# Woylie Symposium

## Recent Woylie Declines
## Situation Overview and Diagnosis Progress

Thursday 14th February 2008, Murdoch University

## Abstracts

Photo courtesy of Sabrina Trocini

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# Woylie Symposium

## Recent Woylie Declines - Situation Overview and Diagnosis Progress

Thursday 14th February 2008,

Murdoch University, Vet Clinical Science Building VCS1.106

## Program Overview

*To ensure we address as many of the issues as possible abstracts will be made available, regarding each of the presentations. This will allow participants to be aware of the general issues and research to date, as well as allowing discussions to be specific and direct.*

*After each presentation approximately 5 minutes will be allocated for questions.*

*The Symposium will be chaired by Keith Morris to ensure all speakers adhere to the allocated time.*

| Time | Subject | Presenter | Duration (min) *excluding question time* |
|---|---|---|---|
| 0830 | Welcome and Introduction | Keiran McNamara *Director General DEC* | 5 |
| | **WOYLIE POPULATION DECLINES SITUATION OVERVIEW** The Big Picture | | |
| 0835 | Conservation Status Review | Christine Freegard | 10 |
| 0850 | Western Shield Overview | Peter Orell | 10 |
| 0905 | South Australia Situation | David Armstrong | 10 |
| 0920 | Australian Wildlife Conservancy Woylie Populations | Jacqui Richards | 10 |
| 0935 | Dryandra Woylie Overview | Nicky Marlow | 10 |
| | **RESEARCH PROJECT** | | |
| 0950 | Woylie Conservation Research Project Overview | Adrian Wayne | 10 |
| | **POPULATION MONITORING** | | |
| 1005 | Upper Warren Population Monitoring | Julia Wayne | 10 |
| | **META-ANALYSIS** | | |
| 1020 | Population Trends (Temporal)<br>Demographics<br>Other Species | John Henstridge | 10 |
| 1030 | Population Trends (Spatial)<br>Direct Human Interference<br>Fire<br>Climate | Adrian Wayne | 10 |
| 1045 | **MORNING TEA** | | |
| | **POPULATION COMPARISON STUDY** | | |
| 1115 | Overview | Adrian Wayne | 10 |
| 1130 | Demographics | Colin Ward | 10 |
| 1145 | Survival and Mortality | Adrian Wayne | 10 |
| 1200 | Predators | Marika Maxwell | 10 |

| | | | |
|---|---|---|---|
| 1215 | Resources | Kerry Rodda (PhD) | 10 |
| 1230 | LUNCH | | |
| | **DISEASE** | | |
| 1330 | Rationale to the approach to disease investigation | Adrian Wayne | 5 |
| 1340 | Field health and disease sampling | Adrian Wayne | 10 |
| 1355 | Clinical, Pathology & Haematology | Paul Eden | 10 |
| 1410 | Trypanosomes | Andy Smith / Susana Averis | 10 |
| 1425 | Toxoplasma | Nevi Parameswaran (PhD) | 10 |
| 1440 | Endoparasites | Unaiza Parkar (PhD) | 10 |
| 1455 | Ectoparasites | Halina Burmej (PhD) | 10 |
| 1510 | Bacteriology | Yazid Abdad (PhD) | 10 |
| 1525 | Identification of potential diseases and risk assessment in relation to recent woylie declines | Carlo Pacioni (PhD) | 10 |
| 1540 | Disease Synthesis | Andy Thompson | 10 |
| 1555 | AFTERNOON TEA | | |
| | **CONSERVATION GENETICS** | | |
| 1625 | Conservation Genetics | Carlo Pacioni (PhD) | 10 |
| | **SUMMARY OF PRELIMINARY FINDINGS** | | |
| 1640 | Summary of progress | Adrian Wayne | 10 |
| 1655 | Summary of key findings | | 10 |
| 1710 | Speculative hypothesis of the cause(s) for the recent woylie declines based on preliminary information. | | 10 |
| 1725 | Close | Keith Morris | 5 |

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# Woylie Conservation Workshop

## Where To From Here?

Friday 15th February 2008

Murdoch University, Veterinary and Biomedical Science Education Centre, VBSEC 3.106

