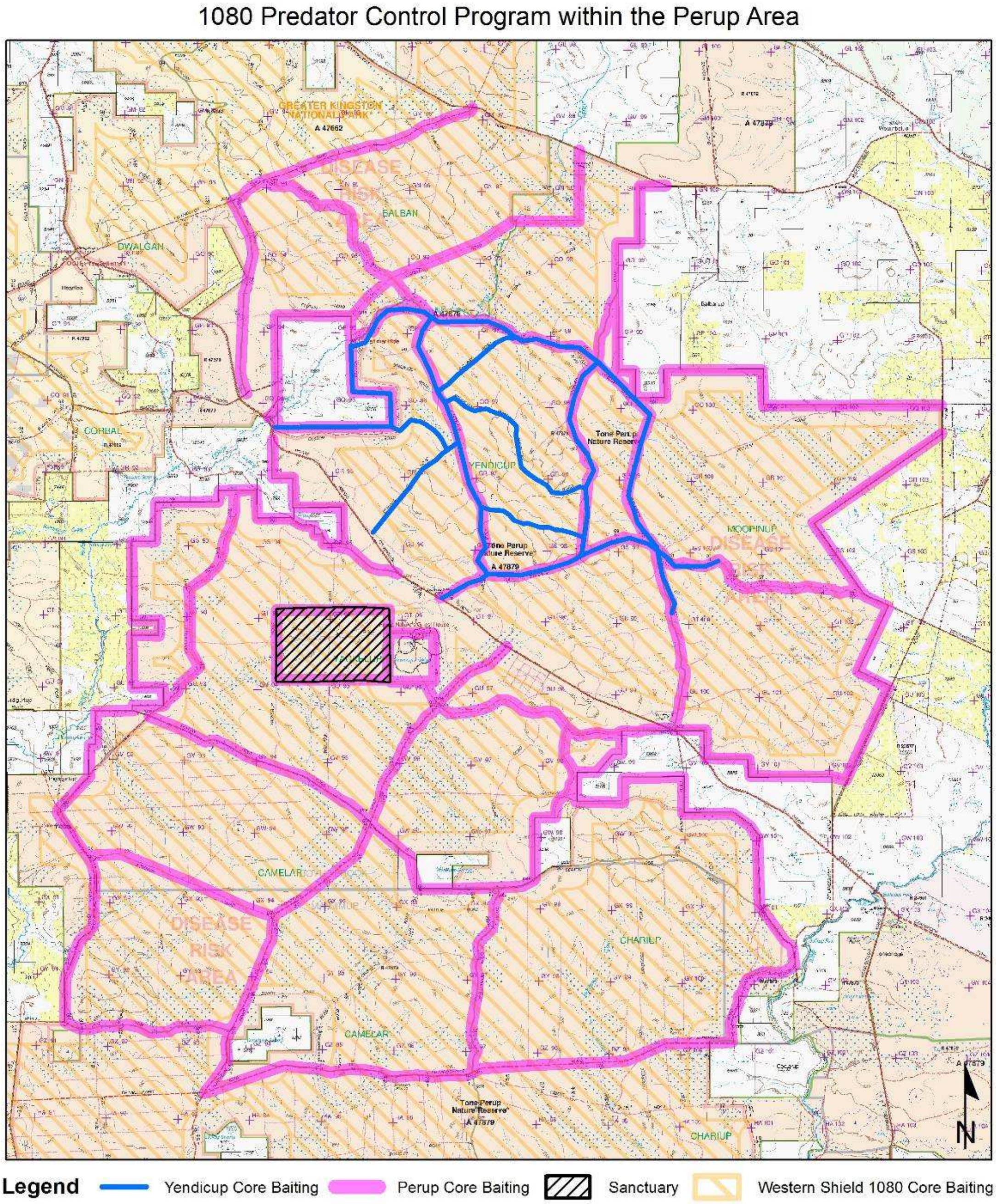


Figure 3. Fox-baiting program within the Perup area surrounding the Perup Sanctuary (black diagonal hatching; established October 2010), including *Western Shield* aerial baiting (light diagonal hatching; since 1996) and transects used for monthly baiting (pink lines; since October 2010) and weekly baiting (blue lines; July–October 2013).

4.3 Control—Landholders

Kathy Dawson (Warren Catchments Council)

Summary: Landholders in the Upper Warren region were canvassed through advertisements placed seasonally in the local print media; telephone, email and personal contact for the purposes of engaging them in an interest in local native wildlife and in introduced vertebrate pest control. Project coordinators contacted 34 landholders occupying in excess of 16,000 hectares in the course of seeking support in a range of project-related activities. Information sessions for landholders were held at Perup: Nature's Guesthouse and Tonebridge. Two training sessions—accreditation to lay 1080 baits and egg-lacing—were also provided. Many landholders participated in several predator control activities on their freehold land, in coordination with predator control efforts on adjacent DPaW-managed land, either directly or by providing access for professional contractors to undertake the work.

The *Caring for Our Country* and State NRM funded projects and the ancillary South West Catchments Council devolved grant all involved introduced predator control within three overlapping geographic areas totalling in excess of 60,000 hectares. The *CFOC* project focused predator control within a 10 km buffer zone around the Perup Sanctuary (since October 2010). Subsequent predator removal and survey calibration trials were conducted within 31,000 ha zones (10 km radius) in the Balban (September–October 2012) and Boyicup (January–March 2013) forest blocks, the central 3 km radius of each being where sand pad and camera monitoring was being undertaken (see section 4.5.4). Additionally, in July 2013 the Yendicup release site for the woylies translocated from Perup Sanctuary (see section 6.2.2) was within the same core area of Tone-Perup Nature Reserve that relied on landholder support to reduce the threats to endangered native fauna from introduced predators (Figure 4).

4.3.1 Landholder profile

Private landuse in the area includes cropping and grazing (sheep and cattle), some horticulture, viticulture and plantations of bluegums and pine. Many of these plantations were involved in managed investment schemes and in recent years have changed ownership and management arrangements. Several private plantations are managed by absentee landholders. Most of these properties do not usually actively control introduced vertebrate pests.

Landholders who are livestock producers control predators, by shooting or baiting, when the threat breaches acceptable thresholds. Historically, those who have multiple properties are more likely to additionally employ a licensed shooter to cull kangaroos and also to control foxes, pigs and cats.

4.3.2 Landholder engagement

Advertisements placed seasonally in the local print media; telephone, email and personal contact with those landholders who were able to be traced were the methods used to engage landholders in introduced vertebrate pest control. Project coordinators contacted 34 landholders occupying in excess of 16,000 hectares in the course of seeking support in a range of activities: spring and autumn baiting to complement departmental aerial and ground baiting; shooting and recording kills and sightings of feral cats and foxes; allowing contracted pest animal control operators access to their properties to trap and/or shoot introduced predators and assisting DPaW staff by not disturbing sand pad arrays when traversing through conservation areas when moving between properties.

Information sessions were held at Perup: Nature's Guesthouse and Tonebridge variously with invited landholders, DPaW woylie project staff, Murdoch University collaborating researcher Narelle Dybing, Steve Edwards from Wild Things Animal Control Solutions, DAFWA Biosecurity and WCC personnel. Landholders were updated with the progress of the woylie recovery effort and planned control activity. Research on foxes and feral cats sourced from the predator removal and survey method trials was explained. Besides the obvious effects of predation, the role of foxes and cats in the transmission of parasites that negatively impact on livestock health, carcass condition or lamb abortion was discussed with landholders in an attempt to demonstrate cooperation in predator control was of mutual benefit to farmers and conservation agencies.

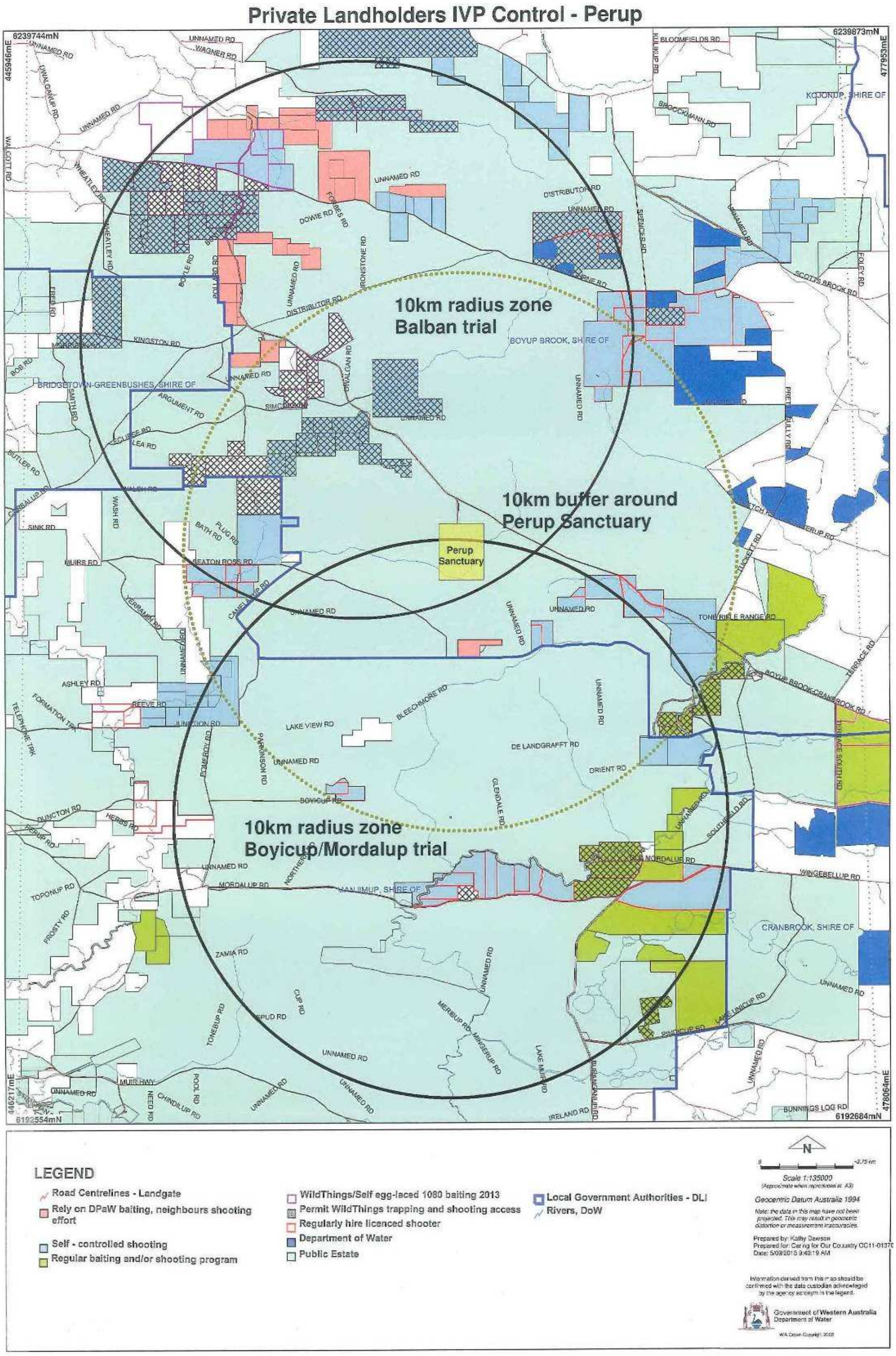


Figure 4. Map of private landholders adjacent to the Tone-Perup Nature Reserve, indicating introduced predator control measures undertaken to complement woylie and other native species conservation effort.

4.3.3 Landholder preferred control methods

It was revealed in discussion with the 34 landholders that a range of control strategies was employed to reduce the threats of vertebrate pests on their agricultural land. These varied in duration, method and intensity according to the threat to agriculture from kangaroos and emus as well as introduced vertebrate pest animals.

Landholders' least preferred option for introduced predator control was the use of 1080 baits (Figure 5). Numerous reasons were offered: a belief there was no need to bait as their property or properties were surrounded by the publicly-managed lands that were subject to regular baiting as part of the *Western Shield* program. There was also vehement opposition by some to baiting as it was seen as a direct threat to valuable sheep dogs. This impacted on the relationship between the landholders who had lost dogs and Department of Parks and Wildlife officers. Another reason for the increased resistance to baiting by landholders was claimed to be because of the growing bureaucracy (through DAFWA)—the need to be accredited and the paperwork involved in accessing baits. The most recent objection is the perceived lack of efficacy of the baits available to private landholders—the reduced rate of active ingredient and the appeal of the bait material to the targeted predator. The belief is that foxes in particular are receiving non-lethal doses and making the animals extremely bait shy. Those who have baited regularly would prefer to use the meat baits of the past. Another criticism has been that non-target native species are removing the bait.

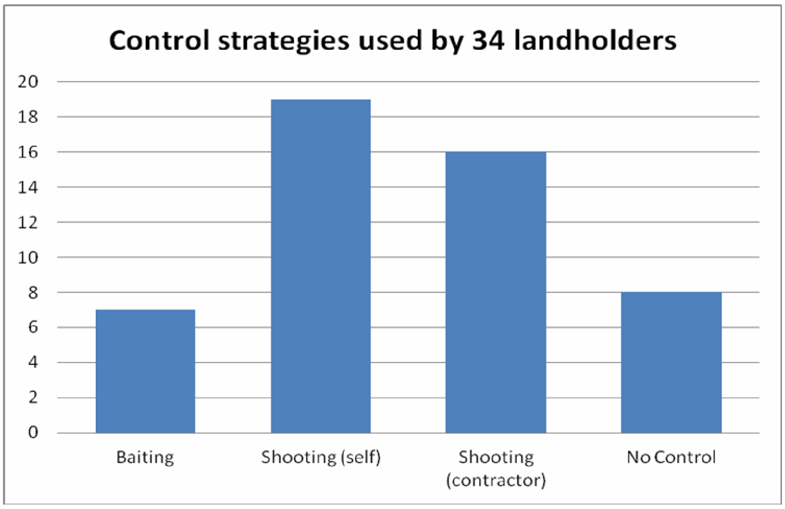


Figure 5. Landholder preferences for controlling introduced predators in the Upper Warren region.

Landholders shared a pragmatic interest in conserving native fauna and cooperated to varying degrees during the predator trials and beyond. In practice it proved difficult to coordinate their records of sightings, especially nil sightings, as landholders, despite good intentions, did not rate this as a high priority.

Agents, managers and owners of tree plantations cooperated in the predator trials by enabling professional pest controllers access to undertake trapping or shooting. They also participated in the 1080 baiting program carried out by a professional pest controller in autumn–winter 2013.

4.3.4 Landholder training

Two training sessions enabled 12 local landholders to gain accreditation to lay 1080 baits and to learn how to lace eggs with the poison (Figure 6).

Figure 6. DPaW officer, Marika Maxwell, addressing attendees at a 1080 accreditation training course.

The project funds subsidised the cost of baits (2011–2013) and also the engagement of a professional pest control agent (2013) to lay baits on properties of landholders who were not accredited but agreeable to participating in a baiting program. The 2013 autumn–winter session saw 222 baits laid over 5,263 hectares—involving properties of ten landholders within the project area. An additional 84 baits were known to be baited simultaneously by four private landholders over 1,978 hectares of agricultural land in the Boyup Brook Shire but beyond the perimeters of this project area. The training sessions and subsequent assisted baiting reduced to zero the number of the 34 properties contacted who were not applying any control measures—though the regularity, frequency and consistency of the application of control measures across the wider area cannot be verified.

4.3.5 External assistance to landholders' control effort

A professional shooter was contracted to sweep the private properties in the Yendicup area before the translocation of woylies from Perup Sanctuary back into the wild. Two foxes were removed during this July 2013 activity (26th and 30th June from Mead's property).

The predator control efforts of the multiple projects also liaised with local community fox shoots conducted by Manjimup and Boyup Brook landholders, such as Red Card for Foxes (March 2013), which saw more than fifty foxes removed from the wider Perup area.

4.3.6 Recommendations

The three year *Caring for Our Country* project has emphasised the need for coordinated predator control with a central reporting point where data can be collated of feral animal sightings, kills recorded and baiting activity undertaken. It is a challenge to develop a system that will be acceptable to all stakeholders and that can be implemented efficiently.

Continued assistance for absentee landholders and those reluctant to handle poisons is urged to maintain and extend the number of properties willing to apply this most reliable form of predator control, especially to coincide with and complement the aerial and ground baiting conducted by the Department of Parks and Wildlife.

Engagement with the Invasive Animals Cooperative Research Centre on effective control methods, feeding back landholder experience and disseminating updated information is required, in addition to ongoing training—in the field or via DAFWA's online portal.

4.4 Monitoring

Summary: Monitoring of introduced foxes and cats across the Upper Warren region, using arrays of sand pads, indicate that fox activity has increased substantially since 2006 and differs significantly between sites. Cat activity has been less variable over space and time and not related to fox activity. These results have important implications for the conservation and recovery of the woylie and other native species.

4.4.1 Introduction

The monitoring of introduced predators began across the Upper Warren region in 2006 in response to the woylie declines and the commencement of investigations into the causes of the declines. This was considered particularly important given that foxes and cats were previously identified as key factors in past woylie declines and other species in Western Australia (Burbidge and McKenzie, 1989; Start *et al.*, 1995; Short *et al.*, 2005; Abbott, 2006, 2008), an ongoing threat to their conservation (e.g. Wyre 2004) and a possible factor in the recent declines. Quantifying the abundance or density of introduced predators has historically been difficult so the approach adopted was based on monitoring their activity using a similar methodology used by collaborating mesopredator projects elsewhere in Western Australia (Morris *et al.* in prep.). Originally established as part of the Woylie Population Comparison Study (2006–2007), activity indices were derived from arrays of sand pads located at five key sites across the Upper Warren region (Maxwell *et al.* 2008, Wayne *et al.* 2011). The aims of the study included measuring predator activity at different sites and relating these to fox control activities and to the spatio-temporal patterns of woylie decline. As far as resources have allowed, predator monitoring has continued to build on the early results and develop a better understanding of fox and cat activity over space and time.

4.4.2 Methods

Since spring 2006 predator activity has been monitored using five principal sand pad arrays (25 sand pads (1 m x ~4 m) across forest tracks, spaced 500 m apart). The sand pads were constructed using either a kanga or backhoe to dig a shallow trench, which when filled with sand was approximately flush to the surrounding ground surface. An additional site at Moopinup was added in 2010 but has been monitored less consistently than the other sites primarily because of poor track conditions after rain. At the onset of the program sand pad arrays were systematically monitored pre and post *Western Shield* aerial baiting for four consecutive baiting events between spring 2006 and winter 2007, with alternate sand pads having lures (FAP and fish oil; Maxwell *et al.* 2008). From July 2007 surveys have been conducted using entirely passive sand pads (i.e. no lures). Surveys were conducted opportunistically between July 2007 and March 2010 when resources were available and from March 2011 they were consistently conducted bi-annually in spring and autumn (key times in the life history of foxes); with additional monitoring as part of predator control projects in 2012–2013. Each regional survey session was conducted for 4–9 nights (Table 1).

Table 1. Summary of monitoring predator activity using sand pads in the Upper Warren region.

The values indicate the number of nights surveyed per session (including days for which the data has subsequently been removed from analysis because of poor weather conditions). Highlighted sessions indicate key periods of sampling in relation to foxes; spring (green) and autumn (orange). Surveys were conducted either immediately before aerial fox-baiting (pre) or 10–28 days after aerial fox-baiting (post), with the exception of the October 2012 survey which was conducted immediately post baiting as it coincided with the conclusion of the active control period.

*=Additional days associated with predator projects and not included in the regional summary.

Baiting	Block	Keninup	Balban	Warrup	Boyicup	Winnejup	Moopinup
Pre	Aug-06	9	9	9	9	9	
Post	Oct-06	4	4	4	4	4	
Pre	Dec-06	4	4	4	4	4	
Post	Jan-07	4	4	4	4	4	
Pre	Feb-07	6	6	4	4	4	
Post	Apr-07	4	4	4	4	4	
Pre	Jun-07	4	4	4	4	4	
Post	Jul-07	4	4	4	4	4	
Post	Feb-08	6	6	6	6	6	
Pre	Aug-08	4	4				
Pre	Mar-09	6	6	6			
Pre	Jun-09	6					
Pre	Mar-10	6	6	6	6	6	6
Pre	Mar-11	6	6	6	6	6	6
Pre	Sep-11	6	6	6	6	6	6
Pre	Mar-12	6	6	6	6	6	6
Pre (pre control)*	Sep-12	4*	9*				
Pre (during control)	Sep-12	6(4*)	6(4*)	6	6	6	6
Post (post control)*	Oct-12	7*	7*				
Pre (pre control)	Feb-13				10*	10*	
Pre (post control)	Mar-13	7	7	7	7(3*)	7(3*)	3

All feral and fauna activity was recorded on each pad with a print identification confidence rating (1–certain, 2–probable, 3–possible). Only prints identified with confidence (1) were included in the analysis, resulting in over 85 predator records being removed (51 Cat; 34 Fox). Pad condition was also recorded as a measure of print decipherability. A mark was made on each pad (a print condition gauge) and if the mark was obscured the pad was not considered available for analysis. If less than 15 pads were available from a site then the entire day was removed from analysis (18 days). Approximately 1975 (15%) pads were removed because of disturbance from weather, namely rain, and 525 (4%) pads were removed because of vehicle activity out of a total of 13202. Fox and cat spoors were often recorded only from within the wheel ruts, so in these cases, any vehicles driving over the pad removed any sign of the predator. As a result, all sand pads with vehicle activity that could not be accounted for were removed from analysis, this included 3% (37/1256) pads with fox spoors and 1.3% (7/525) with cat. The resulting effect of removal of pads for analysis is underestimation of predator activity with a bias to areas with greater vehicle activity, in this case Keninup and Winnejup.

The predator activity index is a relative measure of encounter rate that can be used as a simple estimation of the probability (or risk) of a woylie encountering a predator, notwithstanding the assumptions required to do so (i.e. activity, behaviour, and interactions between and within prey and predator species). A variant of the Allen Activity Index (EPA 2007) was used in this study to determine predator activity. In summary, the Activity Index (AI) for a species (per site/session) is the average of the daily calculation of the total number of sand pads with confidently identified prints divided by the total number of available (readable) sand pads.

4.4.3 Results

The average detected fox activity index (AI) generally increased over time across the Upper Warren region since monitoring began in August 2006 (2.3%) with a peak of 18.3% in March 2009 (Figure 7). Based on the moving average (3 consecutive sessions) there has been a 9–fold increase in fox AI between the average of the first three survey sessions (AI=1.7%) and the peak in the moving 3–session average in March 2011 of 16.1% (see trend line in Figure 7).The AI in the last three survey sessions appears to be more stable (3–session average AI in March 2013 = 12.8%).

Cat activity across the region slightly increased from an average of 5.4% in the first three sessions to a peak in February 2008 of 7.7% before decreasing to an average of 2.9% in the last three sessions (Figure 7). Site level comparisons show considerable variation in detected fox AI and cat AI over space and time (Figures 8 and 9).

Fox AI differed significantly between areas (ANOVA, p=0.003) and was much greater in northern Perup (Keninup and Balban) than elsewhere. Cat AI did not differ significantly between sites (ANOVA, p=0.76) but on average tended to be least in Warrup and greatest in Balban. At Winnejup since March 2010, fox activity has increased markedly and cat activity has decreased. Preliminary investigations indicate no significant relationship between fox AI and cat AI.

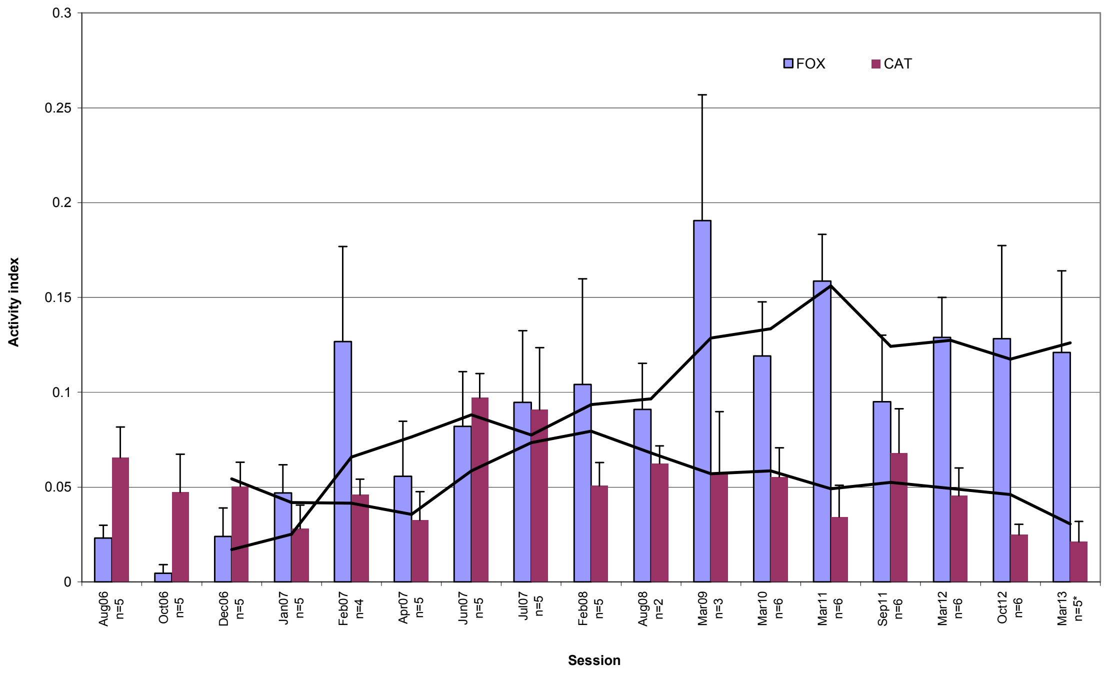


Figure 7. Average predator activity indices (AI) across the Upper Warren region using sand pad arrays since August 2006, with moving average (n=3) trendlines.

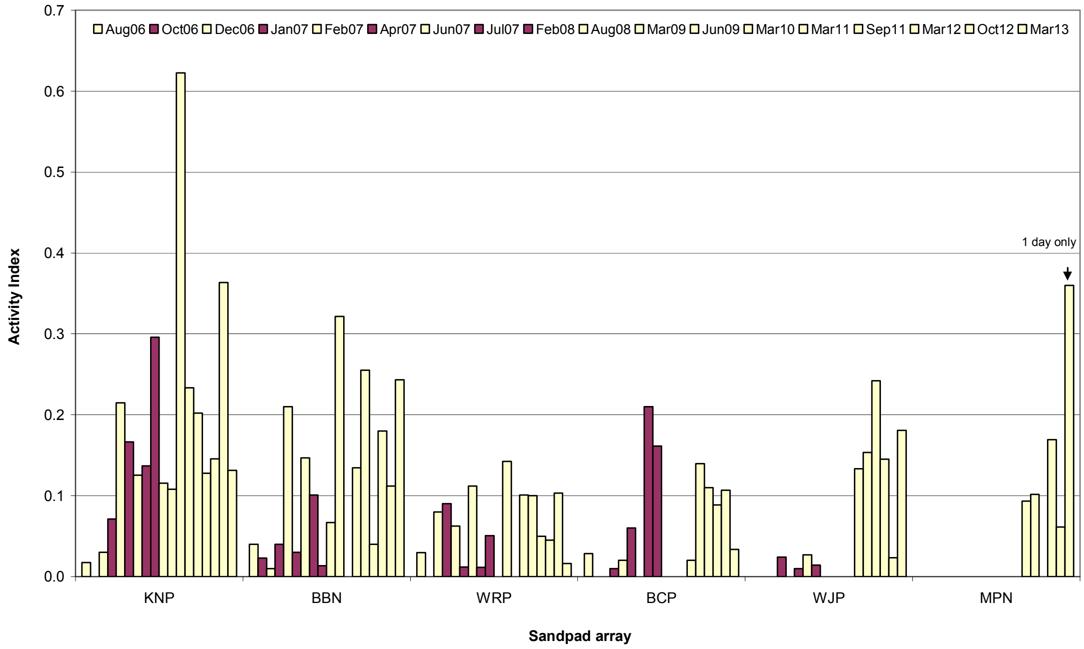


Figure 8. Fox activity index (AI) derived from sand pad arrays at the 6 Upper Warren region monitoring sites since August 2006.
Light bars indicate pre fox-baiting surveys and dark bars indicate post fox-baiting surveys. Note: Moopinup was only surveyed in March (2010–2013) and October 2012 and only 1–3 sites were sampled in August 2008, March 2009 and June 2009.

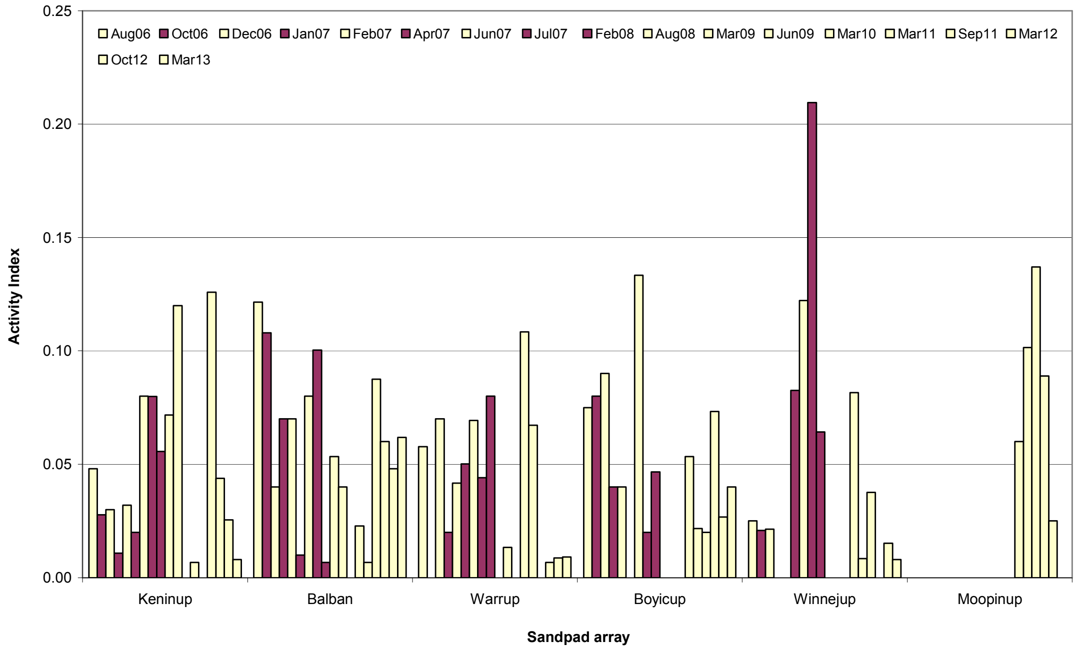


Figure 9. Cat activity index (AI) derived from sand pad arrays at the 6 monitoring sites in the Upper Warren region since August 2006.
Light bars indicate pre fox-baiting surveys and dark bars indicate post fox-baiting surveys. Note: Moopinup was only surveyed in March (2010–2013) and October 2012 and only 1–3 sites were sampled in August 2008, March 2009 and June 2009.

4.4.4 Discussion

Being able to relate AIs derived from sand pads to actual densities of introduced predators over time and space remains the highest priority for helping to relate introduced predators to woylie and other native prey abundance/density and the effectiveness of predator control methods. A high correlation between predator AI and abundance has been found elsewhere (for example WA rangelands, D. Algar *et al. pers. comm.*) and it may be possible to derive estimates of abundance from the sand pad data using the approach of Paul de Tores as part of his mesopredator research program (P. de Tores pers comm.), based on methods developed by J.A. Royle *et al.* (e.g. Royle and Nichols 2003; Stanley and Royle 2005; Royle *et al.* 2007). Also the results from the predator removal and survey method calibration trials in the Upper Warren region (section 4.5.4) will also be directly relevant. In the interim, the predator AIs are measures of encounter rate that can be inferred as predator encounter probabilities, which can be considered an index of predation risk.

The substantial increase in average fox activity since 2006 cannot be directly related to the woylie declines because the vast majority of the declines in the region had occurred before this. Nonetheless they may indicate that fox predation is of increasing importance in limiting the recovery, or even the viability, of post decline woylie populations in the region. That considered it is encouraging that since March 2011 the trend in fox AI has apparently stopped increasing and possibly stabilized, albeit at an average of 7.5 times the 3–session average initially observed in 2006.

Fox AIs have remained significantly different between sites and greatest in northern Perup (Balban and Keninup). The high fox activity in Keninup may be because of the high interface with adjacent agriculture and much of the area has remained outside of the area fox-baited quarterly by air. However, by contrast much of Balban has quarterly aerial baiting and monthly ground baiting.

Having initially increased since 2006, the regional average in cat activity appears to have reduced slightly since February 2008. Cat activity does not differ significantly between sites, nor does it appear to be related to fox activity. Given that cats were the primary predator of woylies during the decline in the Upper Warren region (DEC 2008a) and in Dryandra (Marlow *et al.* submitted a) effectively controlling them in critical habitats for the conservation of woylies must remain a high priority.

Relating predator activity to the spatio-temporal patterns of woylie decline remains a high priority for future analyses.

4.5 Improving the quantification of introduced predator activity, abundance and/or density

Key predator related issues in relation to fauna conservation in Australia briefly include;

1. Effectiveness of methods used to quantify introduced predators
2. Effectiveness of control methods on the density of introduced predator
3. Introduced predator behaviour and ecology
4. Impacts of introduced predators on native fauna
5. Responses of fauna to predator control

This project component presents an opportunity to directly address some of these key issues. In particular, quantifying predator density is critical to understanding the potential role of predators as an agent of decline and/or limiting factor in the recovery of woylies in the Upper Warren region and population changes in other fauna here and elsewhere. Measures of introduced predator activity using sand pads have been used extensively across Australia. However reliably quantifying actual abundance or density is more problematic. The use of remote sensor cameras for monitoring introduced predators and native fauna is relatively new and had not previously been trialled in the region before this project. Similarly, DNA capture/recapture methods have been trialled elsewhere with mixed success (Berry *et al.*2012; Marlow *et al.* submitted b) but not in the southern forests of Western Australia.

The overall objectives of this project component were to;

1. Quantify the density of introduced predators from defined area(s) of DPaW-managed lands in the Upper Warren region.
2. Compare alternative survey methods and determine if there is a suitable predator survey method(s) that reliably relates to actual predator density.
3. Collect biological information on introduced predators in the Upper Warren region

Key strategies to meet these objectives were;

a. Trial and refine predator survey methods (Obj.2 partial)
b. Quantify the density of introduced predators using known removal methods (Obj.1)
c. Deploy predator survey methods before, during and after the predator removal treatment to calibrate the results from these survey methods with actual predator densities (Obj.2 partial)
d. Sample introduced predators to examine, genetics, diet, diseases and parasites and reference material for forensic odontology. Collect data on biometrics and demographics (Obj 3).

A series of developmental trials were conducted to address these objectives and strategies designed to examine the effectiveness of different survey methods, particularly in relation to introduced predators in the Upper Warren region. A brief summary is provided below of the trials conducted within the woylie conservation program including;

- A comparison of the detection rates of wildlife between different remote sensor cameras models and between cameras and existing sand pad monitoring methods
- Camera set up trials to compare detection rates of introduced predators located on- or off- track and using different lures
- Hair trap trials to examine the potential for a DNA capture/recapture method to measure abundance/density
- Predator removal and survey method calibrations
- Biological information from introduced predators

4.5.1 Camera model / sand pad comparison pilot trial

Summary: Introduced predator survey methods (sand pads and remote sensor cameras) were compared in the Upper Warren region in March 2012. Significant differences in the detection of target and native fauna was found between the two different camera models tested. The detection rates from the Reconyx camera model were roughly comparable to those on the sand pads or greater based on preliminary comparisons and within the constraints of the trial design. Some of the relative advantages of the cameras are discussed. Cameras also proved themselves a useful validation and training tool for species identification from prints on the sand pads.

4.5.1.1 Introduction

The use of remote sensor cameras to quantify and monitor animals has increased rapidly over recent years in response to major improvements in the technology and affordability. To date, much of the work with remote sensor cameras has been conducted on large felids and canids in the Americas, Europe and Asia, in forest ecosystems and predominantly focusing on measurements of population density (McCallum 2012). The use of remote sensor cameras in Australia has also recently increased, with much of the research activity focusing on methodological comparisons and development, particularly for the purposes of measuring populations (e.g. Meek *et al.* 2012).

Activity indices of introduced predators, derived from sand pads, have been used in the Upper Warren region in several programs since the 1990s, including the Woylie Conservation Research project, since 2006. However, remote sensor cameras present a new opportunity to potentially improve our understanding of foxes and cats and in particular measures of abundance. The purpose of this study was therefore to begin investigating the potential benefits of remote sensor cameras as a tool to aiding investigations and management of foxes and cats for fauna conservation, including woylies. The aims of this study were therefore; i) Compare sand pads and two remote camera models in the detection of foxes, feral cats and native fauna, ii) validate species identifications from sand pads using remote sensor cameras. As such this constitutes the first study of its kind in the southern forests of Western Australia. The results presented here are only preliminary and must be regarded as such. More rigorous assessment of the data is necessary before more confidence and reliability can be attributed to their interpretation.

Parts of this study were used to support an international student project conducted by Bennett (2012). This component focused on attempting to derive a population density estimate for foxes and cats from sand pad survey data and comparing the effectiveness and efficiency of using sand pads versus cameras to estimate density.

4.5.1.2 Methods

The camera and sand pad comparisons were conducted in the Upper Warren region in March 2012. The trials were conducted in conjunction with the routine region monitoring of introduced predators using sand pad surveys (i.e. 6 x sand pad arrays (25 pads ea) surveyed for 6 nights; see section 4.4 for more detail on methodology). Two different camera models were trialled, (24 Pixcontroller Digital eye cameras and 25 Reconyx HC600 cameras). A pair of cameras (one each of the two models) were randomly allocated to 5 of the 25 sand pads at each of 5/6 sand pad arrays (at one site in Balban a Reconyx was deployed without a Pixcontroller; no cameras were deployed on the Warrup array, because of the risks of human interference in the area at the time because of timber harvesting and forest protesters). The cameras were set up next to each other at the end of the allocated sand pads to detect animals near the sand pad. The Pixcontroller models were deployed for the same 6 nights that the sand pads were run. The Reconyx cameras were only deployed for the last three nights (because of a delay in their delivery). Therefore the comparisons between survey methods were restricted to the data collected from the last three nights only (i.e. 75 sand pad- or trap- nights per method per site x 25 replicates).

4.5.1.3 Results

Camera comparisons with sand pads

Restricting the image data to Reconyx only (3 nights) and to only those animals probably or actually intercepting the sand pads, the Reconyx missed one of four cats recorded on the sand pads, 100% of foxes (n=10), and 83% (n=77) native animals detected on the sand pads (Figure 10). When all available image data on the Reconyx cameras were considered (i.e. includes multiple visits and animals travelling off-track away from. the sand pad), the number of detections were equal or greater than sand pads (Figure 11).

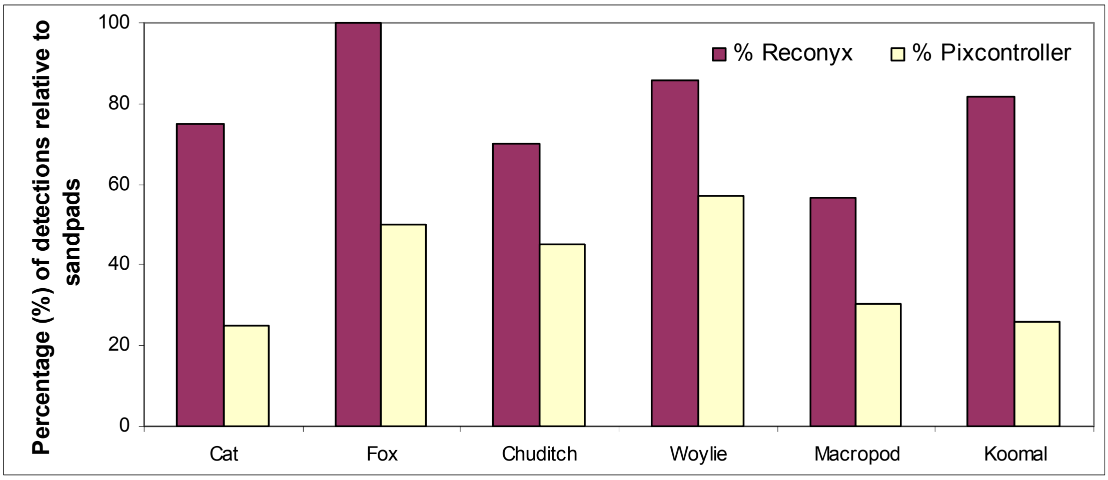


Figure 10. Comparison of the detection of species by two remote sensor camera models (Reconyx HC600 and Pixcontroller Digital Eye) relative to the detections recorded on sand pads.

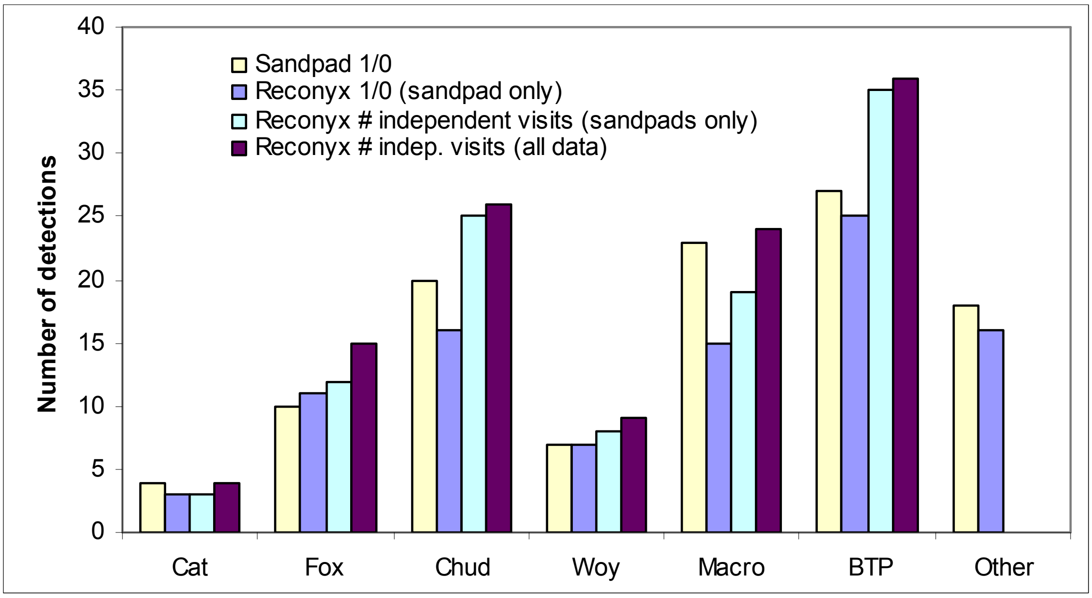


Figure 11. Comparison of the detection of the presence/absence (i.e. 1/0) of species from sand pads with the number of detections of species by the Reconyx HC600 remote sensor camera.

Comparisons are made considering i) only the detected presence/absence near the sand pad, ii) number of independent visits near the sand pad, and iii) all available image data (i.e. including animals not likely to intercept the sand pad).

Validation of species identification on sand pads using images from cameras

Using all available data (6 nights), a total of 222 camera trap nights from either one or two cameras per sand pad were available to verify the species identifications from sand pads for 150 of the 900 sand pad nights involved in the routine monitoring conducted in the Upper Warren region in March 2012. Overall, 10 /11 foxes were identified correctly but one was misidentified on the sand pad as a cat while all (5) cats were identified correctly.

The greatest misidentification occurred with rabbits (*Oryctolagus cuniculus*), with 6/6 detected on camera and not recorded at all from the sand pads. Whether this was because of the prints not being detectable or misidentified as another species is difficult to determine unless the location of the prints are also recorded on the sand pad to directly compare with the image. This process did however highlight some confusion with chuditch (*Dasyurus geoffroii*) prints and the need for greater vigilance in rabbit spoor detection. This was also the case with woylie (4/15) whereby there was some uncertainty in distinguishing between woylie and other wallaby species. Koomal (or common brushtail possum *Trichosurus vulpecula hypoleucus*) identification was generally good but 5/36 were not recorded from the sand pad. In one case this appeared because of interference from high amounts of chuditch activity but in the other four cases the spoors were missed altogether. Throughout the sand pad surveys koomal have been considered the indicator species for determining sand pad condition. i.e. koomal prints are least likely to be seen on a poor quality sand pad. Hence, it is likely that prints were not visible on these pads—highlighting an advantage of cameras. There was also one case of a numbat (*Myrmecobius fasciatus*) misidentified as koomal.

Camera model comparisons

Some minor camera, battery and operator failures were experienced but are not considered to affect the overall results of this study. Overall the Pixcontroller detected 55% (n=78) of the animals detected by the Reconyx camera model. In particular, the Pixcontroller detected only 33% and 55% of the cats and foxes detected respectively by the Reconyx camera model. The Reconyx camera performed much better in capturing photos of positively identified species on the sand pad than the Pixcontroller cameras and at identifying multiple individuals and animals some distance from the sand pad. (for example the Reconyx captured 3 fox and 1 cat away from the sand pad while the digital eye captured none of these). The Reconyx camera also performed better in capturing small animals, including a dunnart and birds.

An additional benefit of the cameras was the ability to record multiple visits over time and to potentially distinguish between individuals of some species. For example, Figures 12 and 13 relate some of the camera images for foxes and cats, respectively, with their detection on sand pads during the 6–day routine surveys. It is particularly evident for cats, that multiple individuals were present during the surveys. Incidental insights into animal behaviour may also be possible with cameras, which may not be so evident or possible from sand pads. (for example, habitual temporal and spatial patterns and interactions between individuals). A particular observation from the cameras was that a large proportion of the animals stopped on the sand pad and looked at or investigated the camera (all species). This has occurred in all subsequent camera projects whether the camera was covert, emitted no light or sound (Reconyx), or not (Pixcontroller). On this basis, a certain degree of neophobic behaviour towards the cameras was inferred from these observations, highlighting the importance of having some degree of a settling-in period after the cameras have been deployed before commencing observation studies or trials with the cameras.

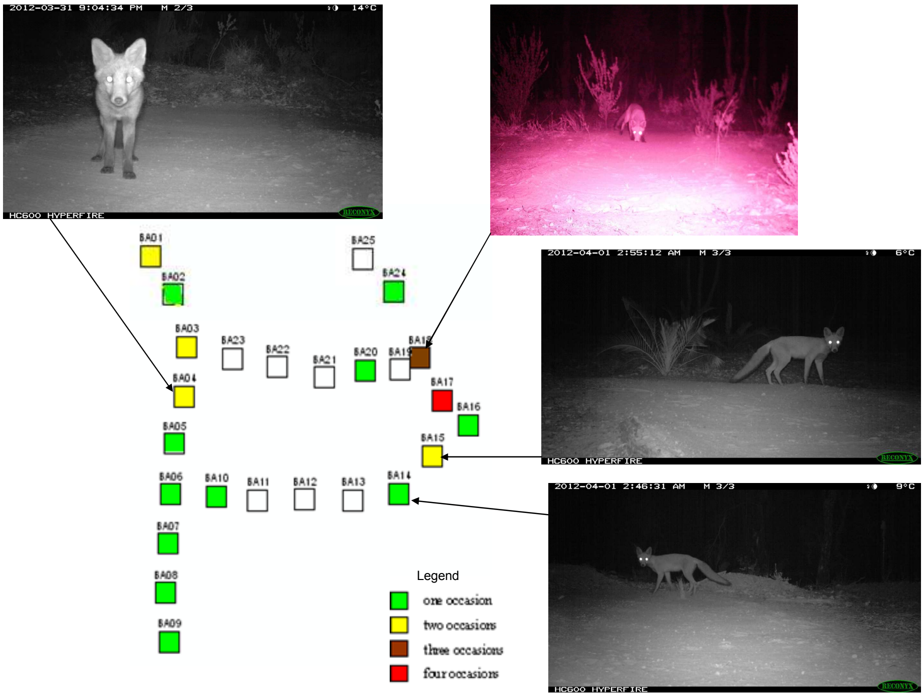


Figure 12. Spatial schematic map of the Balban sand pad array (25 pads spaced 500 m apart) indicating the number of evenings that foxes were detected on each sand pad and some example images of the foxes detected at these sites by remote sensor cameras.

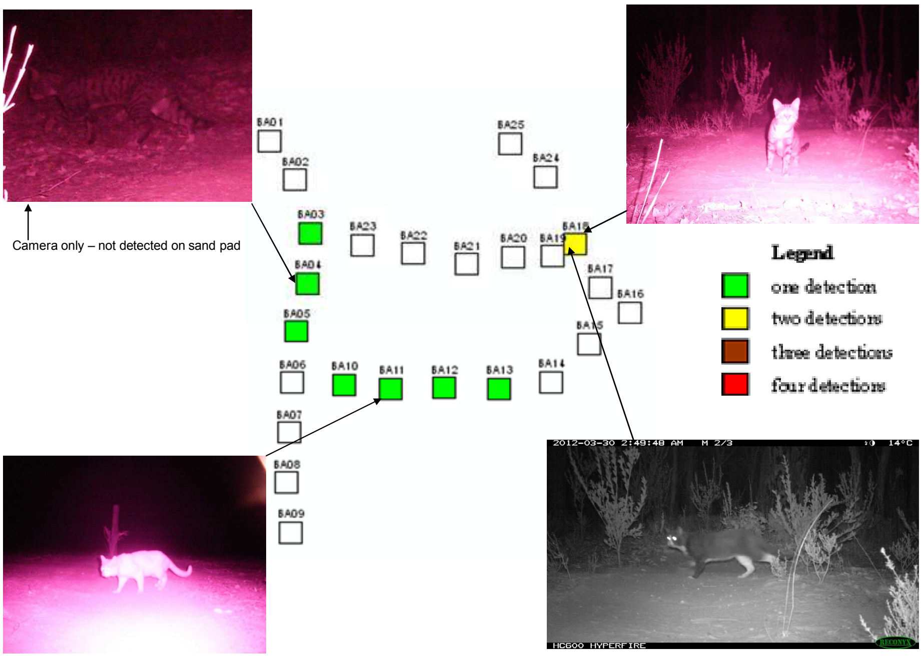


Figure 13. Spatial schematic map of the Balban sand pad array (25 pads spaced 500m apart) indicating the number of evenings that cats were detected on each sand pad and some example images of the individuals detected at these sites by remote sensor cameras.

4.5.1.4 Discussion

The significant differences in the detection of target fauna between camera models has been shown elsewhere as it was also found in this study. In this case, the Reconyx HC600 model was vastly superior to the Pixcontroller Digital eye (an older model) in detecting introduced predators and small to medium-sized vertebrates. The faster trigger speed and larger, more sensitive detection zone of the Reconyx model are major factors in these differences. The longer battery life and more covert nature of the Reconyx are among its other advantages. The suitability of this particular model for this type of work has been demonstrated by others also (e.g. Neil Thomas pers com., Meek *et al.* 2012).

Comparisons between cameras and sand pads need to be designed and interpreted carefully to ensure reliable and dependable results. For instance, the set up of the cameras was constrained by being located at the end of the sand pads, the constraints imposed by the site characteristic (for example slopes and heights of roadside gutters) and directed at the sand pad. Better detection results from cameras may be expected in alternative locations (for example off track, more covert, etc), different orientations to the sun and tracks, with or without the use of lures or baits, different heights above ground, etc. The noise and light from the adjacent Pixcontroller cameras may also have deterred some individuals.

Despite the constraints imposed on the cameras and bearing in mind the analyses of these results are only preliminary, the detection rates from Reconyx camera model were roughly comparable to those on the sand pads or greater. The cameras also provided more types of information, including timing of detection, multiple detections per night, potentially distinguishing individuals of some species (for example cats) and some behavioural information. Another key advantage of the cameras includes overcoming the susceptibilities of sand pads to disturbance by weather and vehicles, which can result in substantial information loss and possible biases (see section 4.4).

Used in conjunction with sand pads, cameras were also shown to be a useful validation tool for species identification from prints on the sand pads. Some misidentifications were detected but overall the identification of target species (fox and cat) from sand pads was reasonably accurate. The use of these validation methods is highly valuable for training and improvement of sand pad observers. This study alone gave the observers involved a much higher confidence in their species identification and refined their skills where needed.

4.5.2 Camera setup trials

Summary: Set up trials for remote sensor cameras conducted in July–August 2012 demonstrated that locating the cameras next to forest tracks detected significantly more foxes and cats than off-track. There was no significant difference in the detection rates between cameras using no attractants versus those using a smell (tuna oil) or sound (bird tweeter). This provided the basis for developing introduced predator monitoring protocols using remote sensor cameras in southern Jarrah forest habitat.

4.5.2.1 Introduction

The aim of the camera setup trials was to determine the optimal placement and baiting method for camera trap monitoring of foxes and cats (and, potentially, non-target fauna). This is important for the development of an effective monitoring program for introduced predators. The results from these trials can also inform the optimal setup for other ‘trap' types, such as hair (DNA) traps. In particular we were interested to know whether detection rates for target species were different on versus off forest tracks. We were also interested to know whether lures significantly increased detection rates compared with cameras that had no lures (i.e. passive). Reward attractants or baits (such as food) were not investigated because of the impracticalities associated with the ongoing requirement to replenish consumed baits on a daily or more regular basis, the potential disturbance to animals from bait replenishment activities and the interpretation of results considering the likelihood of changing animal responses and interactions over time because of the baits (for example increased visitation over time and competition between individuals for the food). The use of food baits also potentially compromised the planned use of cameras associated with predator control activities that used food baits to either trap or poison foxes and cats.

4.5.2.2 Methods

The camera setup trials were conducted July–August 2012 on DPaW-managed lands in the Upper Warren region, east of Manjimup. Sites were excluded from within a 10 km radius of the Balban sand pad array centroid. This was to avoid affecting the behaviour and influencing the results of the predator control and monitoring program in Balban conducted in September–October 2012 (see below).

A factorial design to the camera setup trials included;

2 x Positions (on track / off track)

3 x Lures (nothing / sound—tweeter / smell—fish oil)

11 x replicates (6 cameras per replicate, i.e. 2 positions x 3 lures)

2 sample periods (week 1, 20–25 July 2012; week 2, 2–8 August 2013)

A total of 66 cameras were used per sample period, resulting in a total of 132 camera locations over the two week trial.

Remote sensor cameras (Reconyx HC600 Hyperfire) were deployed in pairs (on track and 200m off-track) that were separated by 5 km (i.e. spatial independence between pairs based on expected home range sizes and movement pattern by foxes and cats; Figures 14 and 15).

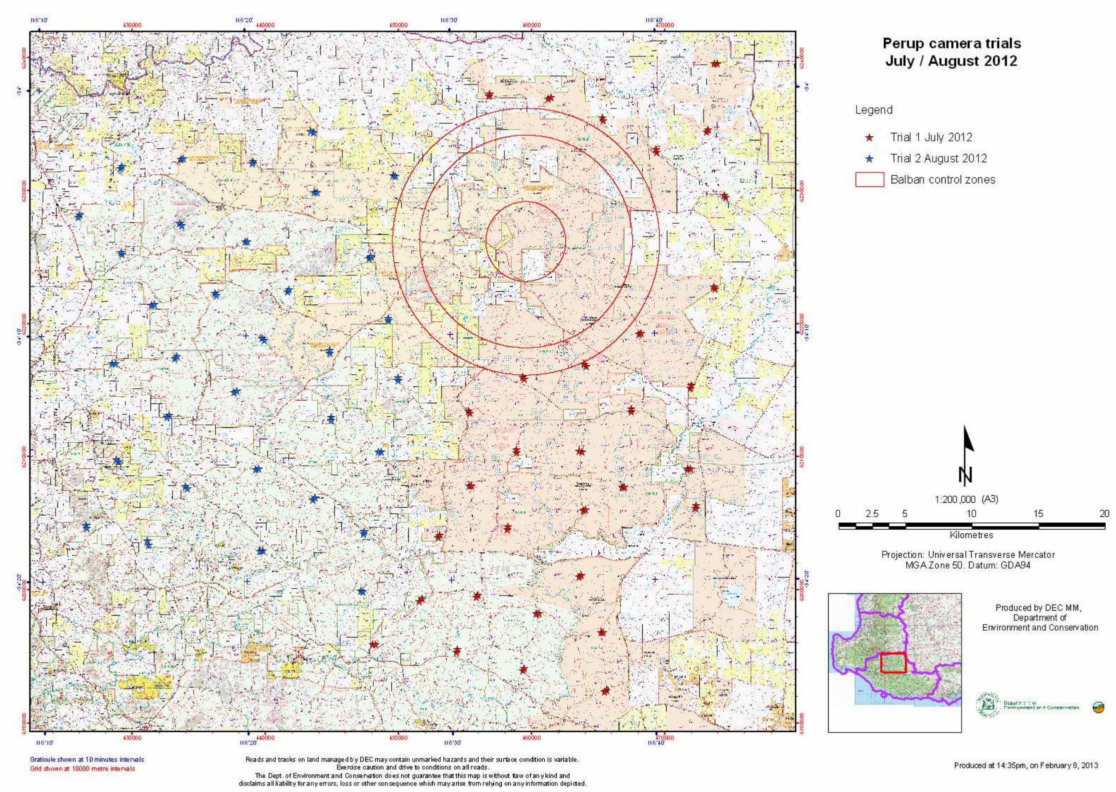


Figure 14. Map of the Upper Warren region showing the location of remote sensor camera pairs (on track and off track) spaced 5 km apart used in the camera setup trials in July–August 2012.

Cameras were placed and installed in a consistent manner to optimise detections and comparison between track and off-track locations. Cameras were secured to customised stakes (short galvanized star pickets with a camera staging platform) or a tree when present, at a standardised height of 20 cm. Orientation was approximately SW–SE to avoid false detections from the sun and angled across tracks to maximise coverage and distance on track, this angle varied depending on road width but was approximately 45 degrees. Sites were selected to provide a detection zone in front of the cameras that was relatively clear of vegetation and obstacles for >5 m x >2m (min distance achieved of 4.3 m in dense vegetation) so that detection functions were otherwise relatively comparable between track and off-track locations.

Figure 15. Remote sensor camera placement, on-track (left) and off-track (right).

For analysis, the survey duration in both sample periods was standardized to five consecutive nights immediately after the deployment of lures. However, cameras were in the field for up to nine days because the set up of cameras in the field took several days, lures were then deployed over a 1–2 day period and the collection of the cameras also took two days.

A logistic regression model was used in which the response (dependent) variable was whether the target species was detected or not (i.e. 1/0) and variables included position (on or off track), lure type (passive, smell or sound) and sample period (1 or 2).

4.5.2.3 Results

A total of 918 trap nights resulted in 844 detections of 21 animal taxa on the remote sensor cameras while deployed (Table 2). For the subsequent analysis, the detections of foxes and cats from only 660 trap nights were used (i.e. 5 nights x 132 camera locations). As a result foxes and cats were detected on 43 and 12 cameras respectively during the 5 sampling days per camera (Table 3, Figure 16). The detection of foxes on tracks was significantly greater than off track ($p=0.001$, Odds ratio=4.2 (SE=1.7)), but there was no significant difference between lure types ($p>0.7$). All cat detections were on track and there was no significant difference between lure types ($p>0.6$).

Table 2. Tally of all detection events (not number of individuals) of species during the camera set up trials in the Upper Warren region (July–August 2012).

Species	Week 1	Week 2	Grand total
Fox	37	49	86
Cat	18	2	20
Koomal	82	49	131
Chuditch	38	38	76
Woylie	74	36	110
Western grey kangaroo	90	148	238
Western brush wallaby	12	9	21
Tammar wallaby	15	4	19
Macropod	7	0	7
Numbat	2	0	2
Quenda	11	10	21
Rabbit	2	0	2
Emu	37	29	66
Masked owl	1	0	1
Raptor	2	3	5
Bird	20	1	21
Owl		9	9
Echidna		1	1
Dog		2	2
Horse		1	1
Goat		5	5
Vehicle	4	11	15
Unknown	15	11	26
Other	8		8
Total detections			**893**
Total detections with species ID			**844**

Table 3. Summary of fox and cat detections on remote sensor cameras deployed in the Upper Warren region July–August 2012, according to position (on or off track) and lure (smell, sound or nothing).

Fox	Oil	Tweeter	Passive	Total
On track	9	10	12	31
Off track	5	4	3	12
	14	**14**	**15**	**43**

Cat	Oil	Tweeter	Passive	Total
On track	4	4	4	12
Off track	0	0	0	0
	4	**4**	**4**	**12**

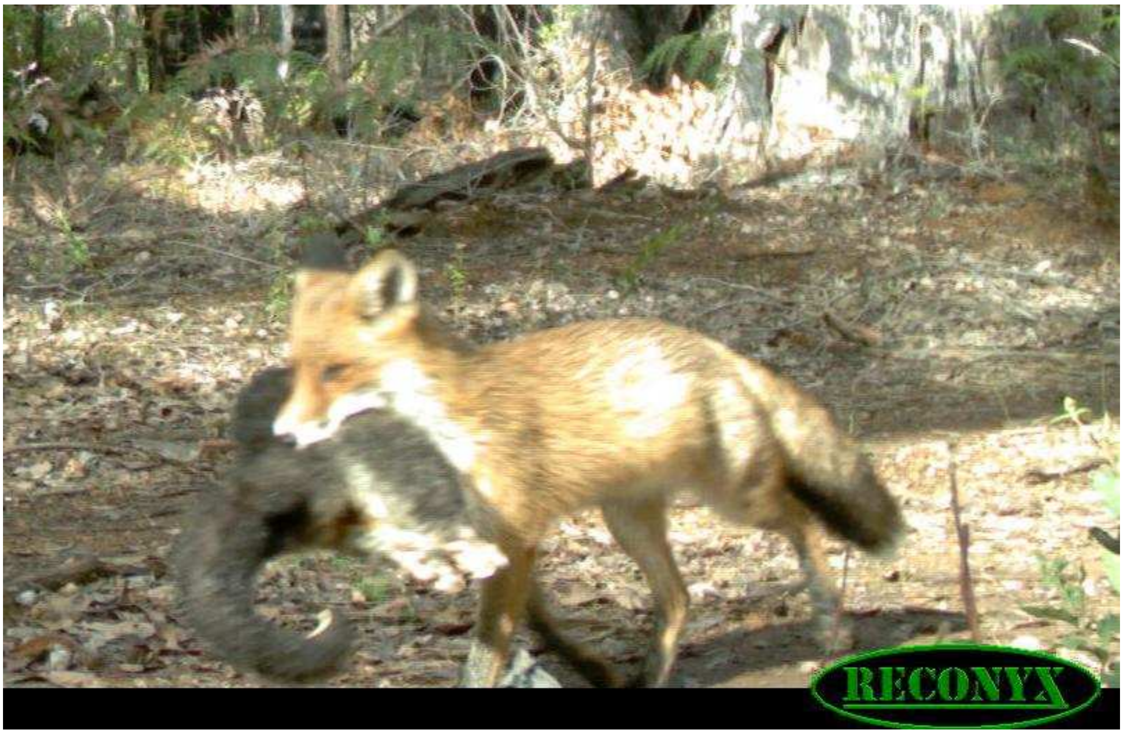


Figure 16. Fox with a koomal (common brushtail possum) detected during the camera set up trials in the Upper Warren region, east of Manjimup, Western Australia.

4.5.2.4 Discussion

This study found that introduced predators were detected more frequently on cameras set along tracks than off track but that lure type did not significantly affect detection rates. On this basis the future use of cameras for monitoring foxes and cats in the Upper Warren region is recommended to be restricted to on-track locations and without the use of a lure (i.e. passive). The advantages of using no lures when using remote sensor cameras includes the more straight forward interpretation of the results given the reduced bias in animal detections, the potential of changed animal behaviour over space and time associated with the use of lures, and the possibility for confounding and influence between monitoring and predator control methods using baits and possibly lures associated with more conventional traps. Furthermore, cameras that do not use lures do not require approval from the DPaW Animal Ethics Committee.

Only two lures were examined in this study. A more comprehensive assessment of different lures may well identify higher detection rates for particular target species. However the detection of foxes and cats on cameras set along tracks, with no lures over a five day period (54% and 18%, respectively) were sufficient for our purposes. Longer survey periods, repeated across all seasons and across a broader range of sites and forest types would help to build our understanding on the most efficient use of remote sensor cameras for these purposes. Whether the detection rates change over time is also worth investigating, given the potential for neophobia by foxes, and possibly cats, to new objects in their environment.

4.5.3 Hair trap trial

Summary: A hair trap pilot trial for DNA mark recapture for foxes and cats was conducted 20–24th August 2012. Based on the results, hair traps were not subsequently deployed as an introduced predator monitoring method as part of this project.

4.5.3.1 Introduction

DNA samples from introduced predators can be used to identify individuals in a way that enables population estimates to be derived using mark recapture methods. The aim of this preliminary pilot trial was to assess the effectiveness of a hair trap design to collect hairs suitable for a DNA capture recapture method of measuring introduced predator abundance and demographics in the Upper Warren region.

Hair trap methods to collect the DNA of introduced predators were explored, developed and tested by collaborators within the mesopredator release research program. The outcomes of which were two superior models were identified and used to estimate introduced predator populations. The ‘sticky wicket’ design developed by Algar *et al.* was shown to be effective in the rangelands (Berry *et al.* 2012) and was subsequently applied as a survey method in the Rangelands and wheatbelt (Marlow *et al.* submitted b). The ‘Garretson pipe’ model was developed and tested by de Tores *et al.* in the northern jarrah forest. In a direct comparison between the two models de Tores (pers. comm.) found the ‘Garretson pipe’ to be more successful in sampling hair than the ‘sticky wicket’ in the northern jarrah forest. The ‘Garretson pipe’ was also more suited to wetter conditions (because the adhesive tape used to collect hairs was sheltered from moisture within the pipe) and so was selected as the hair collection method for this preliminary pilot trial in the Upper Warren region.

4.5.3.2 Methods

An original ‘Garretson pipe’ (loaned from de Tores *et al.*; Figure 17) was placed at 10 sites (>5 km apart from each other) where introduced predator detections were recorded on remote sensor cameras in the preceding weeks (July–August 2012) as part of the camera setup trials. The hair traps were used following the protocols used by de Tores *et al.*, located within 5 metres of seldom-used forest tracks and baited with fresh chicken wings. Generally three cameras were set at each Garretson pipe to document any animals that approached either end of the pipe and the third camera to detect animals along the adjacent forest track. In two of the 10 cases there was no camera set up on the adjacent track. All pipes and cameras were deployed for four consecutive nights (20th–24th August 2012).

Figure 17. Example of the ‘Garretson pipe’ setup during the preliminary pilot trial showing the hair trap baited with a chicken wing and a remote sensor camera in the background to monitor approaches by fauna.

4.5.3.3 *Results*

Five independent (i.e. different evenings) approaches by foxes were detected at 3 of the 10 Garretson pipes. In all cases foxes appeared to be extremely cautious when investigating the pipe (Figure 18) and on no occasion were they observed putting their head inside the pipe in an attempt to reach the bait. No fox or cat hair was found on any of the tapes from any of the 'Garretson pipes'. A fox and cat were detected on the track next to the 'Garretson pipe' but not recorded approaching the pipe on two and one occasions respectively.

Figure 18. Example of a fox investigating a 'Garretson pipe' recorded on one of the three remote sensor cameras deployed to observe introduced predator behaviour and visitation at the hair traps deployed in the Upper Warren region.

4.5.3.4 *Discussion*

These hair trap trials were only preliminary and the results should be only regarded as indicative. More comprehensive trials are required to investigate the potential suitability and efficacy of this survey method. Given the wariness evident by foxes and their potential neophobia, the installation of any form of hair trap should allow sufficient time for individuals to become more accustomed to the devices (i.e. weeks or months). The effectiveness of hair traps should also be adequately examined over time (i.e. across seasons) and space (for example habitats, land use, regions, etc) as appropriate for their intended subsequent use.

DNA capture recapture methods have been used elsewhere to estimate fox and/or cat abundance and demonstrate turnover of individuals associated with predator control methods (Berry *et al.* 2012 and Marlow *et al.* submitted b). They are, therefore, worth further serious consideration. However the costs to undertake the DNA analyses also need to be considered given that they may be substantial. Quotes received at the time of this study were as much as $134 and $151 for each of 5 samples of fox and cat respectively. Costs for DNA analysis from scats were even more expensive. While the per unit costs decreased with the number of samples analysed at any one time, unit costs still exceeded $70 each for 100 or more samples. Nonetheless, with sufficient samples, these costs may be very competitive compared with the feasibility and costs of alternative methods, such as GPS collars, to collect potentially comparable information on introduced predators. Further advances in technology may also make these methods increasingly more affordable.

While these methods hold great promise, they were not pursued any further as part of this project. Deciding factors in this regard included the results of this preliminary pilot trial, the time needed for future development and testing, the associated costs, and the other resource requirements necessary to refine and use DNA capture recapture methods in an effective, efficient and informative manner.

4.5.4 Predator removal and survey method calibrations

Summary: Two replicate trials were conducted in the Upper Warren region (September 2012–March 2013) to quantify the density of introduced predators and calibrate the results from survey methods (sand pads and remote sensor cameras). A coordinated targeted removal of introduced predators by professionals on DPaW-managed lands and professionals and landholders on adjacent private properties resulted in trapping or shooting of 9 foxes and 3 cats. Within the core surveillance zone (3 km radius, 2,800 ha) at Balban at least 5–6 different adult cats, 2 kittens and 7 fox individuals were identified. At Boyicup at least 6–7 different adult cats, 3 kittens, and 4 fox individuals were identified. Future analyses will derive predator density estimates and investigate the accuracy and precision of camera and sand pad survey methods used to monitor introduced predators.

4.5.4.1 Introduction

The aims of the predator removal and survey method calibration trials were to;

1) Quantify the density of introduced predators within defined areas of DPaW-managed lands in the Upper Warren region.

2) Determine the most accurate survey method of measuring predator density using surrogate survey methods (sand pads and remote sensor cameras) and by comparing the results from these methods with actual density estimates.

The strategy to quantifying predator density was to use known removal methods that could quantify the number of predators within defined forest areas within a limited time frame (i.e. trapping and shooting that enable all predator carcasses to be recovered). Targeted and intensive efforts to remove introduced predators from key woylie habitats also directly addressed reducing key threats to the declined woylie populations in these areas. By deploying predator survey methods (sand pads and remote sensor cameras) before, during and after the predator removal treatment the resultant measures of detection could then be compared and calibrated with the actual predator densities determined by the number removed during the treatment period.

4.5.4.2 Methods

Two replicate trials were conducted in the Upper Warren region; Balban (northern Perup in September–October 2012) and Boyicup (southern Perup in January–March 2013; Figure 19). The trials were centred on the existing sand pad arrays (25 sand pads spaced 500 m apart), with 50 remote sensor cameras (Reconyx HC600 Hyperfire) deployed at 500 m spacings along existing forest tracks within a 3 km radius (2,800 ha) of the centre of the sand pad array. The cameras were staggered to approximately midway between sand pads where they occurred. Both the sand pads and cameras were unbaited (i.e. passive). The existing sand pad array at Keninup was selected as a control for Balban and monitored simultaneously and likewise the Winnejup sand pad array for Boyicup.

Cameras were secured to trees with python cables where available and/or customised stakes. The same protocols for installation were applied as for the Camera Setup Trials (see section 4.5.2.) with camera height approx 20 cm and angle of camera SW–SE and angled across the road to optimise coverage. Cameras were placed on level ground wherever possible to optimise detection and clear of vegetation and other obstacles to avoid false triggers. Cameras were routinely checked throughout the study to ensure they were functioning properly and to provide camera maintenance such as lens cleaning, obstacle clearing, etc. Sand pads covered the full width of the road (~1m x ~4m) and were read and prepared every day. Several days and individual sand pads were removed from analysis because of weather or vehicle disturbance.

Cameras were active 2–4 weeks before control, 3–4 weeks during control and approx 2 weeks post control. Sand pads were monitored 9–10 days before control and 7 and 10 days post control at Balban and Boyicup respectively. Sand pads were monitored during the control period at Balban, and not at Boyicup, to minimise interference with the trapping and control operations (Table 4).

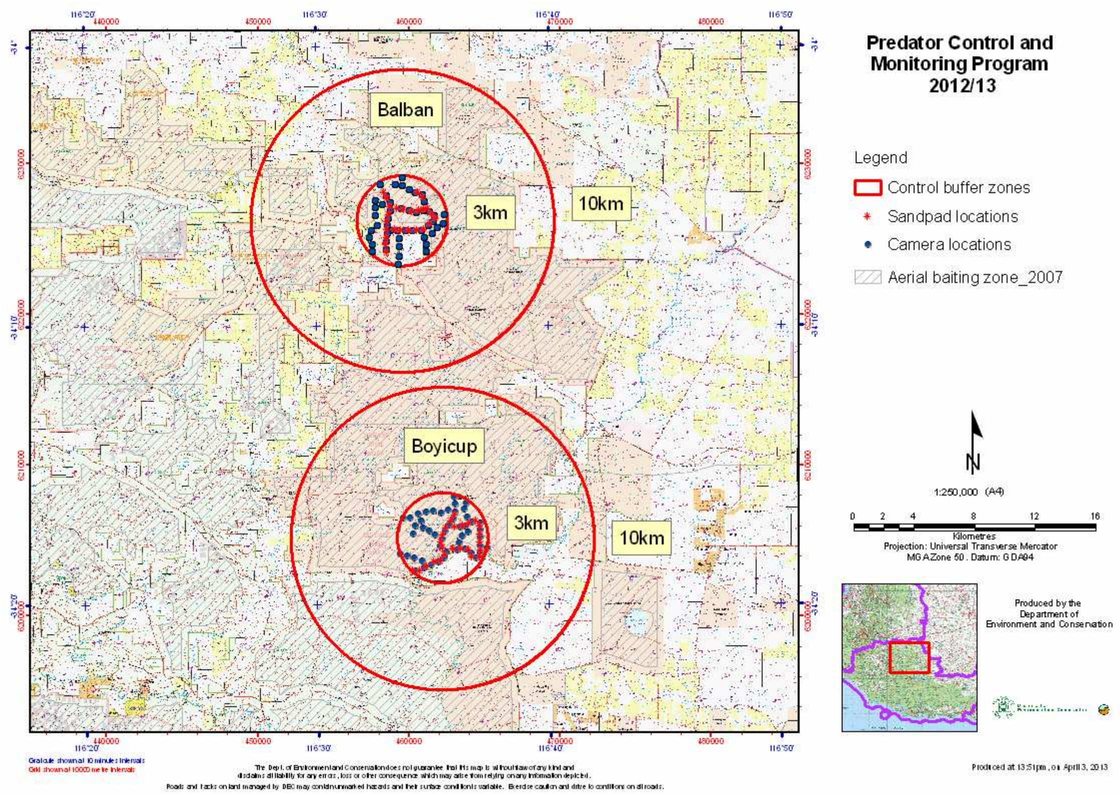


Figure 19. Map of the Upper Warren region showing the two replicate trial areas (Balban in 2012 and Boyicup in 2013) used to remove introduced predators to derive density estimates and to compare and calibrate these density estimates with predator survey methods. The central surveilance areas (3 km radius) contained 25 sandpads (red dots) and 50 remote sensor cameras (blue dots). Efforts to remove predators were conducted on DPaW-managed land and private property within a 10 km radius of the centre of the surveilance zones.

Table 4. Summary of the survey effort (number of days) using remote sensor cameras and sand pads to monitor introduced predator activity during the predator removal and survey method trials in Balban (September–October 2012) and Boyicup (*January–March* 2013) in the Upper Warren region, Western Australia.

Balban	**Camera**	**Sand pads**	**Boyicup**	**Camera**	**Sand pads**
Pre control	14–19	9	Pre control	15–27	10
Control	28	10	Control	20	-
Post control	16	7	Post control	15	10

Introduced predator removal was conducted within a 10 km radius (31,000 ha) of the centre of the sand pad array but with an increasing emphasis of effort toward the centre of this area, (i.e. within and close to 3 km radius surveillance zone). This sized treatment area was thought sufficient to be able to target resident predators likely to be detected in the central surveillance zone (i.e. animals within 5 km from the 3 km outer edge of the surveillance zone), plus another 2 km buffer to reduce the possibility of reinvasion during the treatment period).

Predator removal on DPaW-managed land was done under contract to Wild Things Animal Control Solutions (WTACS) using leg-hold traps (Edwards 2012, 2013). Predator removal on private free-hold land was coordinated by WCC and done by the land owners, their existing delegated pest control contractor or by permission to WTACS. Shooting and trapping methods (leg-holds and traps) were used on private property. The period of predator control aimed to be as short a period as possible to enable reasonable and efficient rates of predator captures but to limit the time and opportunity for reinvasion of areas made vacant by the removal of resident animals.

4.5.4.3 Results

The predator control program resulted in the removal of 12 introduced predators (9 foxes and 3 cats) during the operational control phase of the project. Within the Balban treatment zone, 5 foxes were removed by WTACS and 1 cat was removed through the control actions of a private landholder. Within the Boyicup treatment zone, 4 foxes and 1 cat was removed by WTACS and 1 cat was removed through control by a private landholder (Figure 20).

Of the 9 foxes dispatched during the project, 8 were captured with leg-hold traps on DPaW tenured land. One fox was shot on private property. All cats controlled in the study were shot on private property, evading all attempts of capture in leg-hold traps.

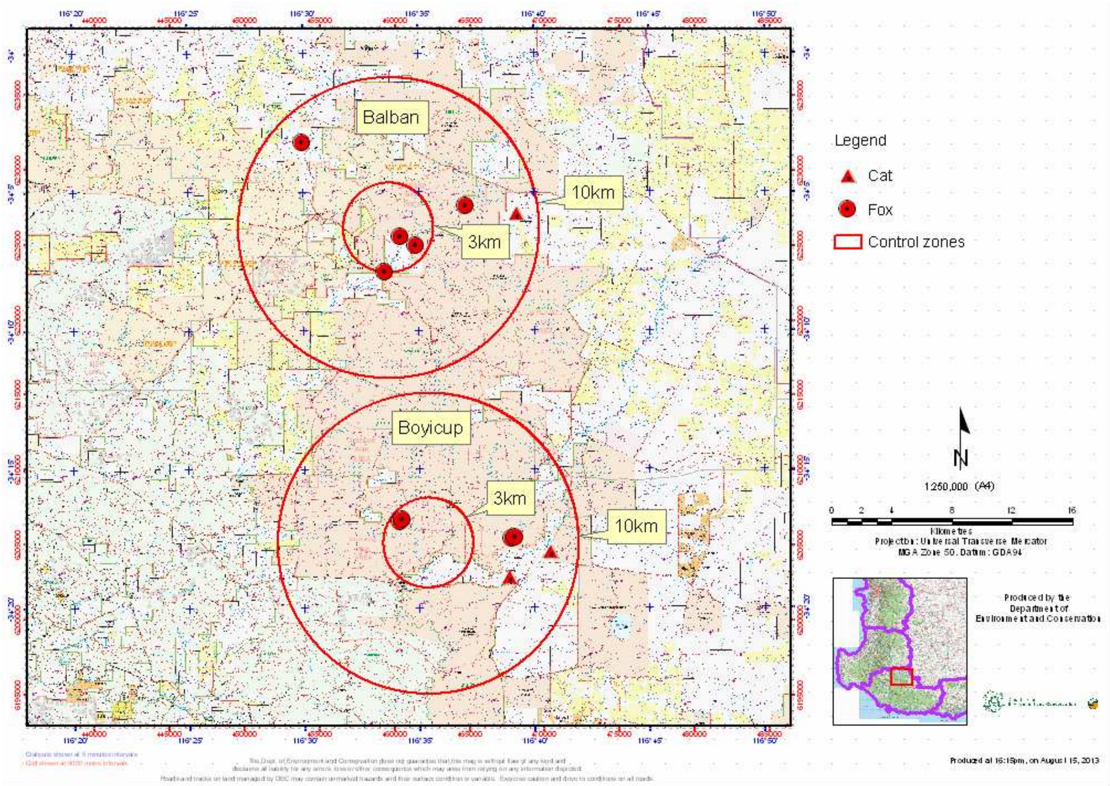


Figure 20. Location of the foxes (circles) and cats (triangles) removed from the Balban and Boyicup control zones during the control phase of the study. Note that two foxes were removed in close to each other in two separate locations within the Boyicup control zone (i.e. at the scale on the map, it appears that there are two single circles indicating fox locations, when in fact there are two at each of two locations).

From the core surveillance zone (3 km radius, 2,800 ha) at Balban (3796 camera trap nights), a total of 203 separate cat detections involved at least 5–6 different adults plus 2 kittens (Table 5, Figure 21). There were also 196 fox detections, which equated to at least 7 individuals (4 of which were captured and removed, one of these having been detected on camera but ultimately trapped just east of the 3 km surveillance zone).

Table 5. Summary of the distinguishable individual feral cats detected in Balban, September–October 2012

Cat #	Identifier	# detections
1	Large black and white male	89
2	Light uniform colour, large head	104
3	Ginger with white back legs	5
4	Uniform shiny dark colour	1
5	Tabby pattern? Possibly could be ginger cat?	1
6*	Dark (only rump visible)	1
7*	Tabby	1
8*	Kitten—tabby? (possibly more than 1)	1
Total		**203**

*Individuals 6, 7 & 8 were captured together in one event

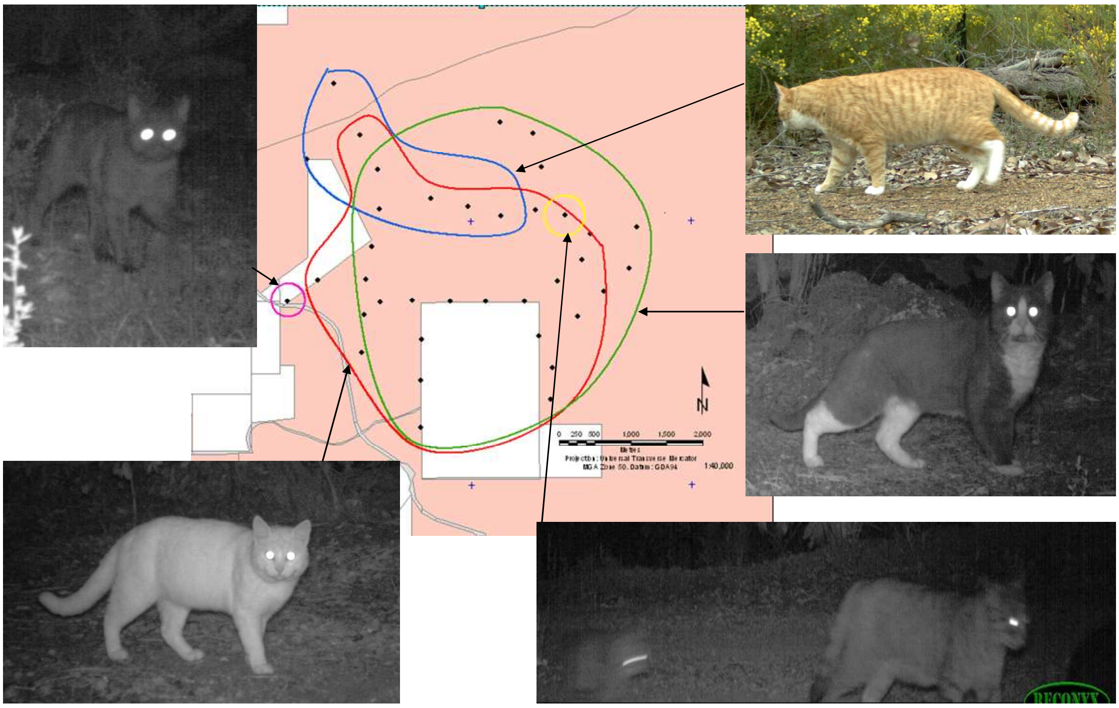


Figure 21. Rough estimates of the home ranges of the cats based on the detections on 50 remote sensor cameras within the Balban surveillance zone.

From the core predator sampling area (3 km radius, 2,800 ha) at Boyicup (2851 camera trap nights), a total of 91 separate cat detections involved at least 6–7 different adults plus 3 kittens (Table 6, Figure 22). There were 18 detections of dark coloured cats that were difficult to discriminate because of the lack of distinguishing characteristics. Two of the dark adult cats (Cat #2 and #3) may be the same individual. There were also 103 fox detections, which equated to at least 4 individuals (2 of which were captured and removed from within the core surveillance area) (Figure 23).

Other species photographed by remote sensor cameras at Balban and Boyicup included the introduced rabbit (*Oryctolagus cuniculus*), fallow deer (*Dama dama*), mouse (*Mus musculus*) and black rat (*Rattus rattus*) and native species including koomal (*Trichosurus vulpecula*), chuditch (*Dasyurus geoffroii*), woylie, western grey kangaroo (*Macropus fuliginosus*), tammar wallaby (*Macropus eugenii*), western brush wallaby(*Macropus irma*), numbat (*Myrmecobius fasciatus*), quenda (*Isoodon obesulus*), ngwayir (or western ringtail possum, *Pseudocheirus occidentalis*), echidna (*Tachyglossus aculeatus*), wambenger (*Phascogale tapoatafa*), dunnart (*Sminthopsis spp.*), emu (*Dromaius novaehollandiae*), goanna (*Varanus spp.*), and various birds (Figure 24). Data from the Balban and Boyicup programs are being prepared for analysis.

Table 6. Summary of the distinguishable individual feral cats detected in Boyicup, February–March 2013.

Cat #	Identifier	# detections
1	Large tabby male with distinctive swirl patterns on torso	48
2	Dark with no visible marks, small head	3
3	Black with no distinctive marks? Picture quality poor)	2
4	Black and white female , with large kittens (2 tabby & 1 black)	16
5	Dark with small white mark on chest, small head	2
6	Dark all over, no visible marks, large head	1
7	Tabby with thin body and finer pattern than Tabby #1, stripy tail	7
Dark	Could be #2, 3, 5 or 6. Not clear.	12
Total		**91**

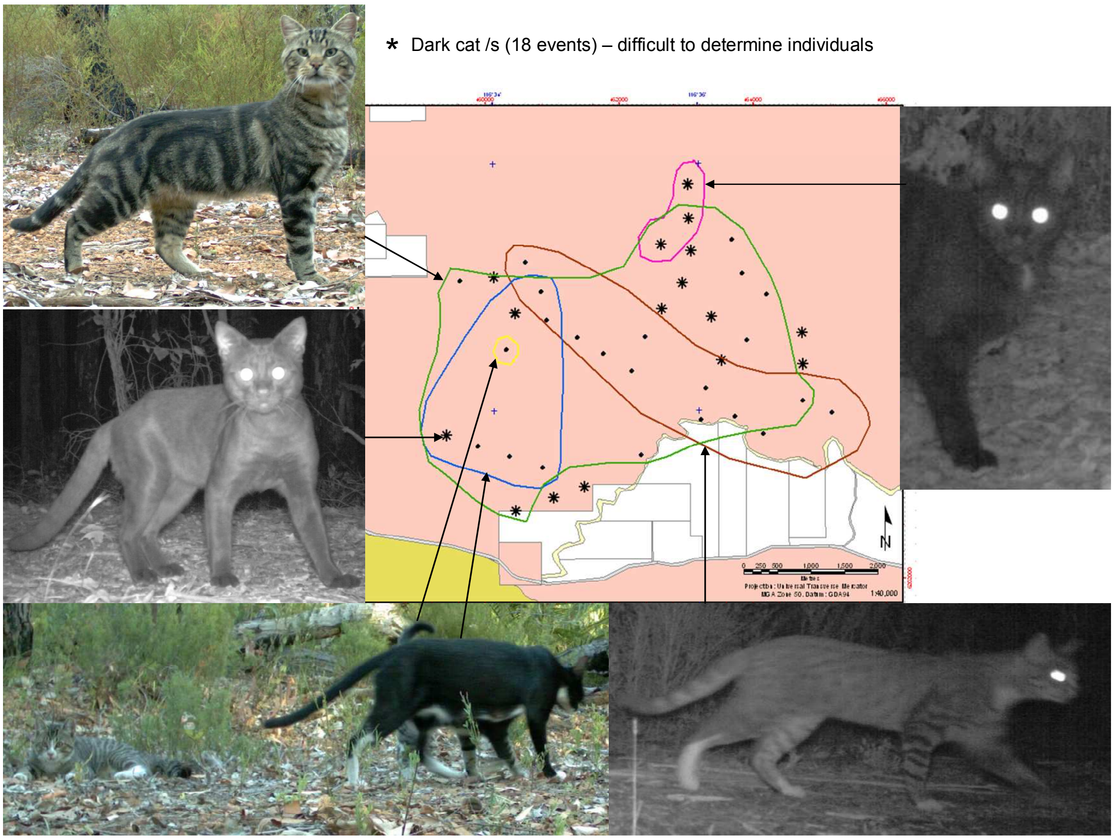


Figure 22. Rough estimates of the home ranges of the cats based on the detections on 50 remote sensor cameras within the Boyicup surveillance zone.

Figure 23. Fox with a tammar captured on remote sensor camera during the predator removal and monitoring trial at Balban, Upper Warren region.

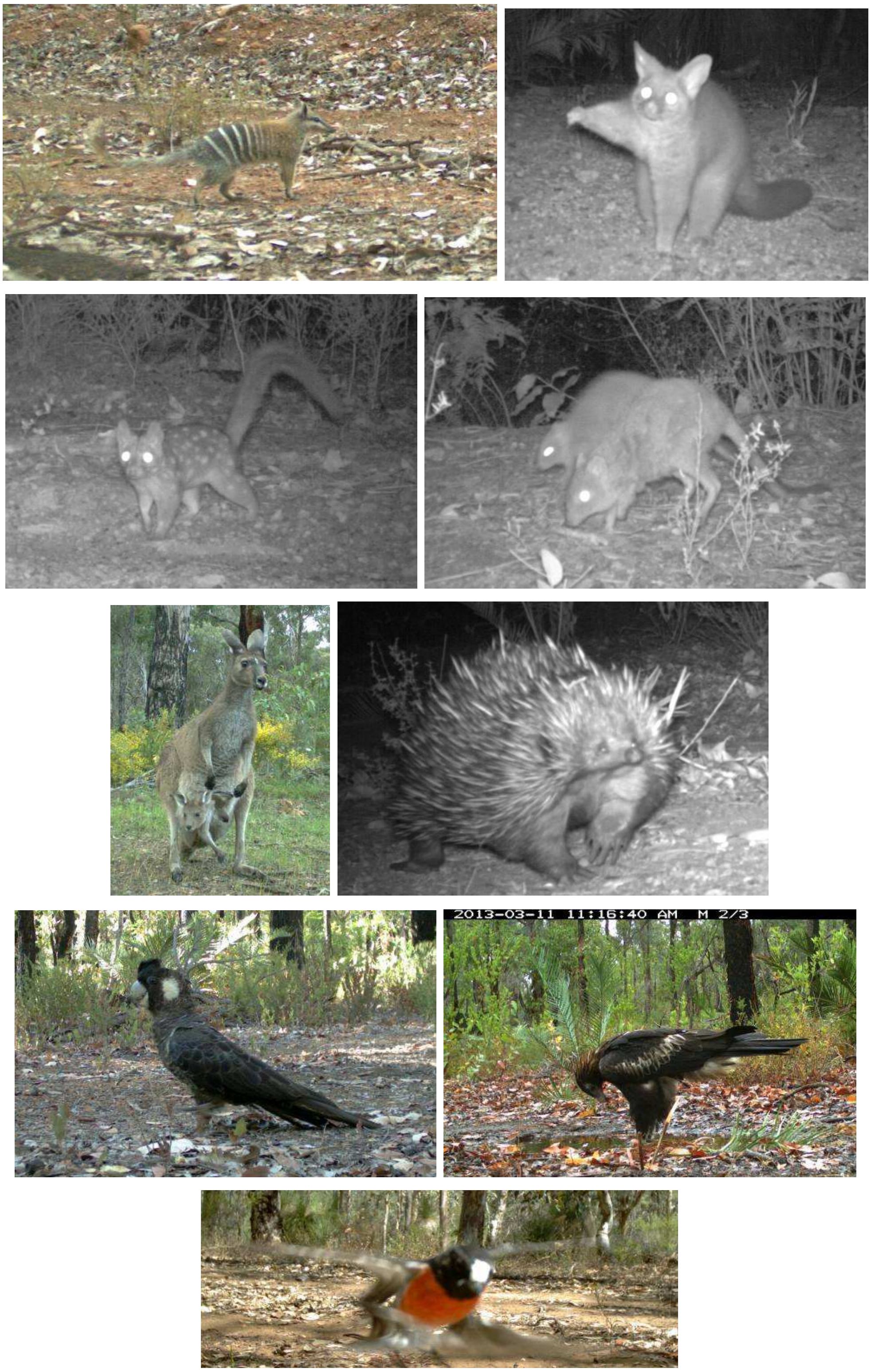


Figure 24. Selected images of native fauna detected during remote sensor camera surveillance in Boyicup and Balban; numbat, koomal (common brushtail possum), chuditch, woylies, western grey kangaroo and joey, echidna, Carnaby cockatoo, wedgetail eagle, scarlet robin.

A total of 1,300 and 1,000 sand pad nights were conducted at Balban/Keninup and Boyicup/Winnejup, respectively (Figure 25). After filtering this raw dataset to remove sand pads deemed unsuitable for analysis (disturbance from weather or vehicles) there were 916 and 865 sand pad nights available for analysis (Table 7). Detection rates from cameras were greater than AI from sand pads. This is due in part to differences in the measures; cameras recorded multiple detections of individuals over time within a day, whereas AI from sand pads is only derived from the presence or absence of at least one fox or cat.

At Balban and Boyicup fox detection on camera was high or highest post control, this possibly could reflect increased activity from remaining foxes within the surveillance area and/or reinvasion. Further analysis and identification of individual foxes will aid in determining this. Cameras have also shown that some cats travel over large areas (for example Cat #1 and #2 at Balban and Cat #1 at Boyicup). Further analysis of the data will reveal more information about the movement and activity patterns of cats and foxes.

Figure 25. Sand pad preparation and a detailed image of feral cat spoors detected on a sand pad.

Table 7. A comparison of the detection rates from remote sensor cameras and activity indices (AI) from sand pads at Balban and Boyicup and their respective reference sites.

	Balban						Control—Keninup		
	Camera activity (%)			Sand pad AI			Sand pad AI		
	Fox	Cat	n	Fox	Cat	n	Fox	Cat	n
Pre-control	3.95	3.70	1596	0.16	0.09	200	0.20	0.00	74
Control	6.14	6.71	1400	0.10	0.06	173	0.36	0.02	161
Post-control	5.88	6.25	800	0.13	0.05	150	0.08	0.03	158
	Boyicup						**Control—Winnejup**		
	Camera activity (%)			**Sand pad AI**			**Sand pad AI**		
	Fox	**Cat**	**n**	**Fox**	**Cat**	**n**	**Fox**	**Cat**	**n**
Pre-control	2.66	2.83	1201	0.01	0.00	225	0.10	0.00	231
Control	3.16	3.16	950						
Post-control	5.86	3.86	700	0.04	0.03	225	0.18	0.01	184

4.5.4.4 *Discussion*

The results and analyses of the measures of predator activity and density based on sand pads and cameras remain to be completed including;

- Density estimates based on predator removal activities
- Density estimates based on capture-recapture population modelling using camera data on individuals (particularly cats, possibly foxes)
- Activity indices from cameras
- Comparisons between survey methods (cameras and sand pads), calibrations with density estimates and sensitivity tests of survey methods to changed fox densities
- Potentially assess the re-invasion times after the removal of resident predators

4.5.5 Introduced predator biology

Heather Crawford (DPaW/Murdoch University), Narelle Dybing (Murdoch University)

Summary: The analysis of contents of the gastro-intestinal tracts of 15 foxes and six cats from the native forests and adjacent agricultural lands in and around the Balban and Boyicup areas of Tone-Perup Nature Reserve indicate that stock and introduced rodents associated with the agricultural areas represent a significant

proportion of their diets. Native animals (koomal, birds, frogs, reptiles and invertebrates) also constitute a significant proportion of the diet. The parasites found in these cats (Toxocara cati, Taenia taeniaeformis, Spirometra erinaceieuropaei, Oncicola canis and Cyathospirura dasyuridis) are known to be potential issues to humans, stock, wildlife and their hosts but their significance in the Upper Warren region remains to be determined. Analyses of samples from these foxes and cats are ongoing as part of larger collaborative projects with experts at Murdoch University.

4.5.5.1 Introduction

Fox and cat carcasses were recovered as part of the predator removal and survey method trials at Balban and Boyicup by WTACS and by collaborating landholders undertaking predator control on their own properties adjacent to Perup. Additional animals were also subsequently collected from collaborating landholders during ongoing control efforts in the area associated with the woylie conservation program and more generally. These presented an opportunity to examine some aspects of the biology of these pests, not otherwise known in the region; particularly diet, parasites, and simple demographics. Most of this was made possible through collaboration with researchers at Murdoch University. While some sample analyses have been completed many aspects remain to be completed in association with comparable samples collected as part of larger research programs.

4.5.5.2 Methods

Sample packs and instructions were provided to collectors of fresh carcasses. Fresh blood was collected where possible and immediately after humane euthanasia of introduced predators. Carcasses and plain blood were frozen as soon as possible. When collected, a second blood sample was left in a fridge to settle for about a day to allow blood platelets and serum to separate before the serum was siphoned off with a pipette into a separate vial and all blood products frozen. The carcasses and blood samples were transported frozen to Murdoch University for distribution and processing (Table 8).

After the completion of the removal and monitoring trial, which resulted in 9 foxes and 3 cats, an additional 7 foxes and 3 cats were removed over a 9 month period from the Balban area by private landholders. All but one of these foxes was subsequently used in the dietary analyses for these species (i.e. 22 predators removed from within the control areas of which 15 foxes and 6 cats were included in the dietary and *Toxoplasma* analyses).

Table 8. Summary of samples and analyses being undertaken on fox and cat caracasses collected during woylie-related programs in the Upper Warren region 2012–2013.

WHO	WHAT	WHY	HOW
Narelle Dybing	Whole body (cat only)	comparative investigation of disease, parasites and diet	body necropsy and identifying parasites present (body measurements, condition scoring, collection of ectoparasites, complete organ examination, diet identification, microscopic examination of gastrointestinal tract, collection and identification of helminth parasites)
Heather Crawford	Whole body (fox only)	dietary analysis (fox)s	
Mike Bunce	Gut/faeces samples	dietary analysis	next gen sequencing
Andy Thompson	Blood, brain & other tissues	Toxoplasma	Serology and PCR
tbc	Tissue sample	Genetics	PCR

Heather Crawford (DPaW, formerly DEC) conducted the diet analyses at Murdoch University on foxes using a similar methodology that she used as part of her honours research project at Murdoch University (Crawford 2010). Narelle Dybing (PhD candidate, Murdoch University) conducted the diet and parasite analyses on the cats as part of her research project at Murdoch University (Dybing *et al.* 2013). Necropsies were conducted on cat carcasses with an external examination for ectoparasites and an internal examination of organs for any visible macroparasites. All cats were weighed (W) and head and body lengths (HBL) were taken for an estimate of body condition. Body condition was calculated by the equation W (kg)/HBL (cm): the higher the value, the better the body condition. Diet was calculated as a proportion by volume that the dietary item contributed to the contents. Parasite analysis was conducted by the scraping method as described in Dybing *et al.* (2013).

4.5.5.3 Results

Fox diet analysis

The gastrointestinal tract was investigated from 15 foxes collected from within the control zones at Balban and Boyicup. Of these, 3 (1 male, 2 female), 7 (1 male 6 female), and 5 (4 male, 1 female), were juvenile, subadult, and adult respectively. The average adult body mass was 5.6 kg (maximum 6.7 kg). The stomachs were analysed for all but one of these animals, which had an empty stomach. Introduced and native fauna (koomal, birds, frogs, reptiles and invertebrates) represented 70% and 23% of the diet, respectively (based on the index of relative importance). Sheep constituted 65% of the diet. Other dietary items included cattle carrion, introduced rodents, plant material, and carrion maggots (Figure 26). The greatest minimum distance to agriculture recorded in this study was for two foxes captured at the same trap point (Trap #7, Boyicup), ~3.3 km from the closest agricultural land: one contained 79% cattle remains and the other 98% koomal. An additional 11 foxes were provided by the Boyup Brook Red Card event on the 9/03/2013 that were made available for *Toxoplasma* testing.

Table 9. Foxes used for dietary analysis that were collected during and after the predator removal trials in Balban (September–October 2012) and Boyicup (February–March 2013).

Date	Method	Collector	Location	Sex	Wt (kg)	Age
1/10/12	Trapped	WTACS	Balban, Trap 18	F	4.6	Adult
3/10/12	Shot	WTACS	K. Lloyd	M	6.7	Adult
9/10/12	Trapped	WTACS	Balban, Trap 17	M	4.5	Adult
12/10/12	Trapped	WTACS	Balban, Trap 9	F	4.7	Sub Ad.
14/10/12	Trapped	WTACS	Balban, Trap 23	M	5.6	Adult
12/11/12	Shot	T. Sims	G.&S. Mead, Boomer Flats	F	2	Juvenile
23/01/13	Shot	M. Deas	Rylington Park, Paddock 33	F	3.8	Sub Ad.
2/02/13	Shot	M. Deas	Rylington Park, Paddock 33	F	4.8	Sub Ad.
2/02/13	Shot	M. Deas	Rylington Park, Paddock 33	F	3.1	Juvenile
27/02/13	Trapped	WTACS	Boyicup, Trap 7	M	6.6	Adult
28/02/13	Trapped	WTACS	Boyicup, Trap 19	F	4.2	Sub Ad.
1/03/13	Shot	M. Deas	Rylington Park, Paddock 17	F	3.9	Sub Ad.
3/03/13	Trapped	WTACS	Boyicup, Trap 19	F	5.8	Sub Ad.
7/03/13	Trapped	WTACS	Boyicup, Trap 7	M	4.7	Sub Ad.
19/03/13	Shot	M. Deas	Rylington Park, Paddock 34	M	3	Juvenile

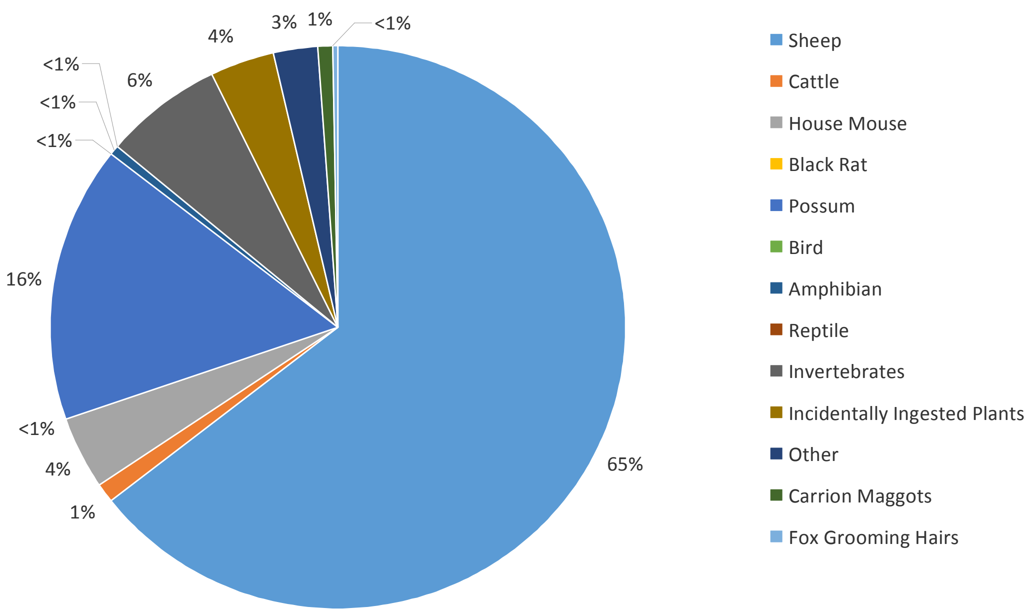


Figure 26. Stomach contents of foxes from the Upper Warren region (n=14) sampled in 2012–2013, using Index of Relative Importance

Cat parasites and diet

Only the main points from a preliminary examination of the six cats from the Balban and Boyicup are provided here. A total of two females and four males were collected in this project and all were tabbies. All were adults except one male kitten (≤1.5kg) (Table 10). More detailed analyses and comparisons with feral cats from other locations in Western Australia will be reported later as part of Narelle Dybing's PhD research.

Table 10. Demographics of cats caught and sampled during the predator removal trials in Balban (September–October 2012) and Boyicup (February–March 2013)

Cat number	Date caught	Sex	Age category	Head Body Length (cm)	Weight (kg)	Body condition index (weight/HB)	Infracommunity Richness
SWC 110	23/04/2013	M	Kitten	43.6	1.5	0.034	1
SWC 107	19/02/2013	F	Adult	57.5	2.2	0.038	3
SWC 106	16/09/2012	M	Adult	48.6	2.2	0.045	2
SWC 109	4/04/2013	F	Adult	52.6	2.6	0.049	2
SWC 108	26/02/2013	M	Adult	50.2	3.2	0.063	3
SWC 111	8/07/2013	M	Adult	57.1	4.2	0.073	3

All six cats examined harboured gastrointestinal parasites, with infracommunity richness (number of parasite species within a host) ranging from 1–3 parasite species (Table 10). None of these cats were found to be carrying ectoparasites. Three of the parasite species, including *Toxocara cati* (25% of the cats), *Taenia taeniaeformis* (67%) and *Spirometra erinaceieuropaei* (50%), have been found in humans. The other species found, *Oncicola spp* (50%) and *Cyathospirura dasyuridis* (25%), are found in native wildlife, including birds and dasyurids respectively. *Spirometra erinaceieuropaei* is also known to cause clinical disease in wildlife and can cause problems at a population level.

Looking at body condition score versus infracommunity richness, there was a general increasing trend, as body condition increased so did the number of internal helminths the individual carried (Figure 27). Body condition was also examined with parasite intensity (number of individuals of a parasite species) of the parasite species that were found in four or more individuals. This included *T. taeniaeformis*, *Oncicola* spp and *S. erinaceieuropaei*. Body condition showed a positive increasing trend with *Oncicola* spp and a negative trend was found with *S. erinaceieuropei* versus body condition (Figures 28 A and B).

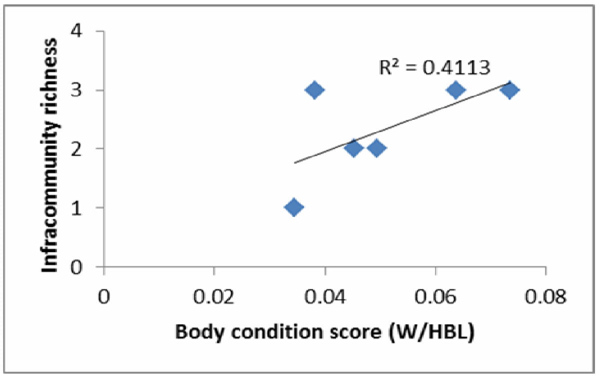


Figure 27. Infracommunity richness vs body condition scores of six feral cats from the Upper Warren region.

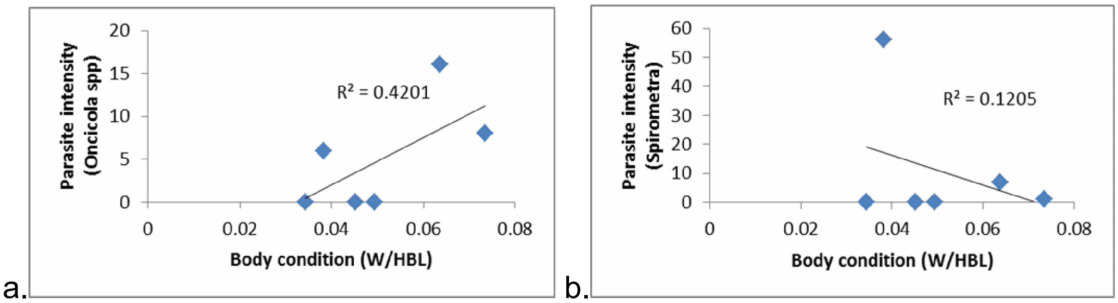


Figure 28. a) Parasite intensity of *Oncicola* spp vs Body condition, b) Parasite intensity of *Spirometra erinaceieuropaei* vs body condition.

All of the cats were found to have ingested *Mus musculus*. Fifty percent of the cats had ingested bird, potentially honeyeaters. One of the cats had two *Rattus rattus* individuals in its stomach. Four of the cats were found to be eating invertebrates, which included grasshoppers, beetles, ants, centipedes and spiders. A slender tree frog was found in the stomach of one cat and one cat had ingested carrion bovine. Three of the cats were found to have ingested sheep however they were considered carrion (docked tails in one and a pile of matted wool in two others). Fifty percent of the cats had also ingested plant material including grass, small tree branches (presumably from eating next to vegetation) as well as seeds and oats, potentially from a farm shed. Percentage volume of dietary contents was estimated for stomachs and large intestines separately (Figure 29 and 30). These proportions were also based on broad categories for example *Mus musculus* and *Rattus rattus* are included in the introduced rodent category.

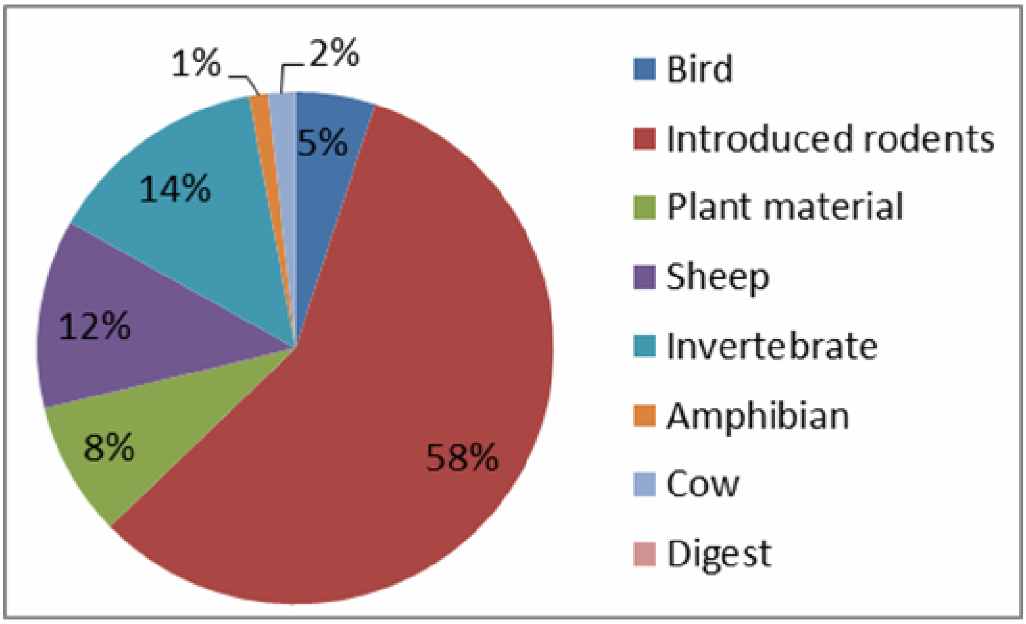


Figure 29. Percentage volume of dietary contents from the stomachs of feral cats

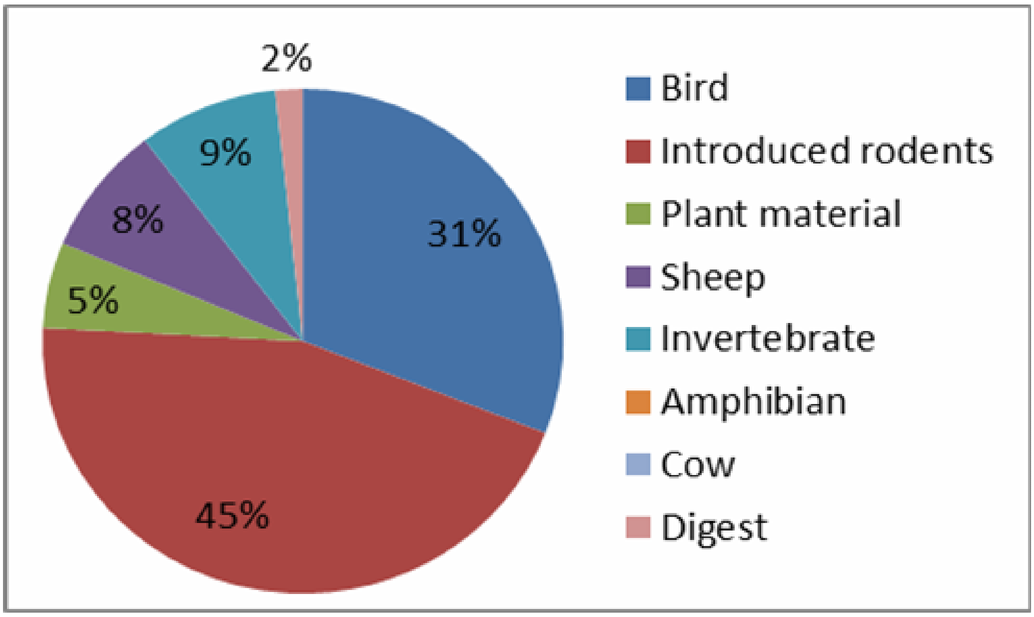


Figure 30. Percentage by volume of dietary contents from the large intestine of feral cats

4.5.5.4 Discussion

Agricultural stock (sheep and cattle carrion) represented two thirds of the fox diet, even of individuals that were caught several kilometres from private property. Evidently fox individuals were ranging widely for food. Some of this food includes the carrion of already dead agricultural stock. These results are also suggestive that fox numbers may be elevated in the forest areas because of food subsidies available from agricultural land. More effective reduction of foxes on adjacent land is therefore probably beneficial to agricultural commercial enterprises and conservation values in nearby forests. This could be achieved through coordinated broadscale control across DPaW-managed areas and private properties but also by the reduction in the availability of dead stock by immediately burying or removing the carcasses.

It is interesting to note that kangaroo (for example, carcasses from road kill) was not detected in the stomachs of the foxes. This maybe because there was little traffic in the area and/or few carcasses available at the time—perhaps less than can be observed elsewhere or at other times of the year.

The significance of the parasites to the feral cat population, humans, agricultural stock, and wildlife in the Upper Warren region remains to be determined. However, at least some of these have been found elsewhere to cause clinical diseases that can cause problems at the population level in at least some species. The increasing positive trend of infracommunity richness versus body condition suggests that a greater body condition is more suitable for providing a greater number of niches in which the parasites can reside (Mourand and Poulin 1998). The parasite load versus *Oncicola* spp’s increasing trend also indicates the suitability of a better conditioned host to harbouring a parasite. The opposite trend was occurring with body condition versus *S. erinaceuieuropaei*. This could suggest a couple of things. The higher intensity of *S. erinaceieuropaei* could be negatively affecting the body condition of cats or the cats could have a low immunity/naivety to infection by this parasite and so are more susceptible to infection (Chandra 1981).

The high prevalence of introduced rodents, carion from agricultural stock and grains in the diet of cats is probably a consequence of all of these cats having been located on agricultural properties adjacent to Tone-Perup Nature Reserve. Although they were all feral farm cats, some native species were also being consumed (invertebrates, a frog, birds and mammal). The fact that cats were foraging across large areas of agriculture and native forest is supported by the evidence of large home ranges from the remote sensor camera monitoring associated with the introduced predator removal and monitoirng programs at Balban and Boyicup (see section 4.5.4).

Analyses that remain to be completed from the cats and foxes include the confirmation of the identity of some dietary items (for example mammal hairs), genetic analysis of diet by Mike Bunce and the analyses for *Toxoplasma* (from blood and tissue samples) by Andrew Thompson. All of this work is dependent on existing collaborations with respective experts at Murdoch University.

5 Perup Sanctuary

5.1 Introduction

Located in the Tone-Perup Nature Research, the Perup Sanctuary was established to support an insurance population to conserve the genetics of the woylie in case the natural wild populations became extinct. It could also assist efforts to identify the cause(s) of the recent declines and factors limiting recovery in the wild and, once well established, become a ready source of woylies for translocations to help in the recovery of the species in the wild.

At 423 ha, the Perup Sanctuary is maintained predator free (introduced fox and feral cat and native chuditch) by means of a 2 m high fence with apron pegged along the ground (to resist digging under the fence), a ‘floppy top’ and outrigged electric wires (to resist animals climbing over). In the absence of terrestrial predators, the sustainable carrying capacity of woylies in the Perup Sanctuary is expected to be between 400 and 900 individuals.

5.2 Management

Summary: The Perup Sanctuary was constructed January–September 2010 based on a design to maximise the ongoing prospects of maintaining the predator-free status of the facility and to minimise the ongoing costs of maintenance and repair. All emus and chuditch, most western grey kangaroos and western brush wallabies and 43 koomal were removed September–October 2010. The sanctuary was confirmed free of foxes and cats in October 2010. Monitoring for predator incursion using a range of methods remains ongoing, as does the monitoring and management of rabbits, weeds and indicators of forest health such as wandoo decline and dieback. Planned guidelines for the management of the Perup Sanctuary will also include fire.

5.2.1 Construction

The design of the fence used for the Perup Sanctuary was based on research (e.g. Long and Robley 2004; Moseby and Read 2006; Bode and Wintle 2009) and experience elsewhere (for example, AWC, DPaW, and Arid Recovery (SA) facilities). Key design considerations included the combined use of 3 cm diameter mesh for a 200 cm fixed apron at the base of the fence, a vertical mesh barrier for 190 cm, a 70 cm outward-facing floppy top and outrigged electrical wires (Figure 31). Other key design elements included adequate drainage (for example, culverts and pipes), a stable, deep and compact foundation (gravel road base), minimum clearing of vegetation within 6 m either side of the fence and the removal of potentially dangerous trees that might fall and impact the fence and the construction of two vehicle access gates. Particular attention was given to potential weak points of the barrier to introduced predators, including the foundations, fence (especially corners), gates and cross-boundary drains (Figure 32).

The Perup Sanctuary is located immediately west of the Perup accommodation facilities (Perup: Nature's Guesthouse; Figure 33). Construction of the 423 ha enclosure began in January 2010 and was completed in September 2010. Some of the materials used included;

- 1700 x 2.4 m galvanized star pickets used
- 32.64 km of netting used.
- 52 km of standard tensile wire used to support the netting
- 9.9 km of high tensile wire to support the floppy top.
- 4,500 Reo-bar pegs used to pin the skirting to the ground.
- 460,000 clips used by the pneumatic guns with an average output of 15,000 clips per day.
- The 8.5 km perimeter electric fence builds up voltage at the furthest point from the energizer. 6.5kV at the energizer entering the fence line to 7.0kV at the furthest end point.

Internal track management included rehabilitating existing unwanted vehicle tracks, upgrading strategic vehicle tracks to be suitable in all weather, and the establishment of a minor small vehicle seasonal access track running parallel and midway between Alf Road and the southern boundary of the sanctuary. Consideration of the containment for the pathogen *Phytophthora cinnamomi*, responsible for jarrah forest dieback, was also very important as part of the designing, construction and ongoing management of the facility. As well as surveying and mapping dieback before construction, the area was also surveyed for culturally significant sites and declared rare flora (DRF). The removal of vegetation and ground disturbance associated with the initial phases of the construction was conducted under the supervision of monitors from the South West Aboriginal Land and Sea Council. A grid of reference points spaced 100 m apart was also installed using GPS and fence droppers for general management purposes (for example, monitoring points and plots; Figure 33).