**Agenda**

| Time | Subject | Presenter | Duration |
|---|---|---|---|
| 0900 | Welcome | TBA | 10min |
| 0910 | General House Keeping | Peter Mawson | 10min |
| | **WCRP: INTERIM AND PRELIMINARY RESEARCH AND MANAGEMENT RECOMMENDATIONS** | | |
| 0920 | Recovery Plan | Peter Mawson | 20min |
| 0950 | Research Recommendations | Adrian Wayne | 20min |
| **1020** | **MORNING TEA** | | |
| 1050 | Management Recommendations | Peter Orell | 20min |
| 1120 | Species Prognosis | Adrian Wayne | 10min |
| 1140 | General Discussion | Peter Mawson | 20min |
| **1200** | **LUNCH** | | |
| | **EXTERNAL REVIEWERS THOUGHTS** | | |
| 1300 | Mesopredator Review Panel | Andrew Burbidge/Dave Choquenot/Peter Jarman | 10min |
| 1310 | Disease Reviewers | Rupert Woods / David Obendorf | 10min |
| 1320 | Project Comparison -Tasmanian Devil | Steve Smith | 10min |
| | **PRIORITIES** | | |
| 1330 | Participants will be split up into two groups to discuss priorities:<br><br>Group 1: Researchers<br>▪ Research Priorities - 40 min<br>▪ Management Priorities - 20 min<br><br>Group 2: Managers<br>▪ Management Priorities - 40 min<br>▪ Research Priorities – 20 min | Chair Group 1 - Researchers<br>Keith Morris<br><br>Chair Group 2 - Managers<br>Ian Wilson | 1hr |
| 1430 | Regroup for further development and dialogue | Peter Mawson | 45min |
| **1515** | **AFTERNOON TEA** | | |
| | **STRATEGIES** | | |
| 1530 | Group 1: Researchers<br>▪ Research Strategies<br><br>Group 2: Managers<br>▪ Management Strategies | Chair Group 1 - Researchers<br>Keith Morris<br><br>Chair Group 2 - Managers<br>Ian Wilson | 1hr |
| 1630 | Regroup for further development and agreement | Peter Mawson | 45min |
| 1700 | Wrap-up and Close | Adrian Wayne | 30min |

*Note: Each presentation will be followed by 10 minutes of questions from the floor.*

# Woylie Population Declines Situation Overview

## Conservation Status Review

*Christine Freegard*
*Department of Environment and Conservation*

### Abstract

There are very few examples where a species has been removed from a list of threatened species due to conservation efforts. An example of such a species is the woylie, *Bettongia penicillata ogilbyi*, which was removed from Western Australian, national and international lists in 1996, following the successful implementation of the species' recovery plan. Since downgrading of its conservation status (Start *et al.* 1998), the woylie has been considered conservation dependent. Conservation efforts have continued, primarily in the form of fox baiting but also monitoring to identify trends in distribution and abundance, and translocation to help restore ecosystem function and further secure the conservation status of the species.

Recent observations of a decline in abundance of the species and a resulting review of the conservation status of the species have shown the value of these continued conservation efforts and ongoing monitoring programs. Results of the monitoring programs showed that the species underwent a rapid decline between 2001 and 2006, reducing the population by approximately 75% to around 10 000 individuals. The cause/s for this population reduction are unknown but have been under investigation. The species now qualifies for listing as Endangered using IUCN criteria, and was listed under Western Australian legislation on 22 January 2008.

## Western Shield Overview

*Peter Orell*
*Department of Environment and Conservation*

### Abstract

Fauna recovery mediated by fox baiting has been demonstrated at a number of sites in south west Western Australia since 1982 and led to the launch of Western Shield in 1996. Over 40 survey sites have been established to monitor the response of native fauna to fox control and native fauna translocations have also been undertaken to designated 'fauna reconstruction sites' and other locations.

The Woylie was one of the first species to show a positive and dramatic response to fox control and has been a target species for monitoring and the most widely translocated species. Three extant populations have survived in Western Australia: Tutanning Nature Reserve, Dryandra Woodland and the Upper Warren. All of these populations have undergone dramatic recovery as a result of fox control and equally dramatic declines. Trap capture rates have peaked at up to 75% but all have declined to less than 7.5% and currently persist at low levels.