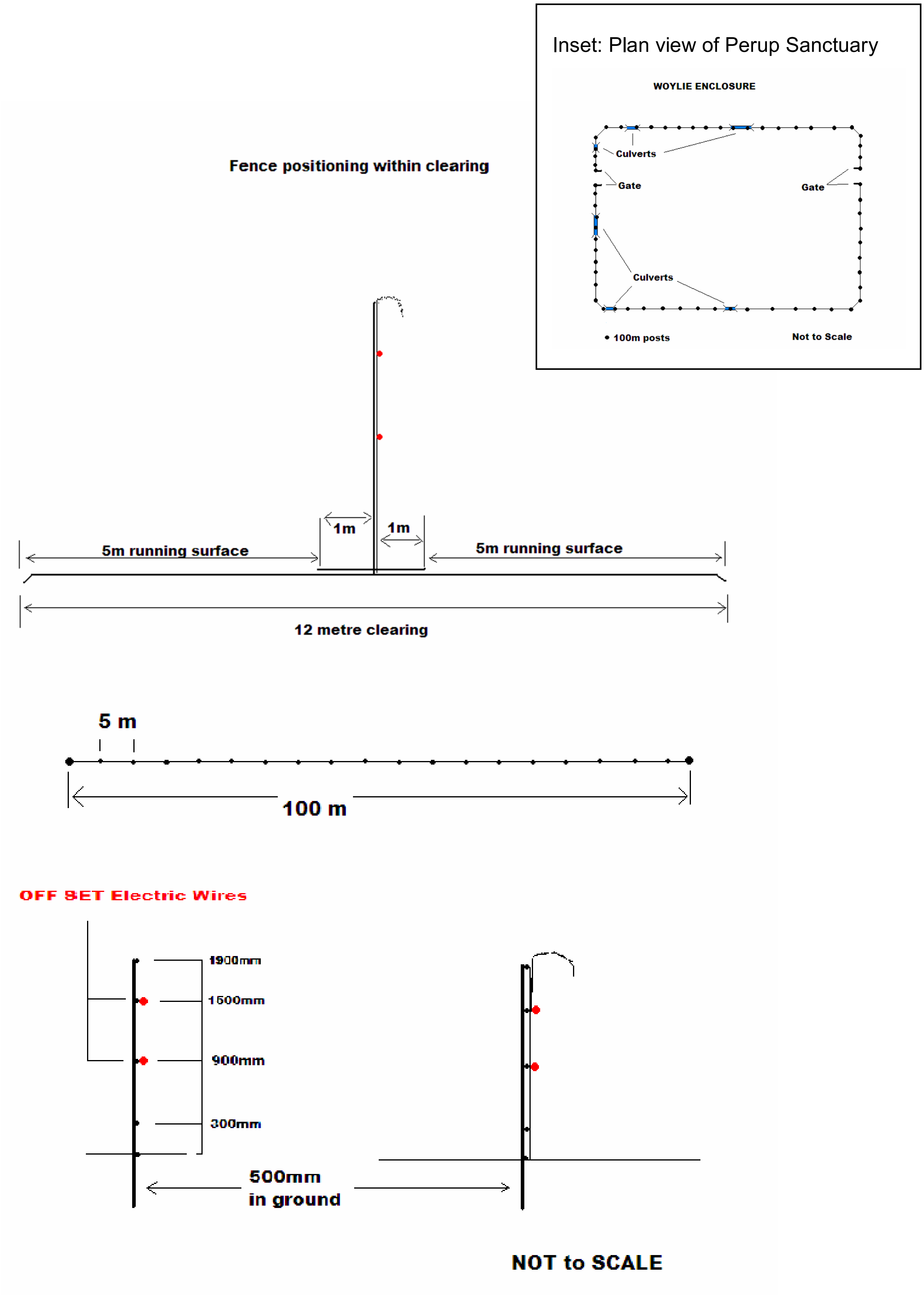


Figure 31. Fence design used at the Perup Sanctuary

Figure 32. Selected images of design elements of the Perup Sanctuary infrastructure under construction including a & b) 12 m fence clearing and gravel road base foundation, c) culvert and pipe construction for drainage, d) detail of drain, e) vehicle access gate, f) detail of fence

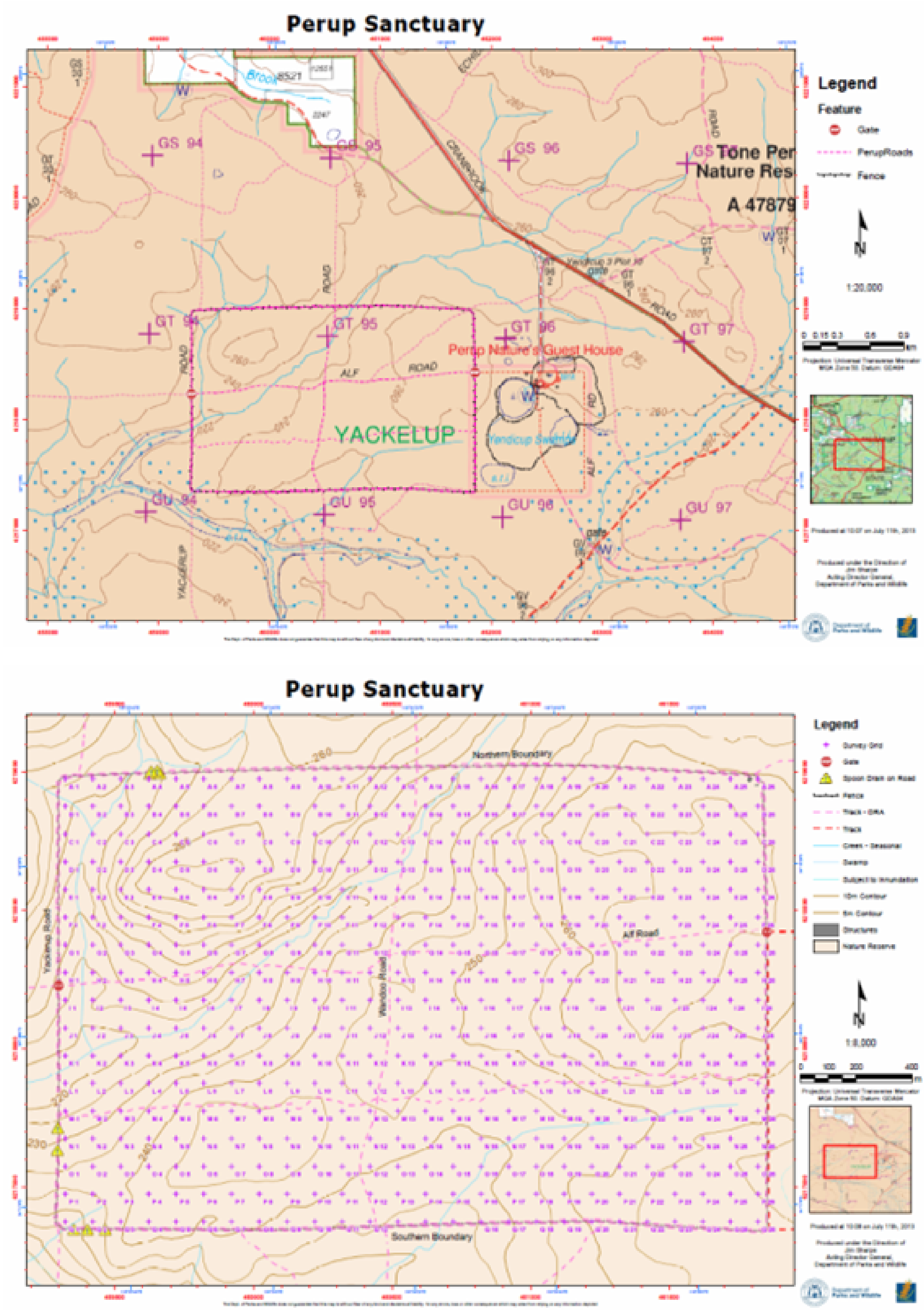


Figure 33. General map of Perup Sanctuary and surrounds and a detailed map of the reference point infrastructure within the sanctuary.

5.2.2 Unwanted fauna removal and management

5.2.2.1 Fauna muster to remove large wide-ranging species

Prior to completing the corners of the perimeter fence of the sanctuary a ‘fauna muster’ or battue was undertaken on 22nd September 2010. The aim was to ‘herd out’ the emus, kangaroos and western brush wallabies from within the sanctuary that would benefit from having a free and greater range outside the fence. The muster involved an organised line of people spaced approximately 10 metres apart across the full 1.5 km width of the sanctuary (Figure 34). Starting on the eastern boundary and organised into teams of 10 people, each lead by a sector commander, the line of people walked slowly and quietly in an arrowhead formation toward the western boundary encouraging fauna to retreat. Every effort was made to avoid panicking the wildlife. When the western boundary was reached, first by the teams at the apex of the arrowhead, the lines of walkers then progressed towards the open corners to help direct the target species out of the sanctuary. Once completed, dedicated fencing teams wired closed the two corners. The same exercise was repeated from west to east to encourage any other remaining target wildlife to retreat through the eastern corners, prior to them being closed. The muster involved 160-180 people including departmental staff and volunteers.

The muster was successful with no emus having been recoded within the sanctuary since. A few western grey kangaroos, western brush wallabies and Tammar wallabies are known to remain within. These will be monitored to keep their numbers low.

Figure 34. Volunteers and departmental staff lined up along the eastern boundary before starting the second sweep of the Perup Sanctuary as part of the 'fauna muster' to encourage unwanted large fauna out through the open corners of the fence before being closed, 22 September 2010.

5.2.2.2 Introduced predators

After the completion of the Perup Sanctuary fence and the fauna muster, cage trapping was conducted (276 trap nights, 4–7 October 2010) to survey the medium sized mammals in the sanctuary and to remove chuditch before the translocation of woylies in November 2010. It was necessary to remove chuditch because their home ranges are larger than the size of the sanctuary (Serena and Soderquist 1989) and they are predators of woylies (DEC 2008a). Some koomal were also removed to minimise interference and potential non-target captures during the planned survey and control of foxes and cats. As a result two chuditch and 36 koomal were relocated immediately outside of the sanctuary. One of the male koomal has since been recaptured within the sanctuary (February 2011, April 2011 and April 2013).

Later in October 2010 surveys were conducted by expert departmental staff to determine whether any foxes or cats were present within the sanctuary, and if so to remove them. Sand plots, remote cameras, leg hold traps, cage traps and active searches for animals and their sign were used to satisfactorily confirm that no foxes or cats were present in the sanctuary. Seven koomal and one Australian raven were captured and released unharmed outside the sanctuary. This work is reported in more detail by Hamilton and Rolfe (2011).

5.2.2.3 Rabbits

Low numbers of European rabbits have been observed within the sanctuary, and if numbers increase they may have a significant impact upon vegetation. They will be controlled, and if possible completely eliminated from within the sanctuary, with a one shot oats mix.

5.2.3 Predator incursion monitoring

The incursion of an introduced predator (primarily fox and cat) into the Perup Sanctuary is a serious threat to the insurance population of woylies and other native fauna. A surveillance and detection system has been developed to ensure that any incursion can be acted on immediately. The system relies on remote sensor cameras, sand pads and regular patrols.

At least 22 remote sensor cameras have been semi-permanently set adjacent to key locations viewing along and through the fence and at track junctions (Figure 35). Other roving cameras have also been set in and around the sanctuary from time to time for additional surveillance as required. Images from the cameras are downloaded twice weekly and reviewed immediately for the possible presence of introduced predators and other key points of interest. Images are stored for further use.

Naturally occurring areas of sand, particularly associated with tracks, have been used opportunistically to monitor for signs (foot prints and scats) of introduced predators within the sanctuary. As the vegetation growth increases on these sites they will become less effective as monitoring plots. Therefore the installation of purpose-built sand pads is planned.

Patrols are generally conducted three times a week, principally to monitor the sanctuary infrastructure including any signs of damage to the fence, for example from kangaroos or fallen tree limbs, and to test the functioning of the electric fence. Access within the sanctuary is restricted and controlled however, anyone entering the sanctuary is generally briefed on the need to remain vigilant for any signs of a predator (including carcasses), issues related to the infrastructure and/or the wildlife within. Sightings of unwanted and introduced fauna are routinely reported.

Since its completion in October 2010, the Perup Sanctuary has remained free of foxes and cats, while they are frequently detected immediately outside the fence.

Figure 35. Remote sensor camera used to monitor predator incursions in the Perup Sanctuary

5.2.4 Vegetation management

Blackberry (*Rubus anglocandicans*) and bridal creeper (*Asparagus asparagoides*) are known to occur within watercourses in areas adjacent to the sanctuary. A visual inspection of weed incursion was undertaken along the watercourses within the sanctuary and failed to detect blackberry or bridal creeper, however a number of other weed species were found. All of these weeds have also been sighted within the creekline vegetation plots (see section 5.3.2 and Appendix D) and are generally considered to be disturbance opportunists associated with agriculture and at this stage are not thought to constitute a major management issue.

Dead and dying mature wandoo trees are common along the creek line within the sanctuary. This occurrence has been mapped to compare monitor the possible wandoo decline at regular intervals into the future. One of the creekline vegetation monitoring plots ((see section 5.3.2) is also situated within an area impacted by the wandoo decline.

A management guideline for the Perup Sanctuary remains to be formally adopted but should include a consideration of fire within and surrounding the sanctuary and the ongoing management and monitoring of dieback in addition to the matters addressed in the above sections of this report.

5.3 Baseline biological surveys

Summary: Surveys indicate that at least 13 mammal, 66 bird species, 19 reptile, 10 frog species and 164 vascular plant species are found in and immediately adjacent to Perup Sanctuary. The sanctuary provides refuge for many of these species that are also vulnerable to introduced predators. Ongoing monitoring inside Perup Sanctuary, in conjunction with monitoring at comparative sites on the outside, will help to understand what other effects a predator-free enclosure may have on the plants, animals and ecosystems within.

5.3.1 Introduction

Large fenced enclosures, such as the Perup Sanctuary, are being increasingly used for species conservation. It is seen as an effective way of removing or reducing some of the key threats of priority species such as their predators and/or competitors. While the objective is usually to increase the abundance of target species, it is generally unclear or overlooked as to what other ecological changes may occur as a result of creating these enclosures and associated management interventions. Some of these effects may be considered positive (for example increases in other native species of value), while others may be negative and/or may lead to a compromise in the viability of priority populations (for example, overexploitation of some resources that may result in population reduction or collapse). An understanding of these consequences can better inform the ongoing management of these facilities for broader conservation purposes and/or to promote their longer term sustainability. The purpose of this program is to establish a baseline reference of the species, communities and ecosystems within the sanctuary at the time of establishment. This is an essential component to being able to quantify what the effects of the enclosure and associated management may be over time.

Key ecosystem components targeted in the baseline surveys included: vegetation structure and floristics, frogs, reptiles and mammals. Fauna survey methods included, pit trapping for small terrestrial vertebrates, cage trapping for medium-sized mammals, nest boxes for wambenger, spotlighting for arboreal mammals, larger macropods and nocturnal birds, and remote sensor cameras for vertebrates more generally. The initial work from these activities is reported here.

5.3.2 Vegetation structure and floristics

Summary: A total of 164 species of vascular plants, including eight alien species, have so far been recorded within the vegetation plots in the Perup Sanctuary that have been monitored annually since 2010. Analyses remain to be conducted on the vegetation data. Further consideration is needed of the species, vegetation complexes, soils, leaf litter and animals activity (digging and nests) not being monitored under the current program.

5.3.2.1 Introduction

The purpose of the baseline surveys and monitoring of vegetation structure and floristics is to track and quantify any changes that might be associated with changes in fauna as a result of the establishment of the predator-free sanctuary.

5.3.2.2 Methods

Three replicates of paired 10 x 10 m vegetation plots were established within each of three vegetation associations within the Perup Sanctuary in 2010 (Figures 36 and 37). While six Mattiske and Havel (1998) vegetation mapping units were identified, three of these constitute the vast majority of the vegetation within the sanctuary. These generally corresponded with the topography; ridge (Bevan 2 vegetation unit), mid-slope (Yerraminup) and streamline (Yerraminup flat). Each site had a fenced plot (90 cm high fence, 3 cm diameter mesh, designed to exclude medium–large herbivores) and an open plot (the corners of which are demarcated with 1.2 m fence droppers).

A baseline survey of the plots was undertaken in spring 2010 and autumn 2011, and has been re-scored twice per year since then. Plot scoring is undertaken using the *FORESTCHECK* monitoring methodology, which includes quantifying cover, abundance and spatial distribution for each species present (Ward *et al.* 2011). Samples of non-identifiable flora were sampled for later identification.

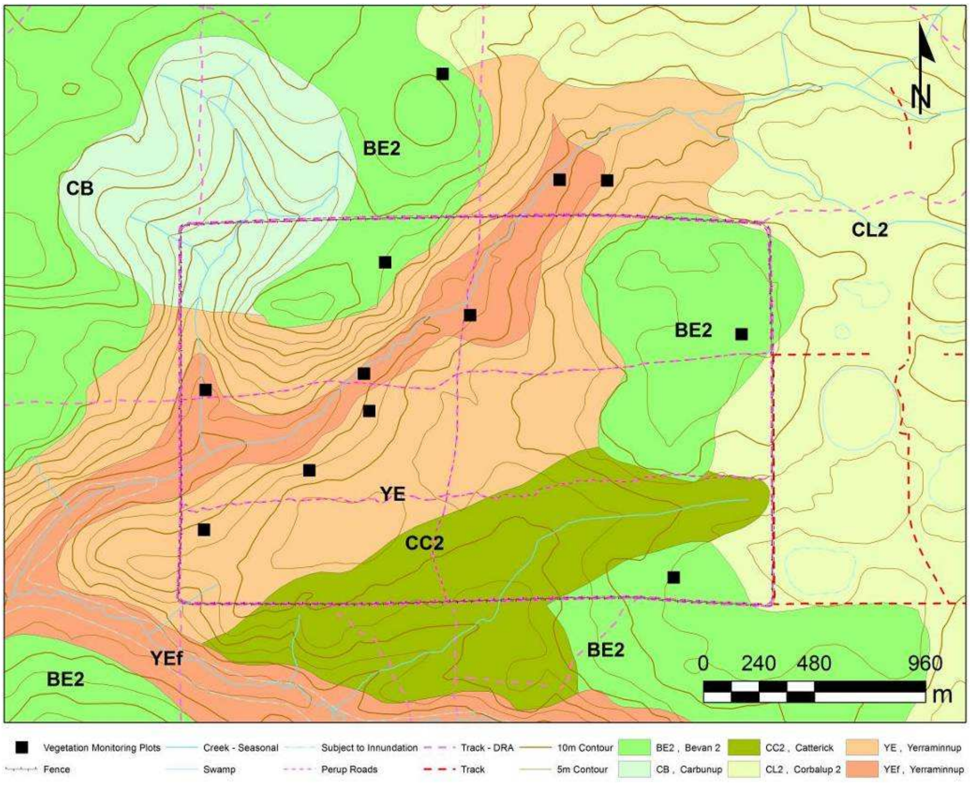


Figure 36. a) Aerial image of the Perup Sanctuary showing some of the topographical and vegetation differences (the northeast corner of the sanctuary is in the foreground and the southwest corner in the background), b) Map of the vegetation types and vegetation monitoring plots in the Perup Sanctuary

Figure 37. Vegetation monitoring plot within the Perup Sanctuary

5.3.2.3 *Results*

A total of 164 species of vascular plants, including eight alien species, have so far been recorded within the vegetation monitoring plots in the Perup Sanctuary (Appendix D). Analyses on the vegetation data have not yet been done.

5.3.2.4 *Discussion*

The data collected to date from the vegetation plots provides a useful baseline from which to track possible vegetation changes over time. While analyses on this data are yet to be done they could include; i) an assessment of the similarities and differences between and within vegetation types, ii) an assessment of variation within the data between sampling periods and observers to date, iii) a sensitivity analysis that includes determining the statistical power of the data, iv) whether there is a statistically significant difference between the fenced and unfenced plots, and v) whether there is any early indication of vegetation change over time. The species lists also provide a useful reference for these vegetation complexes for other research and management purposes (for example, plant list for the rehabilitation of disturbed sites such as old gravel pits).

While it is too early to detect substantial vegetation changes over time and/or differences between fenced/unfenced plots to date, this needs to be closely monitored as the woylie population approaches the predicted carrying capacity in 2015. This will inform, in a timely manner, any potential adverse effects that increasing mammal densities may be having on the vegetation, which management can then consider whether and how it might be appropriate to respond accordingly. On this basis the vegetation plots will continue to be re-scored each autumn and spring and an initial analysis of the vegetation data should be completed in 2014–2015.

While 164 species have been recorded across the nine paired plots established so far, this will be a gross underestimate of the total number of species in the sanctuary. For example, records in NatureMap (http://naturemap.dec.wa.gov.au/) in 2013 indicated that 428 flora taxa have been recorded within the Tone-Perup Nature Reserve, many of which are likely to be within the Perup Sanctuary. While many of the more common species are likely to have been recorded for the three vegetation complexes sampled, the less common, more patchily disturbed and/or those present in the other three vegetation complexes not sampled will be absent from the species inventory list (Appendix D). Therefore consideration should be given as to whether the current extent of monitoring is adequate for management. An assessment of the species accumulation curves over space and time within each vegetation complex should be included in these considerations.

An original objective of the baseline surveys and monitoring was to also quantify possible changes in leaf litter and soil attributes and evidence of animal activity (for example, diggings and nests). These changes are expected to be both substantial and ecologically important (e.g. Garkaklis *et al.* 2004; Flemming *et al.* 2013). Because of resource issues these elements of the habitat within the Perup Sanctuary have not been adequately addressed to date. The paired fenced/unfenced vegetation plots provide an excellent opportunity from which to begin a comparative monitoring and investigation in this regard. This should be a priority for the management of the sanctuary but more so to help quantify the importance of digging mammals in the forests of southwestern Australia.

Other aspects of the vegetation that should be considered for comparative survey and/or monitoring include dieback (*Phytophthora cinnamomi* infection), wandoo deaths/decline, other indicators of vegetation health, crown condition and leaf area of overstorey species (for example, possible responses to increased browsing from possums), non vascular plants and species of special interest. The latter may include declared rare flora (DRF), sensitive and/or susceptible species. For instance, it is thought that at least two orchid species may have been lost from Karakamia Wildlife Sanctuary as a result of predation from high densities of woylie and quenda; however no systematic monitoring was in place to be able to verify this (J. Kuiper pers. comm.). Similarly *Persoonia* abundance and distribution is thought to have decreased in the jarrah forest due to reduced recruitment because of the palatability of seedlings to kangaroos and wallabies that have increased in density since the 19^{th} century, due to a lack of traditional hunting and increases in grasses associated with agriculture (Abbott and Van Huerk 1988, Monaco 2012)

There may be opportunities to further develop our understanding of the soil, litter and vegetation changes associated with the creation of a fauna sanctuary, through collaborative research projects such as university student projects. There is also an opportunity to compare the results from this monitoring with the vegetation surveys conducted by Georgina Yeatman as part of her current PhD project within the same three vegetation complexes as part of the surveys of small terrestrial vertebrates (see the next section 5.3.3).

No DRF, priority or sensitive species have yet been detected within the sanctuary. The alien species found are common weeds of disturbed bushland across the South West (Hussey et al. 2007). Most occur within the stream systems within the sanctuary, some extending onto the lower slopes. All are killed outright by fire, however being disturbance opportunists they respond well to the disturbance.

5.3.3 Small terrestrial vertebrate surveys using pitfall traps

Summary: Three small mammal, thirteen reptile and nine frog species were recorded in and immediately adjacent to the Perup Sanctuary in the first 18 months of its establishment. Significant differences in the small vertebrate assemblage existed between habitat types. Species richness and overall capture rates were greatest in the valley (creek) habitats.

5.3.3.1 *Introduction*

Patterns in the small vertebrate assemblage inside and outside Perup Sanctuary were investigated by Yeatman *et al.* (2013) as part of a larger monitoring project on the flora and fauna of the area. A very short summary is provided here.

5.3.3.2 *Methods*

Nine sites were selected inside and nine outside to the south west of the sanctuary. There were three replicates of each of three habitat types inside and outside the sanctuary. Each of the habitat types is characterised by position in the landscape, soil structure/hydrology and vegetation structure/composition.

Each site was surveyed using a web array of 25 pit-traps (spaced 25 m apart along eight evenly spaced radial arms for a common central point).

5.3.3.3 Results

A total of 751 captures were recorded in 450 pit traps between September 2011 and July 2012. Six trapping sessions of four nights each were conducted during this time, totalling 9625 trap nights. Three small mammal, thirteen reptile and nine frog species were recorded at 18 sites (Table 11; Figure 38).

There were significant differences in the small vertebrate assemblage between habitat types. There was a decline in species richness and overall capture rates moving upwards in the landscape from creeks to ridge top sites. There was no clear change in the species diversity across habitat types. Eight of the small vertebrate species trapped accounted for 95% of the variation in the total species set. Creek sites were characterised by a greater relative abundance of frog species, particularly *Crinia glauerti*, *Pseudophryne guentheri* and *Heleioporus eyrei*. Slope sites had a greater abundance of *Sminthopsis griseoventer* and *Morethia obscura*. Ridge sites were dominated by reptiles, in particular, *Lerista distinguenda*. There was no difference in the body size of individuals between habitats.

Table 11. Total number of amphibian, mammal and reptile captures and number of species trapped during the six survey sessions according to habitat. Number in brackets indicates the total number of species (Source: Yeatman *et al.* 2013).

		Habitat		
Taxon	**Species**	**Creek**	**Slope**	**Ridge**
Amphibians	*Crinia georgiana*	6	7	-
	Crinia glauerti	18	3	-
	Crinia sp complex	79	10	4
	Heleioporus eyrei	75	15	5
	Heleioporus inornatus	-	-	1
	Heleioporus psammophilus	5	1	4
	Limnodynastes dorsalis	31	5	57
	Neobatrachus pelobatoides	2	-	-
	Pseudophryne guentheri	95	3	-
		311 (8)	44 (7)	71 (5)
Mammals	*Sminthopsis griseoventer*	16	37	13
	Mus musculus	17	3	1
	Cercartetus concinnus	4	1	1
		37 (3)	41 (3)	15 (3)
Reptiles	*Acritoscincus trilineatum*	3	1	2
	Christinus marmoratus	-	2	-
	Ctenotus catenifer	-	1	-
	Ctenotus labillardieri	-	1	3
	Egernia napoleonis	1	1	1
	Hemiergis peronii	9	19	6
	Lerista distinguenda	13	43	71
	Lerista microtis	-	1	-
	Menetia greyii	2	2	2
	Morethia lineocellata	-	1	3
	Morethia obscura	11	23	6
	Parasuta gouldii	1	-	-
	Ramphotyphlops australis	1	-	2
		41 (8)	95 (11)	96 (9)

Figure 38. Humming frog, pygmy possum and Gould's hooded snake caught during baseline surveys of the Perup Sanctuary and comparative sites immediately outside the sanctuary.

5.3.3.4 Discussion

The differences in the communities between habitats suggest that habitat level monitoring should continue as broader scale observation may lack sensitivity to changes within the different communities in the area. This study provides vital information for the management of the Perup Sanctuary and as part of the wider monitoring project, has the potential to inform the management of other fenced areas.

5.3.4 Wambenger surveys using nest boxes

Summary: Wambenger activity and individuals have been monitored using a grid of nest boxes originally established in the 1990s and then modified and

incorporated into the Perup Sanctuary. Detection rates are very low but consistent with comparable data elsewhere in Tone-Perup Nature Reserve and substantially lower than observed in the 1990s. A synthesis of all wambenger data and a review of the nest box methods used throughout the Upper Warren are required.

5.3.4.1 Introduction

The wambenger (brush tailed phascogale or *Phascogale tapoatafa*) was the focus of a PhD research project (Rhind 1998) conducted in parallel with the 'Kingston Project' (Burrows et al. 1994) investigating the impacts of disturbance from timber harvesting in the jarrah forest. Grids of nest boxes were used to monitor wambenger at five sites across the Kingston and Perup forests as part of this study. Monitoring was continued at two of these sites (Site 1 [known as the 'Perup' nest box grid] and Site 2 [Stretch Rd]) by the Donnelly District Nature Conservation team. The first of these sites became enclosed within the Perup Sanctuary and has been used to survey wambenger within.

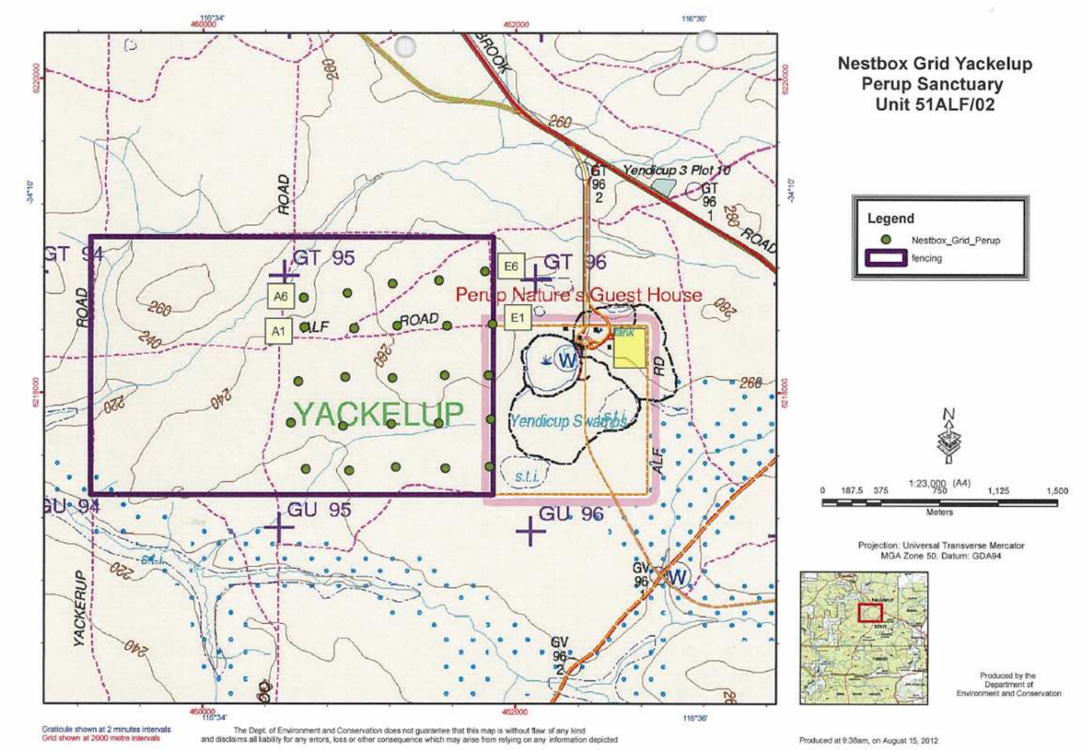
5.3.4.2 Methods

The use of conventional traps (for example, medium-sized Elliott box traps) for wambenger has been problematic with animals readily able to escape without modification to the traps, some animals causing injury to themselves trying to escape, and the exclusion of wambenger from the traps because of interference or occupancy of the traps by other abundant mammal species (Traill and Coates 1993; Rhind 1998). An alternative to traps is the use of nest boxes, which Rhind used across five sites within the Upper Warren region. The nest box grids used by Rhind were generally based on five rows of five points each spaced 300 m apart (Rhind 1998).

The original nest boxes were made from rough sawn untreated pine (19 mm thick) and were approximately 21 x 21 x 21 cm (~9 litre volume) with a circular entrance of 35 mm diameter. Nest boxes were fixed 3–4 m above on trees and positioned to provide shelter from the sun and rain (Rhind 1998).

These nest boxes had a short lifespan, with many needing to be replaced after five years. Departmental staff in the Donnelly District replaced, as required, the original nest boxes with ones made from sawn jarrah offcuts (19 mm thick), with box dimensions being approximately 25.5 cm high x 18.5 cm deep x 14 cm wide (~6.6 litre volume) with a circular entrance of 35 mm diameter. The hinged lid of the nest box had overhangs on the front and back to provide shelter from the elements and to block the entrance once opened to prevent the escape of wambenger within. Rocks have also been routinely placed on top of the lids to discourage koomal from opening and leaving the lid up. Some nesting material (jarrah and paperbark scrapings) was also placed inside the nest boxes to encourage their use. Over time all of the original nest boxes within the sanctuary have been replaced with jarrah boxes fixed to mature trees 3 m above ground.

The southernmost line of nest boxes from the original grid established by Rhind was largely decommissioned because these points were located immediately outside the southern boundary of the sanctuary fence under construction at the time. This line was replaced with an equivalent row of five nest boxes (A6–E6) immediately to the north of the original northern line (A1–E1) to retain the standard 5 rows x 5 points grid layout (Figure 39).



a)

b)

c)

Figure 39. a) Map of wambenger nest box grid within the Perup Sanctuary, b) nest box on site, c) wambenger inside a nest box.

5.3.4.3 *Results*

Monitoring of the nest boxes has been conducted in February and/or June in those years where surveys have been conducted. The presence/absence of a wambenger and/or evidence of recent occupancy (within the last twelve months based on scats and nest material condition) were recorded for each nest box on each occasion.

In 2002 there was no sign of activity or animals on the Perup nest box grid. Generally low levels (4–8%) of recent activity (for example, fresh scats and new nest material thought to be less than 12 months old) have been recorded since 2002. Three, one, one and zero wambenger were found in nest boxes in 2005, 2009, 2012 and 2013 respectively.

5.3.4.4 *Discussion*

The low activity and detection rates from the Perup nest box grid are roughly comparable with other contemporary data from elsewhere in the Perup-Tone Nature Reserve and less than those in Greater Kingston area (McCracken 2009; DPaW unpublished data). While not directly comparable with earlier data because of differences in the number, location and arrangement of the nest boxes on the Perup grid, the numbers of wambenger are less than reported by Rhind (1998; 3, 1, 5 individuals from 19 nest boxes in 1994, 1996 and 1997 respectively). Nonetheless, the reduction from the 16% mean detection rate in the 1990s to 4% since then is consistent with overall regional trends in the reduction of wambenger observed in nest boxes (McCracken 2009; DPaW unpublished data) and trapping data (see section 8.5).

A review of all wambenger data from nest boxes within the Upper Warren is highly recommended given that there are a number of separate datasets, that once synthesised would provide valuable insights. This includes the spatio-temporal pattern of wambenger distribution and abundance within the region and an assessment of the inferential power and relative merit of nest boxes as a monitoring tool for this species. How nest box occupancy rates relate to actual population size is also not known.

Wambenger have also been detected within the sanctuary by trapping (April 2013, see next section 5.3.5) but not yet by spotlighting or remote sensor cameras (sections 5.3.6 and 5.3.7 respectively). Whether nest boxes are the most effective and efficient means of monitoring wambenger in the sanctuary needs to be determined. For instance, modified Elliott box traps that prevent wambenger from escaping (as used in the Kingston study, Wayne et al. 2001b), placed on arboreal platforms to reduce competition and interference from terrestrial species, may be a better alternative.

Given that the mesh size of the sanctuary fence (30 mm diameter) is greater than mean adult crown width (26-28 mm) and is comparable to the size of hollow entrances used by wambenger (Rhind 1998), the fence is likely to be an incomplete barrier to their movement. Therefore, while the sanctuary may afford the species some protection from terrestrial predators, wambenger numbers are not likely to become superabundant inside. It is possible however, that it becomes an important source for the surrounding forest that may help a local recovery in their numbers if predators are a limiting factor.

5.3.5 Medium-sized vertebrate surveys using cage traps

Summary: Cage trapping within the Perup Sanctuary indicates that in addition to the reintroduced woylie, koomal are relatively abundant, quenda are present in low numbers and the numbat and wambenger have also been detected. Egernia kingii, Varanus rosenbergi, and Tiliqua rugosa and the Australian raven have also been recorded in traps.

5.3.5.1 Introduction

An understanding of the species and their abundances in the Perup Sanctuary are necessary for their ongoing management. Cage trapping has been the primary means of surveying and monitoring medium-sized mammals in the Perup Sanctuary. A brief overview of the results of these activities is reported here for the purposes of providing an understanding of the medium-sized mammals and estimates of their abundances.

A survey of the area designated for the Perup Sanctuary was conducted in May 2009 before construction of the sanctuary commencing (50 traps over 4 consecutive nights = 200 trap nights). Koomal, quenda, chuditch and a tammar wallaby were recorded. While woylies had also been previously recorded from the site (DPaW unpublished data), none were recorded in 2009. Trapping was conducted again in October 2010 immediately after the fence had been completed. On this occasion 36 koomal and 2 chuditch were trapped (69 traps x 4 nights = 276 trap nights) and removed from the sanctuary for the purposes of removing all terrestrial predators and assisting the surveys and control of introduced predators within the sanctuary (by reducing trap interference by koomal), which occurred immediately after the cage trapping was completed. Again no woylies were detected.

The results from monitoring using cage traps in the Perup Sanctuary, since woylies were introduced in later 2010 are reported here, with a particular focus on medium-sized mammals other than the woylie, which is reported in more detail in section 6.3.2.

5.3.5.2 Methods

Fauna monitoring was conducted from February 2011 to November 2012 with 80 small Sheffield cage traps, at 200 m intervals, utilizing all existing tracks within the sanctuary. Ten of these trap points were off the track/transects to sample within the largest areas away from the trapping transects to maximize coverage of the trap sampling area and in particular to improve the probability of encountering the woylie founders (Figure 40). In April 2013, the number of trap points was increased to 144 (100 m intervals along the pre-existing transects, but not including the 10 sample points previously used away from the roads; see Figure 59 in section 6.3.2) to try to overcome the issue of trap saturation by woylies that occurred in previous trap sessions. This was an increase in the overall density of traps from less than one trap for every 5 ha to less than 1 trap for every 3 hectares. All survey sessions were four consecutive nights and involved up to 6 trapping teams and 20 people (animal handlers and assistants) within a given trapping session.

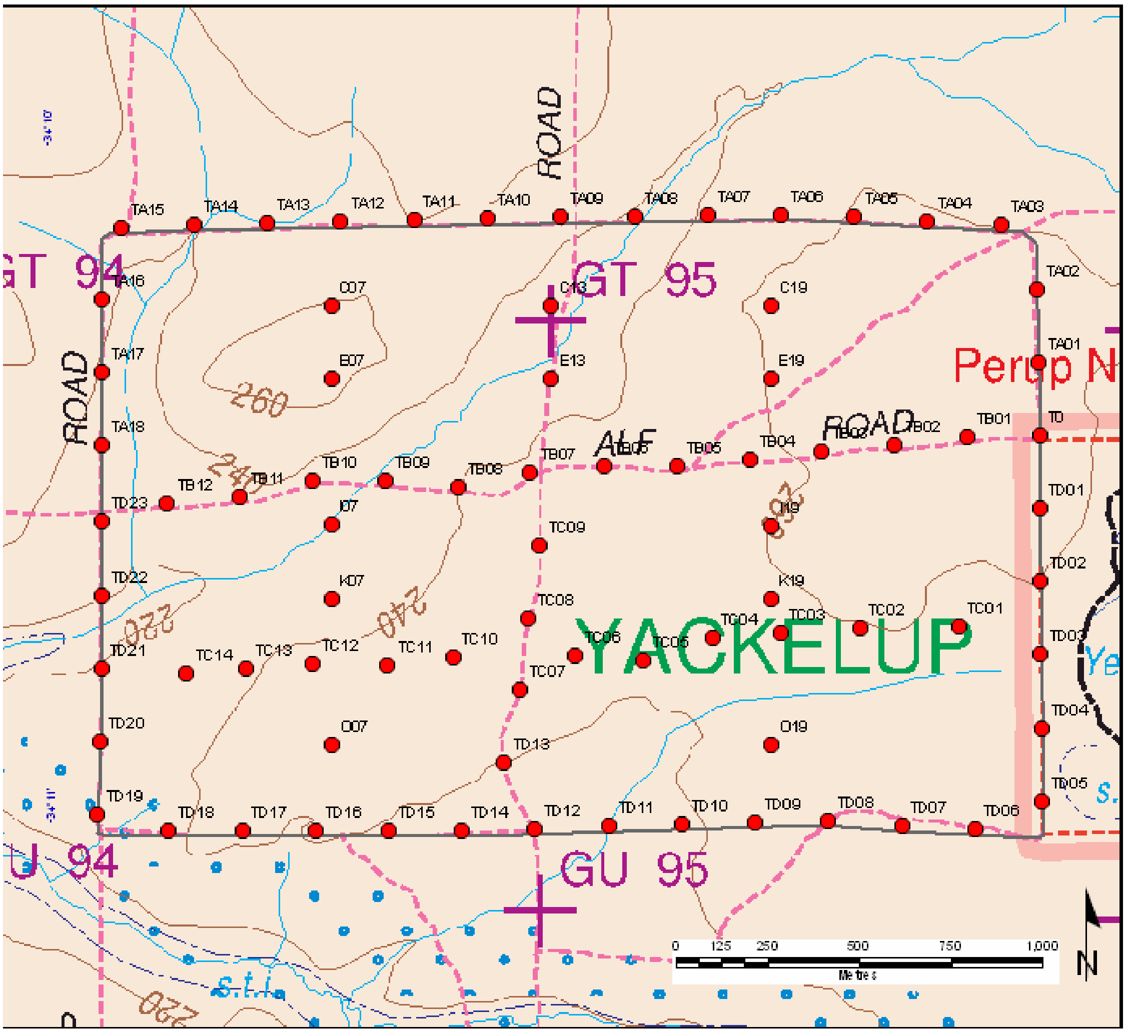


Figure 40. Map of the Perup Sanctuary showing the 80 original trap monitoring points used in 2011 and 2012.

Unique identities were attributed to all medium-sized mammals using ear tags. Morphometrics were recorded as per the standardised protocols listed in The Woylie Conservation Project Field Operations Handbook (DEC 2008b). A summary of the methodology is provided in DEC (2008a). Detailed health checks and sampling was conducted on woylies (see section 6.3.2).

5.3.5.3 Results

Except for the reintroduced woylies, koomal are the most abundant medium-sized mammal in the Perup Sanctuary (Figure 41). Low numbers of quenda have also been consistently captured. Other mammals captured have included a numbat (with two pouch young) in April 2012 and a male wambenger in April

2013. Captured reptiles have included *Egernia kingii*, *Varanus rosenbergi*, and *Tiliqua rugosa*. The only bird captured has been the Australian Raven.

Trap saturation by woylies within the sanctuary rapidly became a problem with the proportion of traps open and undisturbed when checked being 61.6%, 24.4%, 10.6%, 3.4%, 1.2% and 1.7%, for the six trapping sessions conducted between February 2011 and April 2013. The increase in the number of traps from 80 to 144 in April 2013 evidently did little to overcome the growing density of woylies within the Sanctuary. Because of the trap saturation by woylies since October 2011, it is difficult to assess the abundance of other species using this data. For example, while the capture rate of koomal has reduced over time, it is likely that this has no bearing on the actual population trends given the confounding with trap saturation by woylies. The total number of koomal individuals trapped in the 2 years between February 2011 and April 2013 was 96 (11 to 63 individuals per trap session). The corresponding number of quenda individuals trapped during this period was 26 (1–16 individuals per trap session).

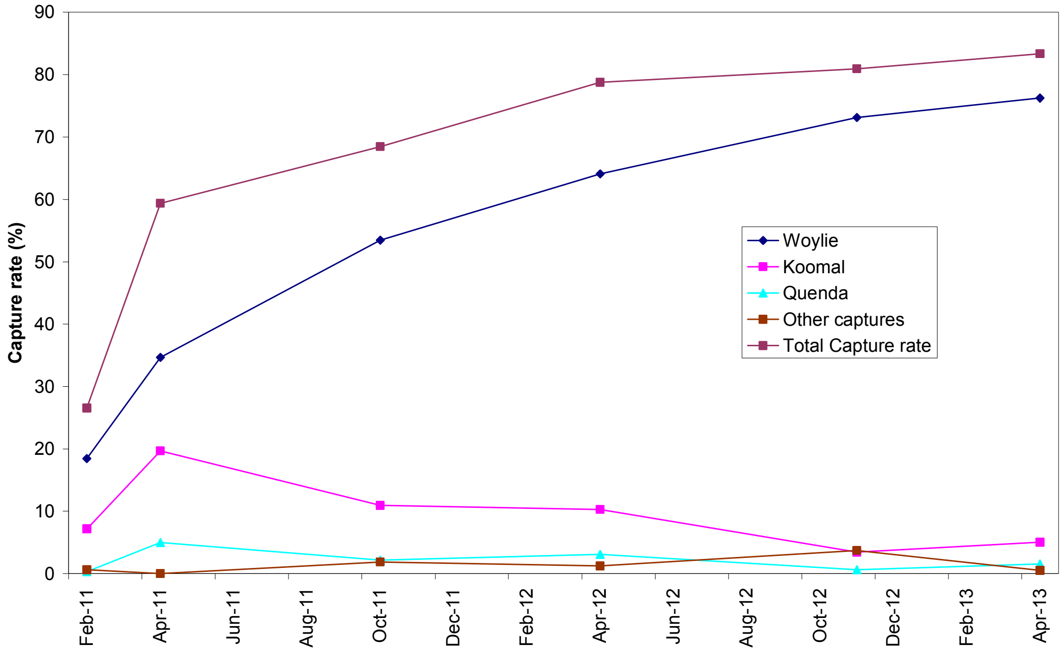


Figure 41. Trap capture rates of medium-sized mammals within the Perup Sanctuary.

5.3.5.4 *Discussion*

Overcoming trap saturation by woylies in future monitoring is important for understanding population changes for woylies as it is for other medium sized mammals in the Perup Sanctuary. This is because it is not possible to get reliable measures of population size or change under saturated conditions. For example, spatial explicit capture-recapture models assume no competition for traps, and to do this total trap rates need to be at least less than about 86% (Efford *et al.* 2009).

The most effective means of overcoming trap saturation is to ensure the density of traps is substantially greater than the anticipated maximum likely density of all medium-sized mammals that might occur in the Sanctuary. Based on the trap results from the site, the goal should be to achieve maximum total trap capture rates of about 60% because up to 20% of traps can be unavailable (disturbed and not available to capture an animal), thereby having at least 20% of traps still available to capture animals if they were present. The density of traps also needs to account for the fact that the movement of animals increases the effective trapping area beyond the actual area occupied by the traps. Therefore trap densities will probably need to be around at least 20 per hectare, assuming maximum medium-sized mammal densities of 3 per hectare, a 4 ha trapping grid (i.e. 25 m spacing between traps) and an effective trapping distance of an additional 100 m beyond the grid (i.e. 16 ha effective sampling area). Trapping webs that effectively calculate animal densities may be an alternative approach to a grid, however, their susceptibilities to trap saturation (particularly the outer regions of the web) need to be carefully considered. Given the importance in being able to adequately monitor medium-sized mammals in the Perup Sanctuary, it is highly recommended that careful design and planning for an adequate monitoring regime is developed and resourced as a matter of priority.

5.3.6 Vertebrate surveys by spotlighting

Summary: Systematic spotlight surveys repeated 3 times every spring and autumn in the Perup Sanctuary since its establishment have detected 8 mammals, 4 birds and 1 reptile. These surveys provide evidence that increasing trap saturation may be negatively biasing koomal and quenda in particular which, contrary to the trapping data, appear to be increasing in numbers. Five of the mammals that have not been detected by trapping include species of particular management (rabbit and large macropods) and conservation interest (reintroduced ngwayir or western ringtail possum). Spotlighting may become an increasingly more practical means of monitoring a broader suite of species and as an effective alternative or complementary approach to trapping and/or remote sensor cameras.

5.3.6.1 Introduction

Nocturnal spotlight surveys can be a means of monitoring the abundance of animals that may not be adequately detected by other means and/or be complement to other survey methods such as trapping. Spotlighting is particularly beneficial for arboreal species (for example ngwayir, koomal and wambenger), larger macropods (for example wallabies and kangaroos), nocturnal birds and introduced species such as rabbit, fox and cat. In the event of trap saturation, spotlighting may also provide some indication of the relative abundance of species that may be excluded from the traps (for example quenda). The aim of the spotlight surveys in the Perup Sanctuary were to survey and monitor those species less readily detected by trapping, with a particular interest in the ngwayir, quenda and wambenger that are not readily detected by other methods being used (trapping and remote cameras).

5.3.6.2 Methods

Five spotlighting sessions have been completed from spring 2010 to autumn 2013. Sessions consisted of three nights each and were conducted in October–November for spring and March–April for autumn. The transect length was 10.8 km and covered the entire perimeter of the fence and the internal track running west to east between the gates. The methods used are the same as those used for the three long-term monitoring transects in Kingston (Wayne *et al.* 2001a, 2005a). Each survey involved two observers spotlighting either side of the vehicle with the same equipment and spotlighting from the same height and travelling at the same speed. All vertebrate sightings were recorded and information including species, number, location (inside/outside, position, height) and behaviour was recorded.

The first session in October 2010 was conducted after the completion of the fence but immediately before the removal of 36 koomal and 2 chuditch (October 2010) and the subsequent introduction of 41 woylies (November–December 2010).

5.3.6.3 Results

Koomal were the most readily detected species in the Perup Sanctuary by spotlighting (mean = 8.2, range of 2–14 koomal per survey) (Figure 42). There was a 23% reduction in the detection of koomal after the removal of 36 individuals in October 2010. Koomal detections declined from autumn 2011 (mean = 9) to their lowest in spring 2012 (mean = 5.3), to return to their previous levels by autumn 2013 (mean = 9.3).

Ngwayir (up to 5 per survey) were only detected on the three occasions in spring 2012. The detection of woylies and quenda have steadily increased over time, while the Tammar and Western Brush wallaby have been frequently detected but only in very low numbers (Figure 42). Other species sighted infrequently within the sanctuary have included the Western Grey Kangaroo (1), European rabbit (1), Australian Owlet-nightjar (3), Tawny Frogmouth (17), Southern Boobook (1), Wedge-tailed Eagle (1) and Southern Heath Monitor (1). No wambenger were detected by spotlighting.

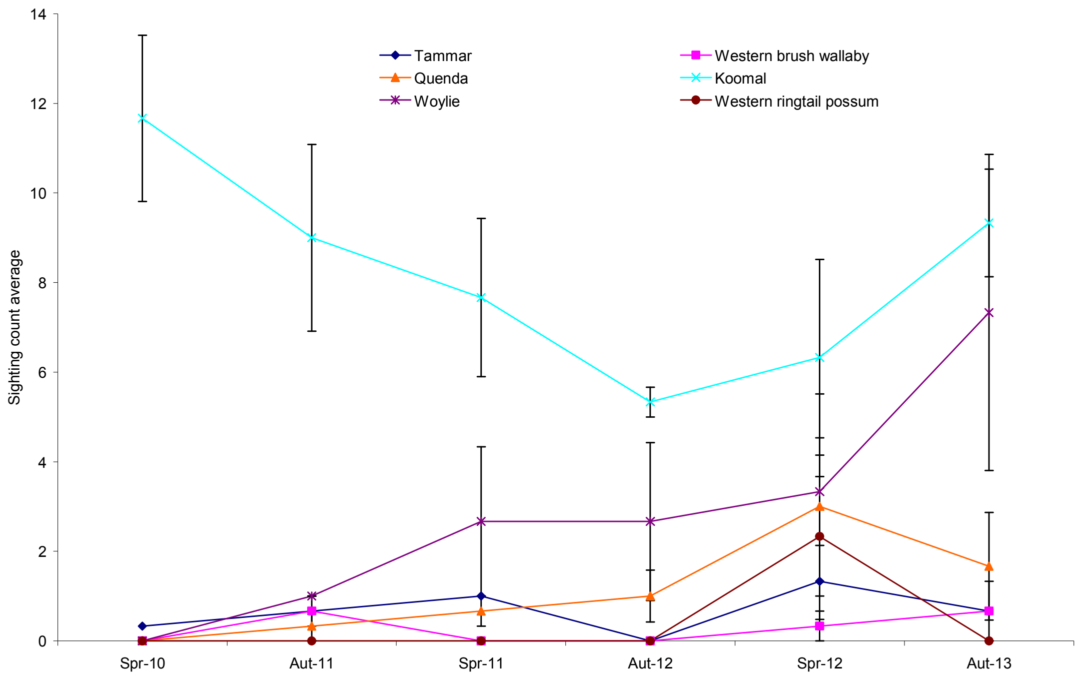


Figure 42. Summary of the mean spotlight detection counts from within the Perup Sanctuary.

Note: 36 koomal were removed immediately after the spring 2010 surveys.

5.3.6.4 Discussion

Of the 13 species detected by spotlighting in the sanctuary 5/8 mammals were not otherwise detected by cage trapping (rabbit, ngwayir, tammar wallaby, western brush wallaby and western grey kangaroo). The spotlighting data also reflects the increase in woylies over time. The potentially exponential increasing trend over time is consistent with the number of known individuals but not the capture rate (logarithmic) of woylies derived from trapping (section 5.3.5 and 6.3.2). The change in the spotlight detection of koomal over time was not reflected in the trapping data, which shows a general declining trend over time (section 5.3.5). Similarly, the capture of quenda has declined with time whereas spotlighting indicates the contrary. This provides further evidence that the increasing trap saturation in the Perup Sanctuary is increasingly excluding the capture opportunities of woylie, koomal and quenda individuals in particular. Therefore under the current trapping regime, these species are not being adequately monitored to measure population change over time. The spotlighting data would indicate that quenda numbers may have actually increased over time and koomal, although variable, remain at similar detection rates in autumn 2011 and 2013.

A total of 20 adult ngwayir were released in the Perup Sanctuary in late August–early September 2012. Spotlighting only detected up to 5 of these individuals in October–November 2012. Despite at least one individual being detected by remote sensor cameras in the sanctuary in August 2013 (section 5.3.7), no ngwayir were detected in autumn 2013. The spotlight results, in conjunction with the other survey methods, indicate that it was unlikely that ngwayir had been present in the Perup Sanctuary before the release of animals in 2012.

Spotlighting detected some birds, such as diurnal and nocturnal birds of prey, that were not otherwise detected by other methods. The spotlight and camera data also provide evidence of the number of species of particular management interest including the European rabbit and the western brush wallabies and western grey kangaroos that evaded being herded out in September 2010 before the closure of the sanctuary fence.

Given the increasing problem of trap saturation with continuing increases in mammal densities in the Perup Sanctuary, ongoing spotlighting may become an increasingly more practical means of monitoring a broader suite of species. For this to be an effective alternative or complementary approach, further consideration of the sensitivity, accuracy and precision of spotlighting to provide acceptable measures of abundance would be needed.

5.3.7 Vertebrates detected by remote sensor cameras

Summary: Remote sensor cameras used for predator incursion surveillance and associated with woylie translocations from and into the Perup Sanctuary also record data on other species, particularly larger reptiles, birds and mammals. Similar species have been recorded that have been detected by other methods. A more thorough exploration and analysis of the camera data has not yet been conducted.

5.3.7.1 Introduction

The incursion of an introduced predator into the sanctuary is a serious threat to the survival of the native fauna within. A number of predator surveillance methods have been implemented, one being the ongoing use of remote sensor cameras placed strategically within (see section 5.2.3). Additional cameras were also distributed throughout the sanctuary as part of the woylie translocation monitoring activities (see sections 6.2.2 and 6.2.5). These cameras collectively provide the opportunity to detect and survey other species within the Perup Sanctuary.

5.3.7.2 Methods

Twenty two remote sensor cameras have been strategically located within the sanctuary, with another two adjacent to the outer perimeter, primarily for the purposes of predator incursion surveillance (see section 5.2.3). Camera images are downloaded twice per week and viewed to check for possible incursions.

Fifty four cameras distributed throughout the sanctuary at 300 m spacings from 28 June 2013 and removed 2-5 September 2013 (see sections 6.2.2 and 6.2.5) were periodically checked and images downloaded. Due to the interference with cameras by the wildlife, cameras varied in effective deployment time from full term (9 weeks for 40 cameras), 6-8 weeks (5 cameras), 2-4 weeks (3 cameras) and <2 weeks (6 cameras). Some of the cameras with less than full term were checked and batteries replaced 27-29 August and therefore have a further weeks of images before being removed start September.

Images of interest from both of these sources were recorded and stored in case of future use.

5.3.7.3 Results

A range of native fauna has been recorded on the cameras within the sanctuary including western grey kangaroo, western brush wallaby, tammar wallaby, woylie, quenda, koomal, ngwayir, numbat, several bird species, particularly Australian raven, Australian magpie and grey currawong, and *Varanus rosenbergi* (Figure 43). All of these have also been detected immediately outside the sanctuary (except numbats and ngwayir), as well as fox, cat, rabbit, chuditch, echidna, and emu (Figure 44). Species not yet detected inside that could potentially be included dunnarts, wambenger, western pygmy possum, mice, rabbits and *Varanus*.

Figure 43. Images of species detected inside the Perup Sanctuary (woylie, tammar, koomal, quenda, numbat, ngwayir)

Figure 44. Images of species detected immediately outside the Perup Sanctuary (emu, echidna, chuditch, western grey kangaroo, fox and cat).

5.3.7.4 Discussion

The data from the remote sensor cameras within and immediately outside the Perup Sanctuary are yet to be formally analysed but similar species have been recorded that have been detected by other methods such as cage trapping, spotlighting and nest boxes. While the primary objectives of the two major activities where these cameras have been used have been predator surveillance and woylie detection rates and calibration, there is an opportunity to use these data to provide other insights. These opportunities include species inventory and relative abundance, the relative effectiveness and detection probabilities of species from these cameras, and aspects of the behaviour (for example, activity patterns and interactions) and ecology (for example, habitat associations and preferences) of those species detected.

5.3.8 Bird surveys

Summary: Bird surveys have not been conducted within the Perup Sanctuary but annual surveys conducted immediately adjacent to it have recorded 66 of the 125 bird species likely to occur in the area.

5.3.8.1 A brief overview

A total of 66 of 125 birds listed for the Perup Ecology Centre area in the Birds Australia Atlas (http://www.birdata.com.au) have been sighted during the Fauna Management Courses conducted in November of each year between 2005 to 2012 (Appendix F). Bird surveys have not been conducted actually within the Perup Sanctuary itself but, except for the water birds, the list is considered to be a reasonable indication of the most common species likely to occur within the Sanctuary.

6 Woylie conservation

6.1 Introduction

Woylie conservation actions in the Upper Warren region directly address the key priorities identified in the National Recovery Plan for the Woylie (Yeatman and Groom 2012). They also deliver on the priority objectives outlined in the draft Woylie Population Management Strategy (June 2013). The strategy sets the goal and objectives, and presents strategies and actions that aim at ensuring the long term conservation of the species. It is based on the general guidance provided in the Recovery Plan but provides a more detailed approach to population management. It is premised on the recognition that the woylie should be managed at a species level rather than isolated populations, and that a managed 'genetic mixing' process is required. It has been informed by a modelling framework specifically developed to explore population and genetic dynamics associated with different management actions. This has included a modelling project underway by Carlo Pacioni, funded by WWF. The strategy has also been developed in consultation with the Woylie Recovery Team.

The goal of the draft Woylie Population Management Strategy is to conserve and maximise the genetic diversity of the woylie at a species level. This requires the achievement of three objectives, in order of priority:

1. To maintain existing wild populations with optimal genetic diversity
2. To establish at least three 'insurance' populations that represent the majority of the genetic diversity remaining in 2013
3. To secure and optimize the conservation value of existing translocated populations

6.2 Woylie translocations

Perup Sanctuary was originally established in late 2010 as an insurance population to conserve the genetics of the woylie populations in the Upper Warren region (Greater Kingston and Perup areas), which were not adequately represented in translocated populations elsewhere. The insurance was required in case the wild populations went extinct and with it a substantial portion of the genetic diversity of the species.