Fifty translocations of Woylies have occurred in Western Australia. Twenty four translocations have occurred on Department of Environment and Conservation (DEC) managed land since 1996 and fourteen occurred on Western Shield monitoring sites. At least 11 translocated populations are persisting at low densities (less than 7.5% capture rates). Two of these populations (Batalling Forest Block and Boyagin Nature Reserve) have peaked at over 40% capture rates and then declined but still persist. Nine translocated populations have not been detectable through trapping surveys for two years or more. Seven translocated populations have not been monitored for two years or more and their status is unkown.

The data and information provided demonstrates the value of standardized long term monitoring of multiple sites by trained personnel in affording the capacity to assess the status of fauna populations.

# South Australia Situation

*David Armstrong*
*Department of Environment and Heritage, South Australia*

## Abstract

There are currently three viable wild populations of woylies in South Australia. Two are on off-shore islands. Wedge Island, just under 1,000 hectares, approximately 50 kms south-east of Port Lincoln and the much larger 3,500 hectare St Peter Island 10 kms south of Ceduna. Both were established in the 1980's from captive stock descended from a small group transferred from Perth Zoo during the mid 1970's. The third and most genetically diverse population was established within a now fenced 2,000 hectare peninsula at Venus Bay in 1994, through the translocation of 67 woylies from Dryandra, as part of the Woylie Recovery program, which previously led to the improvement in conservation rating of the species, from Endangered to Conservation dependant.

Animals from all three populations have been used in several reintroduction attempts, but all have basically failed. These include Yathong Nature Reserve (October 2001) in NSW, the Flinders Ranges (1999-2001) and Lincoln (1999-2001) National Parks in SA.

Attempts were made during 1994-95 to improve the genetics of the two island populations by adding small numbers (10-15) Dryandra woylies. These were also largely failures as the majority of the new animals died within two months of release, many within a short distance of the release sight. Possibly the resident animals aggressively defended their territories, preventing the newcomers from settling well enough to discover and exploit available food resources.

The most recent monitoring of the two island populations, during the second half of 2006, to collect blood and tissue samples for use in the research into the collapse of the mainland populations, indicated little change in numbers, which remain high.

The Venus Bay population reached extremely high numbers from 2003 to 2005 but subsequently suffered a sudden dramatic crash in mid 2006, following a slow decline over the previous 12 months. Regular monitoring by trapping and spotlight counts along oat trails indicated a drop of at least 90%, with most occurring between monitoring in March/April and early July. The current theory is that as emigration was not possible, the woylies effectively being contained in a 20 square kilometre cage, they had eventually over exploited available food resources, and that this was exacerbated by a series of six frosts in a week during June.

As the cause of the crash was unclear at the time, 53 woylies were trapped and transferred to Monarto Zoo for safe keeping and health checks. 30 of these have since been reintroduced successfully. As cat predation was considered to be a possible contributing factor and even more critical with low woylie numbers, a concentrated cat trapping program was undertaken and 20 feral cats removed over the following three months.

Quarterly monitoring by trapping and spotlighting has continued since the crash in mid 2006. A slow recovery appears to be beginning to accelerate, judging from the most recent monitoring during December and January. Hopefully the current figures will be maintained through the coming year.

Future management of woylies in SA is unclear, but two possibilities may be considered

- a second attempt at reintroduction to Lincoln National Park, which is currently being investigated
- Movement of woylies from Venus Bay to St Peter, or Wedge Islands to improve the genetics of the island populations. Obviously dependent on continued recovery of the Venus Bay population.

# The Status of Woylies at Australian Wildlife Conservancy Wildlife Sanctuaries

*Dr Jacqui Richards*
*Australian Wildlife Conservancy, Perth*

**Abstract**
The Australian Wildlife Conservancy (AWC) is an independent non-profit organisation dedicated to the conservation of Australia's threatened biodiversity. AWC's strategy for conserving all Australian animal species and the habitats in which they live includes: establishing wildlife sanctuaries, implementing practical, on-ground conservation programs, conducting scientific research, and public education. AWC currently owns and manages 16 wildlife sanctuaries covering 1.8 million hectares in Australia.

The woylie *Bettongia penicillata* was reintroduced to three of these sanctuaries. Forty animals were reintroduced to Karakamia Wildlife Sanctuary, a 265 ha fenced area near Chidlow in Western Australia, between 1994 and 2004. Over 500 woylies have since been transferred from Karakamia to other reintroduction sites in Australia.

Over 300 woylies were transferred from Karakamia to the 2,000 ha Paruna Wildlife Sanctuary in the nearby Avon Valley between 2000 and 2006. Paruna functions as a corridor running between the Department of Environment and Conservation's (DEC) Walyunga and Avon Valley National Parks. Foxes are controlled with 1080 baiting but there has been no means of controlling feral cats. Reintroductions have been successful in the short-term (first few months) but the woylie population has experienced lower then expected rates of survival and recruitment in the long-term.

At Scotia Wildlife Sanctuary in western New South Wales 190 woylies were reintroduced to a 4,000 ha enclosure free from introduced predators in 2004 and 2005. The population declined in the first two years during a period of drought, with no successful breeding recorded. Trapping sessions throughout 2007 have recorded new woylies and females with nearly independent pouch young after more rainfall that year. There is some indication of intraspecific competition between woylies and reintroduced boodies *B. lesueur* based on studies of microhabitat use at Scotia.

The eradication of introduced predators is likely to be a key factor contributing to the success of woylie reintroductions, while drought and both intra and interspecific competition may play a role in limiting woylie population increase.

# Dryandra Woylie Overview

*Dr Nicola Marlow*
*Department of Environment and Conservation*

**Abstract not provided. [Excerpt from draft WCRP Progress Report Section 4.6 PCS expansion – Inclusions of woylie data from external program]**

*Marnie Swinburn, Adrian Wayne, Nicola Marlow*
*Department of Environment and Conservation*

**Dryandra Nature Reserve:**
Site history: Dryandra supports one of the three last remaining natural (indigenous) woylie populations. The woylie capture rate has declined by 93% (2000 – 2006).
Reason for inclusion: The cause(s) of this decline are unknown making the Dryandra population of interest to this study.

*Data/Sample collection: Data and samples were collected on 21st-24th November 2006 by Nicky Marlow and the meso-predator research project team. Western Shield trapping data is available but not yet analysed. Pathology samples were collected from dead radio-collared woylies sent to Murdoch University for necropsy to assist in the determination of factors associated with the mortality.*

# Research Project

## WCRP Overview

*Dr Adrian Wayne*
*Department of Environment and Conservation*

### Abstract

The history and recent changes in abundance and distribution of woylies is briefly summarised. The principal aim of the woylie conservation research project (WCRP) is to determine the causal factors responsible for the recent woylie declines in southwestern Australia. Using a diagnosis framework based on the 'declining population paradigm' (*sensu lato* Caughley, 1994) and a classification of possible agents of decline into resources, predators, disease and direct human interference, the WCRP focussed on determining the causes in the Upper Warren region, east of Manjimup. The WCRP has been organised into three major components; 1) Meta-analysis, 2) Upper Warren Fauna Monitoring, and 3) Population Comparison Study (PCS). Effective and extensive collaborations with numerous agencies and experts have been critical to the effectiveness of this project. The nature of these collaborations, the project management framework, and project milestones are very briefly summarised. The context and purpose of this report is discussed.

### Research Approach Summary

The Department of Environment and Conservation (DEC) has established a comprehensive and collaborative project to diagnose the cause(s) of recent woylie declines.

The principal aims of the woylie conservation research project (WCRP) are;

a) Determine the causal factors responsible for the recent woylie declines in southwestern Australia;

b) Identify the management required to ameliorate these declines; and,

c) Develop mammal monitoring protocols that will better inform factors associated with future changes in population abundances.