Subsequent genetic research showed that the remaining extant woylie populations (Upper Warren region, Dryandra and Tutanning) were the remnants of a genetically contiguous woylie population that formerly occurred across the entire southwest (Hunt 2010), and therefore any genetic differences observed today (Pacioni 2010, Pacioni *et al.* 2011) were an artefact of subpopulations becoming isolated and genetic drift resulting from human activity since the 20th century, including habitat fragmentation, introduced predators, etc. These findings informed in part the draft woylie population management strategy being developed by the Woylie Recovery Team. The outcome of which was that the function of the Perup Sanctuary should be expanded to be an insurance population for the entire species and therefore receive genetic material from the Dryandra and Tutanning populations. Wild woylies from the Dryandra population were translocated to Perup Sanctuary in July 2013.

A captive colony of the 6 last remaining animals alive from the Tutanning population, was established as part of the woylie population management strategy to maximise the conservation of the genetics of this population, which had recently gone extinct in the wild. Genetic advice and population modelling (Pacioni 2013) recommended that the most effective way to do this was to cross breed between the remaining Tutanning animals and translocate their offspring, once of independent age, to the Perup Sanctuary to freely interbreed with the insurance population established there. The first of the offspring from this breeding program were translocated to Perup Sanctuary in August 2013 and is planned to continue as long as offspring are produced by the Tutanning parents.

At the time when the Dryandra and Tutanning translocations were being planned for the Perup Sanctuary, it was evident that population growth rates in the Sanctuary were excellent and numbers were in the order of 300–400 individuals. The capacity of the sanctuary is estimated to be in the order of 600–900. While the carrying capacity of the Perup Sanctuary was sufficient to receive Dryandra and Tutanning stock directly, the removal of some woylies from the sanctuary would increase the proportional representation of the genetics from Dryandra and Tutanning. Woylies removed from the sanctuary also provided the opportunity to translocate them elsewhere to determine whether a woylie recovery could be stimulated in the wild. A substantial woylie recovery had not been sustained in the wild and it was possible that the remnant low densities may be suppressed from recovering because of being ‘stuck’ in a so-called ‘predator pit’, whereby low woylie densities maybe unable to overcome the attrition from low to modest predation rates that higher woylie densities would otherwise be able to sustain or even increase with. Therefore, immediately before the introduction of animals from Dryandra and Tutanning woylies were removed from Perup Sanctuary to nearby Yendicup, when and where the prospects for a successful translocation in the wild was considered most likely.

The following sections outline these translocation activities.

6.2.1 Upper Warren region to Perup Sanctuary (October–December 2010)

Summary: A total of 41 (21 males, 20 females), 8 (4 males, 4 females) and 5 woylies (2 males, 3 females) were sourced from across the Upper Warren region and translocated to Perup Sanctuary, Native Animal Rescue facility (Malaga) and Perth Zoo captive colony, respectively, in November–December 2010. The survivorship of the woylies in the Perup Sanctuary in the first 12 months since translocation was substantially greater than comparable woylies in the wild populations of the Upper Warren region. Predation by foxes and cats were associated with most of the mortalities outside of the Perup Sanctuary, whereas no predation was observed inside the sanctuary.

6.2.1.1 Introduction

The aim was to translocate woylies from wild populations within the Upper Warren region (Greater Kingston and Perup areas) to the Perup Sanctuary, Perth Zoo and Malaga Native Animal Rescue to establish and secure 'insurance' populations of the species and to further investigate the factors involved in the species decline.

The translocation targets were +40 woylies (20 radio collared) into Perup Sanctuary, 8 woylies (trypanosome positive) to Native Animal Rescue, Malaga and 5 woylies to Perth Zoo Captive insurance population.

6.2.1.2 Methods

Woylies were sourced from across the entire Upper Warren region but not within 1.5 km of existing trap points associated with 10 priority monitoring sites. Specific selection criteria for candidates for each of these destinations included: equal sex ratio (PS), females with no or small pouch young only (to minimise welfare risks associated with larger pouch young), appropriate age—preferably young adults with proven past breeding (PS to some extent but particularly for PZ) and healthy (determined by wildlife vets and wildlife experts with candidates under anaesthesia). Importantly, to maximise genetic diversity and minimise closely related individuals being translocated into the Perup Sanctuary, some minimum separation distances between individuals were used. Based on the findings of Pacioni (2010), where possible individuals were selected that were >3 km apart for males and >1 km for females in the Perup area and >6 km apart for individuals in the Kingston area. Also based on genetic advice from the woylie recovery team, the target was also for a numerical bias towards woylies from Perup relative to Kingston (3:1, respectively). For the woylies going to Malaga, relatedness was not a criterion but a positive trypanosome infection status based on microscopy was (for the purposes of research into this parasite being conducted by PhD students C. Thompson and A. Botero).

Comprehensive health checks were conducted and blood, faeces, ectoparasites, ear tissue for DNA and hair samples for chronic stress analysis were sampled from all selected candidates for reference and research (for example K. Skogvold health monitoring program).

6.2.1.3 Results

Five weeks of trapping conducted along a total of 21 transects (50 traps each spaced 200m apart along each transect; Figure 45) in November–December 2010 resulted in a total of 210 km of transect surveyed, using 1050 trap points producing a total of 4200 trap nights. Between 15 and 20 DEC staff, Perth Zoo staff, WCC staff, students and volunteers were involved each week.

In total 136 woylie individuals were captured (4.3% overall capture rate), 85 candidates were examined at the processing centre (at the Perup Ecology Centre lab), 62 of which were examined under anaesthesia and 54 woylies were selected and translocated (3 destinations; i.e. 40% of individuals encountered; Table 12; Figures 46, 47 and 48). Individuals of the same gender were selected to be >3 km and >6 km apart in Perup and Kingston areas respectively. But because of the limited availability of suitable candidates in many cases these spatial rules did not apply between individuals of the opposite gender.

Twenty of the woylies translocated to the Perup Sanctuary were fitted with radio transmitter collars. Other captures included 99 chuditch individuals (3.8% overall capture rate) and 255 koomal individuals captured (7.9% overall capture rate).

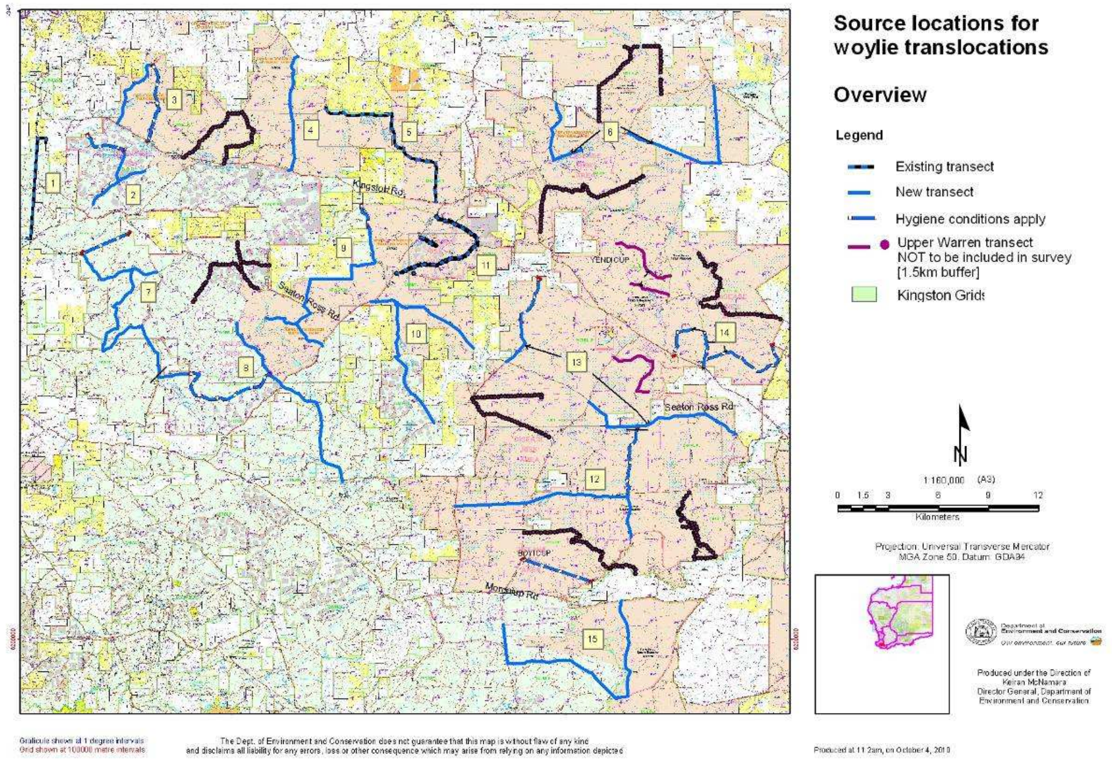


Figure 45. Location of existing key monitoring transects (black and red lines) and the 21 transects (blue lines) used to source woylies from the Upper Warren region, in November–December 2010, for the Perup Sanctuary, Perth Zoo and Native Animal Rescue facility in Malaga, Western Australia.

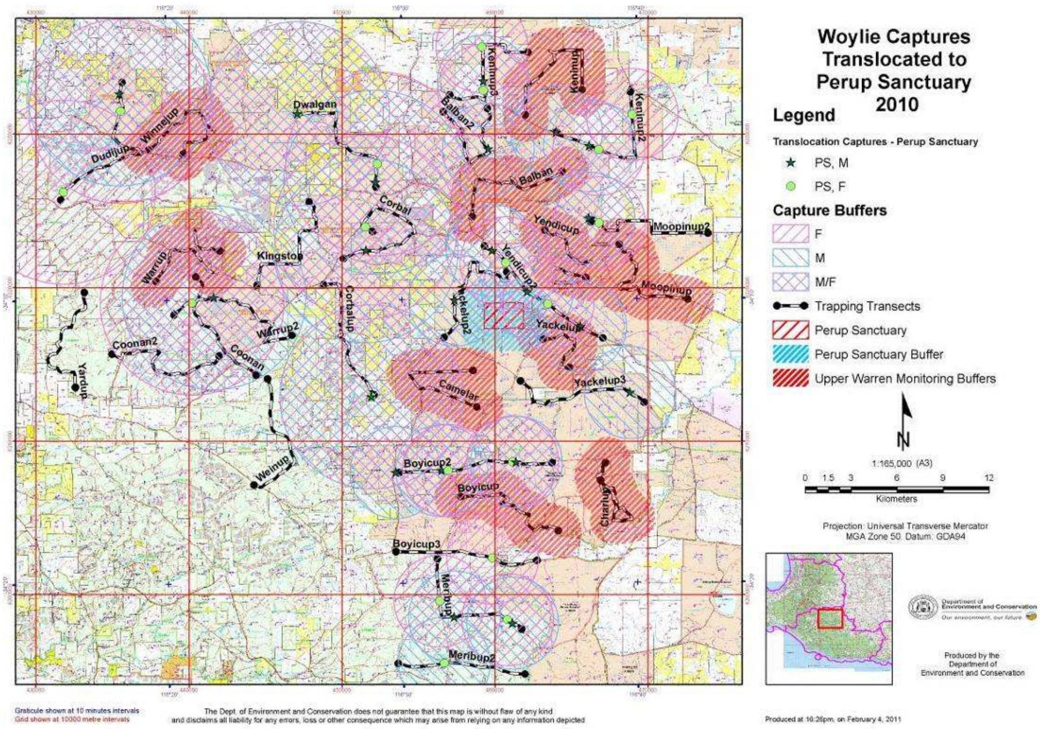


Figure 46. Location of the woylies sourced from the Upper Warren for the Perup Sanctuary, including buffers to existing monitoring transects.

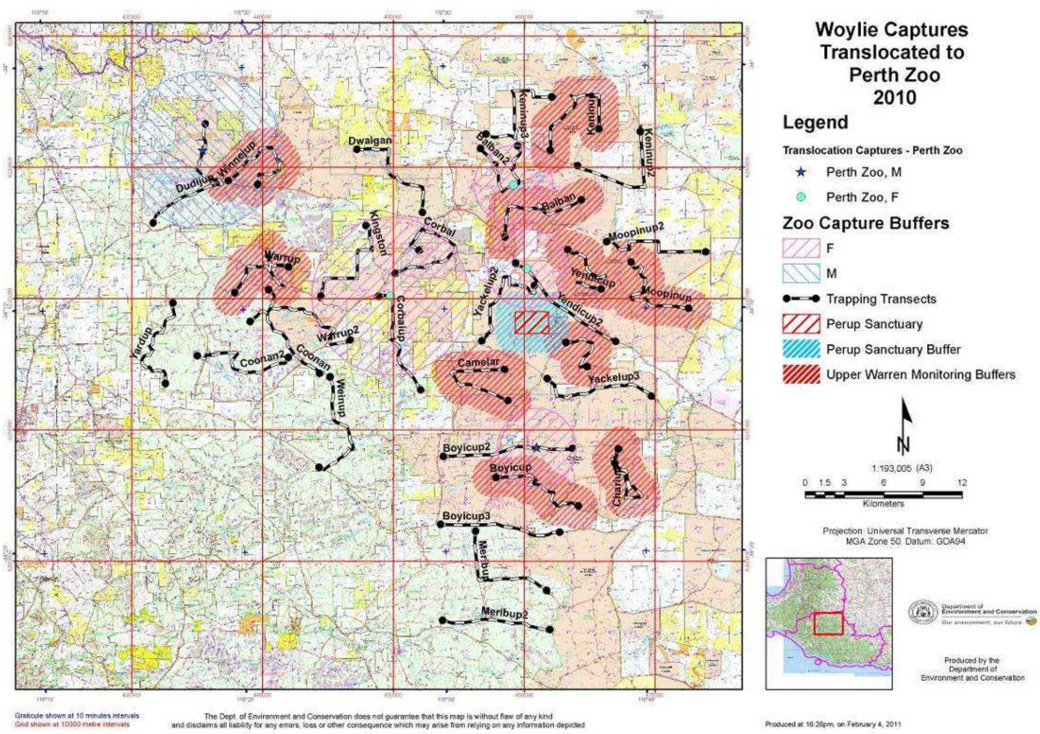


Figure 47. Location of the woylies sourced from the Upper Warren for the Perth Zoo insurance colony, including buffers to existing monitoring transects.

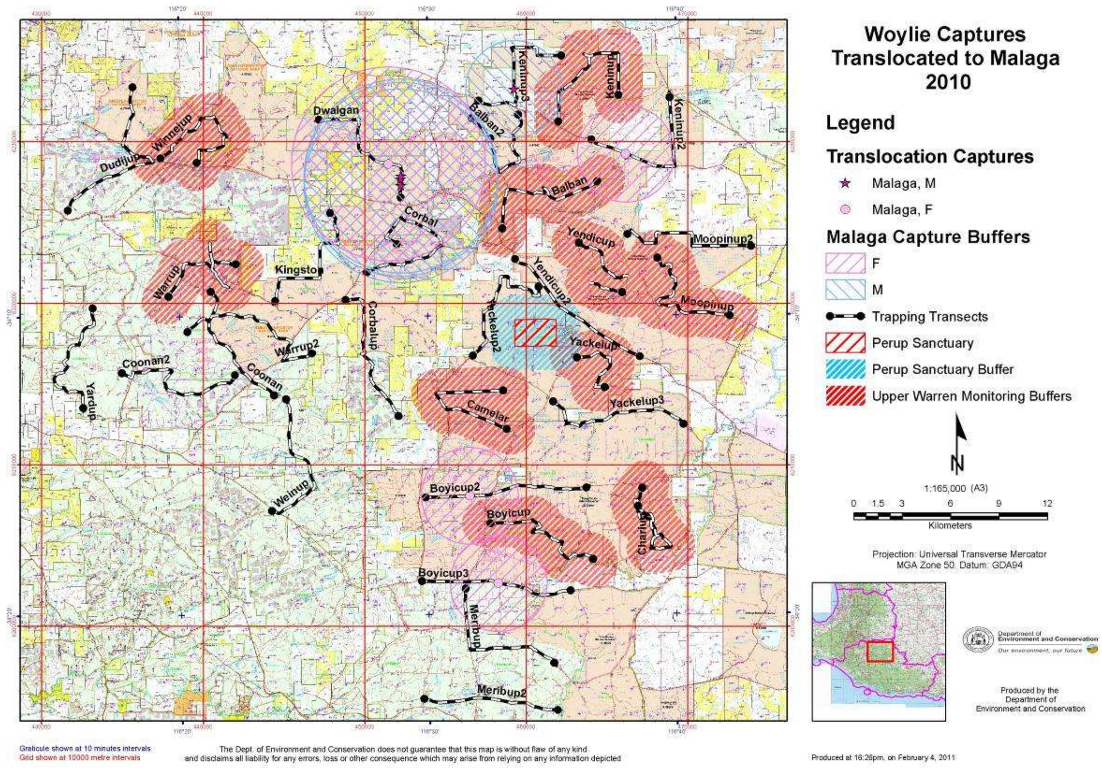


Figure 48. Location of the woylies sourced from the Upper Warren for the colony at the Native Animal Rescue facility in Malaga, including buffers to existing monitoring transects.

Table 12. Summary of the woylies translocated from the Upper Warren region in November–December 2010.

Woylie Translocations	Total		Target
Perup Sanctuary	41	(21M:20F)	≥40
Malaga NAR	8	(4M:4F)	8
Perth Zoo	5	(2M:3F)	5
Total Relocated	**54**	**(27M:27F)**	**≥53**

Comparative survivorship monitoring using radio transmitters

As a comparison for the 20 woylies fitted with radio transmitters and translocated into the Perup Sanctuary (November–December 2010), 13 and 11 woylies were radio collared from October 2010 from Keninup and Warrup forest blocks, respectively. Radio collared woylies were monitored generally at least 3 times per week for 12 months from either the air (light aircraft) and/or the ground. Table 13 provides a summary of the radio telemetry monitoring results. There were four cases of equipment failure—either the collar failed (haultain collar broke apart at the nut and bolt join—evidently a point of weakness) or the transmitter failed. There was a suspected fifth case of equipment failure in which the transmitter signal was lost and extensive ground and aerial searches failed to detect the signal. In six cases the collar was removed before the completion of the study as a precautionary animal welfare consideration (rubbing of the skin around the neck and shoulders). In five of these cases the woylies were recaptured in October 2011 and found to be in good condition.

There was one case of accidental death, in which the toe nail of the right hind leg was caught under the collar, behind the neck and its left hind leg was caught under the right leg. The post mortem (by Murdoch University Pathology staff) confirmed that the injuries sustained were consistent with self-inflicted strangulation by the radio collar. In the 103 cases of woylies being radio collared in the Upper Warren region since 2006, this was the first case of strangulation.

The post mortem (by Murdoch University Pathology staff) of a woylie from the Perup Sanctuary displayed evidence of significant trauma (spinal and rib fractures), however the cause of the trauma and whether it occurred ante or post mortem remains unclear. Scavenging (possibly by a varanid or raptor) was evident and the possibility of an impact with a vehicle could not be dismissed. There was no evidence of cat or fox being involved.

In summary, there was a substantial survivorship difference between woylies in the Perup Sanctuary versus wild populations (5% and at least 33% confirmed mortality within 12-months respectively, not including the accidental death at Warrup). Evidence of predation was observed in eight cases from the wild populations (5/13 from Keninup and 3/11 animals from Warrup) (Table 14). Most of these were attributed to fox (4 confidently, plus 3 unverified) and one was attributed to cat.

Table 13. Summary details of the radio collared woylies from the Perup Sanctuary and two comparative sites in wild populations within the Upper Warren region (October 2010–October 2011).

	Keninup	**Warrup**	**Perup Sanctuary**	**Total**
Total number of individuals radio collared	13	11	20	**44**
Death—evidence of predation	5	3	0	**8**
Death—trauma, cause uncertain	0	0	1	**1**
Death—accidental	0	1	0	**1**
Transmitter failed—confirmed by trapping	0	1	1	**2**
Fate unknown—broken collar	0	2	0	**2**
Fate unknown—signal lost. Suspect transmitter failed	1	0	0	**1**
Collar removed during study (animals alive)	1	1	4	**6**
Collar removed at the end of the study (animals alive)	6	3	14	**23**

Table 14. Summary details of the predator/scavenger associated with the mortality radio collared woylies from the Keninup and Warrup sites in the Upper Warren region (October 2010–October 2011).

*Eagle feathers located at site as well as two chuditch scats on log next to remains (fresh, but unlikely from previous night).

Site	**Date**	**Woylie ID**	**Field Evidence**	**DNA Collar**	**Deduced Primary Predator / Scavenger**
Keninup	4/02/2011	DO8188/DO8189	Cat	Cat	Cat
	18/03/2011	DO6788/DO6789	*Fox		Unverified
	9/05/2011	DO8895/DO8895	Cat / Fox	Fox /Chuditch	Fox
	21/07/2011	DO8279/DO8280	Fox	Fox	Fox
	5/10/2011	DN3398/DN3399	Fox		Unverified
Warrup	16/11/2010	DO1152/DO600	Fox		Unverified
	14/02/2011	DN0391/DN0392	Fox	Fox	Fox
	18/04/2011	DN0710/DN0348	Fox	Fox	Fox

6.2.1.4 Discussion

The five woylies translocated from the Upper Warren region to Perth Zoo were added to the existing six woylies from Tutanning to continue building the captive insurance population there. At the time this filled the zoo's facilities to capacity, while funds were sought to expand the colony to a total of 30. Sufficient funds were never secured and the colony at the zoo was eventually disbanded. The woylies from Upper Warren region were relocated to the colony at Whiteman Park and the woylies from Tutanning were relocated to Kanyana Wildlife Rehabilitation Centre for breeding.

The eight woylies (all confirmed by microscopy to be infected with Trypanosoma) translocated to the Native Animal Rescue facility at Malaga were housed in four outdoor enclosures to undertake observational studies on the life history and genetics of Trypanosoma and the effects on its host (C. Thompson and A. Botero student projects). The colony continues to be maintained and the research is ongoing.

The radio telemetry monitoring demonstrated that the survivorship of the translocated woylies into the Perup Sanctuary (in the absence of terrestrial predators) was substantially greater than what was concurrently observed in the wild populations of the Upper Warren region. Predation by foxes relative to cats appears to have increased over time. During the woylie declines 62% of the mortalities were attributed to cats (Wayne *et al.* 2011). Based on previous survivorship and mortality research (2006–2009) fox predations accounted for 10% of the woylie mortalities before the woylie declines, 24% during and 42% shortly after the woylie declines were largely complete (Wayne *et al.* 2011). The more recent findings from Warrup and Keninup (2010–2011) are suggestive of this increasing trend continuing with ~88% of mortalities attributed to foxes (subject to revision and verification; Figure 49).

The monitoring by trapping and the growth of the woylie population founded in the Perup Sanctuary is reported elsewhere (see section 6.3.2).

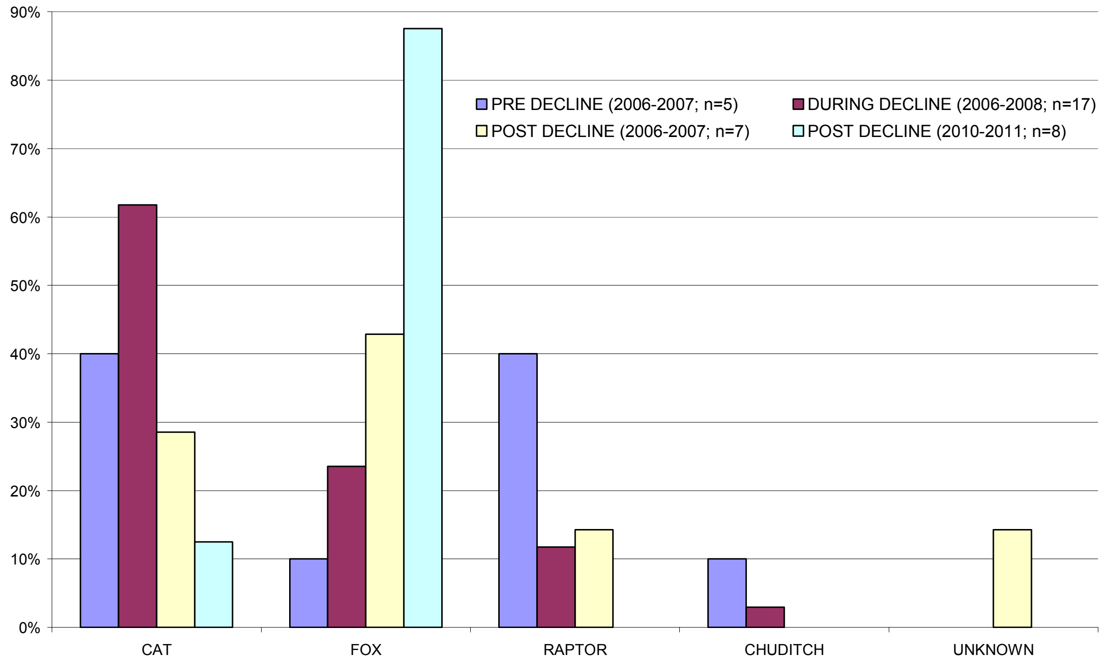


Figure 49. Preliminary assessment of the proportion of woylie mortalities (n=37) in the Upper Warren region attributed to specific predators/scavengers in relation to the decline status of the population at the time of mortality (i.e. results may change subject to revision and verification).

6.2.2 Translocation Perup Sanctuary to Yendicup (July 2013)

Summary: A total of 87 woylies (51 males, 36 females) were translocated from Perup Sanctuary to Yendicup 9–11th July 2013. The translocation area has been subject to weekly ground-based fox baiting since a week before the release of woylies into the area and will continue for at least 2–3 months. Monitoring using 50 remote sensor cameras within a 3 km radius of the centre of the release site remains ongoing. Follow up monitoring by trapping is planned at 3 and 9 months post release and at least annually thereafter.

6.2.2.1 Introduction

The translocation from Perup Sanctuary to Yendicup constituted the first major woylie translocation to the wild since the species wide declines first became apparent in late 2005. Since then DPaW and the woylie recovery team have restricted the movement of woylies as a precautionary measure until the causes of the decline were better understood. This was therefore an important opportunity to achieve some meaningful conservation and learning outcomes directly relevant to the recovery of the species (Yeatman and Groom 2011). The objectives of this activity included;

- The establishment and persistence of a woylie population in Yendicup at a higher density/abundance than at the same site before the translocation and at comparable sites in the Upper Warren region that have not received a supplementation of woylies.
- Test whether the fox control regime applied in Yendicup is sufficient to achieve a successful translocation.
- Explore whether the lack of recovery of woylies in the wild may be because the remnant populations were 'stuck' in a 'predator pit', and
- Use the translocation as an opportunity to test the sensitivities and calibrate the detection indices derived from remote sensor camera methods being used to monitor the woylie and predators at the source (Perup Sanctuary) and release sites (Yendicup)

Yendicup forest block was identified as the preferred site for this initial relocation, principally because the prospects of success were considered to be greatest here. Related and other reasons why this was the preferred site included;

- The release site was within the centre of a core area of the Tone-Perup Nature Reserve (i.e. secure conservation tenure) subject to a high level of predator control (see below), and therefore provided a very high level of management of a key threat to woylies.
- The site had a long history of woylie monitoring and a pre-existing commitment to continue long-term monitoring at the site at least annually.
- Woylies persisted at low numbers at the site, and before the recent declines (2004–2006 at this site) Yendicup supported high densities of woylies
- The close proximity and habitat similarity to the Perup Sanctuary made the site ecologically suitable.
- Fire management plans for the site were compatible with the woylie translocation (i.e. being a no planned burn area, there was a low probability of disturbance by fire particularly in the first few years post release).
- Logistically it was a feasible site to undertake the translocation and follow-up monitoring. This release site was located between 1 and 8 km from the Perup Sanctuary and within an hour from departmental resources based in Manjimup.
- Incidentally it was historically the first site for a woylie translocation in 1976.

The Tone-Perup Nature Reserve is aerially baited for foxes as part of the *Western Shield* program four times per year. Yendicup is also within a core area (~14,500 ha) that is ground-baited monthly for at least another two years (2015). In collaboration with the Warren Catchments Council, coordinated introduced predator control occurred on adjacent free-hold land immediately before and for at least a month after the release of woylies in Yendicup. Ongoing introduced predator control by neighbouring landholders will also be encouraged wherever possible. Therefore, current commitments will be providing the best available protection (outside the sanctuary) from predation in the Upper Warren region.

The timing of the translocation in July 2013 was influenced by several factors including;

- Removal of woylies from the Perup Sanctuary once the colony there was well established but immediately before the introduction of genetic stock from Dryandra and Tutanning. The removal of woylies from Dryandra was restricted until after research underway there was completed on 30th June 2013 (Tony Friend pers comm.). The first offspring from the captive breeding program of Tutanning stock were not expected to be available for release until at least July 2013.
- Winter is the seasonal peak in food (hypogean fungi) abundance for woylies—2013 was a particularly good year (i.e. more than a 2–fold increase in the species richness and abundance of fungi detected than in any given year in the past 10 years) according to fungi monitoring conducted across the region (R. Robinson pers. comm.).
- Mild weather conditions at this time is conducive to better survival prospects (i.e. not hot or dry) and long nights enable more time for woylies to adjust and settle in to their new environment
- Foxes at this time should have finished their energy building phase and are more focused on breeding (Winstanley *et al.* 1999), and are therefore likely to momentarily reduce predation pressure
- The expenditure of external funds (CFoC) for the translocations could not be delayed any further.
- The timing fitted in very well with follow-up woylie monitoring in the Perup Sanctuary and Yendicup that can coincide with routine monitoring periods in spring (October–November) and autumn (March–April)—i.e. 3 months and 9 months post release.

Historically the numbers of woylies that have been translocated have generally been around 40 individuals (Orell 2009). However, in accordance with the recommendations that founder sizes should be larger (e.g. Fischer and Lindenmayer 2000; Pacioni *et al.* 2013a) the goal of this exercise was therefore to translocate up to 100 individuals from the Perup Sanctuary to Yendicup in July 2013.

6.2.2.2 Methods

Trapping methods to source woylies from the Perup Sanctuary were consistent with medium-sized cage trapping conducted in the sanctuary and across the Upper Warren region previously. Traps were however, set in the afternoon and checked and cleared during the evening (between 20:30 hrs and 03:00 hrs). At the completion of checking all traps, (12:00–03:00hrs), individuals selected for translocation were immediately transported to Yendicup in thick animal handling bags contained with animal transportation containers inside vehicles. Females with pouch young had the pouches taped as a precautionary measure before transportation.

All individuals were uniquely identifiable by ear tags, or in the case of individuals first captured as dependent juveniles by PIT tags implanted between the scapulas. Details on age, sex, and breeding status were recorded for all individuals. All individuals not previously sampled for DNA (ear biopsy) were done so. Candidates for translocation also had details on their condition and morphometrics recorded. Further details are provided in the translocation proposal (July 2013).

Selection criteria for translocation candidates included;

- Up to 100 individuals
- As close to gender parity as possible
- Not individuals that were either the original founders of the Perup Sanctuary or their first generation young (i.e. only individuals born or captured for the first time in 2012 or 2013). A “Founder list” of 86 individuals was used to identify the ineligible candidates.
- Females with no dependent young or with pouch young <50 mm Crown Rump (i.e. reduced welfare risks to young). If there was an elongated teat indicating a possible dependent young at heal then there needed to be some indication that the teat was no longer active and/or any accompanying pouch young needed to be >20 mm (i.e. > 60d old, meaning that the young at heal would be >160d old—when they should be entirely weaned, potentially sexually mature and independent).
- Animals in good condition,
- Young adults preferably with evidence of previous breeding

6.2.2.3 Results

Preliminary results from monitoring using remote sensor cameras in the release site immediately before the translocation indicated that fox activity was relatively high—an average 23.3% detection rate (total number of independent detection events (i.e. >1 hr interval between detections) divided by number of trap nights) over the 8–9 days (25/06/2013–4/07/2013) immediately before the quarterly ground baiting throughout the Perup area. The estimated number of individuals detected was at least 2–3. By comparison, using a similar camera monitoring methodology, the predator control and monitoring experiments at Balban (September–October 12) and Boyicup (February–March 2013) found about 5–7 foxes within the same sampling area (2,800 ha) over the entire duration of the study with much lower activity/detection rates (4–5%). In fact, the detection rates before control were 3.9% and 2.7% for Balban and Boyicup respectively.

Based on this information it was decided to institute a weekly ground-baiting regime in the translocation area (~3,600 ha; Figure 50) immediately before the translocation and for at least 2–3 months thereafter. The first weekly baiting regime was conducted on the 4/07/2013 and coincided with the routine quarterly baiting of the Upper Warren region and was soon followed by the monthly baiting within the core Perup area (12/06/2013 and 16/07/2013). The fox detection rate immediately dropped to an average 10.4% in the 5 days after the first weekly baiting. The corresponding estimated number of individuals detected dropped from 2–3 to 1 (a distinctive wide-ranging individual) plus the one-off detection of a second fox on the periphery. Whether all foxes remained present and were just not in the 5 days post additional baiting will become evident when the remaining camera images are examined. It is thought the high activity of foxes may be related to the beginning of the breeding season and on the basis of the relatively low number of individuals detected, it was decided to proceed with the translocation. The second weekly baiting occurred on the day before the translocation began (8/07/2013).

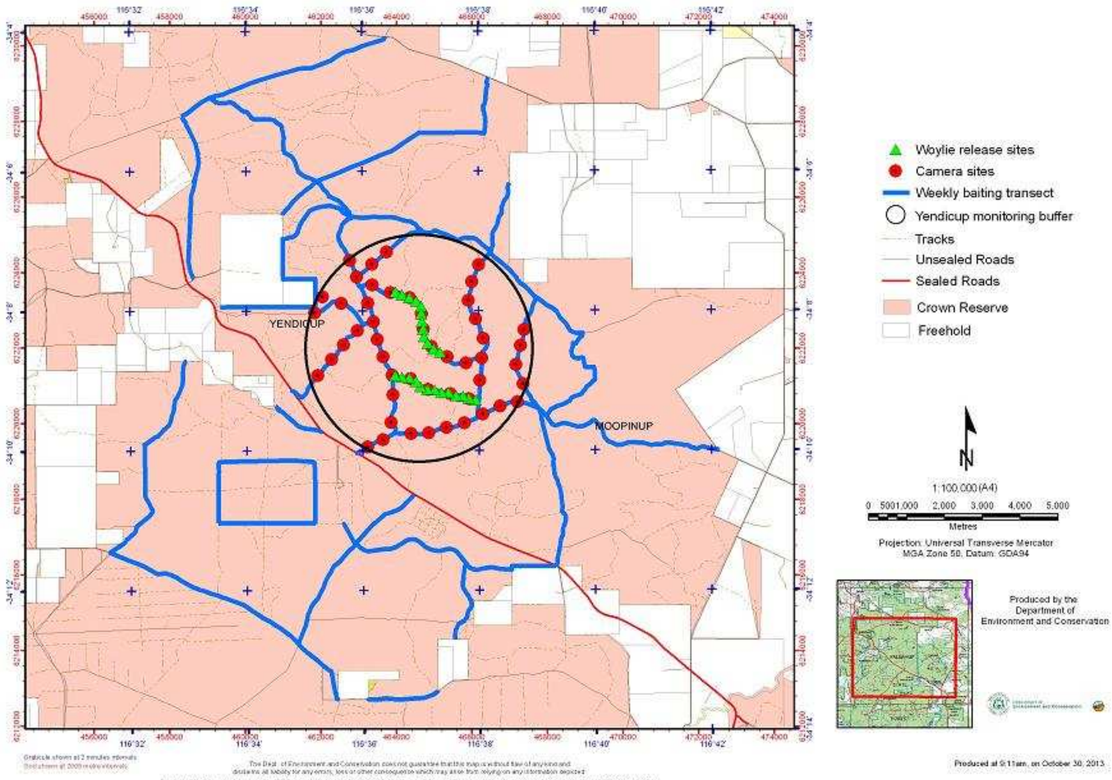


Figure 50. Detailed map of the Upper Warren region showing the fox baiting activities including the monthly ground baiting within the Perup core area (fat B&W line), the, the weekly ground baiting (skinny red line) in and around the woylie translocation release area (fat grey lines) in Yendicup forest block.

Targeted control of introduced predators involving landholders on adjacent freehold land was coordinated by Warren Catchments Council (WCC) to coincide with the translocation and resulted in a coordinated baiting program and two foxes being shot on adjacent private property (see section 4.3).

Trapping within the Perup Sanctuary was conducted 9–11 July 2013, using 6 trapping teams (16 people) and 135 trap points (i.e. generally 100 m intervals along track-based transects). The trap points were similar to the 144 used in April 2013 monitoring (see Figure 59 in section 6.3.2), except traps were not set for the four points closest to the two gates (T0, TA00B, TD00B and TD23), and the six points closest to arboreal traps concurrently set to capture ngwayir (TB08, TB08B, TB09, TB09B along Alf Rd and E13B and C13 along Wandoo Rd). The trapping also included an extra trap point set near the intersection of Wandoo Rd and the southern boundary of the sanctuary. Traps were set with a generous amount of bait (golfball size) to provide candidate woylies a large feed immediately before translocation.

On the first night 135 traps were cleared twice (20:30–00:00 and 00:30–03:00hrs). On the second night 2 traps were set per trap point and cleared once (20:30–01:00hrs). As a result, a total of 209 woylie individuals were captured, of which 87 (51 males, 36 females) were eligible candidates that were translocated and released immediately in Yendicup (3.5–5.5 km away). Candidate females were particularly limiting. The plan was to release two individuals each of both genders at each of 25 pre-existing trap points spaced 200 m apart (Figure 50). Given the shortfall, females were spread across the 25 release points as evenly as possible.

6.2.2.4 Discussion

In accordance with the goal of the National Recovery Plan for the Woylie (Yeatman and Groom 2011) and the draft woylie population management strategy; '*to conserve and maximize the genetic diversity of the woylie at a species level',* the injections of genetics from the Upper Warren region into the Dryandra Woodland and Kingston populations are high priorities for the release of woylies from Perup Sanctuary. The outcomes of the supplementation at Yendicup will inform the planning for the subsequent translocation of woylies from Perup Sanctuary to elsewhere as part of the recovery strategy for the woylie.

The fox-baiting regime applied in the Yendicup translocation is considered to be close to or at the maximum feasible limit within the existing permits and departmental frameworks and protocols for routine fox-control—weekly fox-baiting at Yendicup (~3,600 ha), within a monthly baiting regime within the Perup core area (~14,500 ha) with collaborative predator control efforts on adjacent private properties, within a broadscale-scale quarterly regime (133,000 ha for the

Manjimup cell of which 83,000 ha is aerially baited). Such a baiting regime was considered to deliver a high probability of success for the woylie population (i.e. good conservation outcome) but also provide a useful reference point to test whether this is in fact sufficient to enable a local woylie recovery (i.e. a good learning outcome to inform planning and protocols for future woylie translocations). Higher levels of predator control are possible (for example variation in bait types, placement and timing, targeted removal of individuals using other control methods, etc) and may potentially deliver a better conservation outcome in the short term. However, feedback during the planning phase of this study indicated that this was not likely to be currently feasible for broader routine operational application elsewhere. Therefore the learning outcomes from a higher level of predator control were likely to have lower applicable value than the settings chosen in this instance.

The outcome of this woylie translocation will also help inform efforts to understand the factors limiting a substantial and sustained recovery of woylies in the wild. Three key factors now distinguish woylies at Yendicup from elsewhere in the Upper Warren region where woylies have not recovered—higher level of predator control, higher density of woylies and greater genetic diversity. In this regard Yendicup is very similar to the Perup Sanctuary except that the sanctuary has no terrestrial predators. Therefore, if the translocation fails then terrestrial predators will most probably be the critical factor for woylie recovery. If it succeeds, then the relationships between predator density and woylie density and/or genetic diversity are the putative factors. To better resolve whether this may be the case it is important to have concurrent comparative measures of predator and woylie densities elsewhere in the Upper Warren region (for example comparable array of 50 remote sensor cameras and woylie trapping transect). Resources to include this work would need to be secured by mid-September at the latest to provide adequate comparable data.

The removal and introduction of a known numbers of woylies at Perup Sanctuary, Yendicup and Dryandra are also opportunities to calibrate current remote camera monitoring to determine the sensitivity of this method in detecting changes in population sizes and population responses to harvesting and/or supplementation. Comparisons with density/abundance measures derived from concurrent trapping activities in these sites would also be useful. Such an assessment of the accuracy and precision of this survey method would be directly relevant to its use and the confidence associated with interpreting the results. The monitoring in Yendicup by cameras and trapping is reported elsewhere (section 6.2.5, below).

6.2.3 Translocation Dryandra to Perup Sanctuary (July 2013)

Summary: A total of 36 woylies (23 males, 13 females) were translocated from Dryandra to Perup Sanctuary 22–26 July. Monitoring in the sanctuary *using remote sensor cameras and trapping will be ongoing. Lower than expected trapping rates at Dryandra merit revising abundance estimates for this important natural woylie population.*

6.2.3.1 Introduction

Dryandra woodlands support one of the three last remaining natural populations of woylies in the wild (Pacioni *et al.* 2011). The other two (Kingston and Perup) were already well represented in the Perup Sanctuary. In order for the Perup Sanctuary to be established as an insurance population to conserve the genetics at the species level, a representation of the genetics from the Dryandra populations was needed in the Perup Sanctuary. The goal was to relocate up to 50 suitable woylies from Dryandra to Perup in July 2013.

6.2.3.2 Methods

Trapping sites were originally distributed about 1 km apart throughout much of the more favourable woylie habitat in the main block at Dryandra Woodland. At each trap site 6 cage traps were set >10 m apart for the purposes of maximising that the probability that the capture of non-targets (for example koomal) did not restrict the opportunity to catch woylies in the area. Non-target captures were released immediately on site. Once a woylie had been selected for translocation from a specific site, the traps were closed at that site and relocated to a new trapping site. Paper was placed under traps to aid in the collection of woylie faeces from translocation candidates.

Traps were set in the afternoon, cleared and closed in the first three hours after sunrise and reset, and where necessary relocated, in the afternoon. As the week of trapping progressed and the challenges to find adequate candidates increased, the spacing between some trapping sites was reduced to 500 m and 3 traps per site.

Selection criteria for translocation candidates included;

- Up to 50 individuals
- As close to gender parity as possible
- Where possible select individuals >500–1000m apart to avoid genetic relatedness between individuals and maximise genetic diversity across translocation candidates
- Where possible a roughly even spread of selected individuals across the main block of Dryandra
- Females with no dependent young or with pouch young <50 mm Crown Rump (i.e. reduced welfare risks to young). If there was an elongated teat

indicating a possible dependent young at heal then there needed to be some indication that the teat was no longer active and/or any accompanying pouch young needed to be >20 mm (i.e. > 60d old, meaning that the young at heal would be >160d old—when they should be entirely weaned, potentially sexually mature and independent).

- Of independent age and in good condition,
- Preferably young adults with evidence of previous breeding. Individuals first ear tagged in 2011, 2012 or 2013 (identified on a list of 19 animals recorded on the local database, not including records from recent researchers), or not tagged (i.e. new) were preferred candidates for translocation

Candidate woylies for translocation were retained in dark, thick handling bags in animal transportation containers within vehicles and transported to a central processing laboratory ('Irabina' education centre at the Dryandra village) by either runners or by the trapping teams once all traps had been cleared. Females with pouch young had the pouches taped as a precautionary measure before transportation. All morphometric data, a health assessment and sampling (for collaborative research on parasites at Murdoch University) were collected at Irabina. Samples included ear tissue for DNA, plain blood, blood smears, and ectoparasites. Faecal material collected in the field were also sorted and preserved in formalin and alcohol.

Animals selected for translocation were kept individually in dark, thick bags and transported to Perup Sanctuary in appropriate animal transportation containers, in the covered cargo space of vehicles in which ventilation and temperature could be adequately controlled to maintain the ambient conditions around the animals between 15 and 25 degrees. Animals were transported from Dryandra to Perup Sanctuary (280 km <3.5 hrs travel time) on the afternoon of their capture and released in the sanctuary at dusk. Where possible a male and female were released at pre-existing trap points spaced 100 m apart along internal tracks (Alf and Wandoo Roads, and unnamed east-west track south of Alf Rd). Animals not required for translocation were released at the point of capture in Dryandra late that same afternoon (when the traps were being reset). Females with pouch young were routinely checked immediately before release.

6.2.3.3 Results

Trapping was conducted 22–26 July, using 6 trapping teams, a woylie processing team and runners (17 people, Figure 51). In total 142 trap points were used (3–6 traps per point, 500–1000m between points) throughout the main block of Dryandra. The number of traps set each night was 318, 330, 311 and 293 traps for Monday to Thursday nights respectively (1252 trap nights in total).

A total of 55 woylie individuals were captured, of which 36 (23 males and 13 females; see Figure 52 for capture location) were eligible candidates that were translocated and released between -30 min and +60 min from sunset in the Perup Sanctuary.

Some of the other species captured during the week included koomal (118 captures), chuditch (8 captures), red tail phascogale (2 captures), mardo (2 captures), grey-bellied dunnart (2 captures) and quenda (1 capture). All of these captures were successfully released.

Figure 51. Some of the people involved in the trapping at Dryandra for the translocation of woylies to Perup Sanctuary, July 2013.

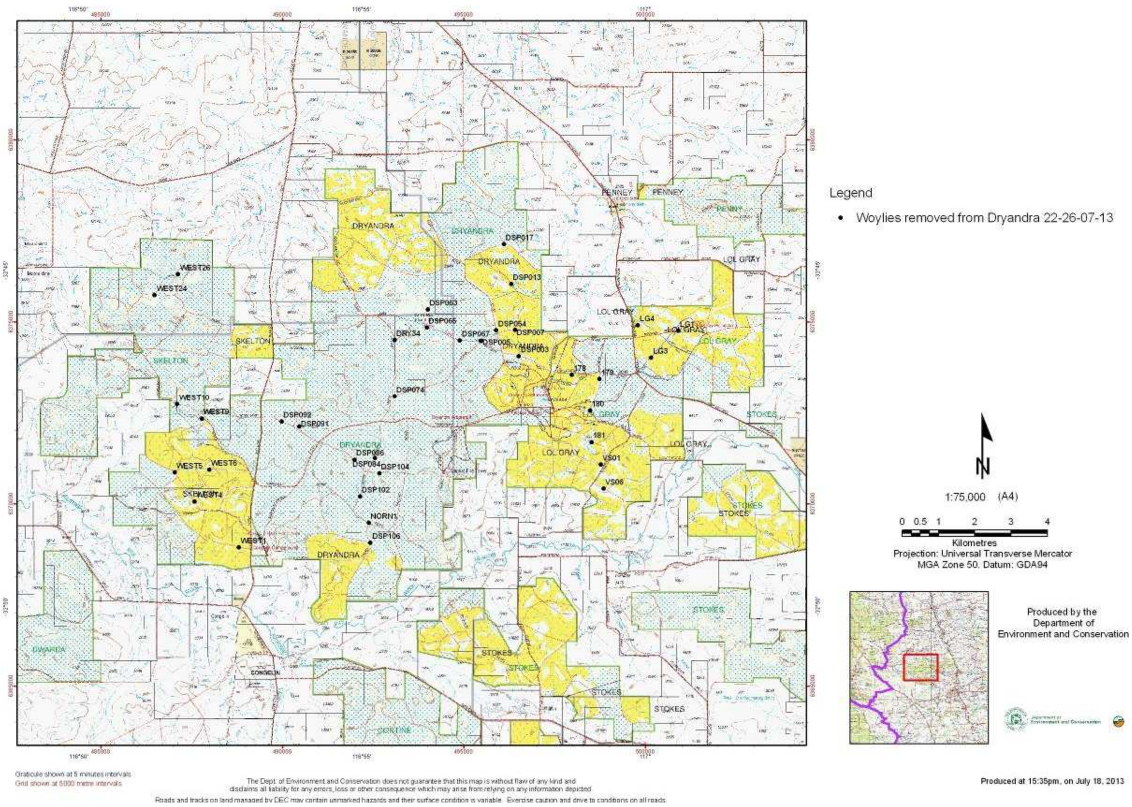


Figure 52. Location of the woylies sourced from Dryandra that were translocated to Perup Sanctuary, July 2013.

6.2.3.4 Discussion

While 36 individuals translocated from Dryandra to Perup Sanctuary was close to the target of 40–50 woylies, the number of suitable females (13) was limited. Nine females were not eligible for translocation because of the presence of a large pouch young or dependent young at heal. Ongoing monitoring in the Perup Sanctuary and Dryandra by cameras and trapping is reported elsewhere (section 6.2.5, below).

Woylie captures were lower than generally expected by field staff familiar with the area. Furthermore it became apparent that estimates of the population size in Dryandra (Wayne *et al.* 2013a) did not account for the no or negligible occurrence of woylies post-decline in brown mallet, where pre-decline, woylies did occupy this habitat to some extent (Brian Macmahon pers. comm.). Given that brown mallet plantations account for approximately 20–30% of the main block at Dryandra (12,000 ha), it may be that population estimates in 2010 (1000–4000) are correspondingly over estimated. Given these factors and that populations <3,000 are probably not sustainable in the long-term (Pacioni 2010), it would be highly advisable to carefully revise current woylie population estimates for Dryandra, and reassess the risks of local extinction associated with smaller population sizes and issues of introduced predator control in the area.

6.2.4 Tutanning offspring to Perup Sanctuary (August 2013)

Summary: The first five independent offspring (3 males and 2 females) from the last remaining 6 woylies from Tutanning, being held at Kanyana Wildlife Rehabilitation Centre, were released into the Perup Sanctuary; two on 20th August 2013, 3 on 24th October 2013. Remote sensor cameras and trapping (October 2013 and March–April 2014) will continue to monitor their progress in Perup Sanctuary.

6.2.4.1 Introduction

In late 2011 it was apparent that the indigenous population of woylies in Tutanning had declined to a critical. In mid-2012, DEC (now DPaW) collected all remaining known animals of Tutanning origin (from the Perth Zoo and Tutanning) and placed them in Kanyana Wildlife Rehabilitation Centre. The total was seven woylies (5F:2M), of which one female subsequently died without successfully breeding and another female is apparently old and has not yet bred. The offspring from these founders are of value as they represent a distinct genetic unit. To maintain the diversity of genetics remaining in the species, it is important to add these offspring to an insurance population, specifically the Perup Sanctuary. In accordance with the draft woylie population management strategy and on the basis of genetic and population modelling, these offspring will be released within the sanctuary as they are produced (small numbers at a time over an extended period). With young leaving the pouch at about 90 days, and females being sexually mature at 150–180 days, it is proposed to release these offspring within 2 months of them being independent.

6.2.4.2 Methods

At Kanyana, offspring are being monitored using cameras and observers to determine when they are considered independent (i.e. out of the pouch for the majority of the time). Within 2 months of this, offspring will be captured (using nets or cages) early evening, will undergo health checks and be individually marked (microchip, ear tag and/or paint marker) and transported immediately to Perup Sanctuary (350 km, ~4 hrs travel time) in dark, thick bags in appropriate animal transportation containers, in the covered cargo space of vehicles in which ventilation and temperature can be adequately controlled to maintain the ambient conditions around the animals between 15 and 25 degrees. Animals will be released immediately on arrival between sunset and midnight.

6.2.4.3 Results

The first two independent offspring (a male and female) from the last remaining 6 woylies from Tutanning being held at Kanyana Wildlife Rehabilitation Centre were released into the Perup Sanctuary on the evening of 20th August 2013. Reflective tape on their ear tags and unique small patches of bleached fur (using mild-strength human hair products) on their flanks and rump will be used to monitor their movements and survivorship using remote sensor cameras over time. Two males and one female were similarly released into the Perup Sanctuary on 24th October 2013.

One of the four adult females from Tutanning has not managed to successfully breed as yet.

6.2.4.4 Discussion

As more offspring from the captive breeding program at Kanyana Wildlife Rehabilitation Centre become available, they will continue to be introduced into the Perup Sanctuary to conserve as much of the remaining genetics representative of the Tutanning population, which is now extinct in the wild. Ongoing monitoring in the Perup Sanctuary by cameras and trapping is reported in the next section (section 6.2.5, below).

6.2.5 Monitoring translocation source and destination sites

Remote sensor cameras will be used to monitor changes in woylie activity/abundance associated with the removal and/or addition of woylies at the three main sites involved—Perup Sanctuary, Yendicup and Dryandra. As well as monitoring, this is an excellent opportunity to calibrate and measure the sensitivity and reliability of woylie detection rates using remote sensor cameras. All sites are using comparable camera models (Reconyx HC600 and PC900).

- Yendicup: 50 remote sensor cameras (spaced 500m along tracks within a 3 km radius of the centre point of the translocation area by Science Manjimup staff) have been monitoring woylies, introduced predators and other fauna since 25th June 2013. Monitoring will continue until follow-up trapping in October 2013 by Science Manjimup staff. Trapping is also planned for March–April 2014 (Science Manjimup—Bush Rangers project) and annually thereafter.
- Perup Sanctuary: 54 remote sensor cameras (arranged in a grid with 300 m spacings, by Donnelly District staff) have been monitoring the sanctuary since 28th June 2013 to supplement the existing 22 cameras semi-permanently installed for predator incursion surveillance. Follow-up trapping will be conducted in October 2013 and March–April 2013 by Donnelly District staff. Monitoring of the Perup Sanctuary by cage trapping

of woylies, which has been conducted since its establishment in late 2010, is reported elsewhere (section 6.3.2, below).

- Dryandra: 60 cameras (semi constrained randomized locations, with a minimum spacing of 750m between cameras and offset from tracks and boundaries by 50m; by Science Woodvale and Great Southern District staff including Neil Thomas, Mark Cowan and Brian Macmahon). Cameras were deployed 24th June 2013 and will be retrieved in late August (i.e. 4 weeks before and 4–5 weeks after the removal of woylies). Ongoing woylie monitoring by trapping will be conducted as part of *Western Shield* in March 2014 by Great Southern District staff.

6.3 Woylie population monitoring

The monitoring of woylies and other native medium-sized mammals has been principally through small live cage trapping programs. Transects across the Upper Warren region provide insights into the spatial and temporal patterns of population change and possible evidence of associations with these changes. An overview of the monitoring in the Upper Warren region and Perup Sanctuary is provided here.

6.3.1 Upper Warren region

Summary: Long-term and extensive monitoring of medium-sized native mammals in the Upper Warren region, using small cage traps, provides an unrivalled resource to conservation managers and researchers. Having declined by 95%, woylie numbers have remained low but relatively stable at the regional scale since 2005. Subregional patterns are also evident, including no signs of recovery in central Perup—including woylies remaining undetectable in Yackelup since 2005, potentially the beginnings of a modest recovery in southern Perup, later and more subdued declines and some recovery in northern Perup, and in Greater Kingston, where the declines first began, the first and only substantial recovery to date has not been sustained having undergone a secondary decline to new record lows. The monitoring provides some of the strongest evidence available for and against the possible causes of the woylie decline and limiters of recovery and represents an excellent resource to inform wildlife conservation managers in a timely manner of population changes and potential issues, and provides insights into the biology and ecology of several native mammal species.

6.3.1.1 Introduction

Long-term monitoring has revealed a remarkable decline phenomenon in woylies in the Upper Warren region. Woylie capture rates were previously shown to reflect real declines in population abundance and to be a reliable estimate of woylie density and abundance (Wayne *et al.* 2013a). So far there has been up to a 95% decline in the woylies in the Upper Warren region since the decline began in 1999. A clear spatio-temporal pattern to the declines has also been apparent, with a front to the decline moving at an average of 4 km per year throughout the Tone-Perup Nature Reserve (Wayne *et al.* 2013b). Population monitoring is fundamental to understanding population change over time, providing evidence of the causes of population change and to alert managers in a timely manner whether further conservation interventions are required. The monitoring of woylies using transects of cage traps throughout the Upper Warren region have been reported previously (e.g. Wayne *et al.* 2006, 2008, 2011, 2013a). This provides an update to include monitoring since 2010, not previously reported.

6.3.1.2 Methods

Eleven key cage trap transects (50 traps spaced 200 m apart; Figure 53) formed the basis for monitoring woylie and other native medium-sized mammal populations throughout the Upper Warren region. These transects were all surveyed biannually for two years (2005–2007), after which there has been a progressive reduction in the frequency to annual monitoring in most cases, except Keninup and Warrup (where woylie populations were most abundant and dynamic) that have remained biannually monitored (Table 15). These surveys have been conducted variously by DPaW Science, Donnelly District, Fauna Management Course and Bush Ranger programs. Each survey consists of four consecutive nights. The Woylie Conservation Project Field Operations Handbook (DEC 2008b) provides the standardised protocols for monitoring woylies and associated wildlife in the Upper Warren region and a summary of the methodology is provided in DEC (2008a).

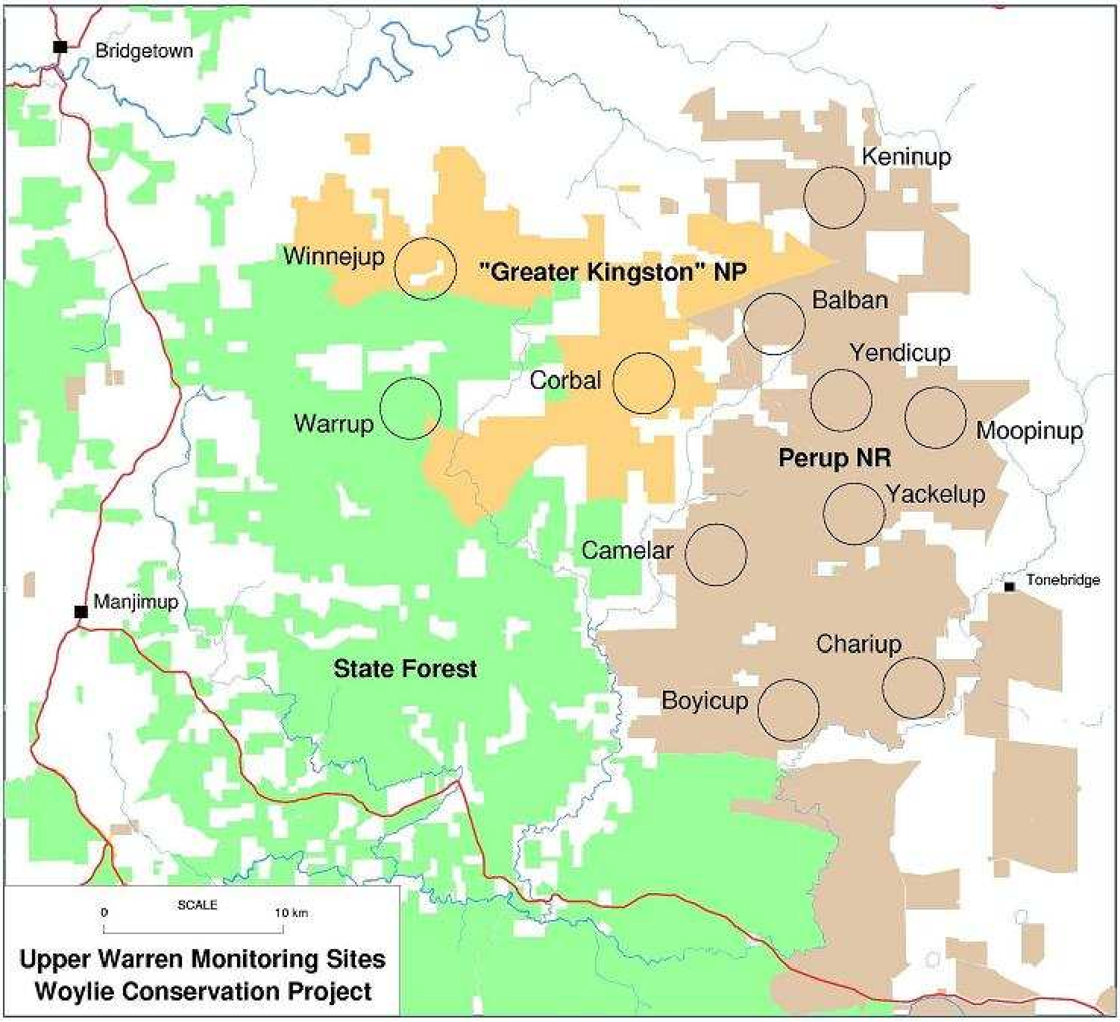


Figure 53. Key monitoring locations within the Upper Warren region involved in the Woylie Conservation Research Project.

Table 15. Summary of the survey history of the key cage trap monitoring transects in the Upper Warren region.

Block	**Keninup**	**Warrup**	**Balban**	**Camelar**	**Boyicup**	**Moopinup**	**Yendicup**	**Yackelup**	**Chariup**	**Winnejup**	**Corbal**
First Survey	1999	1994	2000	2000	1974	1999	1975	2000	1998	1994	2005
# Surveys pre 2005	12	29	8	7	67	9	66	12	8	22	0
Spr'05	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Aut'06	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Spr'06	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Aut'07	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Spr'07	Y	Y	Y	Y			Y	Y			
Aut'08	Y	Y	Y		Y	Y				Y	
Spr'08	Y	Y	Y	Y							
Aut'09	Y	Y			Y	Y	Y	Y	Y		
Spr'09	Y	Y	Y	Y							
Aut'10	Y	Y			Y	Y	Y	Y	Y	Y	
Spr'10	Y	Y	Y	Y							Y
Aut'11	Y	Y			Y	Y	Y	Y	Y		
Spr'11	Y	Y	Y	Y							
Aut'12	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Spr'12	Y	Y	Y	Y						Y	
Aut'13	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
# Surveys since 2005	16	16	13	12	10	10	10	10	9	9	6

6.3.1.3 Results

The median woylie capture rate in the Upper Warren region went through a 92% decline in the three years after 2002 (Figure 54). The woylie population has remained low but relatively stable over the 9 years since 2005. Since 2010, when woylie numbers were at their lowest (95% less than 2002 levels), the median capture rate has increased from 3.25% to 5%. Mean woylie capture rates follow a similar pattern, although slightly buffered by the high capture rates in the last sites (Keninup and Balban) to decline (2006–2010), and the unsustained recovery at Warrup (2005–2010).

The woylie declines were first detectable beginning in the Upper Warren region in 1999 in Warrup—pre decline woylie capture rates in 1998 were 58%. Warrup was also the first and only site to have undergone a significant recovery (2005–2008). However, the recovery was not sustained and began declining again in 2009, having reached a secondary peak of 40.3% woylie capture rate in 2008. In 2013 it was still declining to record lows for the site (3% capture rate; Figure 55). There is scant evidence of the beginning of a possible recovery of woylies elsewhere in Greater Kingston (western parts of the Upper Warren region).

The woylie declines in southern Perup began in 2002 and were essentially completed by 2006. Woylie capture rates before the declines were 42%–70%, dropping to 0%–4% immediately after the declines and have subsequently recovered slightly to 3.5%–14% in 2013 (Figure 56). In central Perup, woylie capture rates before the declines were 65%–80%; they began declining 2003–2004 and dropped to 0%–4% by 2005–2007. There have been no subsequent signs of recovery in central Perup, with woylie capture rates remaining at 0%–3%. No woylies have been detected in Yackelup since 2005 (Figure 57). The last remaining areas in the Upper Warren region to be affected by the woylie declines were northern Perup. Before the declines woylie capture rates were 60%–67%. Beginning in 2006–2007 the declines have not been as comprehensive as elsewhere in the Upper Warren region with minimum woylie capture rates observed so far of 6%–9% (2009–2011). With a modest recovery to a woylie capture rate of 24% in 2013, Balban currently supports the highest density of woylies in the Upper Warren region (Figure 58).

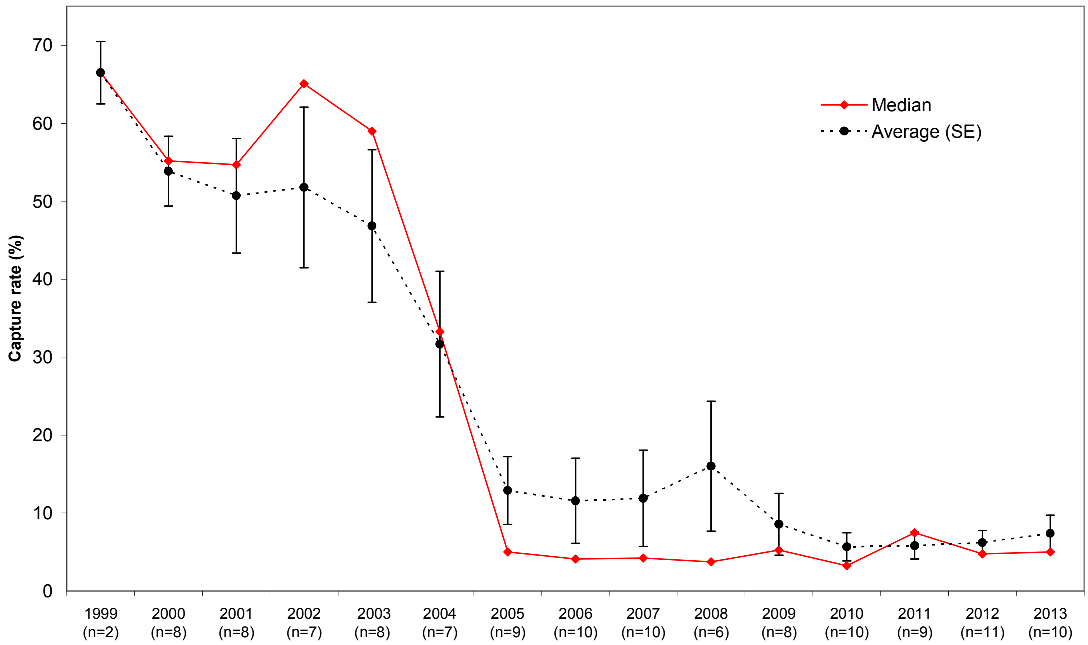


Figure 54. Annual trap capture rates of woylies in the Upper Warren region since their peak in 1999 to 2013 (number of sites surveyed per year, n=2–11).

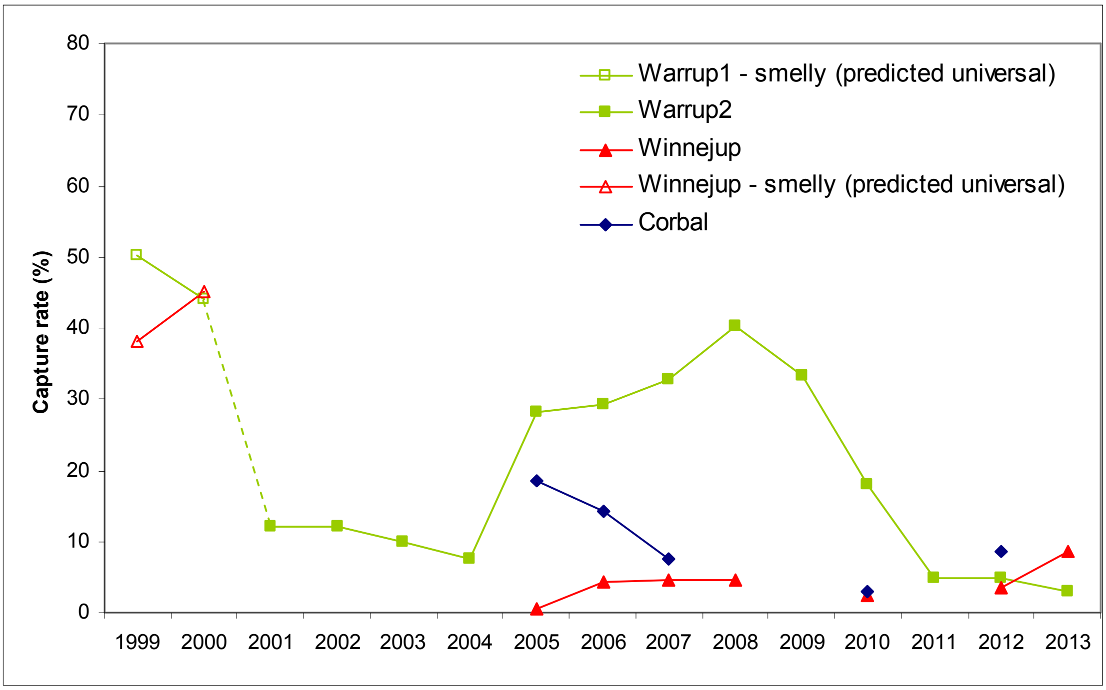


Figure 55. Annual trap capture rates of woylies along monitoring transects in Greater Kingston (western Upper Warren) 1999–2013.

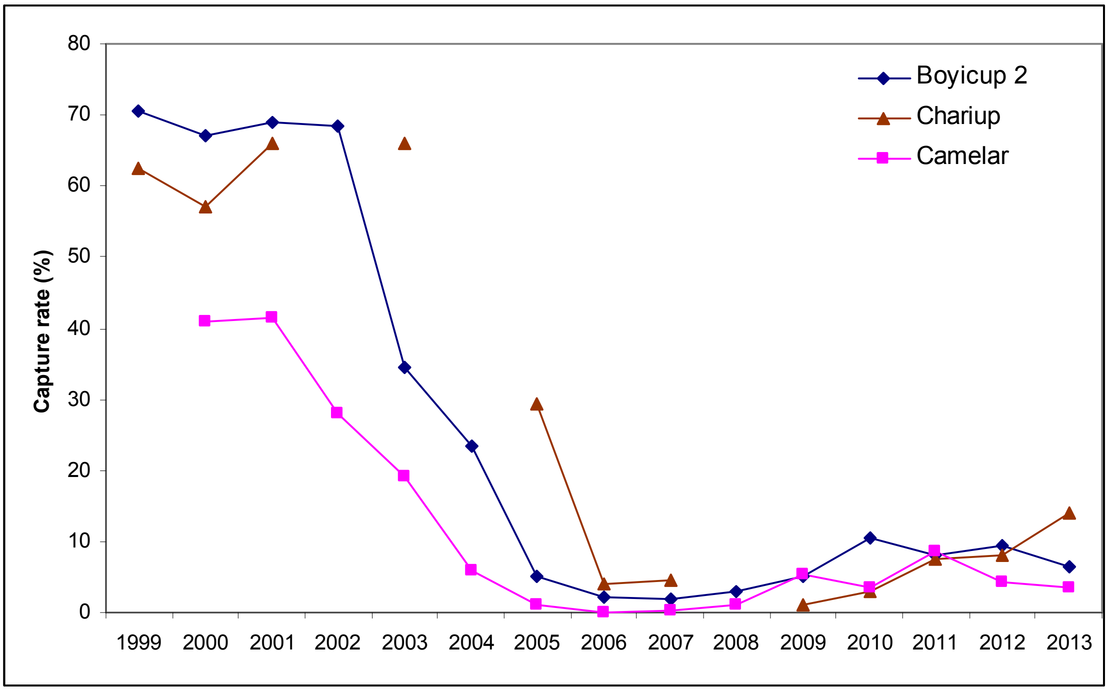


Figure 56. Annual trap capture rates of woylies along monitoring transects in southern Perup (southeastern Upper Warren) 1999–2013.

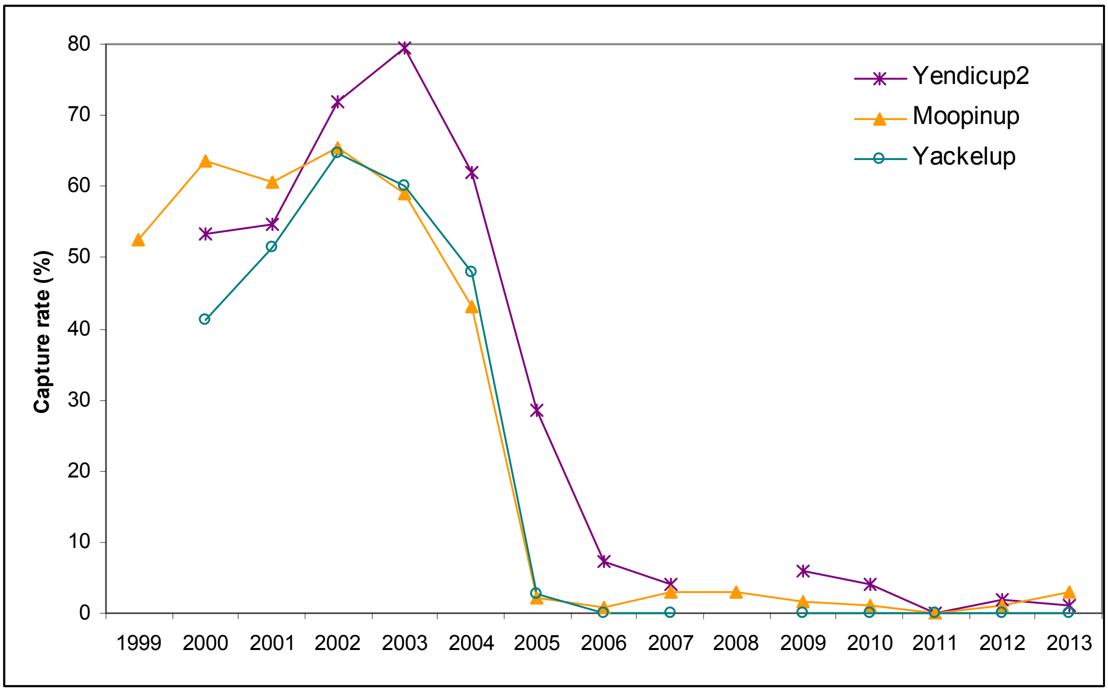


Figure 57. Annual trap capture rates of woylies along monitoring transects in central Perup (eastern Upper Warren) 1999–2013.

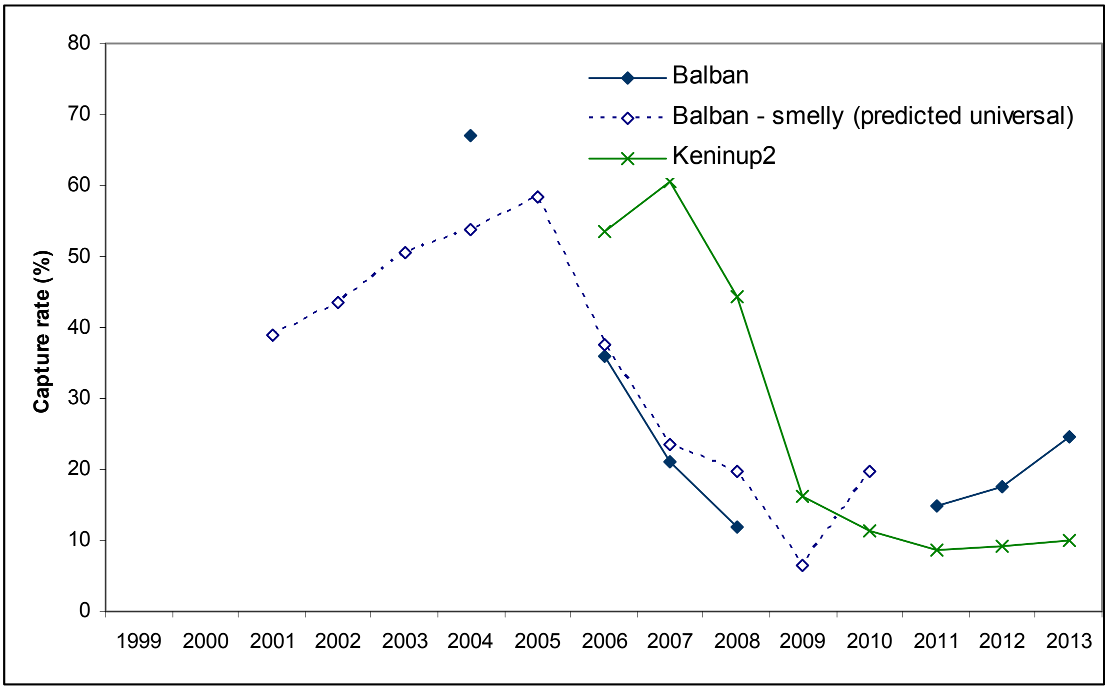


Figure 58. Annual trap capture rates of woylies along monitoring transects in northern Perup (northeastern Upper Warren) 1999–2013.

6.3.1.4 Discussion

Woylie numbers in the Upper Warren region declined by 90% in just three years (2003–2005 inclusive) but have so far declined by 95% overall. In the 9 years since 2005, woylie numbers have remained low but relatively stable at a regional level. But at the subregional scale some patterns are apparent. In central Perup woylie numbers remain undetectable or very low. However in southern Perup, where the declines began relatively early, and in northern Perup, which was affected last and more subdued than elsewhere, there may be the early signs of a recovery. What accounts for this pattern is uncertain but it is probably related to the factors limiting the recovery of the woylie.

Whether the possible early signs of a recovery in northern and southern Perup continue or can be sustained is unknown but of critical importance to the conservation and recovery of the species. Of particular concern, is whether what occurred at Warrup may also happen elsewhere? So far, Warrup remains the most significant and substantial woylie recovery in Western Australia. But having recovered to ~1 woylie per ha (or 40% capture rate), the woylies immediately collapsed again to reach new record lows in 2013. This density represents an apparent minimum threshold common to all woylie populations that have substantially declined, except Tutanning. Given these apparent patterns, it is possible that other recoveries elsewhere may also not be sustained and collapse again.

While woylie populations remain at relatively very low levels, their vulnerability to local extinction because of pressure from key threats and/or stochastic events remains high (for example refer to the small population paradigm, Caughley 1994, Caughley and Gunn 1996). Local extinction of woylies has already occurred at Tutanning and possibly at Yackelup (not detected for 8 years). Without effective mitigation, other sites with especially low woylie numbers are also particularly at risk, for example Batalling, east of Collie and at the other sites in central Perup (Moopinup and Yendicup). In an effort to reduce fox predation pressure, Batalling and central Perup are currently subject to fox baiting regimes greater than the standard applied under the *Western Shield* fox-baiting program (6 times and at least 12 times per year (see section 4.2), respectively and including aerial and ground baiting, compared with the operational standard of 4 aerial baiting events per year). The translocation of 87 woylies from Perup Sanctuary to Yendicup and an associated weekly fox-baiting regime (see section 6.2.2) is also aimed at stimulating a recovery at this site.

Given the magnitude and rapidity of the recent woylie declines (25%–95% declines per annum; Wayne *et al.* 2013b), it is also possible that the larger remaining woylie populations in Western Australia (elsewhere in the Upper Warren region, Dryandra, Boyagin and Karakamia) also still remain at risk of extinction. Understanding the causes of the decline and the factors limiting the recovery, will most assuredly direct woylie conservation and management in the most effective and efficient way to secure the remnant populations and deliver a strong and sustainable recovery of the species. Rapid and substantial recoveries of the woylie in the past and currently in the Perup Sanctuary (section 6.3.2) show, that with adequate management of their key threats, this species has a formidable ability to bounce back.

The continuation of adequate population monitoring is equally as essential to inform managers of population changes in a timely manner and provide evidence of the causes of decline and limiters of recovery. With the conclusion of the WA State NRM and CFOC funded projects and without securing further funding, the areas and frequency of monitoring in the Upper Warren region will decrease from 16 surveys at 11 sites in 2012 to 6 or 7 surveys at 6 or 7 sites per annum. While some sites will continue to be surveyed annually by Donnelly District (Boyicup, Warrup and Moopinup), Science/Bush Rangers (Yackelup and Yendicup) and Fauna Management Course (Balban and possibly Camelar—to be confirmed whether the program may be reduced to Balban only), it is possible that some sites might be monitored every second year (for example Chariup by Donnelly District), but there are currently no commitments to survey other sites at all (Winnejup, Keninup, and Corbal). The biannual or annual monitoring across the Upper Warren region to date has provided a powerful and unrivalled insight into the characteristics of the woylie decline including the spatio-temporal patterns and demographic changes associated with population changes in native medium-sized mammals (e.g. Wayne *et al.* 2013a&b). The monitoring provides some of the strongest evidence available for and against the possible causes of the woylie decline and limiters of recovery and represents an excellent resource to inform wildlife managers and provide insights into the biology and ecology of several native mammal species. The anticipated 62% reduction in monitoring effort will therefore have an impact on the conservation, management and research of threatened species in the region.

6.3.2 Perup Sanctuary

Summary: Monitoring by trapping has shown that at least 83% of the 41 original founders released in the Perup Sanctuary by December 2010 were still alive in 2013. In April 2013, the trapping results conservatively indicate that the population had increased to more than 300. All adult female woylies captured have been breeding, some being sexually mature as small as 620 g. One female has been repeatedly observed with twin pouch young, which is extremely rare. While woylie numbers have grown strongly in the Perup Sanctuary, the capture rates of wild woylies at comparative sites in the Upper Warren region have remained very low.

6.3.2.1 Introduction

Monitoring of the insurance population of woylies in the Perup Sanctuary is a necessary part of its management; to track its progress, measure success and identify potential issues. The main focus of the monitoring has been population size (reported here), individual survivorship (reported in section 6.2.1) and health (reported in section 6.4.2). This has been done within a comparative scientific framework to be able to relate what is occurring in the sanctuary with wild populations (Keninup and Warrup) and the captive insurance population at the Perth Zoo. The monitoring is also an opportunity to understand more about the biology of the woylie and assist in the identification of the factors that may have been responsible for the recent declines and/or factors limiting recovery in the wild. For instance, measurements of the population growth rates over time can potentially quantify for the first time, the actual maximum possible breeding potential and population growth rates (i.e. intrinsic rates of growth) for the species. This is important to help produce more accurate population viability modelling used to develop population risk assessments and conservation strategies. In the absence of terrestrial predators it is also potentially possible to encounter compromised individuals that in the wild would otherwise be readily predated and less detectable.

6.3.2.2 Methods

The trapping monitoring program in the Perup Sanctuary is briefly described in section 5.3.5 of this report. This included 6 trapping sessions, the first 5 of which (February 2011–November 2012) were based on 80 trap points (generally spaced 200 m apart along road based transects, see Figure 40 in section 5.3.5) and 144 trap points (spaced 100m apart along road based transects) in the last session in April 2013 (Figure 59). Morphometrics and routine health assessments were recorded for all woylies as per the standardised protocols outlined in The Woylie Conservation Project Field Operations Handbook (DEC 2008b). A summary of the methodology is also provided in DEC (2008a). Sampling was also conducted as part of Kim Skogvold's PhD research into health and disease comparisons and monitoring of key woylie populations and Craig Thompson's PhD research into trypanosomes. This included collecting samples of hair, blood, faeces and oral swabs in addition to the routine sampling of ear tissue for DNA and ectoparasite collection, that are described in The Woylie Conservation Project Field Operations Handbook (DEC 2008b).

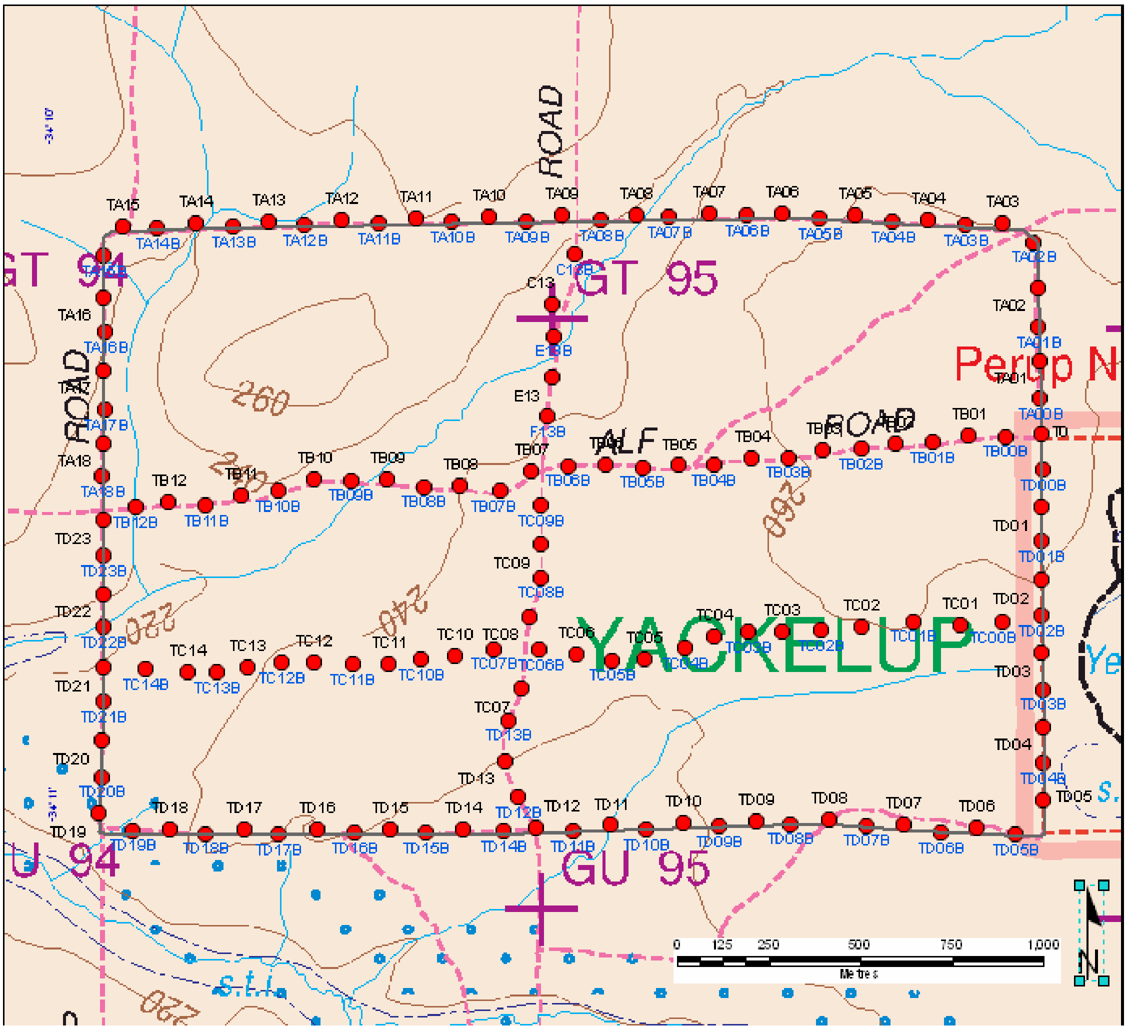


Figure 59. Map showing the 144 trap points used to monitor woylies and medium-sized mammals in the Perup Sanctuary in April 2013.

6.3.2.3 Results

Of the 41 founders originally introduced to the Perup Sanctuary in December 2010, 33 were trapped 2.5 years later in April 2013 (Figure 60). This included 18 of the 19 radio collared woylies known to be alive at the completion of survivorship monitoring (NB: collared female DN2633/34 deceased 21/02/2011; see 3.1.1 for more details). Trapping in July 2013 for the translocation of nonfounders to Yendicup (see section 6.2.2) also trapped an additional founder not recorded in April 2013 (i.e. 34 out of the 40 founders in the sanctuary have been confirmed alive in 2013). The cumulative number of individuals recorded in the sanctuary between December 2010 and April 2013 was 262 (291 after the July translocation).

A total of 227 individuals were trapped in the last monitoring session in April 2013. Robust design mark-recapture models in Program MARK estimated the trappable population size from the April 2013 session to be between 250 and 280 individuals. Given trap saturation was experienced and there were large areas of the sanctuary not readily sampled from the trapping transects, it was conservatively estimated that the woylie population was greater than 300 at the time.

Evidence of the trap saturation issues in April 2013 can be further verified by the results from the trapping program <86 days later, in July 2013 (to source 87 woylies for the translocation to Yendicup), by the fact that all 29 new individuals captured in this session were 945–1620 g and only three males were sexually immature (945–1138 g). Therefore by inference and using growth curves (e.g. C. Thompson in prep for maximum growth rates of woylies in captivity), all except possibly the one individual less than 1,000 g would have been present in the free-living population in April 2013, but just not captured.

While woylie numbers have grown strongly in the Perup Sanctuary, the capture rates of wild woylies at comparative sites in the Upper Warren region have remained very low (Figure 61 and 62).

All adult female woylies captured during all sessions were found to be breeding. Most had pouch young and the remaining few were either lactating (i.e. had a dependent young at heal) or had moist pouches ready for an imminent birth. Females within the sanctuary have been observed being sexually mature as small as 620 g. While the ages of these females are not well known, estimates indicate that other woylies elsewhere in the Upper Warren region were as young as 140–150 days old at the time of conception of their first offspring. One female was observed with twin pouch young in April 2012 and again in November 2012. The occurrence of twins is rare—there are only 3 other records of twin woylie pouch young found in the Upper Warren region since the 1970s from more than 9,000 records of female woylies.

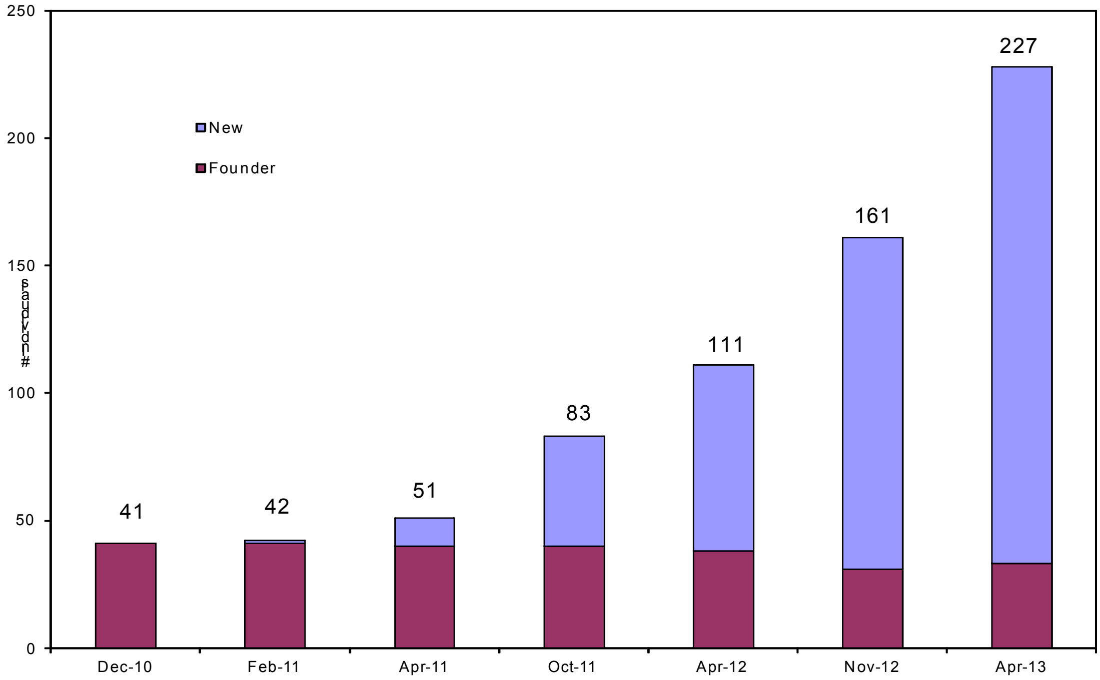


Figure 60. The number of woylie founders and new individuals trapped in the Perup Sanctuary since its establishment with the introduction of 41 woylies in December 2010.

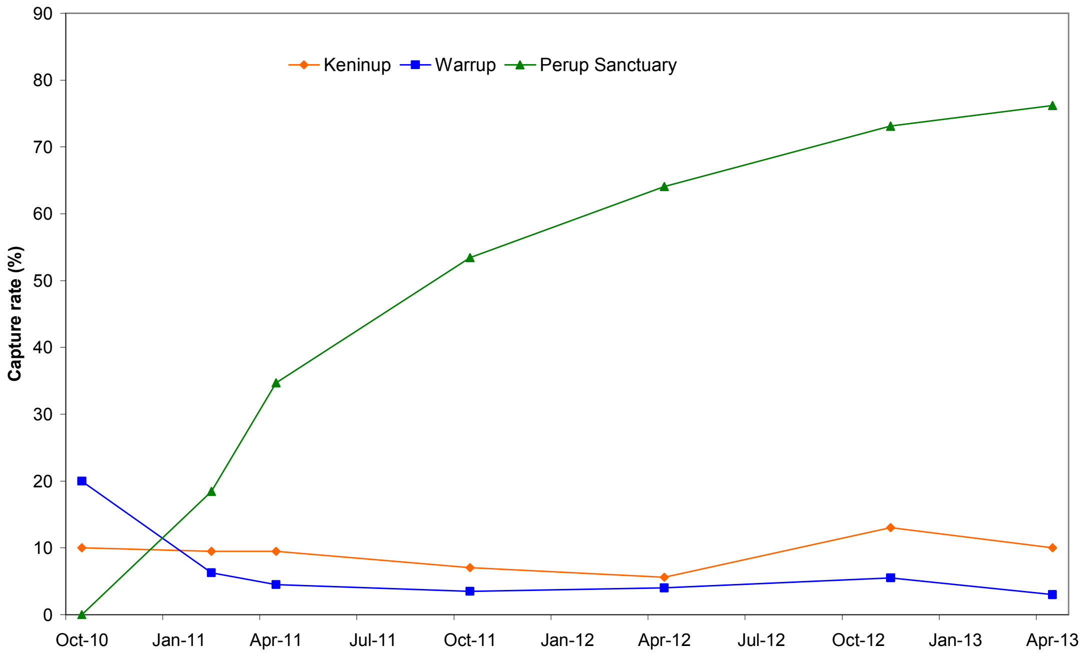


Figure 61. The trap capture rate of woylies in the Perup Sanctuary and two key monitoring sites in the Upper Warren region.

Figure 62. a) Woylie being released in the Perup Sanctuary, b) Most of the people involved in the April 2013 trapping monitoring of Perup Sanctuary

6.3.2.4 Discussion

An estimate of at least 300 adult woylies in April 2013 is considered an underestimate for several reasons including trap saturation resulting in the traps being unavailable for all trappable animals and incomplete coverage of the Perup Sanctuary with traps.

Capture rates are not a reliable measure of abundance in the Perup Sanctuary because of trap saturation since October 2011. Ongoing monitoring of the woylie population in the sanctuary needs to overcome the trap saturation issues to be able to adequately measure changes in population size.

Despite the limitations of the trapping to estimate actual population size the current estimates are strikingly similar to the numbers that have been independently modelled by Carlo Pacioni using Vortex software (Pacioni 2013; Figure 63). For example, the model predicted a population size of 312 in May 2013, and 370 in August 2013 (not accounting for the removal of 87 animals and addition of 38 animals from Dryandra and Kanyana (see section 6.2). The model shows that the woylie population will continue to double in size in 2014 to reach 836 by February 2015 assuming a carrying capacity of 900.

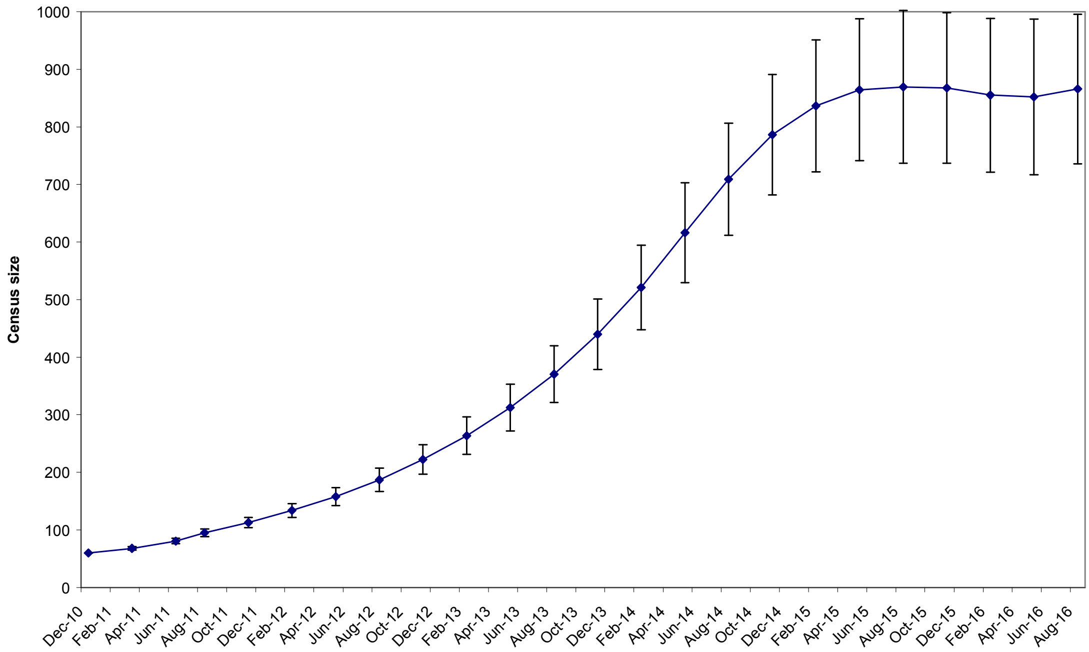


Figure 63. Population modelling of the woylie colony in the Perup Sanctuary (source Pacioni 2013).

All woylie populations that have been observed declining recently in Western Australia (except the particularly small and vulnerable population at Tutanning) had densities greater than 1 woylie/ha before the decline began (Wayne *et al.* 2013a&b). This includes Warrup, the only site to have undergone a substantial post decline recovery, only to decline again to new record lows immediately after reaching 1 woylie/ha (section 6.3.1). Given that it is possible that the causes of the recent declines may be density-dependent and the Perup Sanctuary is expected to exceed this density in late 2013, it is especially important that an adequate monitoring program continues. Consistent with elsewhere, if a decline does occur, the rates will probably be 25%–95% per annum (Wayne *et al.* 2013b). Therefore, monitoring at least biannually at least until 2015 would be necessary to enable an adequate response to the declines if they were to occur.

It is possible that the declines observed in the wild may not occur in the Perup Sanctuary either because of the absence of terrestrial predators in their own right, or the interaction between predators and other agents of decline are disrupted (for example increased vulnerability to predation because of some disease), or because of other factors that make conditions in the sanctuary different from declined or vulnerable populations. Regardless, this emphasises the importance of understanding the agents of decline and limiters of recovery, and the importance of adequate monitoring in the meantime. It also highlights how, by its very nature, the Perup Sanctuary has subtle but profound limitations in being able to directly test and investigate the putative agents of decline. Because of these factors the Perup Sanctuary is subtly but profoundly different from a rigorous and scientific approach to understanding the causes of decline and limiters of recovery. For example, although superficially similar, the predator exclusion study proposed throughout 2007–2008 (i.e. 400 ha predator exclusion area in Keninup established *while* declines in the area were underway compared with adjacent habitat with alternative predator control regimes/densities; Wayne *et al.* unpublished) would have directly tested the role of predators in the declines in a manner that the Perup Sanctuary is fundamentally unable to, despite the likely outcome in both cases being the conservation and recovery of woylie numbers within the predator-free areas.

Given that there is the potential role of disease in the declines it also remains important to monitor the health and disease of woylies, especially in the Perup Sanctuary, to strictly adhere to disease risk management and hygiene protocols (e.g. DPaW SOP 16.2), and carefully manage the movement of woylies. Again, this emphasises the critical importance of rigorously eliminating or verifying whether disease has in fact been involved in the declines and whether it threatens the recovery of the species. Furthermore, if disease has been involved, it would be valuable to know whether the surviving woylies in affected populations have an increased resistance to the agents of decline because of a substantial and rapid selective removal of genetically or behaviourally vulnerable individuals. In the meantime, it would be prudent to prioritise the translocation of woylies from the Perup Sanctuary to sites that have already undergone decline and/or within an experimental framework that enables the possible role of disease to be investigated (for example South Australian Islands).

Determining the optimum and sustainable woylie harvest rates from the Perup Sanctuary is also a key priority. Doing so will maximise conservation of genetics, maximise the recovery potential for the species and minimise the genetic drift of the Perup Sanctuary colony. We estimate that as many as 400 individuals per annum could be sourced from the sanctuary for translocations elsewhere, particularly to stimulate recoveries in the wild such as Upper Warren region, Dryandra and Batalling. Reliable population modelling (for example using Vortex software) is the best means of determining the most appropriate population management and harvest regime for the Perup Sanctuary and population recoveries in the wild.

Monitoring the ecosystem responses to high abundances of critical weight animals (Burbidge and McKenzie 1989) in the absence of terrestrial predators in the Perup Sanctuary is important for the ongoing management of the sanctuary. Surveys conducted as part of this project (section 5.3) provide a baseline reference for future monitoring of other positive and potential adverse effects such as vegetation change and species reductions or loss).

6.4 Other woylie conservation research and monitoring activities

Summary: Many collaborative activities have been linked with the on-ground woylie conservation actions in the Perup Sanctuary and Upper Warren region more broadly. The vast majority of these collaborations have been through student projects and experts at Murdoch University and Perth Zoo. Much of this work is focused on delivering a better understanding of the nature of the woylie declines, the possible causal factors of these declines and the ecology and biology of the woylie relevant to its conservation and in some cases native wildlife more broadly. A very brief outline of these activities and progress is reported here including; strategic planning and management of the possible role of disease in the recent woylie declines, woylie health and disease monitoring, pathology, trypanosomes, Toxoplasma, other parasite investigations, bacteria, viruses, genetics and population modelling, food resources and woylie diet, and ecological factors associated with the distribution and abundance of woylies.

6.4.1 Strategic planning and management of the possible role of disease in the recent woylie declines

Little is known about the present disease status of Western Australia's native fauna. What information is available is sparse, fragmentary and incomplete, and has largely been opportunistically derived from carcasses. The extent to which infectious diseases represent a threat to wildlife populations in WA will depend upon a complex interplay between characteristics of the host and the infectious agent. Nonetheless, it is possible that infectious diseases may, at least partially, be responsible for past (e.g. Abbott 2006) and present declines in Western Australian small mammal fauna. Non-infectious disease agents such as toxicosis, nutrition or genetics, may also be significant causes of decline.

The objectives relating to the possibility of disease being involved in the woylie declines have been;

1. Identify potential disease agents and evaluate their potential role in woylie declines.
2. Use expertise to prioritise which known and unknown diseases may be associated with woylie declines.
3. Examine indirect evidence (for example demographic changes) that may help to determine whether a disease in general or a specific disease may be responsible for recent woylie declines.
4. Assess the prevalence and potential for specific high-risk disease agents to be a causal factor in the decline of woylies.

Given the complexities and diversity of expertise needed to consider the possible role of disease in wildlife decline a Woylie Disease Reference Council (WDRC) was established with expertise from Murdoch University and Perth Zoo in association with representation from DEC (now DPaW).The goal was to have representation of the full breadth of multidisciplinary expertise relevant to the wildlife disease. This included clinicians, ecologists, geneticists, epidemiologists, infectious disease specialists, nutritionists and pathologists. The charter for the WDRC was;

- Be the principle forum for addressing woylie disease issues.
- Assist in the collation of existing information on woylie/wildlife diseases in Western Australia
- Provide expert advice and direction on research priorities into putative disease agents of woylie/wildlife declines
- Facilitate and develop collaborative endeavours into woylie/wildlife disease research between DEC staff and disease experts and students.

The WDRC was particularly active 2006–2010 during which time more than 30 experts were directly involved in the regular meetings (DEC 2008a). More recently, as the scale and type of collaborative activities have changed the WDRC has operated less formally and met less regularly. Nonetheless the key clinical and pathology coordinator roles (Dr Simone Vitali, Perth Zoo and Dr Phil Nicholls, respectively) and woylie disease investigation coordinator (Prof. Andrew Thompson) remain active.

A part-time manager of woylie disease investigation (Dr Andrea Reiss, with assistance from Dr Carlo Pacioni) was hosted for 12 months (2010–11) by the Perth Zoo with funds provided by the ‘Woylie Rescue’ sponsorship program. The role of the manager was to facilitate collaborative endeavours to determine the role of disease in the recent woylie declines. This included assisting in organising and synthesising existing disease-related data and information generated to date, develop a woylie disease investigation plan, develop and assist collaborations regarding woylie disease investigations (including clinical assistance in the field during ongoing monitoring), and identify potential sources of funding and apply for funds where appropriate. **S**ubstantial and significant progress on all of these objectives was achieved however a cessation of funds for this position has meant that this work has no longer continued.

Details of the progress with disease-related activities have been previously reported (DEC 2008a, Wayne *et al.* 2011 and peer-reviewed publications see Appendix A). This section provides an overview and update of many of these activities.

6.4.1.1 External review of disease components of WCRP

An external review panel (Dr Rupert Woods, Dr David Obendorf, Dr Lee Skerratt and Pam Whiteley) undertook a review of the woylie disease investigation components following the interim report (DEC 2008a) and woylie symposium in February 2008 (Woods *et al.* 2008). Key points from this review included that there was insufficient information at the time to determine whether or not disease was a cause of the declines, that disease must be considered as a probable cause, that the highest priority was for an epidemiological framework to be applied to the disease investigation and that this would best be achieved by the appointment of a dedicated epidemiologist and disease investigation manager to coordinate the disease investigation components of the research program. In response, considerable effort was made to secure a means to make such appointments. This was met in part by the appointment of a manager of woylie disease investigation in 2010–11.

6.4.1.2 Disease risk analysis

A Disease Risk Analysis, seeking to identify probable pathogens that may have been contributing to the woylie decline was developed by Carlo Pacioni (2010) as part of his PhD thesis. This desk top exercise gathered information from publications, grey literature, anecdotal reports and personal experiences and developed a risk analysis matrix. This information helped to guide priorities for field and laboratory investigations into woylie disease.

The disease risk analysis was reviewed and updated in 2010–11 (Reiss and Pacioni) to establish disease priorities for further investigation and is being prepared as a submission for publication (Pacioni *et al.* in prep).

6.4.1.3 Woylie disease investigation action plan

A detailed investigation action plan was developed by Andrea Reiss in her role as Manager of Disease Investigation, with input from all members of the WDRC and associated woylie disease investigators. This action plan outlined all major areas of investigation, provided preliminary detail on how each area of investigation could best proceed, and attempted to prioritise the programs. A short list of high priority action programs was agreed upon.

6.4.2 Woylie health and disease monitoring

Monitoring for the clinical signs and symptoms evident in woylies is an important element to determining whether health or disease may or may not be a factor in the woylie declines. The field health checks and sampling activities, the clinical cases, the evidence of skin and fur conditions associated with the decline, haematology and the comparative study into the health of woylies from different populations are briefly described in this section.

6.4.2.1 Field health checks and sampling

Routine general health checks of woylies conducted as part of population monitoring have resulted in 2,537 assessments in the Upper Warren region, plus an additional 452 within the Perup Sanctuary, and 301 from Karakamia, between 2006 and 2013 (Table 16). Extensive collections of blood, ectoparasites, faeces, DNA and other samples have accompanied many of these checks. Some comparable data and samples from other woylie populations have also been collected in collaboration with field staff working in those areas. Much of this material has been made directly available to collaborating research, particularly student projects. Many of the samples also remain in storage as an important resource available for retrospective analysis if and when new and compelling evidence of the agents of decline are identified that require further testing.

Table 16. Summary of health and disease sampling completed as part of the Woylie Conservation Research Project (2006–2013).

* Other sample types include swabs for herpes, biopsies, skin scrapes and urine.

	Keninup	**Perup / Kingston**	**Karakamia**	**SA**	**Dryandra /Tutanning**	**Batalling**	**Perup Sanctuary**	**TOTAL**
Blood—EDTA	316	381	48	146	17	35	157	**1100**
Blood—Smears	467	322	4	165	18	38	181	**1195**
Blood—Sera	650	484	146	144	20	38	196	**1678**
Ectoparasites	679	596	303	105	18	38	98	**1837**
Scats—Endoparasites	580	505	52	135	12	23	195	**1502**
Scats—Diet	648	523	240	128	20	27	na	**1586**
Scats—Salmonella	19	122	27	0	0	0	na	**168**
DNA	277	645	150	156	11	36	201	**1476**
Other*	20	8	0	0	0	0	36	**64**
Routine health checks	1104	1433	301	17	22	25	452	**3354**
Additional sampling as part of K. Skogvold health monitoring (2010-2013)								
Blood—Antioxidant	53	102	na	na	na	na	142	**297**
Hair—Stress	63	105	na	na	na	na	179	**347**
Scats—Faecal Egg Count	45	23	na	na	na	na	194	**262**
Scats—Stress	63	137	na	na	na	na	198	**398**

6.4.2.2 *Skin and fur conditions*

Preliminary analyses of the health check data revealed that skin and fur conditions had a strong association with populations currently declining (Figure 64, Wayne *et al.* 2008). Wayne and Maxwell (2009) provide a visual manual to the sorts of conditions that were being observed and how to document them. Preliminary results from Pacioni (2010) highlighted that prevalence of health problems recorded at physical examinations (the majority of which were various types of skin lesions) increased significantly immediately before the detection of the decline and were moderately (but significantly) correlated with the intensity of the decline. In other words, the quicker the population was declining, the higher the prevalence of health problems. Only minor haematological changes were associated with these health problems.

Twenty woylies from the Upper Warren region had skin scrapes and/or skin biopsies collected to undertake a preliminary investigation into a variety of skin conditions observed (Eden *et al.* 2010). Results showed an increase in the prevalence of skin conditions between October–November 2006 and November 2008 in Keninup (immediately before and initial stages of decline) and Warrup (post-decline recovery and immediately before the beginning of a second decline). The skin conditions were thought to be because of non-specific chronic changes, most likely associated with tick and other ectoparasite burdens. Self-trauma and fighting may have also contributed to some of these skin conditions. No evidence was found of an underlying primary pathogen or disease causing the skin changes (Eden *et al.* 2010).

Given the apparent associations with the woylie declines a more comprehensive and rigorous epidemiological analysis to resolve the exact nature of these associations and further investigate the pathogenesis of skin lesions is merited.

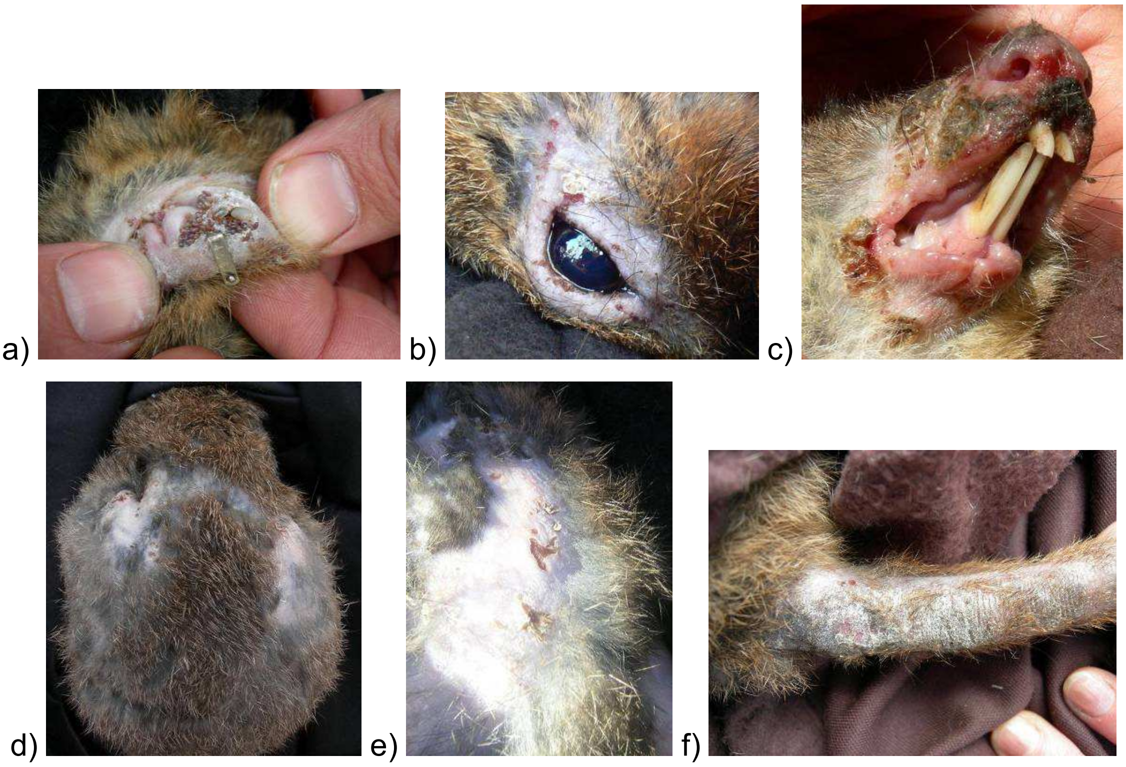


Figure 64. Examples of some of the conditions reported in the woylie field health checks apparently associated with the sites undergoing declines.

a) Ectoparasites (ticks) in the ear, b) hair loss and scabbing around the eye, c) lesions and scarring around mouth, d&e) hair loss and scabbing on the back and rump, f) hair loss and scabbing on the tail

6.4.2.3 An exploration of the field health check data for associations with the declines of woylies in the Upper Warren region

Student project: Michaela Pleitner (Bachelor of Science research thesis, University of Wuerzburg, Germany). Supervisors Dr Dieter Mahsberg, Dr Adrian Wayne

Beginning in September 2013 Michaela Pleitner, a field intern with the DEC Science team in Manjimup in 2012, will begin an honours project investigating some of the data from the field health checks to identify and better quantify possible associations with woylie populations undergoing decline. The study will also look for trends of changes in health measures and indicators over time and between different demographic cohorts (for example age and gender). This will include an assessment of the prevalence and severity of skin and fur conditions, general body condition and body mass. The study will also investigate whether there are any relationships between these health indicators and the survivorship of individuals.

6.4.2.4 Clinical cases

Kim Skogvold, Simone Vitali (Perth Zoo)

There have been a total of 23 woylie clinical cases (seven from Upper Warren region) 2006–2013 (Table 17). Principally all cases have been debilitated individuals, with no suggestion of a consistent, underlying disease process. Of the 22 woylies sent to the Perth Zoo for assessment, seven animals were ultimately returned to their site of origin, 13 were euthanased and sent to Murdoch University for necropsy, one was kept at the Perth Zoo as part of the captive insurance population, and one (assessed as unfit for wild release) was kept by a wildlife rehabilitator as an education animal. In addition, in 2010 one woylie was euthanased at a Busselton veterinary clinic and sent immediately to Murdoch University for necropsy. The animal presented with pneumonia symptoms and pathology revealed oesophageal myopathy. The implications of which require further examination. Necropsies were conducted on all euthanased woylies (see section 6.4.3).

Table 17. Summary of woylie clinical cases administered by Perth Zoo veterinary staff 2006–July 2013

Origin	Year	# cases	Clinical summaries	Fate
Upper Warren	2006	1	Trauma injury	Returned to field
Upper Warren	2007	1	Poor condition / neurological	Returned to field
Upper Warren	2008	1	External lesions	Returned to field
Upper Warren	2009	2	1 Poor condition, 1 Trauma injury	2 Euthanased / Necropsy
Upper Warren	2010	1	Trauma injury	Perth Zoo insurance population
Upper Warren	2013	1	Trauma injury / neurological	Captive—education
Karakamia	2006	3	3 External lesions / abscesses	1 Returned to field, 2 Euthanased / Necropsy
Karakamia	2007	2	1 Neurological, 1 External lesion	Euthanased / Necropsy
Karakamia	2008	3	1 Sternal abnormality, 2 Poor condition / lesions	1 Returned to field, 2 Euthanased / Necropsy
Karakamia	2009	1	Poor condition / trauma injury	Euthanased / Necropsy
Private/Other	2008	1	Poor condition / abscesses	Euthanased / Necropsy
Private/Other	2010	2	1 External lesion,1 Pneumonia*	2 Euthanased / Necropsy
Private/Other	2012	4	2 Trauma injury 1 Trauma injury / osteomyelitis 1 Poor condition / trauma injury	2 Returned 2 Euthanased / Necropsy

6.4.2.5 Haematology

Several haematological attributes (for example lymphocytosis) and health factors (for example skin and fur conditions) of woylies were statistically significantly associated with the contemporary rates of decline (Pacioni 2010). Funds from ‘Woylie Rescue’ extended the haematological data analysis to South Australian woylie populations and other WA populations (Pacioni *et al.* 2013b). These were used to establish hematologic reference ranges for the species and greatly increase knowledge of the health status in these populations. Significant gender differences in hematocrit, red blood cell, total white blood cell, neutrophil, lymphocyte, and eosinophil counts were evident in at least one population. A positive association of the erythron parameters with rainfall was also detected. The populations affected by the decline presented clear haematological signs of immune system stimulations, which were not detected in non-declining woylie populations. The biological significance of these associations, whether they are coincidental or related to population declines and individual mortality need to be investigated further.

6.4.2.6 A Comparative Health and Disease Investigation in the Woylie—Captive vs Free-Range Enclosure vs Wild

Student: Kim Skogvold (Professional PhD, Murdoch University). Supervisors Dr Kris Warren, Dr Simone Vitali, Dr Carly Holyoake, Dr Cree Monaghan and Dr Adrian Wayne

Summary: A comparative assessment of woylie health, stress and disease with a focus on the Perup Sanctuary relative to wild populations in the Upper Warren region and the captive colony previously at Perth Zoo is underway as part of a Professional Doctorate program being undertaken by the Perth Zoo Resident Veterinarian, Dr Kim Skogvold. All samples have been collected and are undergoing analysis. The project is planned to be completed by early 2014.

Introduction

This project contributes to investigations aiming to determine if disease is a significant factor in the recent woylie declines and lack of recovery. The project is unique in that it compares health and disease over time in three different population management systems—wild population in the Upper Warren region; insurance population at Perup Sanctuary; and captive insurance population previously at Perth Zoo. Studying the sanctuary (free-range predator-proof enclosure) population allows the investigation to focus on the role of disease in the absence of introduced predators.

Methods

Health testing included haematology, biochemistry, gastrointestinal parasites, anti-oxidant and vitamin levels, determination of stress levels using hair, faecal and serum cortisol, and screening for a selection of significant marsupial pathogens including herpes virus (Figure 65). Health assessments and sampling were conducted in conjunction with the population monitoring using cage traps in the Perup Sanctuary and comparative wild sites (Keninup and Warrup) at the time of the establishment of the insurance population in the Perup Sanctuary (October–December 2010) and on six subsequent occasions—February 2011, April 2011, October 2011, April 2012, November 2012, April 2013 (see section 6.3). Assessments and sampling at Perth Zoo was conducted at the same points in time and involved anaesthesia, full physical exam and sampling performed by the Perth Zoo veterinarians.

Results

Over 1000 individual samples (250+ blood samples, 400+ faecal samples, 300+ hair samples, 150+ swabs) have been collected for analysis. Complete testing and analyses are pending. The project has validated the use of faecal glucocorticoids as a measure of stress for this species with the help of collaborators at Taronga Western Plains Zoo Wildlife Reproductive Centre, and plans to also validate the use of hair. Screening for significant marsupial pathogens including haemoparasites, toxoplasmosis and selected viruses including Herpes virus and Warrego and Wallal orbiviruses is also underway. A novel gamma herpes virus has been isolated, with the help of collaborators at Melbourne University School of Veterinary Science, in a small proportion of tested individuals in the Perup Sanctuary. Further work to characterise the virus and attempt to measure exposure levels in the population via serology is being conducted.

Figure 65. Blood collection and swabbing for herpes virus on an anaesthetised woylie.

Discussion

The increase in understanding of woylie health, stress and disease this project brings will aid in the recovery and management of this critically endangered species. The project is not only establishing baseline information on woylie health and disease, but determining the usefulness of novel tests in adding to the assessment of woylie health and stress, and contributing towards a disease investigation model for potential use in other Australian fauna declines. Analysis of results is planned for completion in early 2014.