Determining the cause(s) of population or species decline is notoriously difficult (e.g. Caughley, 1994; Caughley and Gunn, 1996; Peery *et al.*, 2004). Common challenges identified in the literature include;

i) Overcoming the complexity due to the likelihood of multiple factors being involved either simultaneously or sequentially.

ii) The need to separate independent effects to avoid the confounding between factors.

iii) Discriminating between causes, effects, and associations (coincidental or otherwise).

iv) Detecting reduced survival or productivity caused by environmental contaminants or disease is rarely straightforward.

v) The influence of habitat upon the decline of a species is particularly difficult to diagnose and that a safer preliminary hypothesis would conjecture that a species ends up, not in the habitat most favourable to it, but in the habitat least favourable to the agent of decline.

vi) The need to reduce some causal agents, such as habitat modification, down to the individual processes and specific effects (e.g. resource elements such as food and shelter).

vii) Avoiding the seduction of the obvious and the easy to measure. Not all agents are so conspicuous, which in no way lessens their importance.

Scientific rigour is, therefore, critical to the success of endeavours to identify the cause(s) of a species' decline. Based on the 'declining population paradigm' and related scientific approaches (e.g. Caughley, 1994; Caughley and Gunn, 1996; Peery *et al.,* 2004) the diagnosis framework used to investigate the recent woylie declines is;

1. Confirm that the population has declined.
2. Determine the spatial, temporal and demographic characteristics of the observed decline.
3. Understand the species' ecology.
4. Identify all potential causes.
5. Use circumstantial evidence to help shortlist the potential causes.
6. Seek direct evidence – test putative causes.
7. Given the evidence, determine the most appropriate conservation and management responses within an active adaptive management framework.

The WCRP uses a hypothetico-deductive approach (as recommended by Caughley, 1994) involving parallel lines of enquiry addressing the numerous possible agents of decline, most of which can be broadly classified into four major groups;

8. Resources – including food depletion and consequences of climate change, fire management, etc.
9. Predation – including native and introduced species, and effectiveness of current control measures.
10. Disease – including known and novel agents (viral, haemaparasites, endoparasites, ectoparasites, bacterial diseases, nutrition and toxicology).
11. Direct human interference – e.g. negative consequences of trapping (over-harvesting for translocations, disrupted breeding success, reduced condition, injuries, increased stress and susceptibility to other mortality factors).

The research has a specific focus on the Upper Warren region to concentrate existing resources in the one area where declines are current. Such a focus is expected to improve the chances of success and eliminate the potential confounding of differences in the factors being potentially at play elsewhere. Nonetheless, information from other woylie populations has been incorporated through collaborations with other research and monitoring wherever appropriate and possible.

The project has three major components that together, address the above diagnosis framework.

1) Upper Warren Fauna Monitoring – an enhancement and co-ordination of existing monitoring and research activities – that provides;

- six-monthly information up-dates on population change and associated characteristics at the regional scale and,
- a regional-scale means of collecting data on woylies and putative agents of decline to complement the finer-scaled population comparison study.

2) Meta-analysis of existing data sets to;

- Confirm that the declines are real
- Quantify the spatial, temporal and demographic characteristics of the woylie decline, which in turn will,
- Provide circumstantial evidence that will aid in the identification of the possible causes of decline.

3) Population Comparison Study (PCS) is a detailed investigation of woylies and the possible agents of decline. This principally involves six sites that support populations at different stages of decline;

- Declined populations now at low densities: Boyicup and Winnejup (Upper Warren Region)
- The last remaining moderate-density woylie populations in the Upper Warren region: Keninup, Warrup and Balban

- High-density and stable population - Karakamia Wildlife Sanctuary (50 km east of Perth), a fenced (i.e. closed) population

The five main lines of enquiry to be investigated at the population comparison study sites are;

- Woylie density and demographics
- Woylie survival and mortality
- Predators
- Resources
- Disease

More detail on the research approach and methodology is provided in the DEC Science Project Proposal (SPP 2007/02).