6.4.3 Pathology investigations in the woylie

Phil Nicholls, Murdoch University

Pathology has been an important collaborative element to the investigation of the possible causes of death and possible underlying diseases of woylies associated with the recent declines. This has primarily involved a necropsy (post-mortem examination) program based at Murdoch University under the initial leadership of Pathologists Dr Graeme Knowles and then Dr Phil Nicholls. So far since 2005 58 necropsies have been conducted on woylies from the Upper Warren region, Dryandra, Tutanning, Karakamia, Batalling and private wildlife carer colonies. About a quarter of these have been opportunistic (for example road kills) to help provide a reference for the species, others have included animals encountered with serious clinical conditions that have had to be humanely euthanased and about 40% have been radio collared woylie individuals that have been found dead in the wild. Knowles *et al.* (2008) and Wayne *et al.* (2011) provide more details of the activities and outcomes relating to pathology.

Of note are several cases that are unusual or have unexplained histological findings worthy of further investigation. In particular are cases of myopathy that have directly or possibly indirectly been a cause of death. In one example (10-058), a woylie that had aspiration pneumonia (with food contents demonstrable within the lung at post-mortem examination) also had degenerative changes in the muscle of the oesophagus and in the tongue (Figure 66). These muscle changes may well have caused swallowing problems, which in turn may have led to the aspiration of the food into the lungs and death.

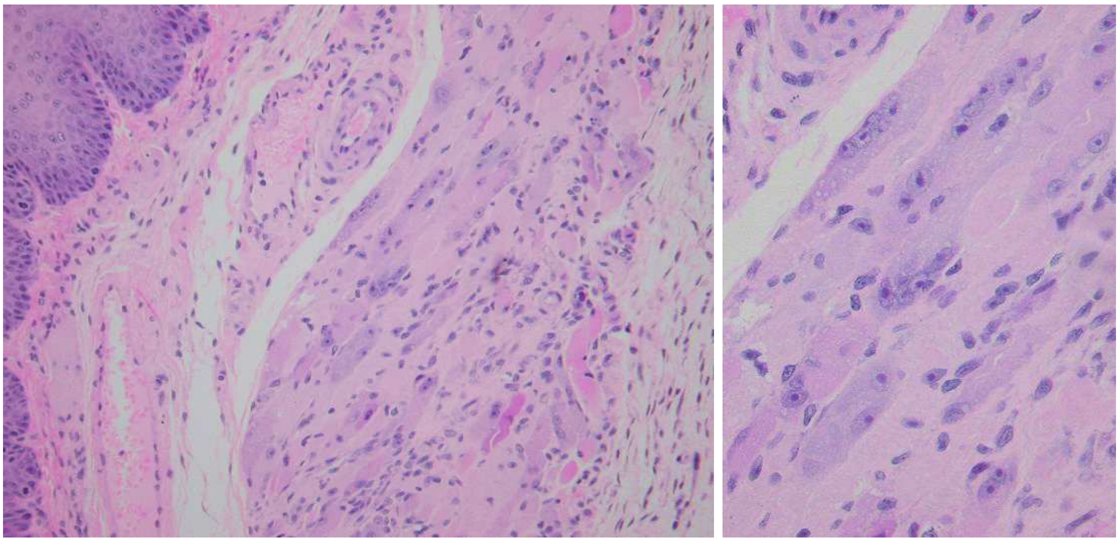


Figure 66. Histological section of oesophagus (left) to show muscle fibres degeneration characterised by basophilic (purple) staining of the muscle cells, coupled with enlarged and centralised cell nuclei (right).Woylie 10-058 (from Yelverton Eco Retreat 15th January 2010).

Two further cases (12-356 and 12-357) were from woylies (Roleystone colony) examined promptly after their reported sudden death. Both had severe inflammatory changes in the heart muscle, considered likely to have been fatal, as well as inflammation in skeletal muscle, tongue and muscle of the bladder wall and elsewhere (Figure 67). These animals also were positive for trypanosomal DNA by molecular testing (PCR), and the findings have been recently published (Botero *et al.*, 2013).

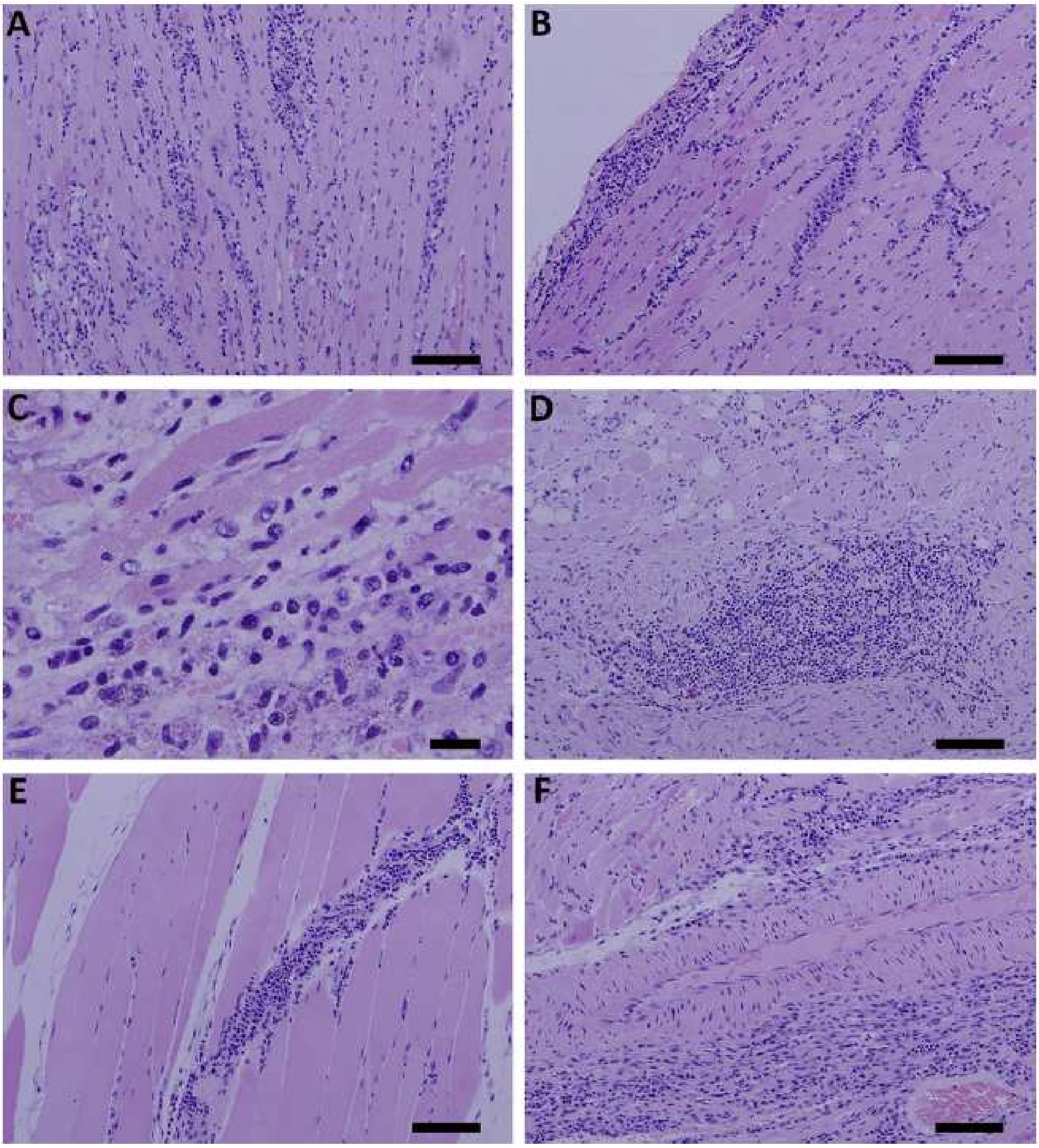


Figure 67. Histopathology of two woylies naturally infected with G2 (Clade A) (H&E stained).

(A) Multifocal, moderate to severe, chronic pyogranulomatous myocarditis and (B) endocarditis. (C) Mineralisation of heart tissue. (D) Tongue showing multifocal, moderate, chronic, pyogranulomatous glossitis. (E) Skeletal muscle degeneration. (F) Inflammatory cells around a blood vessel. Scale bars = 20 µm. (from Botero et al., 2013).

Apparent amastigotes (intracellular phase of trypanosome infections) were seen in affected muscle (Figure 68), and these findings, coupled with the additional findings noted above, have provided an important lead for further investigation.

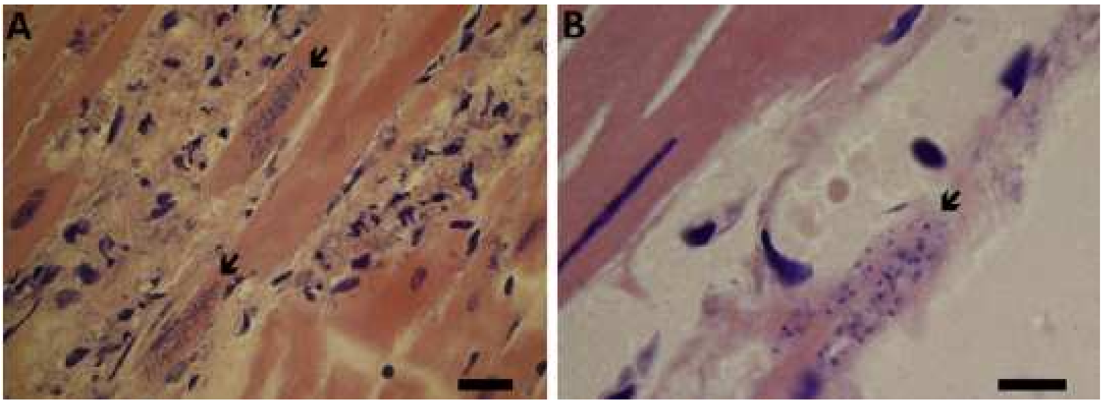


Figure 68. Structures suggestive of amastigotes (arrows) of G2 (Clade A) in heart tissue positive for DNA by PCR (H&E stained). Scale bars (A) 20 µm, (B) 10 µm. (from Botero *et al.*, 2013).

As part of these further investigations, a review of pathology in the woylie is underway (2012–2015) as part of a ‘Research Masters with Training’ in Anatomic Pathology (RMT) at Murdoch University by Ziyuan Lim (supervised by Dr Phil Nicholls and Prof. Andrew Thompson). The project will review our existing archive of pathology from the woylie, focusing on the novel myopathy of oesophagus, tongue and heart described above. The novel and severe myocarditis will be further assessed (by in situ hybridisation and immunohistochemistry) to address in further detail the hypothesis that it relates to trypanosome infection (supported by existing findings from PCR, microscopy and culture from workers in Prof. Thompson’s group).

The pathology review examinations will be based on retrospective, archived materials, and prospectively on new cases that occur during the program. Gross post-mortem examinations, in conjunction with histopathology, electron microscopy and other ancillary diagnostic techniques such as in situ hybridisation and immunohistochemistry will be employed where appropriate. While the review and examinations will be looking for any background pathological changes, there will be a specific focus on the extent and significance of muscular degeneration seen in the tongue and oesophagus of some animals, as well as a severe myocarditis that has been seen in a small number of individuals. This will be pursued in the light of the possible role of trypanosomes in these lesions.

Ongoing investigation of these cases may lead to greater understanding of disease processes contributing to the decline, or at a minimum will further our understanding of health and disease and interpretation of pathology findings in woylies.

6.4.4 Trypanosomes

A novel, host-specific trypanosome was identified in woylies as part of the WCRP (Smith *et al.* 2008, Averis *et al.* 2009). A comparison of the prevalence (by PCR) and parasitemia levels (by light microscopy) revealed a positive association with the declining woylie populations within the Upper Warren region compared with the stable population at Karakamia (Smith and Averis 2008; Table 18). A subsequent detailed analysis of 503 samples from Keninup between March 2006 and June 2009 was made possible because of the Keninup Intensive Study, Wildlife Conservation Action funding and considerable investment by collaborators at Murdoch University. It has provided further evidence of an association in the prevalence of *Trypanosoma* with the progression of the decline of woylies in that area, whereby trypanosome prevalence was 0–10% before the start of the decline, after which the prevalence reached up to 62% and followed a similar pattern to changes in woylie capture rates (Figure 69). Albeit a smaller and temporally more limited dataset, a similar association was also evident at Balban—the only other site where samples have been collected during a decline. There are plans to investigate these associations more rigorously to help determine their significance to the woylie declines by A. Wayne, A. Thompson, A. Smith M. Maxwell and M Williams.

Table 18. Association of *Trypanosoma* with recent woylie declines: a comparison between the Upper Warren region and Karakamia populations.

	Upper Warren region	**Karakamia**
Population state	Declining	Stable
n	124	123
Prevalence—PCR	49%	13%
Parasitemia—Microscopy	High	Not detected

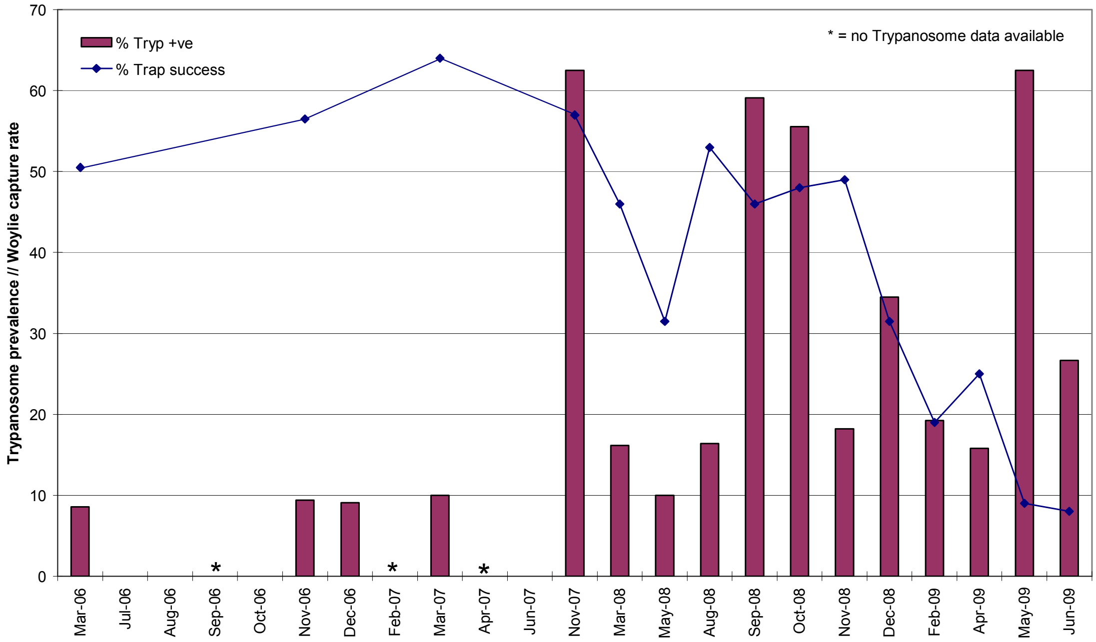


Figure 69. Prevalence of trypanosome infections in woylies at Keninup in relation to capture rates.

A new project began in 2010 on the transmission dynamics of trypanosomes in declining, stable and enclosed populations of woylies (Craig Thompson, Murdoch University PhD project). Another project is looking at the genetic characterization of trypanosomes (Adriana Botero, Murdoch University PhD project). WA State NRM support for these research projects has demonstrated: (1) Woylies are infected with up to 3 different species of trypanosome parasites. (2) The parasites vary in their virulence and pathogenic potential. (3) The virulent trypanosome is the most common trypanosome in woylies from the declined populations in the Upper Warren region. In contrast, the virulent trypanosome is uncommon in woylies in the thriving population at Karakamia. (4) Ticks play a role as vectors of the trypanosomes. (5) Mixed infections with *Toxoplasma* exacerbate the consequences of trypanosome infections. More detail of these projects and the use of the Native Animal Rescue facilities in Malaga to assist with this research are detailed below.

6.4.4.1 *Trypanosome polyparasitism and the decline of the critically endangered Australian potoroid, the brush-tailed bettong* (Bettongia penicillata*)*

Student project: Craig Thompson (PhD candidate, Murdoch University). Supervisors Prof. Andrew Thompson, Dr Stephanie Godfrey, Dr Adrian Wayne

This component of the collaborative endeavour in woylie conservation is focused on investigation into the correlation of the trypanosomes found in the blood of the woylies and the overall population decline of the host. As part of a parasitological study to understand this dramatic decline, it was discovered that the trypanosomes in the blood of woylies were grouped into three morphologically distinct trypomastigote forms, encompassing two separate species. The larger of the two species, *Trypanosoma copemani* exhibited polymorphic trypomastigote forms, with morphological phenotypes being distinguishable, primarily by the distance between the kinetoplast and nucleus. The second trypanosome species was only 20 % of the length of *T. copemani* and is believed to be one of the smallest recorded trypanosome species from mammals. No morphological polymorphism was identified for this genetically diverse second species (Thompson *et al.* 2013).

The trypomastigote morphology of this new, smaller species from the peripheral blood of the woylie has been described and the name *T. vegrandis* sp. nov. has been proposed. Temporal results indicate that during *T. copemani* Phenotype 1 infections, the blood forms remain numerous and are continuously detectable by molecular methodology. In contrast, the trypomastigote forms of *T. copemani* Phenotype 2 appear to decrease in prevalence in the blood to below molecular detectable levels (Thompson *et al.* 2013).

This study has reported for the first time the morphological diversity of trypanosomes infecting the woylie and provide the first visual evidence of a mixed infection of *T. vegrandis* sp. nov. and *T. copemani*. We also provide supporting evidence that over time, the intracellular *T. copemani* Phenotype 2 may become localised in the tissues of woylies as the infection progresses from the active acute to chronic phase. As evidence grows, further research will be necessary to investigate whether the morphologically diverse trypanosomes of woylies have impacted on the health of their hosts during recent population declines.

6.4.4.2 Diversity of trypanosomes infecting Western Australian marsupials: virulence and pathogenicity

Student project: Adriana Botero (PhD candidate, Murdoch University).
Supervisors Prof. Andrew Thompson

While much is known of the impact of trypanosomes on human and livestock health, trypanosomes in wildlife, although ubiquitous, have largely been considered to be non-pathogenic. This project aims to investigate the genetic diversity and potential pathogenicity of trypanosomes naturally infecting Western Australian marsupials with particular emphasis on those parasites associated with the woylie. 554 blood samples and 250 tissue samples collected from 50 carcasses of sick-euthanized and road-killed animals, belonging to 10 species of marsupials, were screened for the presence of trypanosomes using a PCR of the 18S rDNA gene. PCR results revealed a rate of infection of 67% in blood and 60% in tissues. Inferred phylogenetic trees using 18S rDNA and glycosomal glyceraldehyde phosphate dehydrogenase (gGAPDH) sequences showed the presence of three different species of *Trypanosoma*: *Trypanosoma copemani*, *Trypanosoma vegrandis*, and *Trypanosoma sp H25*. *Trypanosoma* infections compared between two woylie populations showed high rates of infection with *Trypanosoma copemani* (96%) in the declining population, whereas in the stable population, *Trypanosoma vegrandis* was predominant (89%). Mixed infections were common in woylies from the declining but not from the stable population. Histopathological findings associated with either mixed or single infections involving *Trypanosoma copemani* showed pathological changes similar to those seen in *Didelphis marsupialis* infected with the pathogenic *Trypanosoma cruzi* in South America: myocarditis and tongue degeneration. *Trypanosoma copemani* was successfully grown in culture and for the first time it was demonstrated that this species has the capacity to not only colonize different tissues in the host but also to invade cells in vitro (Botero *et al.* 2013). These results provide evidence for the potential role of trypanosomes in the decline of woylie and contribute valuable information towards directing management decisions for endangered species where these parasites are known to be present at high prevalence levels.

6.4.4.3 Native Animal Rescue woylie enclosure facilities at Malaga

Lizzie Arravidis (Native Animal Rescue), Andrew Thompson, (Murdoch University)

WA State NRM support for the maintenance of woylie colony (16 founders) at the Native Animal Rescue (NAR) facility in Malaga (Figure 70) has provided, and will continue to do so, a research platform that has allowed comprehensive, longitudinal studies of woylie health to investigate the role of disease in the woylie declines. In particular, it has proved instrumental in understanding the dynamics of infection, transmission and pathogenic potential of trypanosome parasites in woylies and their vectors. Monthly health monitoring has occurred for 23 of the 24 months between March 2011 and February 2013. Data collected from this is being written up by PhD student Craig Thompson. 28 of the 31 offspring born at the facility since December 2010 have been relocated to fenced enclosures around Western Australia. A total of 670 volunteers (58,000 hrs) over the two years up to March 2013 have been involved in care and maintenance of wildlife at the NAR Malaga facility. All of these volunteers and the participants from community and school education programs conducted at the facility have been introduced to the woylie program on site and woylie and wildlife conservation more generally.

Figure 70. Woylie pouch young born at NAR and woylie enclosures.

6.4.5 *Toxoplasma gondii*

Initial serological work (MAT – modified agglutination tests) from samples collected in 2006 identified seropositive woylies from the Upper Warren region but not at other stable and declined populations elsewhere in Western Australia (Table 19; Parameswaran *et al.* 2008, Parameswaran 2008), however, the extent to which this may be a function of sample size is not resolved.

Subsequent PCR tests for *Toxoplasma* infection in the bodies of woylies and other native wildlife sourced across numerous sites including the Upper Warren region and elsewhere in southwestern Australia, as well as Karakamia and the eastern states, has revealed that *Toxoplasma* occurs frequently in native wildlife usually not associated with any clinical disease. Numerous novel genotypes (strains) of *Toxoplasma* not previously recorded in any other hosts or geographical areas have been found (Parameswaran *et al.* 2010; Pan *et al.* 2012). These findings have raised questions about the origin of *Toxoplasma* in Australia, its transmission and most importantly in the context of the woylie decline, the nature of the virulence phenotypes of the ‘novel’ Australian strains of *Toxoplasma* and the circumstances that give rise to clinical toxoplasmosis.

The current student projects on *Toxoplasma* in relation to woylies are described below.

Table 19. *Toxoplasma* seroprevalence (MAT) in woylies across Western Australian populations (from Parameswaran 2010).

Location	Seropositive	Total tested
Upper Warren—March 06	9	153
Upper Warren—Jul–Dec 06	0	143
Karakamia—Jul 06	0	81
Dryandra—Nov 06	0	12
Tutanning—Nov 06	0	8
Batalling—Nov 06	0	17
St Peters Is., S.A.	1	73
Wedge Is., S.A.	0	14

6.4.5.1 Toxoplasma gondii *infection and atypical genotypes in Western Australian wildlife species*

Student project: Shuting Pan (PhD candidate, Murdoch University). Supervisors Prof. Andrew Thompson, Ass. Prof. Alan Lymbery, Dr Andy Smith

In total, 415 samples (342 marsupials and 73 introduced animals) and 171 individuals (132 marsupials and 39 introduced animals) were screened for *T. gondii*. Nested-PCR markers specific for gene locus *B1, SAG1, SAG2, SAG3, SAG4 GRA6* and *GRA7* have been carried out for all samples. Extensive optimisations were carried out to select the right gene markers suitable for Western Australian wild animal samples and reproducible results were obtained. This study has accumulated over 330 DNA sequences across multiple animal species and gene markers.

In total, 60% (256 out of 415) tissue samples and 76% (130 out of 171) individual animals were infected with *T. gondii*. The marsupial samples were detected with typical infection rates of 75% (100 out of 132). Out of the total 30 Western Australian native animal species, including 14/16 marsupial and 12/14 native and introduced animals, in total 26 animal species were infected with *T. gondii* (87%). The study found 23/28 (82%) woylie, 18/22 (82%) chuditch, 6/11 (54%) wambenger, and 8/18(50%) ngwayir had *T. gondii* infection. Results have shown very high variation and unique *T. gondii* genotypes in multiple loci have been revealed in a range of animal species such as western grey kangaroos, chuditch and woylie (Pan *et al.* 2012).

6.4.5.2 *The role of* Toxoplasma gondii *in declining populations of the woylie (*Bettongia penicillata ogilbyi*)*

Student project: Amanda Worth (PhD candidate, Murdoch University). Supervisors Prof. Andrew Thompson, Ass. Prof. Alan Lymbery, Dr Trish Fleming, Adrian Wayne

The aim of this project is to increase our understanding of the role of *Toxoplasma gondii* in wild woylie populations, particularly with regard to the recent population declines. *Toxoplasma* can infect virtually any warm-blooded vertebrate, and has a worldwide distribution. In asymptomatic laboratory and wild rodents, *Toxoplasma* causes subtle changes in behaviour that are thought to make infected hosts more susceptible to predation. If *Toxoplasma* has a similar effect on the behaviour of woylies, this could predispose infected individuals to predation and increase mortality rates, thus contributing towards the decline of woylie populations. Serum samples collected by DEC staff over the past six years will be analysed to determine *Toxoplasma* infection status. This will provide insights into the ecology of *Toxoplasma* infection in woylie populations and an opportunity to investigate whether *Toxoplasma* alters woylie behaviour by correlating infection status with behavioural attributes. An increased understanding of the role of this parasite in woylie populations will aid in the management of this threatened species.

Serological testing of stored samples will begin shortly. Amanda Worth is using behaviour related elements of the woylie trapping data from the Upper Warren region (for example frequency of repeat capture, ejection of pouch young, agitation level, etc) to conduct an ordination analysis to investigate behavioural traits in the sampled woylies. If behavioural groups exist in the woylie population (for example inferred to be less “afraid” or “more afraid” individuals) these cohorts will be compared with the infection status to see whether a particular behavioural type correlates with *Toxoplasma* infection.

6.4.6 Other parasite investigations

Student projects investigating endoparasites and ectoparasites are briefly described.

6.4.6.1 *Genetic diversity of* Blastocystis isolates *found in West Australian native fauna*

Student project: Unaiza Parkar (PhD candidate, Murdoch University). Supervisor Prof. Andrew Thompson.

Before this study, limited data was available regarding the prevalence of *Blastocystis* in Australian native fauna. This study determined the prevalence and the genetic diversity of *Blastocystis* in wild native fauna in the south-west region of Western Australia. As part of this study, four species were examined for *Blastocystis* and four different genetic groups (subtypes) were found within these populations. Furthermore, a molecular tool was developed to screen samples for *Blastocystis*, *Giardia duodenalis* and *Cryptosporidium sp.* simultaneously. This multiplex PCR was tested against singleplex PCRs and microscopy. This test has been found to be equally sensitive or to have greater sensitivity than the singleplex PCR, and greater sensitivity and specificity than microscopy. Data collation and two publications are in progress.

6.4.6.2 *Ectoparasites of threatened mammals in Western Australia: biodiversity and impact*

Student project: Halina Burmej (PhD candidate, Murdoch University). Supervisors Prof. Andrew Thompson, Dr Andy Smith

This project aims to investigate the biodiversity and ecological impact of ectoparasites across a range of threatened mammalian hosts in Western Australia. Mammals from diverse environments including islands, south-western forests and semi-arid regions were sampled in different seasons from 2006 to 2010. The ectoparasite fauna from a variety of threatened mammalian species has been sampled and in most cases identified to species level using existing keys. A literature review has been conducted and new host-parasite lists constructed for animals including woylies and boodies (*Bettongia* species), *Rattus fuscipes*, quenda, golden bandicoot (*Isoodon auratus*) and koomal. Data are being prepared for publication.

A putative new species of *Ixodes* tick found on the woylie was examined using light microscopy and Scanning Electron Microscopy. Ticks and fleas were examined using molecular methods for the presence of Trypanosomes (in an effort to identify the arthropod vector for Trypanosomes found in woylies and other mammals), but none have been found.

6.4.6.3 *Piroplasms*

Student projects: Jia Rong (Honours, Murdoch University) and Steffie Basile (Undergraduate degree project, Murdoch University). Supervisors Peter Irwin

An intra-erythrocytic protozoan parasite belonging to the family *Theileriidae* (piroplasms) was identified in several woylie populations, including Perup, Kingston, and Karakamia in WA. An initial investigation into the piroplasm from six sites was completed in 2009 (Rong 2009; Rong *et al.* 2012). Molecular identification confirmed that this parasite is the same species identified in woylies from the Avon Valley (i.e. *Theileria penicillata,* Clark and Spencer 2007). Overall, 80.4% (123/153) of the blood samples were positive for piroplasm DNA. While five sites (Karakamia, Winnejup, Corbal, Keninup, Boyicup) had a prevalence of *T. penicillata* infection between 73% and 100%, Warrup, the only site to have undergone a substantial post-decline recovery (2005–2008) at the time of the collection of blood samples (2006–2008), had a prevalence of just 20%. But it should be noted that woylies at the Warrup site began declining to record lows in 2009 (see section 6.3.1). While infected animals had a lower mean body weight than uninfected individuals, the difference was not significant when taking into account the variability between localities, which in itself had a significant effect ($p < 0.0005$). Furthermore, microscopic evaluation of the blood films indicated that *T. penicillata* did not appear to cause red cell injury or anaemia.

A follow-up study revealed unreported morphological findings of the erythrocytic cycle of the piroplasm in the woylie. Additionally, preliminary analysis of an extended dataset suggested that the parasite is responsible for haematological changes in infected individuals as well as the overall populations. If confirmed, these findings are potentially the first report of clinical consequences of piroplasm infections in Australian marsupials and, although direct evidence of association between the parasite and woylie declining populations was not found, this study demonstrated that the presence of high parasite prevalence and/or parasitemia could reduce woylie survival (Basile *et al.* in prep). Further work is needed to determine the extent to which *T. penicillata* may be associated with the woylie declines, whether it actually affects the survivorship of infected individuals and what the clinical significance of an infection under particular circumstances may be.

Although not directly part of the WCRP, a parallel study identified a novel species of *Babesia* in woylies from Dwellingup (Paparini *et al.* 2012). The clinical importance of this parasite is not well understood as there were no clinical data (for example haematology) associated with the animals being tested.

6.4.7 Bacteria

Student projects that investigated bacterial infections in wildlife including woylies are briefly described, including the discovery of two novel *Bartonella* species in woylies.

6.4.7.1 An epidemiological and serological study of Rickettsia in Western Australia

Student project: Yazid Abdad (PhD candidate, Murdoch University). Supervisor Prof. Stan Fenwick

The aim of the project was to investigate Rickettsiae in Western Australia. The prevalence of *R. gravesii* in four tick species collected from humans and wildlife in southwest Western Australia was <15% in *Amblyomma albolimbatum*, 75% in *A. triguttatum*, 51% in *Ixodes australiensis* and 25% in *I. fecialis*. Rickettsiae prevalence in feral pigs in Perth water catchments was 49%. Rickettsia prevalence in humans was related to occupational and recreational activities, showing that the risk of infection of people was greatest with higher exposure to activities in the bush and wildlife. Prevalence was 45% in Barrow Island workers, 50% in Whiteman park staff, 23% for recreational rogainers and 2% in the control group (Murdoch University staff and students). No official reports of spotted fever in humans have been reported in WA but increased awareness of the potential for such cases is warranted. The PhD thesis for this work was accepted in early 2012.

*6.4.7.2 Characterisation of two novel Bartonella species isolated in ticks and fleas from woylies (*Bettongia penicillata*)*

Student project: Gunn Kaewmongkol (PhD candidate, Murdoch University). Supervisors Prof. Stan Fenwick, Peter Irwin; Dr Una Ryan

Bartonella species are recognised increasingly as pathogens of humans and dogs. As more *Bartonella* species are being identified from many different countries and animals, their pathogenic potential is also being re-evaluated. The aim of this project was to investigate the presence of *Bartonella* species in ticks and fleas collected from woylies and other mammals in the south-west of Western Australia. Nested-PCRs of the citrate synthase gene (*gltA*) and the ITS region were used for the detection method. The genetic characterisation of *Bartonella* species was established by the multilocus sequences analysis. A novel *Bartonella* species was detected from fleas (*Pygipsylla hilli*) and ticks (*Ixodes australianisis)* collected from woylies. Multilocus sequence analysis of the 16S rRNA*, gltA, ftsZ* and *rpoB* genes and the intergenic spacer region (ITS) revealed that this isolate is a distinct *Bartonella* species and related to *Bartonella australis* previously isolated from kangaroos in the eastern states. Another *Bartonella* species was detected from ticks (*I. australiensis*) collected from woylies. Phylogenetic analysis of the citrate synthase gene demonstrated that this isolate is also a potentially novel *Bartonella* species. Further study is required to extend the investigation of these two novel *Bartonella* species in more ectoparasites collected from woylies and if possible in their blood or tissue samples. It is not known whether these organisms have the potential to cause disease in woylies. Four papers have been published and the PhD thesis was accepted in June 2012.

6.4.8 Viruses

Carlo Pacioni (Murdoch University), Kim Skogvold (Perth Zoo/Murdoch University)

Based on the results of the disease risk assessment and haematological analysis, the serological response to a range of viruses was undertaken including Wallal and Warrego serogroup of orbiviruses, Macropod herpesvirus 1, the alphaviruses Ross river virus and Barmah forest virus, the flaviviruses Kunjin virus and Murray valley encephalitis virus and Encephalomyocarditis virus. Based on serological status, there is no indication of exposure to any of the viral pathogens investigated, indicating that all populations are currently naïve and may be at risk if these pathogens were to be introduced (Pacioni *et al.* submitted).

A novel papilloma virus was detected in several woylies as part of the Keninup intensive study and subsequent monitoring. The complete genomic characterization of the papilloma virus (BpPV1) is a first for an Australian marsupial (Bennett *et al.* 2010). While the consequences of this epitheliotropic virus in woylies remain unresolved, it is considered incidental to the causes of the recent woylie decline.

More recently, PCR screening for herpes viruses using nasal, ocular, throat and cloacal swab sampling has been undertaken as part of Kim Skogvold's comparative health screening program (section 6.4.2). As a result, a novel herpes virus has been detected in a small number of individuals in the Perup Sanctuary with further investigation on the matter underway (K. Skogvold, pers com.).

6.4.9 Genetics and population modelling

6.4.9.1 Genetics

Carlo Pacioni (Murdoch University)

Genetic profiles of extant indigenous and translocated woylie populations were examined to assess whether woylie populations were suffering from reduced genetic "health", as a consequence of past bottlenecks (Pacioni 2010). To do this, suitable microsatellite primers for genetic investigation were first identified (Pacioni and Spencer 2010).

Genetics were found not to be a contributing factor to the present woylie decline with relatively high heterozygosity (H_E ~80%) and allelic richness (N_{AR} = 9–12) in the populations at Dryandra and the Upper Warren region (Pacioni *et al.* 2011). However, substantially reduced genetic diversity was found at Tutanning Nature Reserve (Pacioni *et al.* 2011)—the smallest remnant natural woylie population, now considered extinct. Four genetically distinct indigenous populations (i.e. Dryandra, Tutanning, Kingston and Perup) were evident and recent gene flow between Kingston and Perup is thought to have been in the order of a 2–3% migration rate (Pacioni *et al.* 2011)

Using ancient DNA techniques on archaeological collections it has been shown that woylies began declining around the time of colonial settlement, having previously been relatively stable, and have declined by around 90% and lost up to 50% of their genetic diversity since. It is also evident that historically there was considerable gene flow across more than 1000 km of southwestern Australia (Hunt 2010, Pacioni *et al.* in prep).

Molecular data also confirmed female philopatry with an apparent dispersal range of less than 1 km (i.e. females are settling within or next to their mother's home range). Average male dispersal ranges were apparently 1–3 km for males (Pacioni 2010). Also, it was demonstrated that the decline has caused changes in the genetic spatial structure of woylie populations in the Upper Warren region (Pacioni 2010).

Using mitochondrial and nuclear DNA markers it has also been shown that even the seemingly most successful woylie translocations have lost significant genetic variability and differentiated from their source population (Pacioni *et al.* 2013a). The genetic supplementation program on two island populations was also shown to have failed. Based on these findings general recommendations have been provided for the management of present and future translocations and the appropriate sampling design for the establishment of new populations or captive breeding programs that may mitigate the genetic 'erosion' observed to date. This research provides some practical outcomes and a pragmatic understanding of translocation biology directly applicable to other translocation programs (Pacioni *et al.* 2013a).

6.4.9.2 Population viability modelling

Carlo Pacioni (Murdoch University)

A population viability analysis (PVA) demonstrated that the main potential threat to woylie populations is the interaction of various variables (in particular predation and reduced fitness) that acquire a considerable strength together, while not being greatly significant by themselves (Pacioni 2010; Pacioni *et al.* in prep). It also quantified the minimum mortality rates necessary for the decline to occur (an average juvenile and subadult mortality rate of 28% and 22% for adults per 91 day time period). The minimum viable population size (MVP) estimated through PVA was consistent with the empirical evaluation based on molecular data (i.e. 1,000–2,000 individuals) (Pacioni 2010; Pacioni *et al.* in prep).

More recently population modelling with a focus on genetics has been used to help inform the conservation and management of woylie populations including the colony at Whiteman Park (Pacioni 2012) and several of the key woylie populations, particularly in the Perup Sanctuary and Upper Warren region (Pacioni in prep). Funded by World Wildlife Fund for Nature (WWF) and Whiteman Park, the purpose of the latter project was to assist the development of a woylie population management strategy that would maximise the woylie genetic diversity at a species level. Modelling using a series of scenarios has provided some guidance as to how to capture and conserve as much of the current genetic diversity of the species within the Perup Sanctuary by supplementation of the existing representation from the Upper Warren region with Dryandra and Tutanning stock.

The results were consistent with previous studies (e.g. Pacioni 2010; Pacioni *et al.* 2013a) that indicated that a population of 1–3,000 individuals is needed to ensure long-term conservation. Any discrete population with a smaller size will incur substantial genetic loss over time and, therefore, require some level of active management. The models go further to provide some indications of the specific management requirements across a range of population sizes. Guidance is also provided on an appropriate selective harvesting regime of woylies from the Perup Sanctuary that has the potential triple benefit of assisting in maximizing the conservation of genetics within the sanctuary, genetically augmenting exiting indigenous and translocated populations and helping to stimulate the recovery of the species in the wild in a manner that maximizes the long term conservation prospects for the species (Pacioni in prep). While this project has already been invaluable in directly informing the drafting of woylie population management strategy and the translocations associated with the Perup Sanctuary in 2013, the resources remain to be secured to finish the modelling to develop a more complete population management strategy for all of the key woylie populations, particularly Dryandra and to refine an appropriate harvest strategy for Perup Sanctuary.

6.4.10 Food resources and woylie declines in south-west WA

Student Project: Kerry Zosky (PhD candidate, Murdoch University). Supervisors Dr Kate Bryant, Dr Adrian Wayne, Ass. Prof. Mike Calver

The aim of the project was to examine the dietary ecology of the woylie and investigate its role in current population declines. Specific aims were to examine temporal and spatial variation in the diet of the woylie, examine changes in woylie diet in relation to population decline, and investigate food resource availability.

The study involved two components, an assessment of diet using faecal material collected during woylie population monitoring and seasonal fungi surveys to assess food resource availability. Fifty-six species of hypogeal fungi have been identified (three new). Fungi constitute the dominant dietary component throughout southwestern Australian populations but also include plant, invertebrates and seeds. There was limited spatial variation in diet at regional and subregional scales but strong seasonal changes with fungi being greatest in winter. A strong relationship existed between fungi availability and diet composition. The study concluded that dietary ecology of the woylie is not a primary causative agent of the recent declines in woylie populations. A methodological paper has been published from this work (Zosky *et al.* 2010) and the PhD thesis was accepted in May 2012.

6.4.11 Woylie ecology

Student Project: Georgina Yeatman (PhD candidate, University of Western Australia). Supervisors Dr Harriet Mills, Dr Adrian Wayne, Dr Jane Prince.

An investigation of the ecological attributes of the woylie and other small mammals in the jarrah forest began in 2011. Specifically the project aims to: i) complete a baseline survey of the small terrestrial vertebrates in Tone-Perup Nature Reserve; ii) investigate patterns of distribution and abundance of small vertebrates in the southern jarrah forest in relation to habitat (see section 5.3.3); iii) quantify woylie home range size in and outside the newly constructed Perup Sanctuary; iv) investigate spatial patterns in the current distribution of woylies across the Upper Warren region in relation to habitat variables; and v) investigate temporal patterns in the distribution of woylies across the Upper Warren region over the past three decades. Home range estimates in the Perup Sanctuary in March–April 2011 (~0.1 woylie/ha) were similar to those in Keninup (~0.2 woylie/ha) at an aver 54 ha each. Home range overlap between individuals is large and a preference for Yerraminup habitat types in the Perup Sanctuary was evident (Yeatman *et al.* in prep). Other progress to date includes; the completion of baseline surveys of small vertebrates in and outside Perup Sanctuary, across habitat types (section 5.3.3 and Yeatman *et al.* 2013); and completion of habitat surveys of monitoring trapping points for woylies in the Upper Warren region. This PhD project is planned to be completed in 2014.

7 Community participation and education

Kathy Dawson (Warren Catchments Council)

7.1 Introduction

Community participation in the Woylie Conservation and Research Project (WCRP) has been critical to the successes of the program in advancing our knowledge of the key threats to woylies and to conserving and beginning the recovery of the species. Providing the community with information and a deeper and broader understanding of the Australian wildlife and their conservation and management is also important in being able to enhance their experiences associated with the WCRP directly and increase public awareness and interest in our unique natural heritage more broadly. This section of the report provides an overview of the key elements of the community participation and education undertaken within this project, with a focus on volunteer involvement, the information material provided by way of popular articles, media articles and community education activities. This section also reports on the feasibility study that looked at the ecotourism opportunities associated with the existing assets including the accommodation and teaching facilities at Perup—Nature's Guest House and associated walk trails and natural assets of the area. Local landholder engagement in wildlife conservation and participation in predator control and monitoring is reported elsewhere (see section 4.3).

7.2 Volunteers

Summary: Volunteer involvement is a substantial and critical component to the successes of this project. The CFOC funded components of this project alone involved 159 individuals contributing an average 6.2 days each and a total of 984 days and 9889 volunteer hours, worth at least $250,000 of labour. These calculations do not include the involvement of Bush Cadets, primary and secondary school student experiences, landholder involvement in vertebrate pest animal control or volunteers assisting at public information display booths at events like local shows and festivals. Benefits to volunteers included being provided information regarding the conservation and management of woylies and other wildlife, they received training and inductions relevant to the tasks being undertaken, work experience with wildlife and research professionals, and they experienced and contributed to a diversity of activities including sand pad monitoring, spotlighting, trapping, woylie health and radio telemetry monitoring, woylie translocations, baseline vegetation and small vertebrate surveys and data management.

7.2.1 Volunteer involvement and demographics

The *Caring for our Country* project, “Using well managed native habitat to rescue woylies from the brink of extinction”, provided unique opportunities for community engagement. Many of the tasks within this integrated project are labour intensive and would not be economically possible without volunteer support. Some activities, such as digging 450 pit traps and erecting pit fences required significant physical effort. Other, more specialised activities like the regular monitoring of woylies were enhanced by the recruitment of qualified volunteers: veterinary nurses, conservation science undergraduates, graduates or postgraduates (local, national and international) and experienced field technicians.

A characteristic of much volunteer effort in this project was the duration of each event. Monitoring required a five day commitment and preference was given to those volunteers who were able to capitalise on the training provided on day one to offer continuity of service, enabling team efficiency and a more connected engagement with the task’s ‘big picture’. Undergraduates appreciated the hands-on practical experience and the chance to work intimately with dedicated scientists. Graduates sought the opportunity to extend their on-ground experience and to hone their skills in their chosen field. Consequently, the majority of volunteers worked multiple days and applied for repeat opportunities. This request presented a dilemma requiring a balanced approach: an experienced, trained volunteer adds to the efficiency of the operation however the project target of 200 volunteers encouraged the involvement of new recruits in the rare opportunity to engage with our unique native fauna.

A total of 984 days was worked throughout the project’s three years—the 159 individual volunteers contributed an average 6.17 days. Ninety eight of these volunteers fitted into the category of youth—between 18 and 35 years, representing 61% of the total volunteers and 65% of the days worked (Figure 71). This group’s average commitment was 6.57 days, however female youth dominated both the numbers of volunteers (41%) and total days worked (50%). The economic value of volunteer effort contributed to the project ranges from $247,225–$395,000 (9889 hours @ $25–$40/hour). Irrespective, the contribution is of very significant economic value.

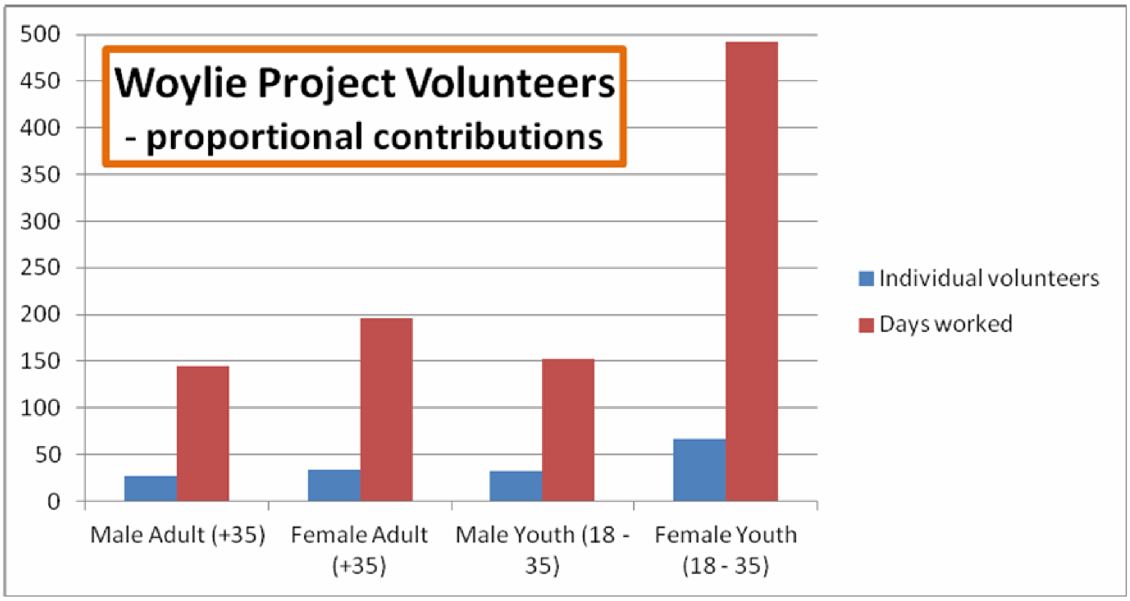


Figure 71. Summary of the demographics of the volunteers involved in the woylie project

It should be noted that these statistics relate to operational activities and exclude contributions made by Bush Ranger cadets and school groups who undertake supervised monitoring where the collected data are used by the Department of Parks and Wildlife. It also excludes landholder involvement in vertebrate pest animal control or assisting in manning display booths at events like local shows.

While research per se was not a component, this project's value was maximised by incorporating doctoral research to provide essential information. An example is PhD candidate, Georgina Yeatman, who, with considerable departmental and volunteer assistance, developed the baseline data infrastructure and coordinated surveys to collect the required data, reported in section 5.3.3. Other collaborating research was also undertaken as part of post graduate projects, value-adding this project but also adding to the load of supervising research scientist, Dr Adrian Wayne.

7.2.2 Volunteer tasks

7.2.2.1 Sand pads

Volunteers provided assistance with sand pad and track maintenance with use of chainsaws, spades, rakes and lots of sweat (Figure 72)! They participated in the sand pad monitoring sessions (for native and introduced fauna) by assisting in foot print identification, recording information, resetting the pads, and downloading motion sensor camera images.

a.  b. 

Figure 72. a) Clearing forest tracks to renovate sand pad arrays to monitor predator activity, and b) Preparing a sand pad for reading animal tracks the following morning.

7.2.2.2 Spotlighting

Spotlighting is another technique used to assess abundance of native fauna and detect the presence of introduced vertebrate pest animals. Volunteers regularly assisted as observers and recorders in the biannual spotlighting surveys along long-term monitoring transects.

7.2.2.3 Woylie health and abundance monitoring

A lot of volunteer involvement has been part of fauna trapping surveys. Volunteers initially undergo an induction and training program to ensure they are adequately prepared for the tasks needing to be performed as well as ensuring they have the necessary bush safety knowledge. Volunteers assisted with setting traps, sample collection, assisting DPaW animal handlers to manage instruments, equipment or the trapped animal, scribe data, label samples (DNA, hair, blood, faeces, ectoparasites), record times, care for ejected pouch young, ensure supplies were stocked, sterilise traps at the completion of the monitoring session, etc. It also involved the occasional use of registered wildlife carers. Initial processing of samples in the laboratory before despatch to Murdoch University or other laboratories for further analysis was another task fulfilled by suitably trained volunteers (Figure 73).

Figure 73. Volunteers undertaking processing of woylie samples in the laboratory and releasing a woylie in the Perup Sanctuary under the direct supervision of a qualified animal handler.

7.2.2.4 Woylie translocation

Extensive trapping took place in November and December 2010 to source the genetically diverse woylies to found the colony in Perup Sanctuary—the insurance population. A total of six subsequent sessions of general health and population monitoring inside and outside the Perup Sanctuary was completed under this program through to April 2013 as described in section 6 of Woylie Conservation Activities (Figure 74).

More recently (July 2013), because of the successful breeding within Perup Sanctuary, volunteers assisted with the first translocation of woylies into the wild since 2005 when the woylie declines were first recognised (see section 6.2.2).

Figure 74. A group of volunteers and DEC (now DPaW) staff undertaking the woylie monitoring in the Perup Sanctuary.

7.2.2.5 Baseline Vegetation and Small Vertebrates

Under the direction of Georgina Yeatman (PhD candidate), 55 volunteers spent 213 days (1741 hours) either digging 450 holes to bury 20 litre pit fall traps in a range of soil types, erect trap drift fencing, uncover and recover traps to conduct surveys of the arrays of pit traps, record data, relocate waterlogged traps and renovate where necessary (Figure 75). As baseline data needed to encompass full seasonal variations volunteers endured the full effects of those seasonal effects.

Figure 75. Volunteers constructing and preparing a pit trap to survey for small terrestrial vertebrates (frogs, reptiles and mammals) as part of the baseline surveys for the Perup Sanctuary.

7.2.2.6 Radio telemetry

Woylies fitted with radio collars were monitored in two aspects of the program: tracking their home ranges as part of the Yeatman woylie ecology study and to monitor survivorship—in the wild and within Perup Sanctuary. Volunteers assisted in nocturnal and daytime monitoring by triangulating radio signals to get a location ‘fix’ for each radio collared woylie without getting close to the animals, so as to not disturb them (Figure 76).

Figure 76. A volunteer using a radio receiver to determine whether woylies collared with radio transmitters were still alive (i.e. survivorship monitoring) and the direction of the animal to use triangulation techniques to remotely locate the woylies to estimate their home ranges over successive weeks.

7.2.2.7 Data inputting

An enormous quantity of data is collected during monitoring sessions. Volunteers have assisted inputting these records into DPaW databases. Longer-term volunteers or those undertaking short-term individual projects extended this to data analysis, such as Kevin Bennett's (student at Colby College, USA) comparison of motion sensor camera and sand pad techniques for predator detection (see section 4.5.1; Figure 77).

Figure 77. a) Setting up a remote sensor camera in the field to monitor introduced predators and native fauna, b) Pixcontroller Digital Eye remote sensor camera.

7.3 Information material

Summary: A large amount of information material has been produced regarding woylie and wildlife conservation and recovery efforts. This includes scientific papers and reports, oral and poster presentations, popular articles, information brochures, web material, videos, newsletters, letters and information packs and interpretation panels along a 'Woylie Walk' trail at Perup: Nature's Guesthouse. Over 181 articles relating to the woylie and this project have appeared in the public media including newspapers, radio, television and other print media.

7.3.1 Popular articles

Communication with the public and community groups has been an important part of this project, translating many of the key points in the scientific and technical communications produced (including three scientific workshops, more than 20 papers published in scientific journals, more than 31 reports including two major progress summaries (DEC 2008a, Wayne *et al.* 2011), more than 50 presentations at national and international scientific conferences). This has included more than 50 presentations at other forums (for example university lectures, seminars to public and interest groups, talks to school groups and local landholder meetings, etc), 6 popular articles (for example *LANDSCOPE*), 3 fact sheets, 2 websites (hosted by DPaW and WCC), a YouTube video and a video training manual (see Appendix C). Interpretive panels for the 'Woylie Walk' are being designed and will be installed along this 2.7 km walk trail that begins from Perup – Nature's Guesthouse. Two trailhead and nine trailside panels will provide visitors the story of the woylie as they walk through a variety of different wetland and woodland habitats. There have also been volunteer newsletters and letters and information packs given to local landholders on several occasions.

7.3.2 Media

Media coverage relating to the woylie declines and the conservation and research efforts has been an important part of increasing public awareness and interest in biodiversity conservation. Data from media monitors indicates that quarterly audiences have been greater than 2 million. An average 23 articles have been published per annum since 2006 (Table 20; Appendix C). ABC regional radio (Bunbury and Albany) have been particularly active in reporting the woylie story as well as other state and national ABC and commercial radio stations. Television broadcasts have included repeated news articles on all Western Australian commercial and ABC stations, 7:30 Report (ABC), Today Tonight (Channel 9), and Totally Wild (Channel 10). Newsprint articles have been dominated by local regional newspapers, The West Australian, Sunday Times (WA), Australian and Sunday Telegraph (UK). Magazine articles have included, The Bulletin, Australian Geographic, RMW Outback, Living Planet (WWF), NewsPaws (Perth Zoo), Wildlife Matters (AWC), Murdoch Campus (MU) and Environment and Conservation News (DEC). Other print articles have included society newsletters including Australasian Wildlife Disease Association, Society for Conservation Biology, Save the Tasmanian Devil Program and WA Naturalists Society.

Table 20. Summary of media articles relating to the woylie declines and the Woylie Conservation Research Project 2006 to August 2013.

	2006	2007	2008	2009	2010	2011	2012	Oct-13	TOTAL
Gov. Media Releases	3			2	1	2	1		**9**
Television	1	4	3	5		1			**14**
Radio	3	19	2	13	2	2		2	**43**
Newspaper	10	3	11	24	11	9	2	3	**73**
Other Print	6	3	7	11	2	1	2	2	**34**
Web Print	1	1	1	1	2	4		2	**12**
Web Video					1			1	**2**
TOTAL	**24**	**30**	**24**	**56**	**19**	**19**	**5**	**10**	**187**

7.3.3 Community education

Kathy Dawson (Warren Catchments Council)

*Summary: The woylie and wildlife conservation issues and recovery efforts have been communicated to a broad spectrum of the public and community groups. Forums have included volunteer, student and work experience programs, visits to the facilities at 'Perup: Nature's Guesthouse' and the development of an interpretation trail, the 'Woylie Walk' that links these facilities with the Perup Sanctuary. Audiences and participants have included school-aged children (*for example *Bush Rangers, Junior Landcare Group, class incursions/excursions), university students, volunteers of all ages from around Australia and internationally, local landholders and tourists.*

The plight of the critically endangered woylie and other threatened native fauna has been communicated to a vast and varied audience throughout the three years of the *Caring for Our Country* project. Volunteers of all ages, especially in the woylie health and abundance monitoring sessions, come from far and wide. Induction training undertaken at each event addresses the practical elements of the task and safety issues. It also includes background information on the woylie decline and steps being implemented through the Woylie Recovery Plan. These activities formed unique opportunities for community members to work alongside eminent ecology scientists and researchers, learning of the many lines of investigation taking place to identify factors contributing to the woylie decline (Figure 78).

Figure 78. a) Volunteers taking a rest having helped dig in 450 pit traps, b) International student and intern, Michaela Pleitner, releasing a koomal during one of the trapping and monitoring programs in Tone-Perup Nature Reserve.

The tasks involved in baseline surveying of vegetation and small vertebrates enabled other areas of natural resource management to be appreciated by volunteers. Local retirees and conservation students provided the bulk of manpower assisting Department of Parks and Wildlife staff and PhD candidate, Georgina Yeatman, establish the 450 pitfall traps for the study. Much learning of different vegetation complexes, soil types, fauna and avifauna took place during the considerable time spent in the Perup forests.

This project emphasised the enormous potential for Perup: Nature’s Guesthouse to be a centre for internationally recognised tertiary education in the biological sciences. University students—undergraduates, masters, doctoral candidates—in fields such as veterinary science, zoology and parasitology, volunteered in the project to gain additional field experience or collaborated as members of the multi-faceted research team. Students from far flung countries—Argentina, France, Switzerland, United States of America, England to name a few, joined with Australian students from universities and technical colleges. Other volunteers made various arrangements with employers, including taking holidays, to participate in monitoring sessions. Many were attracted by word of mouth recommendations from friends and colleagues. Others were drawn by reading one of the many print or online publications outlining project activities or viewing the photographs individuals published online. Michaela Pleitner’s photo album, for example, showcased not only the scientific aspects of a monitoring session but highlighted the wonders of the Australian jarrah forest. It is interesting to see what captures the attention of international visitors. It is often aspects that locals take for granted. In Michaela’s case, a German volunteer intern it was often the small things, like spiders and particular birds such as the scarlet robin.

The many talents of volunteers were used to expand the reach of delivering important natural resource management messages. English tourist, primary teacher Sophia Tolfree, was captivated by her experience in woylie monitoring.

She was equipped with a DPaW camera in her second week of woylie monitoring to record stills and footage for future publication purposes. The quality of the images inspired the creation of a YouTube video *Help Save Woylies*. Footage also enabled Dr Adrian Wayne, senior ecology researcher, to collaborate with Sophia Tolfree (Figure 79a) to develop a video training manual for fauna handling with a special focus on woylie management. This manual will be used by secondary biology students, tertiary students and as a DPaW in-house training tool.

Another volunteer, Pamela Walter, produced line art drawings of endangered native fauna used on Warren Catchments Council's website (Figure 79b).

Figure 79. a) Sophia Tolfree, volunteer and producer of two videos, b) an example of the artwork of volunteer Pamela Walter

Because insurance conditions precluded children from taking part in many of the project activities, special attention was given to providing opportunities to expose them to the unique environment of Perup and its native fauna. The Roleystone Bush Rangers were involved in building baseline survey infrastructure, monitoring a woylie transect and learning how to use radio telemetry. Primary school groups carried out fauna handling activities, spotlighting and sand pad observations at Perup: Nature's Guesthouse (Figure 80). Incursions in primary classes conducted by Warren Catchments Council project coordinator, Kathy Dawson, complemented those offered by DPaW's conservation officers, some serving as a precursor to onsite visits. The formation of Warren Catchments Council's Junior Landcare group is a direct consequence of the interest shown by primary aged children in being involved in natural resource management activities, sparked by their involvement in the woylie project. Secondary biology students were provided with a more comprehensive scientific experience to provide a practical context for their studies.

Figure 80. School children getting involved and learning about wildlife conservation, management and monitoring (i trapping, ii radio telemetry)

Online information was what brought a Victorian family to Perup. Nina Boyce, a Solway Primary School student, was researching the woylie as an example of an endangered species. The ensuing communication resulted in an award winning project and, in the following year, the family's involvement in woylie monitoring in the Perup Sanctuary and now, a lifelong interest in *Bettongia penicillata*.

Visitors to Perup: Nature's Guesthouse are encouraged to walk along several trails—bandicoot scoot, possum path, numbat trail and the woylie walk. University of Western Australia volunteers renovated and extended the woylie walk which will include a rest area in view of the Perup Sanctuary (Figure 81). Signage depicting characteristics of woylies, their indigenous significance, their role in the ecosystem and a description of their habitat is dotted along the trail. Signage is also erected on the access road to Perup Sanctuary, acknowledging the contribution of the various funding bodies to the construction of the enclosure and the conservation activities within the sanctuary.

Figure 81. Volunteers from the University of Western Australia working on the ‘woylie walk’ trail at Perup: Nature’s Guesthouse

Pictorial displays highlighting the woylie story were prominent at community events such as local shows, farmers markets, natural resource management conferences and school careers expo days. Volunteers’ thank you gift, a mug with an image of a woylie and the wording “I helped save woylies from extinction”, have also been visible messages widely dispersed.

Opportunities to inform the public of the woylie situation and work being done to remediate their plight were taken whenever or wherever they arose. Tourists on the Donnelly River cruise were a captive audience for a chance presentation (Figure 82). So too were attendees at a sandalwood workshop when reference to the woylies’ role in sandalwood germination was mentioned.

Figure 82. Kathy Dawson providing an overview of woylie and wildlife conservation in the region to tourists on the Donnelly River cruise.

7.4 Feasibility study

Kathy Dawson (Warren Catchments Council)

Summary: A feasibility study, which was a component of the Caring for Our Country woylie conservation project, was conducted by a group of students from the third year Ecotourism unit at Murdoch University. They produced a document, 'Strategic Destination Management Plan 2012–2016 - Perup: Nature's Guesthouse', which provided recommendations of strategies to address financial viability, marketing, facilities and services, education and interpretation and the introduction of further tourism activities. This paper is being reviewed internally by DPaW as part of the development of a business management plan for the Perup facilities.

Maintaining a high security enclosure on the scale of Perup Sanctuary's 423 hectares is a costly exercise. As vital as Perup Sanctuary is in the effort to maintain an insurance colony of woylies while they remain under the threat of extinction in the wild, avenues to fund its ongoing running costs need to be explored.

A feasibility study investigating possible options for the land managers, Department of Parks and Wildlife, to develop income streams to offset some of these running costs was a component of the *Caring for Our Country* woylie conservation project.

The chance involvement of a volunteer assisting with the first round of Perup Sanctuary's woylie health and condition monitoring who was a high achieving final year Murdoch University Conservation and Wildlife student provided an opportunity to marry two outcomes of the project: the feasibility study and to involve youth in natural resource management activities. Elysia Harradine was to undertake a third year Ecotourism unit in semester two 2011. Subsequent discussions with Elysia and Murdoch University Tourism Program lecturer, Dave Cooper, established project deliverables and negotiated a strategy to ensure the independent study also met the unit's major assessment criteria. As university assessments are largely group based, this real-world task received preferential treatment insofar as Elysia Harradine was appointed group leader and members were selected to ensure the task would be handled competently. It was left to the group—Kasia Borkowski, Elysia Harradine, Sean McMahon, Anette Madsen, Liz White, and Elise Pinto and (Figure 83)—to interpret the objectives of the tasks and to develop an investigative strategy. Resources were put at their disposal but essentially the initiative rested with the group. Assistance came from Perup Ecology Centre manager, Bev Gardiner, Parks and Visitor Services manager, Tim Foley, project volunteer coordinator, Kathy Dawson, and Murdoch University staff, Dave Cooper and Peter Clay. The group was invited to visit Perup: Nature's Guesthouse to gain firsthand knowledge of the extent and capabilities of facilities at the location as well as an understanding of the region's geographic characteristics and current tourist services. Additional information obtained was because of the group's diligence in exploring multiple options.

In November 2011 the *Strategic Destination Management Plan 2012–2016 - Perup: Nature's Guesthouse* (Harradine *et al.* 2012) was presented in the Kim Beasley Lecture Theatre to Murdoch University supervisors and assessors, student colleagues and invited guests. The outstanding presentation of the strategic plan included recommendations of strategies to address financial viability, marketing, facilities and services, education and interpretation and the introduction of further tourism activities.

Figure 83. L–R: Kasia Borkowski, Elysia Harradine, Sean McMahon, Anette Madsen, Liz White, Absent: Elise Pinto from Murdoch University

Elysia Harradine subsequently presented the report to Donnelly District and Warren Region managers and staff involved in Perup: Nature's Guesthouse management, Nature Conservation and Parks and Visitor Services. As the department was concurrently developing a business plan for Perup: Nature's Guesthouse, Kensington staff from the Policy and Tourism Branch used the *Strategic Destination Management Plan 2012–2016 - Perup: Nature's Guesthouse* to prepare management options for the facility. This paper is being reviewed internally.

Key recommendations (below) were supported by a detailed strategic plan identifying implementation steps, criteria for success and suggested monitoring protocols for each overarching recommendation.

- Increase the financial viability of Perup: Nature's Guesthouse (PNG) so that it is sustainable, it offsets operational costs and assists in future sustainable development and conservation efforts in the Perup region
- Improve and expand the ecotourism product along with the identity and services of PNG through a variety of media

- Become an established ecoeducational facility and provide interpretative experiences for all interest groups and tourists who visit PNG
- Expand the tourism product by providing activities that will encourage increased environmental awareness and enrich the nature-based tourism experience
- Improve infrastructure, services, technology and access to allow for increased visitation to PNG that is environmentally, economically and socio-culturally sustainable
- Develop and maintain strong relationships with local and regional businesses, tourism operators and the non-business community, such as schools, interest groups and residents. Engage the local community and develop relationships with local and regional businesses to expand knowledge of the destination and encourage funding and sponsorship
- Provide sufficient human resources for site planning and management to ensure a positive experience for visitors

8 Evaluation of woylie conservation actions

8.1 Introduction

This section of the report addresses one of the components of the CFOC woylie project to evaluate the woylie conservation actions. In the original proposal for the project the scope was more specific; to “Evaluate the change in condition of the fauna and vegetation of Perup Sanctuary compared with the baseline survey.” Since the Perup Sanctuary has only been established for 2.5 years it is still too early to adequately assess to what extent there may have been changes to the vegetation and fauna. However, baseline measures have been recorded for several elements of the ecosystems within the sanctuary including vegetation structure and floristics, frogs, reptiles, and mammals (not including bats) (see section 5.3). Early indications are that no significant changes have yet been observed except for a substantial increase in the number of woylies from zero to 300–400 individuals in the first 2.5 years. This increase is a remarkable success and the best outcome possible based on modelling of the maximum potential growth rates for this species. These densities are, however, considered only about half of the viable carrying capacity for woylies in the Perup Sanctuary. Therefore the numbers of woylies are expected to continue to increase strongly over the next few years. Ongoing monitoring will continue to be used to assess what if any significant changes may occur over time.

In addition to considering the effectiveness of the Perup Sanctuary to delivering an adequate insurance population of woylies, this evaluation has been expanded to include the fox control regimes in the Upper Warren region, putting the work in the Upper Warren region in the context of woylie conservation at the species level and consideration of the conservation issues of other co-occurring medium sized native mammals in the Upper Warren region (i.e. the other potential beneficiaries of actions undertaken primarily for the woylie).

8.2 Perup Sanctuary

Summary: The Perup Sanctuary infrastructure has effectively excluded introduced predators since it was completed in October 2010. Storm damage from strong winds and rain has been minimal because of the design and construction. While ongoing maintenance is required, the initial investment is expected to be more cost effective in the longer run and provide greater security to the investment in the woylie insurance population. Best practice, informed by the best available information, was used to select candidates to establish the woylie colony in the Perup Sanctuary with the greatest available genetic diversity

from the populations in the Upper Warren region. More recently, genetic augmentation from Dryandra stock and offspring from the last surviving animals from Tutanning will help make the Perup Sanctuary insurance colony representative of the genetic diversity across the species. The survivorship of the founders in the Perup Sanctuary has been excellent (at least 83% confirmed alive in 2013, only one confirmed death), all females are breeding and the population growth has been at it maximum potential, resulting in about a 1,000% increase from its original founder colony of 41 to about 400 individuals in mid–late 2013. The Perup Sanctuary is also delivering a conservation benefit to other vulnerable and threatened native species. Adequate monitoring has been and will continue to be an essential aspect of the ongoing management of the biodiversity assets in the Perup Sanctuary.

8.2.1 Introduction

An evaluation of the Perup Sanctuary can be considered with regard to several aspects including the effectiveness and integrity of the infrastructure (fence, drains, gates, etc) as a barrier to introduced predators, the genetic attributes, abundance and survivorship of the woylie colony, the benefits to other fauna and conservation values, and the effectiveness and value of monitoring in the sanctuary. These are addressed accordingly in the following paragraphs.

8.2.2 Infrastructure

The fence at the Perup Sanctuary has successfully excluded introduced predators since it was completed in October 2010. The threat from feral cats and foxes is reflected by the frequency with which they are detected immediately on the outside of the Perup Sanctuary fence by remote surveillance cameras. Storm damage from strong winds and rain has also been minimal because of the design of the fence and foundations, storm drains, roading and management of potentially dangerous trees. Some issues regarding drainage, erosion, sediment accumulation at the base of the fence and continuity of power to the electric wires have been satisfactorily managed to maintain the integrity of the sanctuary, minimise future costs and maximise the longevity of the infrastructure.

The investment in building a well-designed fence has and will continue to pay dividends in securing the gains made to the conservation of woylies within the sanctuary. A key advantage of having a significant, known cost upfront for a well-designed, well-built sanctuary is that it is expected to be a more affordable and secure strategy in the medium to long term by reducing the unknown costs and unpredictability associated with possible predator incursions. The experience of other sanctuaries that have had one or more incursions are testament to how costly dealing with such incursions can be with respect to the resource requirements to address the incursion and the impact to the native species populations being conserved. Delays in the detection and difficulties in removing introduced predators that have breached a sanctuary can result in foxes or cats persisting for many weeks or months within a sanctuary, all-the-while predating and surplus-killing native fauna. Furthermore, it has often been very difficult to confirm when an unwanted fox or cat has finally been killed so increased surveillance and control can continue long after the threat has been removed.

The task of dealing with a predator incursion becomes increasingly difficult (and therefore more costly) as native fauna densities within a sanctuary increases. This is because of the increasing non-target issues associated with baiting and trapping targeted at foxes and cats. Not only are cats particularly difficult to bait or trap, there are also legal constraints in using some methods to target cats (for example leg-hold traps) that can be otherwise used for foxes because they are not listed as a pest species under the *Agriculture and Related Resources (Declared Animal) Regulations (1985) repealed by the Biosecurity and Agriculture Management Act 2013*. These challenges provide additional reason for investing at the outset in a more effective predator barrier fence.

While the fence and gate designs at the Perup Sanctuary are thought to be as effective as reasonably possible, it is evident that they are not complete barriers to the movement of terrestrial medium-sized mammals. One of the 36 koomal relocated from the sanctuary before the trapping for cats and foxes in September 2010 has been repeatedly recaptured inside the sanctuary since February 2011. While more adept at climbing than a foxes and cats, the confirmed incursion of a koomal demonstrates that the fence is not impenetrable. Therefore, ongoing maintenance on the infrastructure and predator surveillance are necessary to minimise the risks of a predator incursion in the future.

Adequate management of the fire risks within and around the Perup Sanctuary remains important to its security and long-term viability. Much of the forest immediately surrounding the sanctuary was last involved in a mild intensity and patchy prescribed burn in spring 2011. The vegetation within the sanctuary and to the south and west of the sanctuary were last burned in the year 2000. A longer-term fire management strategy for the sanctuary is in development.

8.2.3 Genetic attributes of the woylie colony

Best practice, informed by the best available information, was used to select candidates to establish the woylie colony in the Perup Sanctuary. An adequate understanding of the genetic attributes of the extant woylie populations (Pacioni 2010) and an historic context (Hunt 2010) were essential precursors to being able to develop an effective strategy to maximise the conservation of the surviving genetic diversity of the woylie within the insurance population to be established in the Perup Sanctuary. Correlations and modelling between spatial and genetic relatedness of woylies were used to derive population-specific spatial rules for the selection of individuals from within the Perup, Kingston and Dryandra woylie populations that had a high probability of being unrelated individuals. Contrary to past common practice, whereby founding individuals for a translocation are sourced from a limited area, animals were sourced from as far and wide as possible across the respective populations being sampled. Genetics and modelling also informed the numbers of animals to be sourced from each population. Health checks, detailed clinical examinations, under anaesthesia by wildlife clinicians (in the case of animals sourced from Kingston and Perup), and a range of samples (for genetics, health, parasites and disease) were collected from all the woylie founders introduced to the Perup Sanctuary.

The strategy applied to the establishment of the woylie population in the Perup Sanctuary was a good compromise between delivering the best possible outcome and collecting sufficient reference material with what was practical and feasible. For example, the spatial rule set used to select candidates was a practical solution to knowing for certain and in advance the genetic relatedness of potential candidates, which would have cost more than twice as much and taken many more months to complete.

The analysis of the DNA samples collected from all founders and all subsequent animals trapped in the Perup Sanctuary remains to be completed. Doing so will verify the success of the selection strategy used, quantify the genetic diversity and other attributes of the colony, and measure the success of genetic augmentation efforts with Dryandra and Tutanning stock, among other valuable insights for future management. Ongoing monitoring of the genetics is also required to further develop our understanding of the effectiveness of the strategy and to inform what further actions may be required to deliver a desirable conservation outcome for this insurance population; for example, representativeness of the colony to extant genetic diversity and to what extent more augmentation may or may not be required and from where.

8.2.4 Woylie survivorship and abundance

Monitoring by radio telemetry (section 6.2.1 and cage trapping (section 6.3.2) indicate that the survivorship of woylie individuals and the growth of the colony in the Perup Sanctuary is very close to or achieving the maximum potential capabilities of the species. For example, 83% of the founders have been confirmed alive in 2013 (only one confirmed death), all females are breeding and the population has increased about 1,000% in the first 2.5 years from its original founder colony of 41 individuals. On this basis the establishment of the insurance population at the Perup Sanctuary is an unequivocal success. The woylie population is on track to reaching its theoretical carrying capacity of about 900 by 2015 (Pacioni 2013).

In contrast, the comparative survivorship of adult woylies in the wild remains substantially lower than in the Perup Sanctuary (i.e. 67% versus 95% in 12 months) (section 6.2.1) and the woylie population abundances/densities in the Upper Warren region remain very low overall (around 10% of their levels before the recent declines).

8.2.5 Benefits to other fauna and conservation values

While established for the purposes of creating an insurance population of woylies, the Perup Sanctuary also provides a benefit for other conservation priority species vulnerable to predation and/or competition from invasive vertebrate species (fox, cat, rabbit, pig, wild dog, etc). These naturally include the numbat, wambenger, quenda and tammar, all of which are confirmed present and breeding. There are other species, while not currently conservation listed, that also potentially benefit from the absence of introduced predators, such as the western pygmy possum (*Cercartetus concinnus*), dunnarts (*Sminthopsis spp.*) koomal, reptiles and frogs (see section 5.3.3).

Although previously present on the site, the ngwayir (western ringtail possum, *Pseudocheirus occidentalis*), was not detected within the Perup Sanctuary during its establishment. Probably the largest extant population, the ngwayir in the Upper Warren region underwent a substantial (~99%) decline in the region beginning in 1998 (Wayne *et al.* 2011, 2012; see also section 8.5). Although currently listed as Vulnerable by the state and federal governments, a nomination for critically endangered is being prepared because of these and broader scale declines that have occurred in the last decade or so. The sanctuary subsequently received 20 adults translocated from a development site in the Busselton townsite in late August 2012. While eight of the 11 radio collared ngwayir died during the following months ongoing monitoring by spotlighting and remote cameras indicate that several individuals are persisting. In the absence of terrestrial predators, the Perup Sanctuary represents an excellent opportunity to also conserve the genetics of the ngwayir population in the Upper Warren region, which has been shown to be distinct from populations on the Swan coastal plain and important in its own right (Wilson 2009). While there are no formal plans or funding secured as yet, it has been recognised that the Perup Sanctuary provides the best available prospect to establish an insurance population for the ngwayir in the Perup Sanctuary in the same way as it is for the woylie.

Other species that are no longer extant in the area but could be reintroduced into the Perup Sanctuary to assist in conservation and recovery efforts could include the dalgyte (or greater bilby, *Macrotis lagotis*), boodie (or burrowing bettong, *Bettongia lesueur*) and mallee fowl (*Leipoa ocellata*). A management plan being developed for the Perup Sanctuary may consider these and other prospects for the future (I. Wilson pers. comm.).

8.2.6 Monitoring

Monitoring of the woylie population in the Perup Sanctuary has principally been through cage trapping (see section 6.3.2). This is considered the most reliable approach to derive accurate estimates of population size, and therefore to monitor change over time. Other advantages of capturing the animals includes being able to undertake condition and field health assessments, collect samples for other complementary programs and purposes (for example genetic and health monitoring), and to assess demographic attributes of the population (for example breeding, sex ratio, age ratio, size and body mass). All of these aspects provide very important information directly relevant to assessing the success of the insurance population and efforts to understand factors that caused the recent declines and limit the recovery of woylies in the wild.

The rapid and substantial growth of the woylie colony in the Perup Sanctuary has created challenges in estimating population growth. While the frequency of monitoring may be considered adequate (3 times in the first year, biannually thereafter) the trapping effort was nearly doubled in April 2013 in an effort to overcome trap saturation (i.e. a higher density of animals than traps available to sample them). Despite the substantial increase in resources to do this (144 traps for 4 consecutive nights) the problem of trap saturation was not overcome. The result is that models of the population size are compromised and estimates are probably less accurate and precise. This applies as much to woylies as it does to the other species that can be monitored by trapping, including quenda, koomal and tammar wallaby.

Being able to accurately and sensitively monitor population change of woylies is especially critical, particularly over the next few years. Woylie densities will probably reach an apparently important potential threshold of >1/ha (section 6.3.1; Wayne *et al.* 2013b) in late 2013–early 2014. If increasing woylie densities precipitate a rapid and substantial decline, as was observed during the recovery at Warrup beginning in 2009, then the monitoring program needs to detect this sensitively and quickly enough to enable an appropriate response to secure the investments made to date on the insurance population and the conservation and recovery of the species. Equally if a decline does occur, it represents by far the best opportunity to get direct evidence of the cause(s) of the decline, which are probably to be the same for the species-wide declines observed in the wild since 1999.

Adequate population monitoring is also important to inform appropriate harvest rates of woylies from the Perup Sanctuary to maintain a viable and sustainable population, maximise the conservation of genetic diversity of the colony and maximise the recovery opportunities for woylie populations elsewhere by providing a ready source of recolonising stock.

Given the importance of adequate monitoring a practical solution to the trap saturation problem is a very high priority. To date the trapping effort has been based on traps evenly distributed along transects (vehicle tracks) throughout the sanctuary. The density of traps needs to be greater than the density of trappable animals and the methodology to derive population estimates needs to be flexible enough to provide sufficiently accurate and reliable results across a large range of animal densities. This may well involve high density grids or webs sub sampling only representative parts of the Perup Sanctuary. Regardless, every effort should be made to get the design and methods of the population monitoring fit for purpose.

Other monitoring methods used in the sanctuary have included radio telemetry (survival of founders), spotlighting and remote sensor cameras. While the collection of most of the same type or quality of information and samples do not exist with these alternatives it is possible that remote sensor cameras in particular, may be useful in providing a measure of animal abundance/density. Data being collected in association with the recent translocations involving the Perup Sanctuary (sections 6.2.2–6.2.5) will provide a calibration and assessment of the sensitivity of detection measures to known changes in the population size of woylies. In doing so, this will provide an important indication of the practicalities and merit of adequately monitoring woylie abundance using cameras.

Data from the baseline surveys conducted in the early stages of the establishment of the Perup Sanctuary will become an increasingly valuable resource over time. In particular it will enable managers to quantify what changes may occur with increasing densities of woylies and other species in the absence of terrestrial predators. This will provide an indication of what are the ecological consequences of having a sanctuary. While more than 20 sanctuaries exist in Australia, almost none of them have published any indication of having similar empirical baseline data. Furthermore the number of sanctuaries will probably increase. Therefore, the quantification of the ecological consequences of the Perup Sanctuary is nationally relevant as well as important.

8.3 Fox control regimes in Upper Warren region

Summary: In addition to the quarterly aerial and ground baiting regime applied to most of the DPaW-managed lands in the Upper Warren region, monthly ground baiting for foxes has been applied to a core area of Perup (~14,500 ha) as part of this project since October 2010. While monitoring has indicated that fox activity has substantially increased regionally since 2006, it is currently unclear as to whether the monthly baiting program has reduced fox densities. A preliminary

look at the trends in woylie and chuditch capture rates are consistent with the monthly baiting in the core Perup area potentially resulting in a relative increase in abundances, however further testing is need to determine whether this is in fact the case.

8.3.1 Introduction

A core area of Perup (~14,500 ha) had the fox baiting frequency increased from quarterly (4xGround perimeter + 4xAerial) to monthly (12xGround + 4xAerial) as part of the CFOC project to increase viable habitat for the woylie and create a buffer to the Perup Sanctuary (see section 4.2). The monthly baiting regime began in October 2010. The aim of this section is to assess whether the increased fox control made a detectable difference to the introduced predators, the woylies and/or other fauna within the core Perup area compared with elsewhere in the Upper Warren region.

8.3.2 Predators

A preliminary exploration of the fox activity index (AI) derived from sand pad arrays in the Upper Warren region was used to determine if there was a detectable response to monthly baiting in the core Perup area, which began in October 2010. Bearing in mind that these sand pad arrays or this study were not designed specifically for this purpose, initial indications are unclear as to whether a change in the fox AI may be associated with the increased baiting frequency (Figure 84 and 85). While it is evident that the fox AI increased regionally over time (see also section 4.4) any effect of monthly baiting is not yet readily apparent. For example, while there was a doubling in the the fox AI in sites subject to quarterly baiting after October 2010, there was only a 1.5 fold increase in the fox AI on the sites subject to monthly baiting since it began (Figure 85). However, at Keninup there has also been a similar 1.5 fold increase. Keninup is just north of the area baited monthly but is itself only partially baited every quarter.

Limitations of the comparisons of fox AI in this work includes whether there is a strong relationship between the fox AI and actual fox density (which is what we are most interested in) and the high variability in the fox AI is affected in part at least by disturbance caused by weather and vehicles. While it may be possible to derive an estimate of fox density from the sand pad data and/or from the remote sensor camera surveillance work conducted in Balban (September–October 2012) and Boyicup (February–March 2013) (see section 4.5.4) any inference on the differences between baiting regimes is fundamentally compromised by the lack of independent replication. Therefore any differences between the two treatments cannot be confidently attributed to baiting regime over other variables such as inherent site differences, proximity to agriculture and baiting boundaries, etc. Therefore, although a single-site BACI type anlysis could be done, it is not possible with the available data to definitively demonstrate whether monthly baiting frequency has resulted in reduced fox density. What this example clearly demonstrates is that management (such as predator control) within a rigorous scientific framework is critical in being able to demonstrate and account for the outcomes of such actions and provide the opportunities for improved and more effective management. Unfortunately, while the merits of approaches such as active adaptive management are broadly accepted, in practice resources allocated to complete rigorous monitoring adequately tend to be a low priority and insufficient.

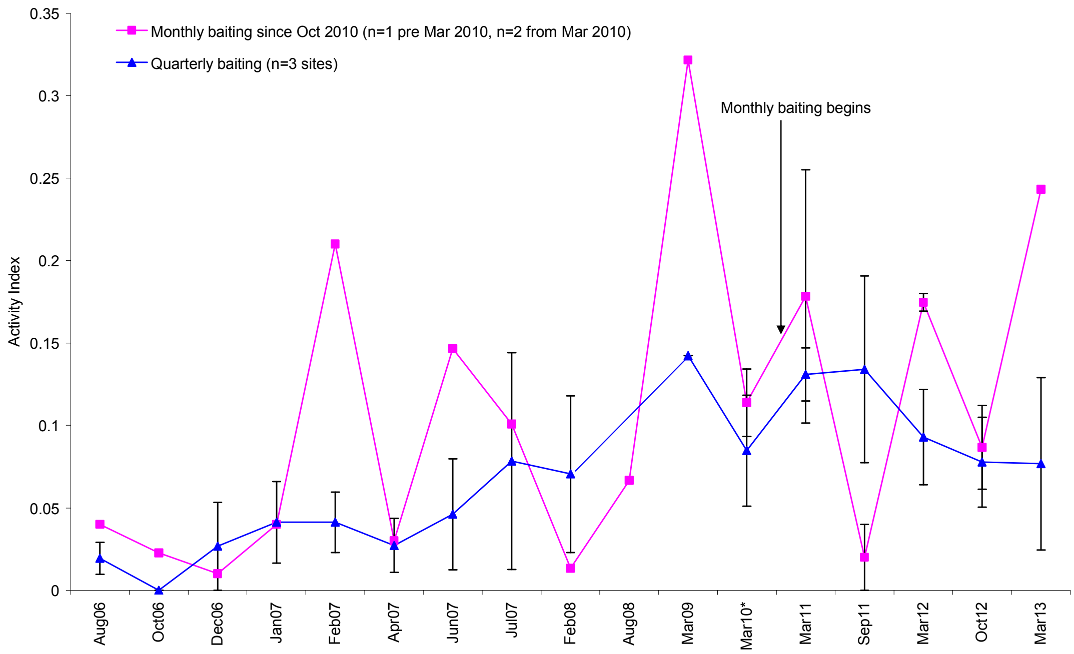


Figure 84. The Activity Index (AI) for the European red fox derived from sand pad arrays in the Upper Warren region according to baiting regime.

Note: The entire Upper Warren region was subject to quarterly baiting during the survey period. Additional monthly baiting began in October 2010 in the core Perup area. Fox activity in areas baited quarterly is represented by the Warrup, Winnejup and Boyicup sand pad arrays. Monthly baiting is represented by Balban and Moopinup sand pad arrays. Moopinup monitoring only occurred between March 2010 and October 2012.

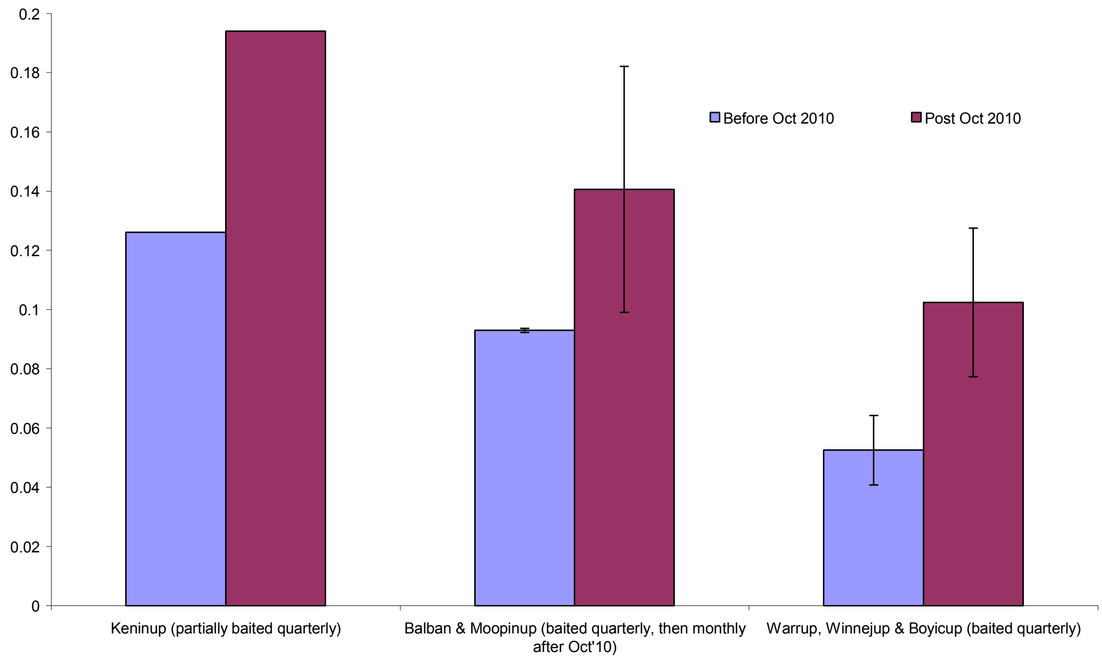


Figure 85. The average Activity Index (AI) for the European red fox derived from sand pad arrays in the Upper Warren region, before and after a monthly fox-baiting regime began in the core Perup area (including Balban and Moopinup forest blocks).

8.3.3 Woylies

The mean capture rate of woylies from the core Perup area was derived from the overall annual mean of the annual means from 3–5 sites (Balban, Camelar, Moopinup, Yackelup and Yendicup). This was compared with a similarly derived mean from the monitoring sites within areas baited quarterly (2–5 sites per year; Boyicup, Chariup, Corbal, Warrup, Winnejup). When the baiting regime was similar, the woylie capture rates were generally similar between these site groupings before 2010 (albeit a tendency since 2005 for core Perup sites to have lower capture rates) (Figure 86). In 2010, however, the standard error ranges indicate that the capture rates were lower in the core Perup area than elsewhere in the Upper Warren region (2.1% and 7.4% respectively). Since the monthly baiting began in the core Perup area in October 2010, woylie capture rates have increased to 6.4% in 2013 in this area but have remained static in areas baited quarterly (8%). While this trend is consistent with the monthly baiting in the core Perup area potentially resulting in an increase in woylies, further verification is required to test whether this is the case. In particular, more rigorous statistical tests and more data are necessary. DPaW (Donnelly District) has committed to continuing the monthly baiting in the Perup core area until at least 2015, which will assist to clarify these preliminary trends.

It is also important to consider the differences between sites within the core Perup area. Subregional trends are apparent whereby central Perup has not yet indicted any recovery in capture rates where southern and northern Perup have potentially begun slight increases from their record lows (see section 6.3.1). While the increase of woylies in Balban corresponds with the duration of the monthly baiting program, there doesn't appear to be a response at the other sites. For example, despite the increased baiting frequency Yackelup has still not yet detected a woylie since 2005.

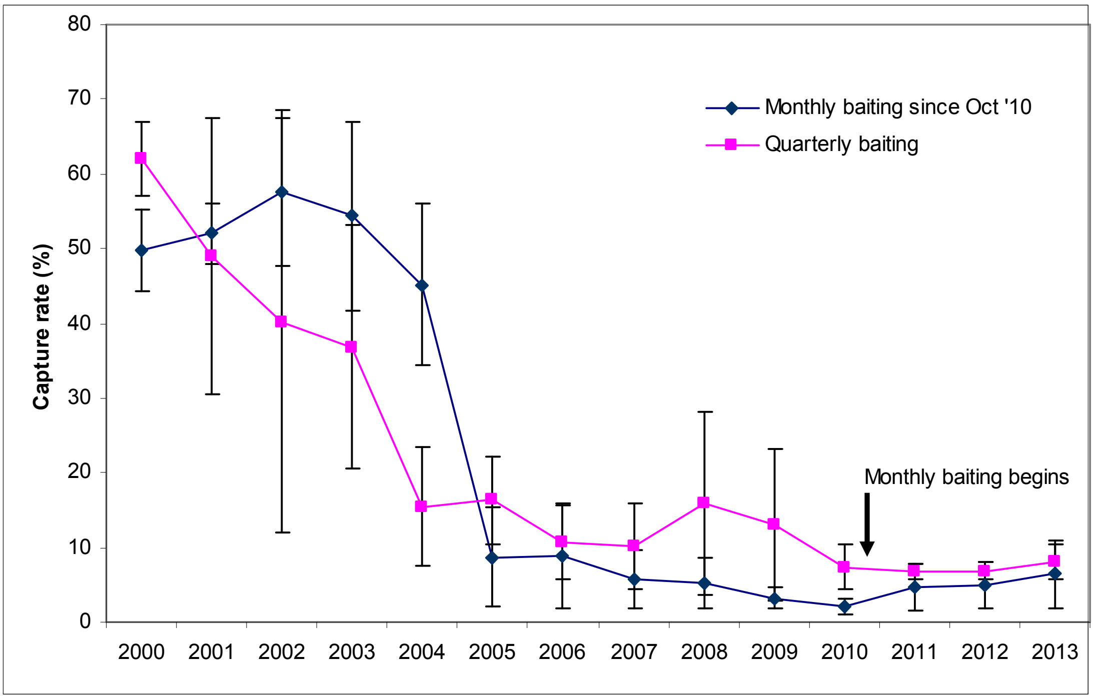


Figure 86. Mean woylie capture rate under different baiting regimes.

8.3.4 Other medium-sized mammals

Chuditch numbers have been increasing in the Upper Warren region since 2005 (see section 8.5) but particularly in the core Perup area even before monthly baiting began in 2010 (Figure 87). Whether the pronounced increase in chuditch in the core Perup area (especially at the Moopinup site) can be attributed to the monthly baiting remains to be verified. Similarly, more rigorous analysis and data over the next few years will help to clarify whether or not there has been a positive response by koomal (Figure 88), quenda (Figure 89) or other species to increased baiting frequency.

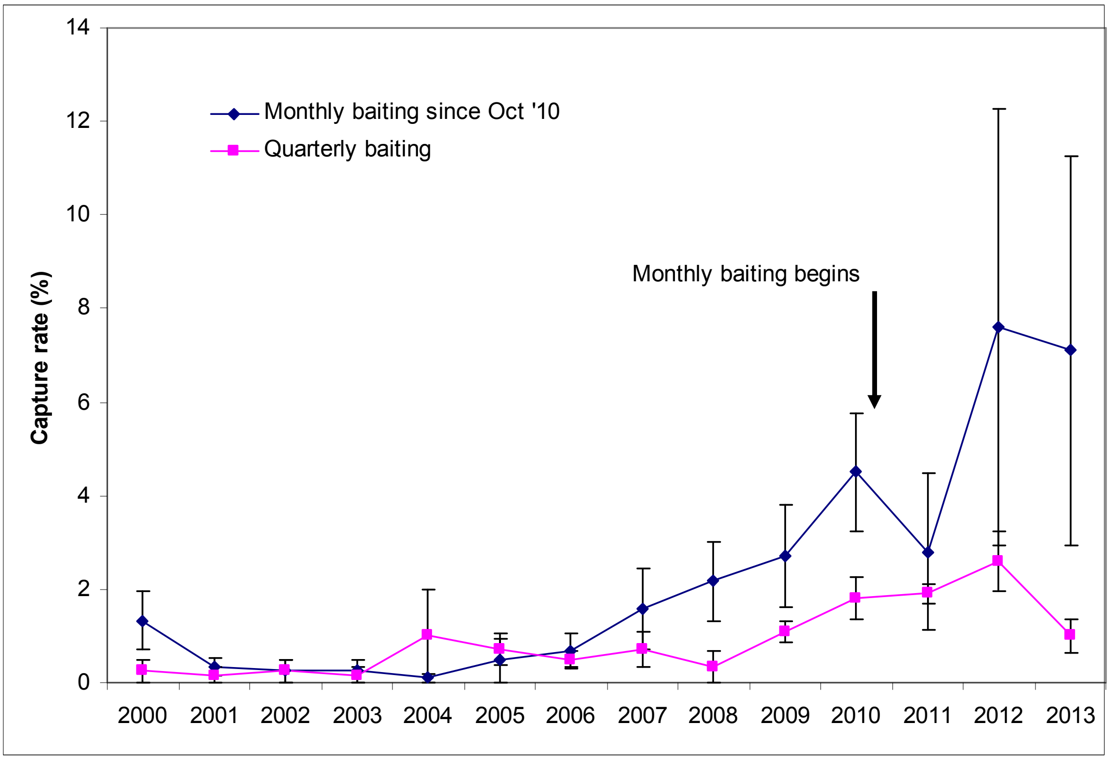


Figure 87. Mean capture rate of chuditch under different baiting regimes in the Upper Warren region.

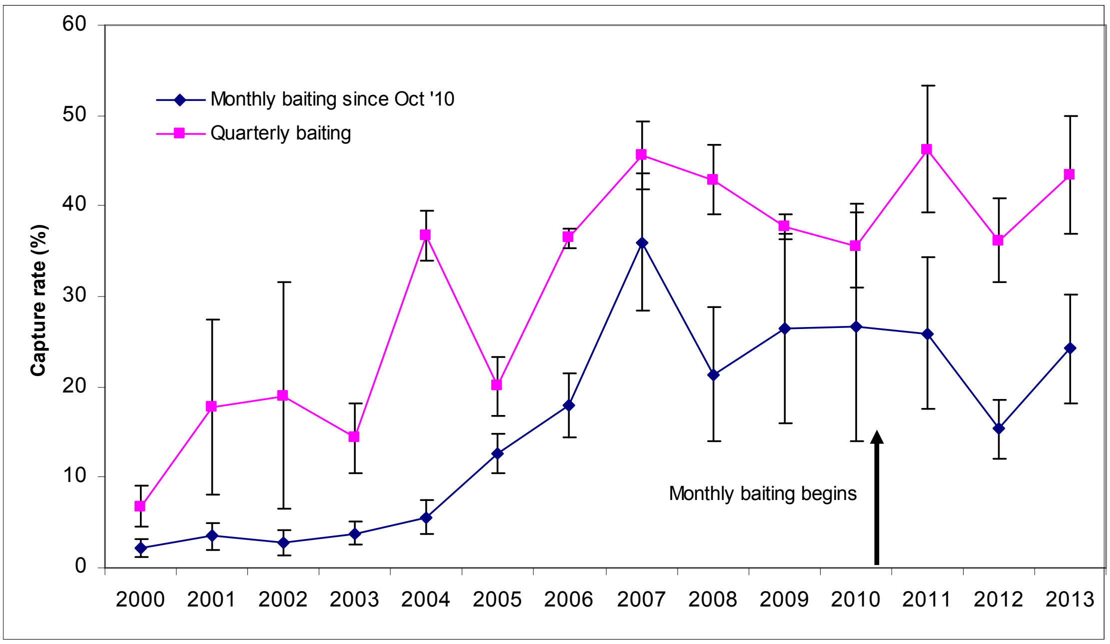


Figure 88. Mean capture rate of koomal under different baiting regimes in the Upper Warren region.

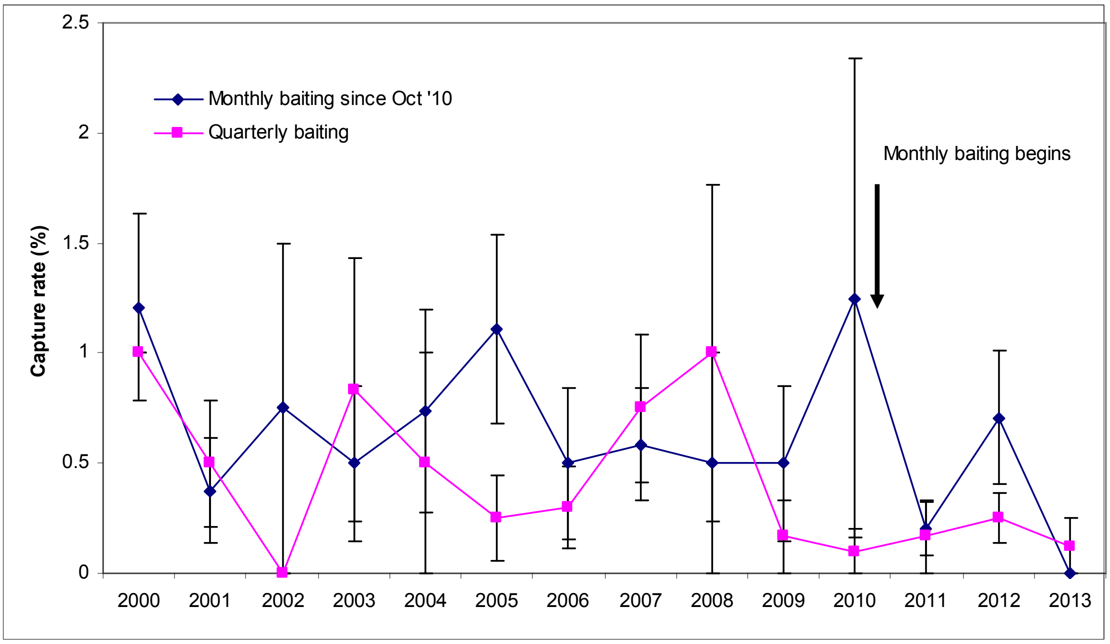


Figure 89. Mean capture rate of quenda under different baiting regimes in the Upper Warren region.

8.4 Woylie species overview

Summary: The woylie is Critically Endangered having undergone 90% decline in the seven years from 1999. The remaining natural populations in the Upper Warren region and Dryandra remain critically important. The risks of local extinction of small populations remain high and likely for at least some of these without increased effective management. Priorities include maintaining the insurance population at Perup Sanctuary, verifying the status of the Dryandra population and undertaking translocations within a scientific framework to augment existing populations, possibly establish other insurance populations and stimulate recoveries in the wild. Confirming the causes of the decline and factors limiting recovery fundamentally remains the most effective and assured way of delivering the best possible conservation outcome for the species.

The woylie underwent a 90% decline in the seven years from a peak of ~200,000 in 1999 (Wayne *et al.* 2013a). All affected populations have undergone 90–100% declines and represented the largest and most important populations for the conservation of the species. The species was recognised as *Critically Endangered* by the IUCN Red List in 2008 (Wayne *et al.* 2008) and in the Western Australian Government Gazette on 17 September 2013 (*Wildlife Conservation (Specially Protected Fauna) Notice 2013*).

The Upper Warren region still supports the largest remnant woylie populations, and with Dryandra and the 6 remaining Tutanning animals, these populations encapsulate almost all of the genetic diversity of the species (SA Island populations are thought to have some unique genes also, despite being otherwise genetically depauperate; Pacioni *et al.* 2013a).

The risks of local extinction remain high for many of the affected populations and other small populations across southern Australia. The recent extinction at Tutanning demonstrates that this risk is real and a likely outcome for other populations without increased and effective management. As well as the risks from predators, by their very nature, small populations are especially vulnerable to stochastic events such as fire, seasonal and climatic changes etc (e.g. Caughley 1994). Batalling, Boyagin and Julimar are examples of long established reintroduced populations particularly at risk as are the smaller more recent reintroduced populations such as Avon Valley, Kalbarri, North Kalgarin and sites in the Walpole-Denmark area. If they manage to persist in the immediate term, all small populations will also become increasingly at risk over time because of reduced fitness as a consequence of genetic loss. Populations need to recover to greater than 1000–3000 in as short a time as possible to reduce rates of genetic loss (Pacioni *et al.* 2013a) and also reduce their inherent risks of extinction. Numbers in the Upper Warren appear to have stabilised at the regional level with some early signs of a potential recovery in northern and southern Perup. Whether it can be sustained or whether a similar phenomenon that has occurred in Warrup (recovery not sustained, rather undergoing a double dip to new record lows) may happen in Perup also is unknown at this stage. Numbers in central Perup and Greater Kingston remain at potentially critically low levels.

The population status at Dryandra has recently become unclear, particularly given that the trapping results from July 2013 were lower than expected (see section 6.2.3). Given the importance of this remnant natural population to the conservation of this species, resolving this should be a priority. Securing and then recovering the natural populations in the Upper Warren region and Dryandra Woodland must remain one of the highest immediate conservation priorities.

Given the current uncertainty of the viability of the most valuable wild woylie populations, the establishment of a second and possibly third insurance population would be prudent by providing added security to the conservation of the species. Genetic augmentation of the South Australia Islands and/or the establishment of another translocated and genetically diverse population with >3000 individuals could also make a substantial contributions to the conservation and recovery of the species. However, without confidence regarding the causes of the decline and factors limiting their recovery the risks of failure remain high.

In light of the declines and current situation with the wild woylie populations, having the Perup Sanctuary as an insurance population has made a major difference in the conservation prospects for the species. Maintaining the Perup Sanctuary insurance populations must, therefore, also be one of the highest conservation priorities. As well as conserving the majority of the genetic diversity of the species, the Perup Sanctuary provides a ready source of hundreds of genetically diverse animals on an annual basis to stimulate recoveries in the wild.

Undertaking woylie translocations and in situ recovery efforts within a scientific framework is the best approach. This is because, by ‘learning by doing’ (i.e. the principle tenement behind active adaptive management (e.g. Walters and Holling 1990, Lee 1999)), complementary gains in learning and conservation outcomes provide the most assured long-term prospects for this species. Past successes unequivocally demonstrate the phenomenal capacity of this species to rapidly and substantially recover when key threats are adequately managed. However, the recent declines demonstrate that the key threats have changed in some way. What is critical to its future success is verifying the causes of the decline and the factors limiting their recovery. Substantial gains to this end have been made in narrowing the probable causes of the decline to the increased vulnerability of woylies to introduced predators (particularly cats), probably because of some other factor such as disease, for which there are several compelling leads. Predation, particularly by foxes in the case of the Upper Warren region, is probably a key limiting factor to the recovery of woylie populations. Rigorously testing these putative causes is what is required next. Future woylie translocations can play a key role in doing exactly this.

Few critically endangered species have the proven history to recover strongly, the genetic diversity still extant, the numbers and readily accessible sources to stimulate a recovery (for example Perup Sanctuary), the potential resources necessary to undertake the work and the foundational investment of effort to understand the key threats. As such the woylie must represent one of the greatest conservation success opportunities. Few critically endangered species are so well placed to recover as strongly as the woylie.

8.5 Regional level trends for other mammals

Summary: The Upper Warren region has long been recognised as one of the most important fauna conservation areas in southwestern Australia. At least five mammal species (wambenger, dunnart, quenda, ngwayir, woylie) have declined substantially (75%–100%) within the last 20 years in the Upper Warren region. Koomal and chuditch have increased substantially (300–500%) since 2004. Population changes in these and other species, such as the numbat, require further investigation.

8.5.1 Introduction

Several other native species have declined in the Upper Warren region before, or during the recent woylie declines including the wambenger (brush-tailed phascogale, *Phascogale tapoatafa*) and dunnarts (*Sminthopsis spp.*) (Wayne *et al.* 2001b), ngwayir (western ringtail possum, *Pseudocheirus occidentalis*) (Wayne *et al.* 2011, 2012) and quenda (southern brown bandicoot, *Isoodon obesulus*) (Henstridge *et al.* 2008). While other critical weight range native species, such as the koomal and chuditch, have apparently increased more recently. Changes in abundance of co-occurring species may provide an indication or evidence of the factors driving population changes. The challenge remains in distinguishing whether associations between species are either coincidence or related, and if related, whether they are a cause or an effect of the change in another species.

This section provides a brief summary of the patterns of population change in other small and medium-sized mammals, with a focus on information available associated with the regional monitoring using the small cage traps that have been used to characterize the woylie declines in the Upper Warren region. The results presented are only preliminary and require substantially more development and rigour to provide greater insight into the ecological interactions and factors driving population changes in the region.

8.5.2 Methods

The monitoring using small cages traps (50 traps spaced 200m apart) along road-based transects are described in section 6.3.1. Trapping data for wambenger and dunnarts using medium Elliott box traps (e.g. Wayne *et al.* 2001b) and ngwayir spotlight detection rates from long-term monitoring transects in Kingston were also used (e.g. Wayne *et al.* 2005a). Spotlight detection rates and trap capture rates are used here as an index of population change. Whether these indices are reliable measures of abundance/density for other species as they have been shown for woylies (Wayne *et al.* 2013a), remains to be tested. The results are therefore preliminary and indicative only and subject to change in future revisions.

8.5.3 Results

Monitoring data using cage traps were limited from 1994 to Warrup and Winnejup transects in Greater Kingston (part of the ‘Kingston Study) until 1998 when surveys along other transects began. While data from Boyicup and Yendicup are available from the 1970s (see Burrows and Christensen 2002), these data remain to be validated and included in the analysis of regional trends.

Koomal – the median capture rates of koomal between 1997 and 2004 were reasonably stable with an average 6.6%, before increasing to a peak of 44.5% in 2007, before returning to around 35% between 2008 and 2013. There is an apparent 2 year lag in the increase of capture rates of the koomal following the beginning of the major regional decline of the woylie in 2003. The corresponding decrease in total capture rates is suggestive of the increase in koomal being more likely, at least partly, because of a real increase in numbers rather than a response to increased availability of traps (in which case a more immediate and corresponding increase in koomal capture rates would be more likely, resulting in a less pronounced decline in total capture rates over time) (Figure 90).

Chuditch – the median capture rates of chuditch between 1994 and 2000 were on average 0.8%, before dropping to effectively 0% between 2001 and 2004, and then increasing to a peak of 2.8% in 2010 before returning to about 2% (2011–2013). Capture rates in Moopinup have been particularly high, reaching 26% (22 individuals) and 23% (30 individuals) in 2012 and 2013 respectively. The timing of the decline in chuditch capture rates coincides with decline of woylies and the chuditch recovery to record highs coincides with period in which woylie numbers have remained low (Figure 90).

Like the koomal, it appears that about 2 years after the commencement of a regional decline in woylie numbers, that chuditch capture rates began to increase. If related, the successive lags in the increases of chuditch and koomal following the woylie declines can be inferred as probably the effects of the decline rather than possible causes of the woylie decline. A characteristic increase in the capture rate to a spike before dropping to a slightly lower level is more apparent in the case of the chuditch (2010) than the koomal (2006).

Quenda – the capture rates of quenda at Winnejup and Warrup were relatively high in the 1990s, peaking in 1995 at 27% and 10% respectively before declining to generally <1% in more recent years (Figure 91). At the regional scale since 1999 (when there have been 3–11 sites used to derive a regional median capture rate), there appears to be a decrease from a peak median capture rate of 1.2% in 2000 to 0–0.3% since 2009. Trapping data from Boyicup and Yendicup (1970s–1990s) remains to be verified and incorporated to provide an insight to what quenda numbers were like elsewhere before 1999. But indications from Burrows and Christensen (2002) were that quenda capture rates peaked at 2.2%–3.3% in the early to mid-1980s at these sites. However, since 1999, when more data are readily available, the regional scale trend in quenda suggests that numbers have been low but continue to decline gradually and over a much longer period than for the woylie over the same period. The trend suggests that quenda declines will probably continue toward undetectable (Figure 90).

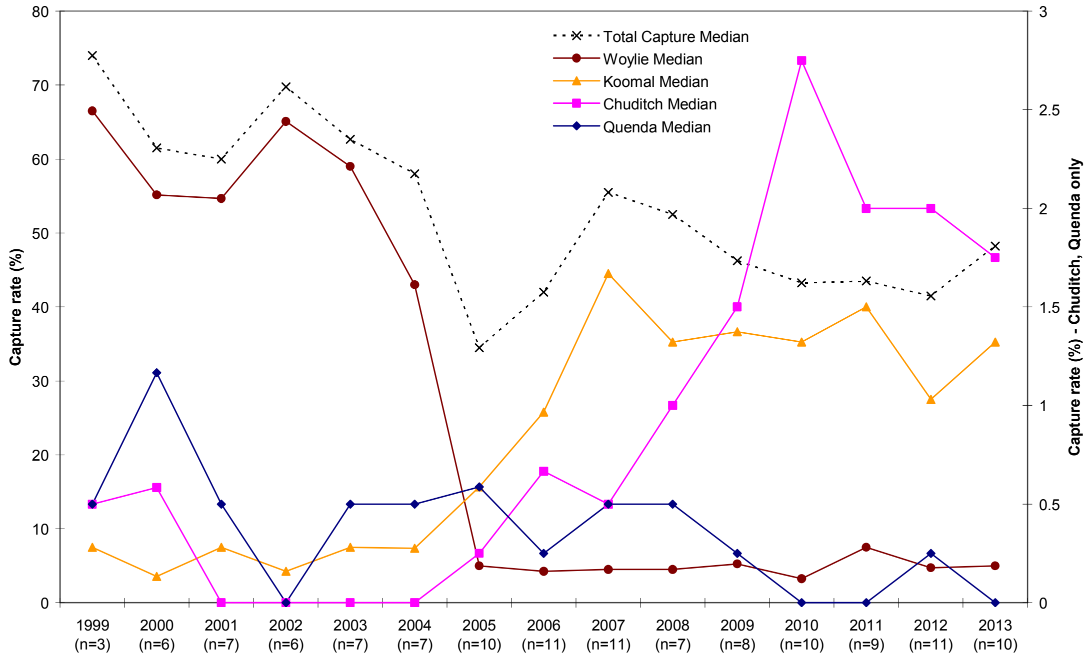


Figure 90. Summary of the regional-scale trends in the median capture rates of the main native mammal species trapped along the key monitoring transects across the Upper Warren region (1999–2013).

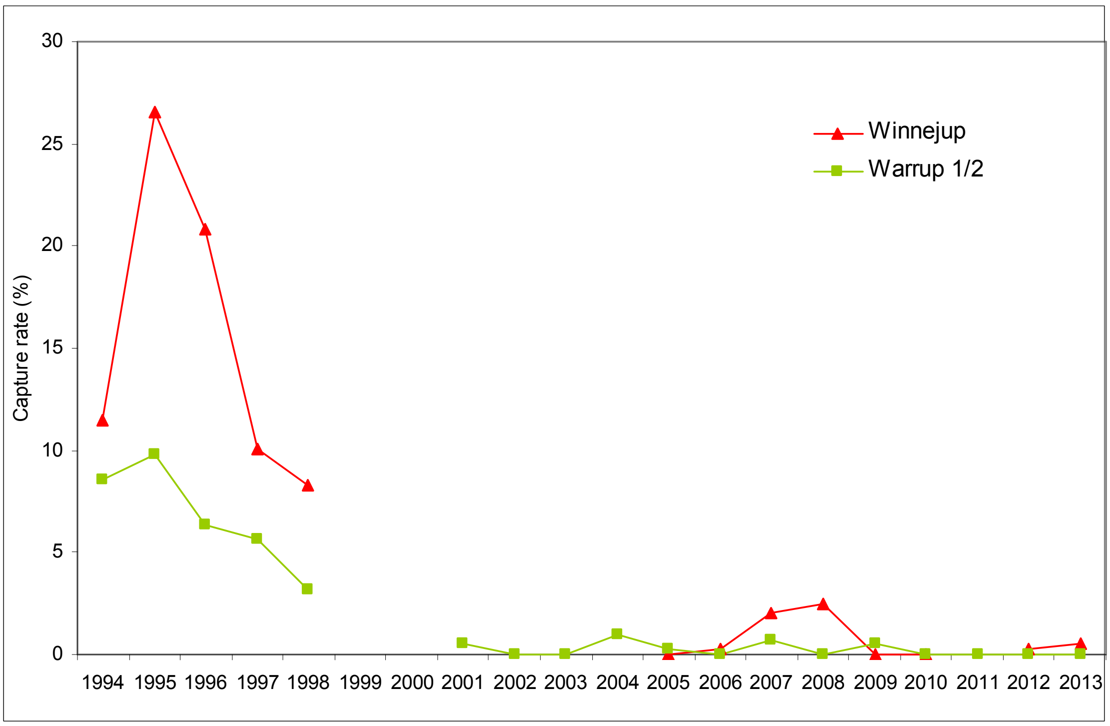


Figure 91. Trap capture rate of quenda from the Winnejup and Warrup transects in the Greater Kingston area of the Upper Warren region.

The population changes observed in the Upper Warren region since the 1990s are summarized in Table 21 and Figure 92, including species surveyed by methods other than cage trapping (i.e. medium-sized Elliott box traps (wambenger and dunnarts), small wire cage traps (wambenger, quenda, and woylie), and spotlighting (ngwayir)). The data used to derive Figure 92 are preliminary and incomplete, and therefore should be considered indicative only and subject to change. For example, there are spatio-temporal biases in the data that need to be factored in, such as the information from the 1990s being predominantly sourced from the Greater Kingston area. Note that the woylie trends are based on the median capture rates across the entire Upper Warren region. Had the trends focused on Greater Kingston only (i.e. more comparable to the datasets used for the other species in Figure 92), most of the decline would have been in 1999–2000.

Some pre-existing speculation of the possible reasons for the changes are included in Table 21, although evidence to support these is generally needed before they can be considered more seriously. The simultaneous or sequential timing of the population changes and other patterns may give some clues as to the possible causes and whether they are related. All species that have declined or increased are within the critical weight ratio (Burbidge and McKenzie 1989) considered to make them particularly vulnerable to predation by foxes and cats. The population changes have all indicatively been substantial (>75% declines or >300% increases) and the rapid rates of decline have been very similar between species. There is also an apparent pattern in populations changes of species according to body size with the smaller species declining first and the largest species (koomal and chuditch) increasing in abundance.

The decline of wambenger and dunnart appear to be associated with respect to timing, diet and taxonomic relatedness. By 2009 wambenger detected in nest boxes was reported to have recovered to 25% of their encounter rates of 2004 and 2005 (McCracken 2009) but trapping rates from small wire cages and medium-sized Elliott box traps across the Upper Warren region show no indication of a recovery since the declines in 1994–1996.

Dunnarts have not been surveyed in the Greater Kingston area since 2000. A decline in food resources because of drought has been widely conjectured as the possible reasons for the decline of these small insectivorous dasyurids (e.g. Scarff *et al.* 1998).

The timing of the decline in quenda capture rates at Winnejup and Warrup (starting in 1996; Figure 91) immediately follows the decline of wambenger and dunnarts (Table 21, Figure 92) and precedes the decline of ngwayir and woylies at these sites. Regionally, quenda remain low and continue to decline (Figure 90). Quenda are terrestrial with some dietary overlap with dunnarts and woylies and are of similar size to woylies, ngwayir, koomal and chuditch. Otherwise little else is apparently common between the quenda and other species. When the declines were first observed in Warrup and Winnejup it was conjectured that it may be associated with the long times since these areas were last burnt (1975/76 and 1986/87 respectively) as had been observed for bandicoots elsewhere (e.g. Claridge and Barry 2000). However, it is now apparent that the declines have been more widespread geographically and across a greater range of fire histories, such that vegetation age since last fire is unlikely to be a primary factor associated with the quenda declines at the regional scale. Predators, food and/or disease need to also be considered (Table 21).

Whether the simultaneous timing of the ngwayir and woylie declines in Greater Kingston is directly related to common causes is unknown. Similarly the subsequent ngwayir declines in Perup (2001–2009) also roughly coincide with woylie declines in these areas (Wayne *et al.* 2012). Changing climate, especially the loss or substantial delays in autumn rains, has resulted in the loss or reduction in the seasonal new leaf flush especially in jarrah (A. Wayne personal observation), upon which the ngwayir is highly dependent, particularly for supporting the energy demands of their major breeding season (Wayne *et al.* 2005b). The loss of this important food at this time is likely to substantially reduce the fecundity of ngwayir and therefore significantly impact the ability of their populations to withstand the predation pressures, particularly by cats and foxes.

Speculation of the role of changing food resources is common for all species in Table 21, except the woylie where several lines of evidence have been used to eliminate this as a possible factor (e.g. DEC 2008a; Wayne *et al.* 2011, 2013a&b; Zosky 2011). In the case of koomal it is possible that increased food, because of reduced competition from woylies is probably a primary factor driving population increases.

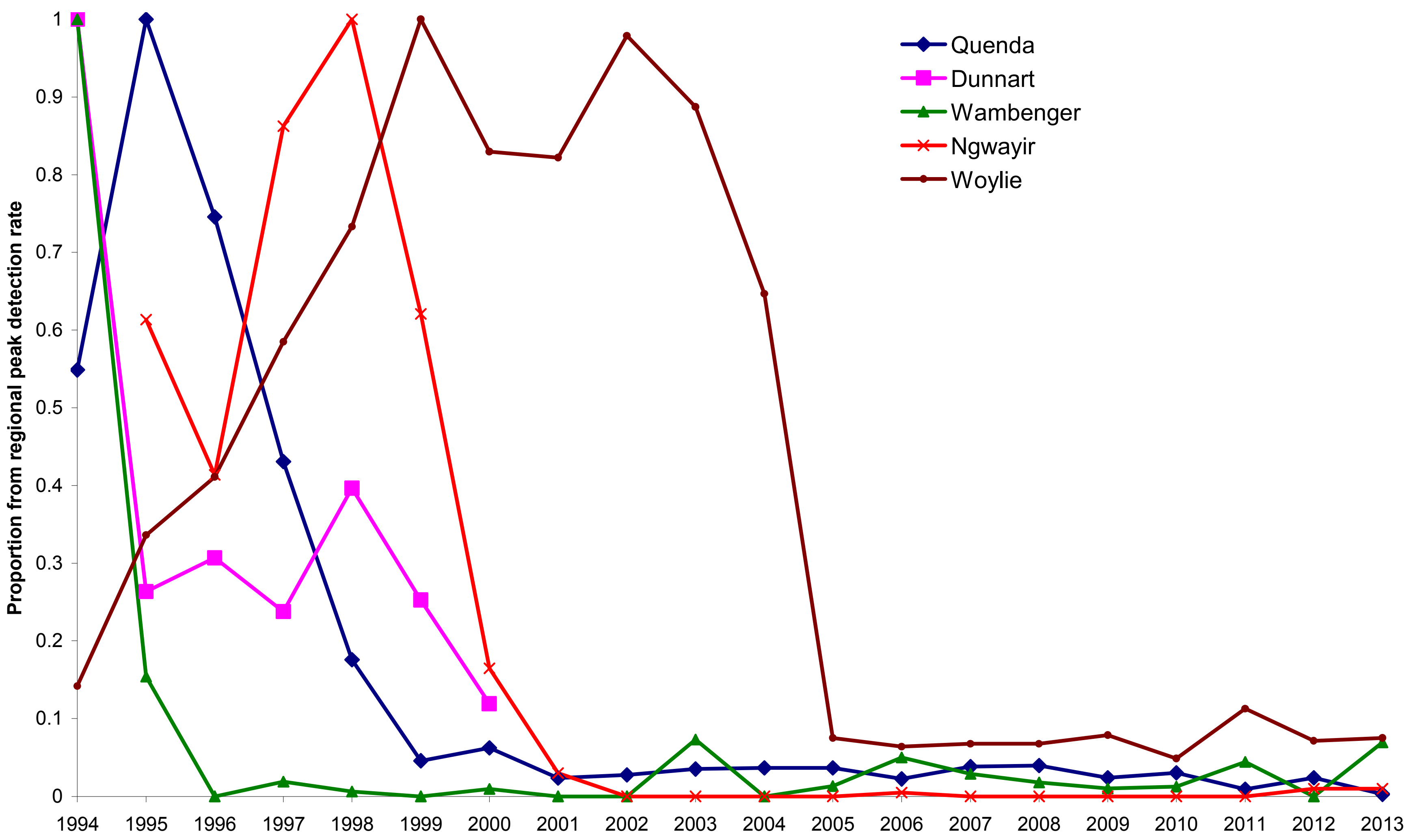


Figure 92. Population declines of mammals in the Upper Warren region since the 1990s. Note: These results are preliminary, incomplete and indicative only. There are spatio-temporal biases in the data with the information from the 1990s being predominantly sourced from the Greater Kingston area. Detection methods include medium-sized Elliott box traps (wambenger and dunnarts), small wire cage traps (wambenger, quenda, and woylie), and spotlighting (ngwayir).

Table 21. Summary of population changes of mammals in the Upper Warren region since the 1990s, speculation of the possible reasons for these changes and some biological and ecological attributes that may relate to the patterns of change.

Species	Population Change	When	Mechanism	Possible causes	Factors	Comments	Diet	Habit	Size	Other reference sources
Wambenger (Dasyurid)	Decline 75%–97%	1994–1996	Failed recruitment?	Food resources?	Drought?	some supporting evidence	Insectivore	Arboreal	<300g	Scarff *et al.* 1998, Rhind 1998, Wayne *et al.* 2001b, McCracken 2009
Dunnarts (Dasyurid)	Decline 75%–90%	1994–2000 at least	?	Food resources?	Drought?	maybe related to wambenger declines	Insectivore	Terrestrial	<37g	Wayne *et al.* 2001b
Quenda (Peramelid)	Decline 75%–100%	1996–ongoing	?	Predation? Food? Disease?	Trap saturation by woylies in late 90s (partially)?		Omnivore	Terrestrial	<1,850g	Kingston data unpublished, Henstridge *et al.* 2008
Woylie (Potoroid)	Decline 95%	1999–2011	Mortality	Predation & disease?	Woylie density	Not fire, logging, food, direct human interference, habitat loss	Mycophageous omnivore	Terrestrial	<1,800g	Wayne *et al.* 2008, 2011, 2013a&b, Zosky 2011
Ngwayir (Pseudocheirid)	Decline ~99%	1998–2009	Failed recruitment?	Food resources—especially during breeding?	Autumn drought reducing jarrah leaf flush		Specialist herbivore	Arboreal	<1,330g	Wayne *et al.* 2011, 2012
Koomal (Phalangerid)	Increase >500%	2004–2007	Increased recruitment?	Food resources? Reduced fox predation?	Reduced competition from woylies	lag indicates maybe an effect of woylie declines	Omnivore	Terestrial / Arboreal	<2,100g	Wayne *et al.* 2008, 2011
Chuditch (Dasyurid)	Increase >300%	2005–2010	Increased recruitment? Reduced mortality?	Food resources? Reduced fox predation?	Season, increased fox control, Trap saturation (partially)?	lag indicates maybe an effect of woylie declines	Carnivore	Terrestrial / Semi-arboreal	<2,200g	

8.5.4 Discussion

At least five mammal species have declined substantially (75%–100%) within the last 20 years in the Upper Warren region, of which two are considered critically endangered (woylie, ngwayir—pending nomination currently in preparation and official assessment), the wambenger is vulnerable, the quenda is conservation dependent (priority 5), and the dunnart is not conservation listed. Two species have subsequently and apparently increased—the chuditch (listed as vulnerable) and koomal (not conservation listed). While each of these declines is a concern in its own right, whether and how these declines are related and/or symptomatic of significant, potentially irreversible ecological changes remains to be substantiated. To what extent they are representative of species or ecosystem changes elsewhere is also of critical importance to biodiversity conservation and wildlife management.

All of the species declines in the Upper Warren region are also of particular significance given that the region has long been recognised as one of the most important fauna conservation areas in southwestern Australia (DEC 2012). It is a rare Australian mainland example of an area that supports a high diversity and abundance of conservation-priority medium-sized mammals within an ecosystem that supports an almost intact indigenous marsupial fauna assemblage (dalgyte were recently reintroduced, the boodie is locally extinct). This includes a range of species that have contracted in range to a limited number of sites (for example Upper Warren region and Dryandra) and/or that have historically declined (for example numbat (*Myrmecobius fasciatus*), woylie, ngwayir, tammar wallaby (*Macropus eugenii*), chuditch, wambenger and quenda) (Wayne and Moore 2011).

Whether there have been changes in other species in the region remains to be confirmed. Of particular importance is the numbat of which the Upper Warren region represents the larger of the two remaining indigenous populations of the species. While anecdotally it appears tammar wallabies have continued to increase in abundance and range and the western grey kangaroo (*Macropus fuliginosus*) appears stable, the western brush wallaby (*Macropus irma*) may have also declined within the region (A. Wayne personal observation). Little or nothing is known regarding possible population changes for other taxa including the bats, birds, reptiles and frogs.

Greater clarity regarding the conservation risks and priorities at the regional scale and southwest area more broadly will help direct a robust and adequate response to current population changes. As well as being more efficient, a holistic and integrated approach to the conservation management and research efforts is probably more effective. Accurately identifying the causes of the declines remains as ever, the most assured way of informing how best to manage the situation. Adequate monitoring is also necessary to inform all of these elements in a timely manner.

The decline diagnosis framework and monitoring approach applied in the case of the woylie declines in the Upper Warren region (DEC 2008a; Wayne *et al.* 2011, 2013a&b) is equally applicable to a multi-species endeavour across a larger spatial scale. This includes characterising the nature of the population changes over space and time and in relation to demographic attributes (for example body mass, reproduction, gender and age ratios, condition, etc). Associative evidence from possible agents of decline (for example predators, food, disease, disturbance, habitat change, etc) can also help shortlist the putative causes of the decline. Determining whether associations are coincidence or related, and if related, whether they are a cause or effect is an important step in this process.

Preliminary indications are that the temporal pattern of the multi-species changes in the Upper Warren region is consistent with an ecological cascade of declines and as a consequence, significant ecosystem change. Whether or not the multi-species declines are in anyway related remains to be tested. Superficially at least, introduced predators and changes to food resources are the most obvious factors possibly common in some way to all or most of the population changes but remain to be substantiated. However, while increased predation by cats and foxes may be putative factors in the declines of some species, reduced predation is probably a contributing factor in the increase of koomal and chuditch. Definitively resolving the role of predators in population changes is clearly, therefore, a high priority. Disease can also not yet be rejected as a possible cause in other species declines given that there is some associative evidence that disease, in conjunction with predation may be the major causes of the woylie declines.

Dealing with the complexities of a single-species, let alone a multi-species decline phenomenon is a significant challenge. The approach to date with the woylie has been to simplify matters by focusing on the woylie only and predominantly within the Upper Warren region. The rationale has been that such a focus may improve the prospects of successfully identifying the causes of decline in at least one population and having done so, the same causes can be tested to determine whether they apply elsewhere. In a similar vein, focusing on the woylie, for which there is more information available, the findings can then be applied as a model to other species to test whether they also apply. While this approach may be valid, attention to the patterns and characteristics of decline across species, space and time is also expected to be a powerful deductive tool to identifying putative factors for focused investigation. Similarly a thorough and broader examination of putative agents of population change potentially common to multiple species (such as food, predators and disease) and factors that may influence these putative agents (for example climate, fire regimes, vegetation change) would also be efficient and productive.

Scientific experimental frameworks (for example active adaptive management) applied to ameliorative management actions, such as predator control, may also be a valuable approach to testing the putative causes of decline as well as potentially delivering a better conservation outcome. Verifying the effectiveness of existing predator control and improving it further (for example feral cat control) are essential as much for the Upper Warren region as elsewhere. Doing so therefore remains one of the highest priorities for the effective conservation of a broad suite of species (e.g. Burbidge and McKenzie 1989).

8.6 Future planning and priorities

Summary: A brief review is provided of the activities that will continue now that current external funding sources have concluded, what will not continue without securing new resources, opportunities for building on the achievements to date, and what management and research priorities there may be for the future.

Projects undertaken directly as part of the Woylie Conservation Research Project through existing external sources of funds (principally WA NRM and CFOC) concluded in 2013. No other new sources of funds have yet been secured to continue these activities. This therefore provides a good opportunity to review what has been done, what will not continue without securing new resources, opportunities for building on the achievements to date, and what management and research priorities there may be for the future. A very brief overview is presented here of the main elements as they relate to woylie conservation in the Upper Warren region and to some extent the species as a whole.

Substantial gains achieved during this project that will continue;

- The establishment and maintenance of the Perup Sanctuary infrastructure
- The successful establishment and ongoing growth of a woylie insurance population that has genetic representation from the three extant indigenous populations (Perup, Kingston and Dryandra) and offspring from the last remaining individuals in captivity from the recently extinct indigenous population at Tutanning.
- Monthly baiting within the core area of Tone-Perup Nature Reserve (14,500 ha) to continue to at least 2015
- The founders in Yendicup to potentially stimulate a substantial recovery of the woylie in the wild
- Sand pad infrastructure at six monitoring sites across the Upper Warren region (although their use and maintenance has been suspended indefinitely)

Activities that will no longer continue unless funds are secured include;

- Predator monitoring in the Upper Warren region by sand pads or remote sensor cameras
- Native fauna monitoring across the Upper Warren region will be substantially reduced (number of sites and frequency of monitoring)
- Spotlight monitoring of the Perup Sanctuary
- Small vertebrate monitoring using pit traps in the Perup Sanctuary (a subset of 3/18 webs have been incorporated into an annual trapping program for the DPaW Fauna Management Course)
- Weekly baiting at the Yendicup translocation site will end in October 2013.
- Health, disease surveillance and associated sampling of woylie populations and other species.
- Opportunities and capacity to take on new students and collaborations to assist in the conservation of the woylie and other species.
- Large volunteer and community engagement program in relation to wildlife conservation
- Development of interpretive material and infrastructure for public education and community awareness raising

Opportunities for development by building on the key achievements of this project include;

- Monitoring of the woylie population in Perup Sanctuary will continue but the methodology used to date is under review to develop an approach that overcomes the current trap saturation issues and that provides an adequate and sensitive means of measuring population change over time.
- At least a minimum adequate monitoring program of the health and screening for possible diseases in wild and sanctuary populations that may be associated the woylie declines or that may be limiting woylie recovery.
- Capacity to build on the investment with local landholders to increase their awareness of wildlife conservation values and issues in the region and to continue to undertake coordinated control on invasive vertebrate species such as the fox, cat, pig, rabbit, etc.
- Continued development of improved predator survey methods using remote sensor cameras and sand pads
- The use of the woylie colony in the Perup Sanctuary as a ready source for regular future translocations to stimulate the recovery of the species in the wild and potentially the establishment of other insurance populations
- The establishment of insurance populations of other conservation priority species that are complementary to the woylie insurance population within the Perup Sanctuary (for example ngwayir, dalgyte, boodie, mallee fowl)

Current woylie related research programs

- Existing collaborations including twelve student projects (see Appendix B)
- Analysis and write of the activities and data summarised in this and previous progress reports (DEC 2008a; Wayne *et al.* 2011)
- Woylie population viability modelling and genetics (led by Carlo Pacioni) to inform the development of a woylie population management strategy

Woylie related research programs just starting

- Outbreak investigation led by Lee Skerratt—a WWF funded project in collaboration with James Cook University and DPaW.
- The ecology of parasite transmission in fauna translocations (ARC project led by Murdoch University in collaboration with DPaW)

General priorities for woylie and biodiversity conservation

- Complete and more formal analyses and publication of the activities and research conducted to date
- Better quantify the population changes in sympatric species (for example wambenger, quenda, ngwayir, woylies, chuditch, koomal) and better understand what might be driving these changes (for example resources, predators, disease) across the southwest including key fauna conservation areas (for example Upper Warren region, Dryandra, Tutanning, and Batalling) to help prioritise appropriate research and management responses
- Promote and support collaborations including students and specialist experts

Top woylie management priorities

- Insurance populations established and maintained to conserve extant genetics—including developing the modelling and strategy for the sustainable harvest rates for the Perup Sanctuary that maximises the conservation of genetics, minimises genetic drift and maintains a viable insurance colony while maximising the number of animals available for translocations to stimulate recoveries elsewhere
- Introduced predators—effective management and monitoring in priority fauna conservation areas
- Monitoring of woylies and covariates including other native medium-sized mammals, health, habitat and disturbance factors
- Strict adherence to wildlife disease risk management and hygiene protocols (e.g. DPaW SOP 16.2)
- Population management and translocation strategy—including maintaining woylie populations above a minimum of >1,000 adults (target >3,000 in

the medium term), genetic augmentation where necessary and a translocation program, all within a scientific framework that directly informs the most effective and efficient methods of delivering and sustaining woylie conservation and recovery.

Top general research priorities

- Incorporate scientific and experimental elements into woylie conservation and recovery actions that directly help to inform effective management and help elucidate the causes of the recent woylie declines and/or factors limiting their subsequent recovery (for example *bone fide* and adequate application of active adaptive management principles)
- A comprehensive synthesis and critical review of the evidence to what extent predators may be involved in the declines (and limitation to recovery) at populations including the Upper Warren region, Dryandra, Tutanning, Batalling, Boyagin and Venus Bay Peninsula (SA)
- A comprehensive synthesis and critical review of the evidence to what extent disease may be involved in the declines (for example outbreak investigation) at populations including the Upper Warren region, Dryandra, Tutanning, Batalling, Boyagin and Venus Bay Peninsula (SA)
- A synthesis and characterisation of the changes in populations of sympatric species (for example koomal, chuditch, quenda, numbat, wambenger, ngwayir, dunnart, etc) and an assessment of the evidence for the putative agents of population change (resources, predators and disease) and related factors (for example climate, fire regimes, etc) at locations including the Upper Warren region, Dryandra, Tutanning, Batalling, and Boyagin

Top publication priorities for the woylie conservation research in the Upper Warren region

- A population comparison study of the survivorship and mortality factors of woylies over space and time
- A review of the evidence to what extent predators may be involved in the declines (and limitation to recovery)
- A test of the strength of the association between population decline and woylie survivorship with the prevalence and infection of individuals with *Trypanosoma*
- A rigorous assessment of the key existing associations with the woylie declines
  - Keninup intensive study – association between survivorship and population decline with prevalence of trypanosome infection
  - Pathology and haematology evidence
  - Skin conditions
  - Toxoplasma

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Appendix A: Bibliography of publications from the Woylie Conservation Research Project

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Wayne, A.F. (Sept 2008). Wildlife Conservation Action Funding: Woylie Conservation Research Project [Successful]

Wayne, A.F. (Dec 2008). DEC: SPP Predator Control Experiment at Keninup, Upper Warren (& Pilot Study)

Wayne, A.F. (Dec 2008). DEC: Woylie Conservation Research Project, Phase 2 Proposal (2009–2011) Prospects for Sponsorship, Bringing the woylie back from the brink

2009

Wayne, A.F. (Jan 2009). DEC EOI funding proposal for caring for our country (CFOC). Bouncing back from the brink: the recovery of the woylie and other threatened fauna by vitiating the critical threats

Wayne, A.F. (Mar 2009). Australian Biosecurity CRC/Woylie Consortium Partnership: Determining the role of disease in woylie declines [AB-CRC Proposal II]

Barton, B, A. Wayne (Mar 2009).State NRM: Emergency Conservation Action for the woylie. [Successful]

Chapman *et al.* (April 2009). Caring for our country federal grant: Improving native habitat resilience in south-west Western Australia—Australia's only international biodiversity hotspot

Wayne, A.F. (2009). Prospective student projects. Help bring the woylie back from the brink.

Prowse *et al.* (Mar 2009). Cooperative research centres program 11th Selection Round

Orell, Wayne, A.F. & Marlow (May 2009). DEC: Securing critically important woylie populations from extinction

Thompson, R.C.A. *et al.* (2009) Australian Research Council (ARC), Linkage Projects 2010, Round 1: Improving threatened species translocation programs: origin, condition and infection

Herbert, C. *et al.* (2009). The University of Sydney, Australian Research Council, Linkage Projects 2010, Round 2

2010

Dawson, K. and Wayne, A.F. (2010). Caring for our country federal grant. Using well managed native habitat to rescue woylies from the brink of extinction. [Successful]

Lymbery A. *et al.* (2010). ARC Linkage (LEIF) project: Improving threatened species translocation programs: origin, condition and infectious disease.

Wayne, A.F. (2010). Wildlife Conservation Action: In situ woylie conservation in the Upper Warren.

2011

Barton, B. *et al.* (2011). Expression of Interest WA State NRM funding. Targeted major recovery actions for the Critically Endangered Woylie [Successful]

Barton, B. *et al.* (2011). Final Application WA State NRM funding. Targeted major recovery actions for the Critically Endangered Woylie [Successful]

Lymbery *et al.* (2011). ARC Linkage (LEIF) project: Breaking the vicious cycle: translocation stress, parasitism and disease in threatened species

Roger, J. *et al.* (2011). CRC: Securing and Rebuilding Biodiversity

Wayne, A., K. Skogvold *et al.* (2011). Wildlife Conservation Action (Perth Zoo). A Comparative Health and Disease Investigation in the Woylie—Captive vs Free-Range Enclosure vs Wild.

2012

Dawson, K. *et al.* (2012). SWCC on-ground incentives funding: Introduced predator control, monitoring and quantification in the Upper Warren [Successful]

Thompson, R.C.A. *et al.* (2012). ARC Linkage (LEIF) project: The ecology of parasite transmission in fauna translocations [Successful]

2013

Howard, K., A.F. Wayne, *et al.* (2013). WWF Woylie Opportunity 1: Support for Kanyana's captive breeding program for the last surviving woylies from the Tutanning population

Howard, K., A.F. Wayne, *et al.* (2013). WWF Woylie Opportunity 2: Support for a systematic outbreak investigation [Successful]

Howard, K., A.F. Wayne, *et al.* (2013). WWF Woylie Opportunity 3: Support for woylie translocations to genetically augment the Perup Sanctuary insurance population with genetics from the Dryandra indigenous population

Thompson, R.C.A. *et al.* (2013). ARC Laureate Scholarship. Molecular ecology of parasites and parasitism

OTHER RELATED ARTICLES (NOT DIRECTLY WCRP)

Clark, P., and P. B. S. Spencer. (2007). Description of three new species of Theileria Bettencourt, Franca & Borges, 1907 from Macropodidae in Western Australia. Transactions of the Royal Society of South Australia 131:100–106.

Paparini, A., Irwin, P., Warren, K., McInnes, L. M., De Tores, P. and Ryan, U. (2012). Identification of novel trypanosome genotypes in native Australian marsupials. Veterinary Parasitology. 131(1): 25–30.

Parkar, U., R. J. Traub, S. Vitali, A. Elliot, B. Leveke, I. Robertson, T. Geurden, J. Steele, B. Drake, and A. Thompson. 2010. Molecular characterisation of Blastocystis isolates from zoo animals and their animal keepers. Veterinary Parasitology 169:8–17. [not directly on woylies]

Richards, J. D. 2007. Karakamia: a stronghold for the woylie. Page 27. Wildlife Matters: Newsletter of Australian Wildlife Conservancy.

Richards, J. D. 2008. Paruna Wildlife Sanctuary. Pages 12–13. Wildlife Matters: Newsletter of Australian Wildlife Conservancy.

Thompson, R. C. A., Kutz, S. J. and Smith, A. (2009). Parasite zoonoses and wildlife: Emerging issues. International Journal of Environmental Research and Public Health 6, 678–693.

Appendix B: Summary of student projects conducted in collaboration with the Woylie Conservation Research Project

Thirty one student projects have collaborated with the WCRP, including 19 completed and 12 current projects.

Completed

1. Abdad, M. Y. (2011). An epidemiological and serological study of *Rickettsia* in Western Australia. PhD Thesis, Murdoch University.
2. Basille, S. (2011) The epidemiology of piroplasm infection in the woylie (*Bettongia penicillata ogilby*i). Undergraduate Project (Independent Study Contract). Murdoch University
3. Bennett, K. (2012). 'An evaluation of two methods for assessing population densities of introduced predators in southwest Western Australia. Undergraduate independent study report.' Biology SIT Study Abroad Program, Cairns, Australia.
4. Eikelboom, T. (2010). A field comparison of survey methods for estimating the population density of woylies (*Bettongia penicillata*) at Karakamia Wildlife Sanctuary. Honours Thesis, University of Western Australia.
5. Hide, A. (2006). Survival and dispersal of the threatened woylie *Bettongia penicillata* after translocation. Honours Thesis, University of Western Australia.
6. Hunt, H. (2010). A temporal assessment investigating the effects of population declines on genetic diversity, in the critically endangered woylie (*Bettongia penicillata ogilbyi*). Honours Thesis, Murdoch University.
7. Harradine, E., White, L., Madsen, A., McMahon, S., Borkowski, K., Pinto, E. (2012). Perup – Nature's Guesthouse: Strategic destination management plan (2012–2016). Tourism Management course unit (TOU303) group project, Murdoch University.
8. Jaimes, S. (2010). Habitat associations of woylies in the Upper Warren. Undergraduate project, Pacific Lutheran University, SIT Study Abroad Program, Cairns
9. Jenkins, G., Rowells, J., Shah, P., Wallace, S. (2013). Comparisons of trapping surveys at Perup Sanctuary, Keninup and Warrup in the Upper Warren in April 2013. Individual student reports, Council on International Educational Exchange.
10. Jia Rong, H. (2009). Investigation of the potential pathogenicity of the erythrocyte piroplasm *Theileria penicillata* (Clark & Spencer, 2007). Honours Thesis, Murdoch University.

11. Kaewmongkol, G. (2012). Detection and characterization of *Bartonella* species in Western Australia. PhD Thesis, Murdoch University.
12. Madon, E. (2006). Mating systems and reproductive anatomy in marsupials: explaining the evolution of the anterior vaginal expansion of *Bettongia penicillata*. Honours Thesis, University of Western Australia.
13. McCalmont, J. (2010). Evaluation of conservation measures for a specific endangered species, *Bettongia penicillata*. 3rd year BSc (Hons) project. Institute of Biological, Environmental and Rural Science, University of Wales, Aberystwyth.
14. O'Brien, R. Christopher (2008). Forensic animal necrophagy in the south-west of Western Australia: Species, feeding patterns, and taphonomic effects. PhD thesis, University of Western Australia.
15. Pacioni, C (2010). A conservation conundrum: the population and epidemiological dynamics associated with recent decline of woylies (*Bettongia penicillata*) in Australia. PhD thesis, Murdoch University.
16. Parameswaran, N. (2008). *Toxoplasma gondii* in Australian marsupials. PhD thesis, Murdoch University.
17. Rogers, P. (2009). Predator profiling as a tool for the conservation of the woylie (*Bettongia penicillata*). Honours thesis, University of Western Australia.
18. Yeatman, G. (2010) Population demographics of a fenced population of woylie. Honours Thesis, University of Western Australia.
19. Zosky, K. (2011). Food resources and the decline of woylies *Bettongia penicillata ogilbyi* in southwestern Australia. PhD thesis, Murdoch University, Western Australia.

Current

1. Botero, A. (PhD, MU) – Genetic characterisation of trypanosomes
2. Burmej, H. (PhD, MU) – Ectoparasites of threatened mammals in Western Australia: Biodiversity and impact
3. Hing, S. (PhD, MU) – Relationship between stress and disease in woylies
4. Jones, K. (PhD, MU) – Social networks and parasite transmission in woylies
5. Lim, Z. (RSM, MU) – A review of pathology in the woylie
6. Pan, S. (PhD, MU) – *Toxoplasma gondii* infection and atypical genotypes in Western Australian wildlife species.
7. Parkar, U. (PhD, MU) – Blastocystis in humans and other mammals
8. Pleitner, M. (BSc, University of Wuerzburg, Germany) – health associations with the declines of woylies in the Upper Warren

9. Skogvold, K. (PhD, MU) – A comparative health and disease investigation in the woylie – captive vs free-range enclosure vs wild
10. Thompson, C. (PhD, MU) – Trypanosome effects on woylies and their vectors
11. Worth, A. (PhD, MU) – Toxoplasma effects on woylie behaviour
12. Yeatman, G. (PhD, UWA) – Woylie and wildlife ecology in the Upper Warren

Affiliated Student Projects

Cherriman, C. (2007). Territory size and diet throughout the year of the Wedge-tailed Eagle Aquila audax in the Perth region, Western Australia. Honours thesis, Curtin University.

Appendix C: Summary of media articles relating to woylie declines and the WCRP

Incomplete log of online videos, radio, television and print articles

Web video

DATE	OUTLET	TITLE/TIME	INTERVIEWEE	INTERVIEWER
26-May-10	ABC Southwest	Ghost Town…	Adrian Wayne	Sharon Kennedy
15-Aug-12	Youtube	Help Save Woylies		Sophia Tolfree
Radio				
DATE	OUTLET	TITLE/TIME	INTERVIEWEE	INTERVIEWER
10-Sep-06	ABC Regional Radio		Adrian Wayne	Tim White
11-Sep-06	ABC Regional Radio		Adrian Wayne	Tim White
12-Oct-06	Radio Fremantle		Adrian Wayne	Amy
14-Feb-07	ABC Southwest		Adrian Wayne	David Petale
15-Feb-07	ABC Southwest	07:30 News	Adrian Wayne	D. Petale/Sarah Hughan
15-Feb-07	ABC Southwest	06:30 News	Adrian Wayne	D. Petale/Sarah Hughan
15-Feb-07	ABC Southwest	6:30am News	Adrian Wayne	
15-Feb-07	ABC Southcoast	6:30am News	Adrian Wayne	
15-Feb-07	ABC Southwest	7:30am News	Adrian Wayne	
07-Aug-07	ABC Southwest	Woylie Update	Adrian Wayne	James Bennet
Feb-07	6PR	Woylie doc	several	Jon Lewis
07-Aug-07	ABC Southcoast	Woylie Update	Adrian Wayne	James Bennet
08-Aug-07	ABC Southcoast	6:30am News	Adrian Wayne	
08-Aug-07	ABC Southwest	6:30am News	Adrian Wayne	
08-Aug-07	ABC Goldfields	6:30am News	Adrian Wayne	
08-Aug-07	ABC Southcoast	7:30am News	Adrian Wayne	
08-Aug-07	ABC Southwest	7:30am News	Adrian Wayne	
10-Sep-07	ABC Southcoast	6:30am News	Adrian Wayne	Jane Norman
10-Sep-07	ABC Southcoast	7:30am News	Adrian Wayne	Jane Norman
20-Sep-07	ABC Southcoast	6:30am News	Adrian Wayne	
20-Sep-07	ABC Southcoast	7:30am News	Adrian Wayne	
21-Sep-07	ABC Great Southern	10:10am interview	Adrian Wayne	E. Prom/ N. Boslypask
13-Feb-08	ABC Radio News	Woylie Update	Adrian Wayne	Aja Styles
20-Feb-08	ABC Southwest	Woylie declines	Adrian Wayne	Janine Unsworth
16-Apr-09	Curtin FM Perth	Woylie decline	Adrian Wayne	Liz Pye
05-Jun-09	ABC North West	Woylie decline	Adrian Wayne	?
05-Jun-09	ABC 720 Perth	Woylie decline	Adrian Wayne	Tiffany Gendes
10-Jun-09	ABC Southwest	Woylie decline	Adrian Wayne	?

DATE	OUTLET	TITLE/TIME	INTERVIEWEE	INTERVIEWER
10-Jun-09	ABC Southcoast	6.30 News	Adrian Wayne	?
10-Jun-09	ABC Southcoast	7.30 News	Adrian Wayne	?
10-Jun-09	ABC Southcoast	Mornings 10:26	Nicky Marlow	John Cecil
13-Jun-09	6PR	Woylie decline	Adrian Wayne	
22-Jun-09	ABC 720 Perth	Perup reserve	Adrian Wayne	Geoff Hutchison
23-Jun-09	ABC Southwest	Woylie decline	Adrian Wayne	Glen Greensmith
23-Jun-09	ABC Southcoast	Perup reserve	Adrian Wayne	?
24-Jun-09	ABC Southwest	A Rocket on legs…	Adrian Wayne	Sharon Kennedy
03-Nov-09	ABC Radio News	Woylie Sanctuary	Adrian Wayne	Sharon Kennedy
24-May-10	ABC Southwest	Woylie Sanctuary,,,	Adrian Wayne	Sharon Kennedy
20-Sep-10	ABC Southwest	Woylie Enclosure	Brad Barton	Ron Tait
22-Jun-11	ABC Southwest	Translocation success…	Adrian Wayne	Ron Tait
17-Nov-11	ABC Southwest	Woylie update	Adrian Wayne	Ron Tait
23-Jan-13	96FM (Perth)	Woylies		?
20-Jul-13	ABC RN Science Show	Sanctuaries …	Adrian Wayne	Victoria Laurie
Television				
DATE	OUTLET	TITLE/TIME	INTERVIEWEE	INTERVIEWER
04-Aug-06	ABC TV News	Woylie decline …		
27-Jul-07	ABC TV News	Woylie declines	Adrian Wayne	Aja Styles
20-Sep-07	GWN	5:30pm news		
Feb-07	Access 31	Woylie doc	several	Jon Lewis
Feb-07	Documentary pilot	Woylie doc	several	Aleisha Caruso
14-Feb-08	ABC TV News	Progress report	Adrian Wayne	Veronica Buck
07-Oct-08	ABC TV	7:30 Report	Adrian Wayne	Leonie Harris
22-Oct-08	Ch10 News	AWC Woylies	AWC	?
21-Jun-09	ABC TV News	Perup reserve	Adrian Wayne	Craig Smart
21-Jun-09	Ch9 News	Perup reserve	Adrian Wayne	Sharlyn Sarac/Matt Tinney
21-Jun-09	Ch10 News	Perup reserve	Adrian Wayne	Natarsha Belling
22-Jun-09	WIN News	Perup reserve	Adrian Wayne	Deborah Kennedy
28-Oct-09	Ch10 Totally Wild	Woylies	Adrian Wayne	Colin Thrupp
04-Mar-11	Ch9 Today Tonight	Perup Sanctuary …	Adrian Wayne	Natalie Bonjourno

Print media

DATE	AUTHOR	TITLE	PUBLISHER
2006	Burrows	$300,000 to research woylie decline in south-west forest areas	CALM Media Release
2006		Saving our species: Biodiversity conservation initiative 2006-07	DEC
14-Jun-06	?	Woylie worry sparks search	Manjimup Bridgetown Times
20-Jul-06	?	Woylie Spotting	Manjimup Bridgetown Times
24-Jul-06	McGowan	Investigation launched into woylie decline	Minister for Environment media statement
27-Jul-06		Woylies on decline	Collie Mail
27-Jul-06		Disappearing woylies are the focus of study	Southwestern Times
1-Aug-06	Wayne	Woylie Declines in the Perup area	Baiting Mailout
2-Aug-06		Probe into woylie decline	Narrogin Observer
3-Aug-06	Wayne	Woylie numbers down 70 per cent	Collie Mail
01-Sep-06	McKenna	Woylie decline a mystery	DEC, Environment and Conservation News
20-Sep-06		Downturn in woylie numbers	Manjimup-Bridgetown Times
01-Oct-06	King	CSI Perup	DEC, Point Source
01-Oct-06	Mayne	Saving our furry friend the woylie	Murdoch?
10-Oct-06	McGowan	Investigations continue into mystery woylie decline	Minister for Environment Media Statement
11-Oct-06		Feral cats take toll on woylie population	ABC Online
12-Oct-06	Jerrard	Woylies in trouble as numbers fall again	The West Australian
18-Oct-06		Cats, disease affect woylies	Manjimup-Bridgetown Times
26-Oct-06	Davey	Saving the woylie has become a labour of love for one South West family	Busselton-Margaret River Times
01-Nov-06		Woylie conservation research project	Wildlife Disease Association Australasian Section Newsletter
Summer 2006/07	Scarparolo	The case of the disappearing woylies	Perth Zoo, News Paws
15-Feb-07		Cats, foxes contribute to disappearing woylie	ABC Online
27-Feb-07		CSI Woylie to the rescue	The West Australian, Inside Cover
13-Mar-07	Fleming	Where's woylie?	The Bulletin
18-Mar-07	Dutter	They are woylie cute - but it's murder to find their killer	Sunday Telegraph

DATE	AUTHOR	TITLE	PUBLISHER
Feb/Mar 2007	Hills	Where have all the woylies gone?	Volunteer account of trapping
01-Dec-07		Woylie (*Bettongia penicillata)*	Shark Bay World Heritage Area Fact Sheet
5-Oct-07	Meates	Declining Woylie Population	Bunbury Mail
15-Feb-08	Hampson	Tiny woylies face extinction for the second time	West Australian
18-Feb-08	Murnane		Southwestern Times
15-Feb-08	?		Bunbury Mail
22-Feb-08	Bromell	Local angle on latest in woylie declines	Augusta Magaret River Times
27-Feb-08	Wood	Woylie population decline Western Australia	Aust Wildlife Health Network
27-Feb-08	General News	Woylie disease worries	Augusta Magaret River Mail
27-Feb-08	Watson	Woylie Decline	Harvey Mail
26-Feb-08	Anon	Woylie report uncovers mystery disease	Donnybrook-Bridgetown Mail
5-Mar-08	Short	Trap foxes and save the woylie	Narrogin Observer
5-Mar-08		Mystery decline in woylie numbers	DEC Environment and Conservation News
29-May-08		Woylie decline article to go in Bushland news	David Mitchell Swan Region
4-Nov-08	Hopkin	Woylie on the brink as research money ends	West Australian
		World heritage area fact sheet	Department of Environment and Conservation 2007
1-Sep-08		Woylie woes	Woylie conservation research project report
1-Oct-08		Celebrating diversity - Rian Caccianiga - EJG Pitman Prize	Data Analysis Australia Newsletter October 2008
7-Oct-08	Dayton	All ours … and they're almost gone	The Australian
11-Nov-08	Vallis	Woylie declines and research	Australasian Wildlife Disease Association annual conference
1-Nov-08		Native fauna reintroduction with land restoration	Bauxite Resources News
29-Nov-08	Hopkin	Parasites push woylies to the edge	West Australian
4-Mar-09	Hopkin	Woylies are winners at luxury resort	West Australian
12-Mar-09		Potential projects - to review health of Woylies kept in captivity	Perth Zoo
12-Mar-09		The case of the disappearing woylies	Perth Zoo
12-Mar-09		Woylie conservation research project	Perth Zoo
15-Apr-09	Rickard	Saving the Woylie	Bullsbrook Ellenbrook Advocate
5-Jun-09	Garrett	Iconic species get national protection on world environment day	Federal Minister for the Environment Ministerial Statement

DATE	AUTHOR	TITLE	PUBLISHER
5-Jun-09	Williams	Reversal of woylie fortunes a puzzle	West Australian
5-Jun-09	Williams	Reversal of woylie fortunes a puzzle	the west online
9-Jun-09	Farragher	Woylie listing a step forward: Minister	Minister for Environment media statement
9-Jun-09		Woylie back on threatened list	Donnybrook-Bridgetown Mail
10-Jun-09		Back from the brink	Augusta Margaret River Mail
11-Jun-09		Woylie back on at risk list	Albany Advertiser
12-Jun-09		Sanctuary thrives as woylies hit the wall	Busselton Dunsborough Times
12-Jun-09	Bromell	Good news for Woylies	Augusta Margaret River Mail
17-Jun-09		Report warns of species loss	Manjimup Bridgetown Times
21-Jun-09	Towie	Haven to stop woylie wipe-out	Sunday Times
21-Jun-09		Funds to boost critically endangered woylie	news.com.au
21-Jun-09	Towie	Haven to stop woylie wipe-out	Sunday times
22-Jun-09	Hatch	Woylie good	West Australian - Inside cover
22-Jun-09		Enclosure to protect woylie	Kalgoorlie Miner
22-Jun-09	O'Brien	Safety zone gives woylie the jump on predators	Australian
23-Jun-09		Woylie survival funding	Bunbury Herald
23-Jun-09		Funding to rebuild Woylie populations	Albany Advertiser
24-Jun-09	Hallett	Perup reserve to protect Woylies	Manjimup-Bridgetown Times
26-Jun-09		Stray serpent secure	West Australian
26-Jun-09		Critically endangered marsupial leads police to missing python	the west online
24-Jun-09		Woylie conservation research project	ABC South West
30-Jun-09		Recovery team projects for native Western Australian fauna	Perth Zoo news paws
1-Jul-09	Hallett	Enjoy the bush and help out with Woylie research	Manjimup-Bridgetown Times
1-Jul-09	Hallett	Manjimup role in recovering python	Manjimup Bridgetown Times
14-Jul-09		New southern sanctuary for the woylie	DEC Environment and Conservation News
29-Jul-09		Decline due to parasite	Manjimup Bridgetown Times
1-Aug-09		Bauxite Resources starts mining	Bauxite Resources News
1-Sep-09	Kirkman	Fencing for Conservation	Save the Tasmanian Devil Program Newsletter

DATE	AUTHOR	TITLE	PUBLISHER
26-Nov-09	Wayne	Focus on the Woylie	Society for Conservation Biology Newsletter
26-Nov-09		BRL to champion the cause of the critically endangered Woylie	Bauxite Resources News
1-Dec-09		Woylie population plummets	Australian Geographic Bush Telegraph
1-Dec-09		Fauna Conservation Program: Science Division	DEC Environment and Conservation News
26-May-10	Kennedy	Ghost town as Woylies disappear from the south west	ABC South West
1-Mar-10		Woylie Rescue - BRL's campaign to save the endangered Woylie	Bauxite Resources News
21-Jul-10	Clarke-Smith	Nature lovers ask: Who loves ya bilby?	Narrogin Observer
1-Jun-10	Bourne	At Risk-The Woylie - one of Australia's most endangered mammals	WWF Living Planet Magazine
24-May-10	Kennedy	Woylie Sanctuary to save species from extinction	ABC South West
15-Sep-10		All set for Woylies	Busselton Dunsborough Mail
29-Sep-10	Fordham	Perup to offer safe spot for marsupials	Manjimup- Bridgetown Times
4-Oct-10	Bennett	Feral cats and foxes wiping out WA species	The West Australian
7-Oct-10		Roo, emu muster	Denmark Bulletin
18-Oct-10	Bennett	Fight for life as list shows WA species under threat	West Australian
24-Oct-10	Paddenburg	Better off on both sides of the fence	Sunday Times
10-Nov-10	Faragher	New enclosure protects critically-endangered woylies	Minister for Environment media statement
11-Nov-10		Cockatoos to benefit from new purpose-built facility in Malaga	Independent Express
16-Nov-10		State-of-art enclosures at Malaga sanctuary	Stirling Times
17-Nov-10	Hunt	BRL woylie work draws scorn	Manjimup Bridgetown Times
24-Nov-10		Wild and Woolly woylies released in sanctuary	Merredin-Wheatbelt Mercury
12-Jan-11	Hunt	South West biodiversity hot spot is precious	The West Australian
13-Jan-11	Kennedy	Predator free fencing worth the effort to save woylie	ABC South West
28-Feb-11		Fossil DNA saving our species	ABC Science Features
1-Mar-11	Fleming	Endangered Woylies in spectacular comeback	The West Australian
1-Apr-11	Eastwood	Second Time Unlucky	RMW Outback
5-Apr-11		Perup reserves to get more protection	Donnybrook-Bridgetown Mail
6-Apr-11	Glover	Park plan open for comment	Manjimup-Bridgetown Times
7-Apr-11		Comments sought on Perup area	Albany & Great Southern Weekender

DATE	AUTHOR	TITLE	PUBLISHER
11-Apr-11	Kennedy	Perup conservation parks management plans reviewed	ABC South West
27-Apr-11	Hunt	Residents welcome logging delay	Manjimup Bridgetown Times
23-Jun-11	Kennedy	Woylies flourish in the Perup Sanctuary	ABC South West
21-Jun-11	Marmion	Translocation success for critically endangered woylies	Ministerial Media Statement
23-Aug-11		Woylie, *Bettongia penicillata*	The West Australian
16-Nov-11	Marmion	Woylie numbers double in predator-proof zone	Ministerial Media Statement
23-Nov-11		Woylies thriving away from harm	Manjimup Bridgetown Times
16-May-11	Edwards	Backpacker joins fight to save woylies	Manjimup Bridgetown Times
1-Jun-12		Woylie numbers increasing in sanctuary	WALGA Eco-News
10-Jun-12		Woylies Bounce Back	Sunday Times
11-Jun-12	Marmion	Woylie numbers booming in sanctuary	Ministerial Media Statement
1-Aug-12		Woylie project update	DEC community involvement unit newsletter
5-Sep-12	Edwards	Manjimup home for rare species	Manjimup Bridgetown Times
1-Jan-13		Sanctuary successful as Woylie numbers grow	DEC Environment and Conservation News
23-Jan-13	Powell	Woylie population bounces back in Perup breeding program	Manjimup-Bridgetown Times
24-Jan-13	Wheeler	Manjimup Woylies make a comeback	The West Australian
31-Jul-13	WWF	Funds for Woylie captive breeding facility (Kanyana)	WWF Media Release
3-Aug-13	Graham	Research confirms south west's Woylie decline	Science WA
10-Aug-13	Miles	Funds help fight to save Woylies	Hills Gazette Perth
24-Oct-13	Crowther	Australian endangered species: Woylie	The Conversation

Appendix D: Plant list from Perup Sanctuary monitoring plots

Species	Creek	Slope	Ridge
Acacia pulchella	Y	Y	
Acacia saligna	Y		
Acacia varia		Y	Y
Acaena echinata	Y	Y	Y
Agrostocrinum stypandroides			Y
Aira cupaniana *		Y	
Amphipogon amphipogonoides	Y	Y	Y
Anigozanthos bicolor	Y		
Astroloma ciliatum	Y	Y	Y
Astroloma drummondii			Y
Astroloma pallidum	Y	Y	Y
Austrodanthonia sp	Y		
Austrodanthonia caespitosa		Y	Y
Austrostipa campylachne	Y	Y	Y
Babingtonia camphorosmae	Y		
Banksia bipinnatifida		Y	Y
Banksia dallanneyi	Y	Y	
Banksia grandis			Y
Banksia seminuda	Y		
Banksia sessilis			Y
Billardiera variafolia			Y
Boronia spathulata		Y	Y
Bossiaea linophylla			Y
Bossiaea ornata		Y	Y
Briza maxima *	Y		
Briza minor *	Y	Y	
Burchardia congesta	Y		
Caesia micrantha		Y	
Caladenia barbata	Y		
Caladenia emarginata	Y		
Caladenia flava		Y	Y
Caladenia reptans			Y
Carduus tenuiflorus *		Y	
Cassytha racemosa	Y		
Chamaescilla corymbosa	Y	Y	Y
Comesperma calymega		Y	Y
Comesperma ciliatum	Y		
Comesperma confertum	Y		Y
Conostylis aculeata	Y	Y	Y
Conostylis setigera		Y	Y
Corybas recurvus		Y	

Species	Creek	Slope	Ridge
Corymbia calophylla	Y	Y	Y
Cotula coronopifolia		Y	
Craspedia variabilis	Y	Y	
Cyathochaeta avenacea	Y	Y	
Dampiera linearis	Y	Y	Y
Daucus glochidiatus	Y	Y	
Desmocladus fasciculatus	Y	Y	Y
Desmocladus flexuosus	Y	Y	
Drosera erythrorhiza	Y		
Drosera menziesii	Y		
Drosera pallida		Y	Y
Drosera stolonifera	Y	Y	Y
Elythranthera brunonis	Y	Y	Y
Elythrea emarginata	Y		
Eriochilus dilatatus			Y
Eucalyptus marginata	Y	Y	Y
Eucalyptus wandoo	Y	Y	
Euchiton collinus		Y	
Gastrolobium bilobum	Y		
Gompholobium ovatum			Y
Gompholobium polymorphum	Y	Y	Y
Gompholobium preissii			Y
Hakea lissocarpha	Y	Y	Y
Hakea prostrata	Y	Y	
Hakea varia	Y		
Helichrysum luteoalbum		Y	
Hibbertia amplexicaulis	Y	Y	Y
Hibbertia commutata	Y	Y	Y
Hibbertia racemosa			Y
Hyalosperma cotula	Y		
Hyalosperma demissum	Y		
Hypocalymma angustifolium	Y	Y	Y
Hypochaeris glabra *	Y	Y	
Isotropis cunefolia	Y	Y	
Kennedia prostrata	Y		
Labichea punctata		Y	Y
Lagenophora huegelii	Y	Y	Y
Lepidosperma leptostachyum		Y	Y
Lepidosperma squamatum			Y
Leptomeria cunninghamii	Y		Y
Leucopogon australis	Y		
Leucopogon capitellatus	Y	Y	Y
Leucopogon propinquus	Y	Y	Y
Leucopogon verticillatus			Y
Levenhookia pusilla		Y	

Species	Creek	Slope	Ridge
Logania serpyllifolia		Y	Y
Logania serpyllifolia subsp. serpyllifolia	Y		
Lomandra caespitosa	Y	Y	Y
Lomandra hermaphrodita			Y
Lomandra integra		Y	Y
Lomandra pauciflora		Y	Y
Lomandra sericea		Y	Y
Lomandra sonderi		Y	
Luzula meridionalis	Y		
Lyperanthus sp.	Y		
Lysimachia arvensis *	Y		
Macrozamia reidlii	Y	Y	Y
Melaleuca viminea	Y		
Millotia tenuifolia		Y	Y
Olax benthamiana		Y	
Opercularia hispidula			Y
Oxalis corniculata *	Y	Y	
Parentucellia latifolia *	Y	Y	
Patersonia babianoides			Y
Patersonia occidentalis	Y	Y	Y
Patersonia pygmaea	Y	Y	Y
Pelargonium littorale	Y	Y	
Persoonia longifolia		Y	Y
Phyllanthus calycinus		Y	
Pimelea rosea	Y	Y	
Pimelea suaveolens			Y
Pimelea sylvestris			Y
Podolepis lessonii	Y		
Poranthera microphylla		Y	
Pterostylis pyramidalis		Y	Y
Ptilotus manglesii	Y	Y	
Pyrorchis nigricans	Y		
Ranunculus colonorum	Y		
Rhodanthe citrina	Y	Y	
Scaevola sp	Y		
Scaevola lanceolata			Y
Scaevola striata	Y	Y	Y
Senecio hispidulus	Y	Y	Y
Senecio sp			Y
Siloxerus humifusis	Y		
Sonchus oleraceus	Y		
Sowerbaea laxiflora	Y	Y	
Stackhousia monogyna		Y	
Stylidium affine	Y		
Stylidium brunonianum	Y	Y	Y

Species	Creek	Slope	Ridge
Stylidium calcaratum	Y	Y	
Stylidium cilatum			Y
Stylidium schoenoides	Y	Y	Y
Stylidium spathulatum	Y		
Stylidium uniformis	Y		
Stypandra glauca			Y
Synaphea petiolaris	Y		Y
Tetraria capillaris	Y	Y	Y
Tetraria octandra	Y	Y	Y
Tetrarrhena laevis	Y	Y	Y
Tetratheca affinis	Y	Y	Y
Tetratheca hirsuta	Y		Y
Tetratheca hispidula			Y
Tetratheca setigera	Y	Y	
Thelymitra antennifera			Y
Thelymitra crinita	Y	Y	Y
Thysanotus manglesianus		Y	Y
Thysanotus multiflorus		Y	Y
Thysanotus tenellus			Y
Trachymene pilosa	Y	Y	Y
Tribonanthes australis	Y		
Trichocline spathulata	Y		Y
Tricoryne elatior	Y	Y	Y
Tricoryne humilis			Y
Trymalium ledifolium	Y	Y	Y
Velleia trinervis	Y	Y	Y
Veronica calycina	Y	Y	
Wahlenbergia gracilenta		Y	Y
Xanthorrhoea preissii	Y	Y	
Xanthosia atkinsoniana			Y
Xanthosia candida		Y	Y
Xanthosia huegelii	Y	Y	Y

* denotes alien species

Appendix E: Terrrestrial fauna confirmed in the Perup Sanctuary

Note: some animals may have been detected from pitfall traps immediately adjacent to but not within the Perup Sanctuary (Yeatman *et al.* 2013), but would still be expected to be present within PS.

Species		Detection method
Native Mammals		
Woylie	*Bettongia penicillata*	Trap, sight, spot, camera
Western Pygmy Possum	*Cercartetus concinnus*	Pit
Quenda	*Isoodon obesulus*	Trap, spot, camera
Tammar wallaby	*Macropus eugenii*	Trap, spot
Western grey kangaroo	*Macropus fuliginosus*	Sight, spot, camera
Western brush wallaby	*Macropus irma*	Sight, spot, camera
Numbat	*Myrmecobius fasciatus*	Trap, camera
Wambenger	*Phascogale tapoatafa*	Trap,
Ngwayir	*Pseudocheirus occidentalis*	Trap, spot
Dunnart	*Sminthopsis sp.*	Pit
Koomal	*Trichosurus vulpecula*	Trap, spot, camera
Introduced Mammals		
House mouse	*Mus musculus*	Pit
European rabbit	*Oryctolagus cuniculus*	Spot, camera, sign
Reptiles		
	Acritoscincus trilineatum	Pit
	Apraisia pulchella	Pit
	Christinus marmoratus	Pit
	Ctenotus catenifer	Pit
	Ctenotus labillardieri	Pit
	Egernia kingii	Trap
	Egernia napoleonis	Pit
	Hemiergis peronii	Pit
	Lerista distinguenda	Pit
	Lerista microtis	Pit
	Menetia greyii	Pit
	Morethia lineoocellata	Pit
	Morethia obscura	Pit
	Notechis scutatus	Sight
	Parasuta gouldii	Pit
	Pseudonaja affinis	Sight
	Ramphotyphlops australis	Pit
	Tiliqua rugosa	Trap
	Varanus rosenbergii	Trap, sight
Frogs		
	Crinia georgiana	Pit
	Crinia glauerti	Pit
	Crinia sp complex	Pit
	Heleioporus eyrei	Pit
	Heleioporus inornatus	Pit
	Heleioporus psammophilus	Pit
	Limnodynastes dorsalis	Pit
	Littoria adelaidensis	Pit, calling
	Neobatrachus pelobatoides	Pit
	Pseudophryne guentheri	Pit

Appendix F: Birds sighted immediately adjacent to the Perup Sanctuary

Summary of Bird Survey Records

Location: Perup Ecology Centre

Date: Summary from November surveys conducted 2005–2012

Time: early a.m., four consecutive mornings in November, per year

Name of Recorder: DPaW Fauna Management Course

List of birds obtained from the Birds Australia Atlas (http://www.birdata.com.au) for the one degree grid cell containing -34.1754, 116.5907 (Centred on Perup Forest Ecology Centre).

Emu			**Button-quails**		
Emu	*Dromaius*	**X**	Painted Button-quail	*Turnix varia*	
Quail			**Pigeons and Doves**		
Brown Quail	*Coturnix ypsilophora*		Common Bronzewing	*Phaps chalcoptera*	**X**
			Brush Bronzewing	*Phaps elegans*	**X**
Ducks			Crested Pigeon	*Ocyphaps lophotes*	
Blue-billed Duck	*Oxyura australis*				
Musk Duck	*Biziura lobata*	**X**	**Cockatoos and Parrots**		
Pacific Black Duck	*Anas superciliosa*	**X**	Red-tailed Black-	*Calyptorhynchus banksii*	**X**
Grey Teal	*Anas gracilis*		Carnaby's Black-	*Calyptorhynchus*	**X**
Chestnut Teal	*Anas castanea*		Baudin's Black-	*Calyptorhynchus*	**X**
Hardhead	*Aythya australis*		Galah	*Cacatua roseicapilla*	
			Western Corella	*Cacatua pastinator*	
Grebes			Purple-crowned Lorikeet	*Glossopsitta*	**X**
Australasian Grebe	*Tachybaptus*		Regent Parrot	*Polytelis anthopeplus*	
Hoary-headed Grebe	*Poliocephalus*		Western Rosella	*Platycercus icterotis*	**X**
Great Crested Grebe	*Podiceps cristatus*		Australian Ringneck	*Barnardius zonarius*	**X**
			Red-capped Parrot	*Purpureicephalus*	**X**
Darters and			Elegant Parrot	*Neophema elegans*	
Darter	*Anhinga melanogaster*				
Little Pied Cormorant	*Phalacrocorax*		**Cuckoos**		
Pied Cormorant	*Phalacrocorax varius*		Pallid Cuckoo	*Cuculus pallidus*	**X**
Little Black Cormorant	*Phalacrocorax*		Fan-tailed Cuckoo	*Cacomantis*	**X**
			Horsfield's Bronze-	*Chrysococcyx basalis*	**X**
Herons, Egrets etc			Shining Bronze-Cuckoo	*Chrysococcyx lucidus*	**X**
White-faced Heron	*Egretta novaehollandiae*				
White-necked Heron	*Ardea pacifica*		**Owls, nightjars and**		
Great Egret	*Ardea alba*		Southern Boobook	*Ninox novaeseelandiae*	**X**
Cattle Egret	*Ardea ibis*		Masked Owl	*Tyto novaehollandiae*	
Nankeen Night Heron	*Nycticorax caledonicus*		Barn Owl	*Tyto alba*	
Australasian Bittern	*Botaurus poiciloptilus*		Tawny Frogmouth	*Podargus strigoides*	**X**
Yellow-billed Spoonbill	*Platalea flavipes*		Australian Owlet-nightjar	*Aegotheles cristatus*	**X**
Hawks, Eagles &			**Kingfishers & Bee-**		
Square-tailed Kite	*Lophoictinia isura*	**X**	Laughing Kookaburra	*Dacelo novaeguineae*	**X**
Whistling Kite	*Haliastur sphenurus*		Sacred Kingfisher	*Todirhamphus sanctus*	**X**
Swamp Harrier	*Circus approximans*	**X**	Rainbow Bee-eater	*Merops ornatus*	
Brown Goshawk	*Accipiter fasciatus*				

Collared Sparrowhawk	*Accipiter cirrhocephalus*		**Treecreepers**		
Wedge-tailed Eagle	*Aquila audax*		Rufous Treecreeper	*Climacteris rufa*	X
Little Eagle	*Hieraaetus morphnoides*				
Brown Falcon	*Falco berigora*		**Fairy-wrens,**		
Australian Hobby	*Falco longipennis*		Splendid Fairy-wren	*Malurus splendens*	X
Peregrine Falcon	*Falco peregrinus*		Red-winged Fairy-wren	*Malurus elegans*	
	Accipiter sp.	X	Spotted Pardalote	*Pardalotus punctatus*	X
Rails, Crakes, Coots			Striated Pardalote	*Pardalotus striatus*	X
Buff-banded Rail	*Gallirallus philippensis*		White-browed	*Sericornis frontalis*	X
Baillon's Crake	*Porzana pusilla*		Weebill	*Smicrornis brevirostris*	X
Australian Spotted	*Porzana fluminea*		Western Gerygone	*Gerygone fusca*	X
Spotless Crake	*Porzana tabuensis*				
Purple Swamphen	*Porphyrio porphyrio*	X	**Thornbills**		
Dusky Moorhen	*Gallinula tenebrosa*		Inland Thornbill	*Acanthiza albiventris*	X
Black-tailed Native-	*Gallinula ventralis*		Western Thornbill	*Acanthiza inornata*	X
Eurasian Coot	*Fulica atra*	X	Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	X
Wattlebirds			**Cuckoo-shrikes &**		
Western Wattlebird	*Anthochaera lunulata*		Black-faced Cuckoo-	*Coracina*	X
Red Wattlebird	*Anthochaera*	X	White-winged Triller	*Lalage sueurii*	X
Honeyeaters and			**Woodswallows**		
Singing Honeyeater	*Lichenostomus*	X	Black-faced	*Artamus cinereus*	
White-eared	*Lichenostomus leucotis*		Dusky Woodswallow	*Artamus cyanopterus*	X
Yellow-plumed	*Lichenostomus ornatus*	X			
Brown-headed	*Melithreptus brevirostris*		**Butcherbirds, Magpies**		
White-naped	*Melithreptus lunatus*	X	Grey Butcherbird	*Cracticus torquatus*	
Brown Honeyeater	*Lichmera indistincta*	X	Australian Magpie	*Gymnorhina tibicen*	X
New Holland	*Phylidonyris*	X	Grey Currawong	*Strepera versicolor*	X
White-cheeked	*Phylidonyris nigra*	X			
Tawny-crowned	*Phylidonyris melanops*		**Ravens and Crows**		
Western Spinebill	*Acanthorhynchus*	X	Australian Raven	*Corvus coronoides*	X
White-fronted Chat	*Ephthianura albifrons*	X			
			Pipits and Finches		
Robins			Richard's Pipit	*Anthus novaeseelandiae*	X
Jacky Winter	*Microeca fascinans*	X	Red-eared Firetail	*Stagonopleura oculata*	X
Scarlet Robin	*Petroica boodang*	X			
Red-capped Robin	*Petroica goodenovii*		**Mistletoebirds**		
Hooded Robin	*Melanodryas cucullata*		Mistletoebird	*Dicaeum hirundinaceum*	
Western Yellow Robin	*Eopsaltria griseogularis*	X			
White-breasted Robin	*Eopsaltria georgiana*	X	**Swallows and Martins**		
			Welcome Swallow	*Hirundo neoxena*	X
Sittelas			Tree Martin	*Hirundo nigricans*	
Varied Sittella	*Daphoenositta*	X	Fairy Martin	*Hirundo ariel*	
Shrike-tits, Whistlers			**Other**		
Crested Shrike-tit	*Falcunculus frontatus*		Clamorous Reed-	*Acrocephalus*	
Golden Whistler	*Pachycephala pectoralis*	X	Little Grassbird	*Megalurus gramineus*	
Rufous Whistler	*Pachycephala rufiventris*	X	Rufous Songlark	*Cinclorhamphus*	
Grey Shrike-thrush	*Colluricincla harmonica*	X	Brown Songlark	*Cinclorhamphus cruralis*	
			Silvereye	*Zosterops lateralis*	X
Flycatchers, Fantails					
Restless Flycatcher	*Myiagra inquieta*	X			
Magpie-lark	*Grallina cyanoleuca*				
Grey Fantail	*Rhipidura albiscapa*	X			
Willie Wagtail	*Rhipidura leucophrys*	X			