# Population Monitoring

## Upper Warren Fauna Monitoring

*Julia Wayne[1], Adrian Wayne[1], Ian Wilson[1]*
*Department of Environment and Conservation*

### Abstract

The Upper Warren Fauna Monitoring component of the Woylie Conservation Research Project comprised biannual monitoring of 11 key transects within the Upper Warren area. Detailed demographic data was collected for all mammal species caught, with the aim of monitoring population change across the region. In addition, detailed health checks of all woylie individuals were conducted and a variety of samples were collected from all mammal species to be used for analysis of health, disease, diet and genetics. Of the eleven transects ten have shown significant recent decline. It remains uncertain when the declines began in some areas due to a lack of data between 1998 and 2005. For areas within the Upper Warren where there is sufficient data, declines appear to have started from 2002 – 2006 and are still continuing. By 2007, the Upper Warren transect populations had undergone a 95% median decline. Nine out of 11 transects currently have 0-8% capture rates (i.e. 0-15% of their pre-decline capture rates). Woylies currently persist at high capture rates at only one transect (Keninup), which has not yet undergone a contemporary decline. The remaining transect (Warrup) currently supports moderate capture rates but appears to have undergone a decline whilst monitoring was not undertaken in this area, between 1998 and 2001. Continued monitoring of the latter two transects, in particular, on a biannual basis is recommended in order to detect the beginning of any decline in a timely manner to enable greatest extraction of information.

# Meta-analysis

## Meta-analysis overview

*Dr Adrian Wayne*
*Department of Environment and Conservation*

Meta-analyses of existing medium-sized mammal data from past and present research and monitoring was used to capitalise on the available data to determine and characterise the attributes and associations of woylie population change. This investigative approach was considered an efficient and potentially critically-important means of providing supporting circumstantial and associative evidence that directly assists in the diagnosis of the woylie declines. The meta-analyses at the Upper Warren regional scale have been addressed and are reported here. Meta-analyses at the southwestern Australian scale have not yet been systematically conducted. The framework for the Upper Warren region meta-analysis investigations included;

1) Fauna data aggregation from multiple isolated datasets into a centralised relational database to enable subsequent analyses (Section 3.2).
2) Assessment of whether the woylie capture rates are indicative of real woylie population declines (Volume 2. Appendix 1)
3) Temporal characterisation of the woylie population changes (Section 3.3)
4) Spatial characterisation (preliminary only) of the woylie population changes (Section 3.4)
5) Demographic changes associated with woylie population changes (Section 3.3), including;
   Sex ratio
   Age structure
   Weight
   Hindfoot length
   Condition index (biometric algorithm based on size and weight)
   Proportion of breeding adult females
6) Associative changes in other sympatric fauna. To date, only the medium-sized mammals for which there is readily available and directly comparable trapping data have been investigated (i.e. koomal, *Trichosurus vulpecula*; quenda, *Isoodon obesulus*; and chuditch, *Dasyurus geoffroii*). These represent potentially comparable resource competitors, similarly-sized prey species and a potential native predator of woylies (Section 3.3).
7) Direct human interference - principally whether there are possible population-scale effects of live trapping and live harvesting for translocations (Section 3.5).
8) Fire – i.e. whether woylie declines were associated with fire regime and/or history differences (Section 3.6).
9) Climate – i.e. whether woylie declines throughout the southwest were associated with the primary climate and weather attributes (Section 3.7)

Some of the meta-analyses (temporal, demographic and sympatric fauna associations) were conducted under contract with 'Data Analysis Australia' statistical consultants. These components are presented together in Section 3.3.

# Population change – temporal, demographics, other species

*Dr John Henstridge, Anna Munday, Shauna Trafalski, Rian Caccianiga*
*Data Analysis Australia Pty Ltd*
*97 Broadway, Nedlands, Western Australia 6009*

## Abstract

Cage trapping data on woylies collected through a number of studies between 1994 and 2007 at fifteen sites in the Upper Warren region was analysed to better understand population trends and in particular to test the hypothesis that the population is currently in decline. To the extent that this analysis used data from independent studies, it was a meta-analysis and needed to cope with significant variation in the quality and detail of the data. However the raw nightly trap data was used in all cases and the analysis used both linear regression and a generalised linear model approach with a "quasibinomial" error term to allow for the variation between studies. The trapping data provides statistically strong evidence that woylie numbers have been in decline since 2002. The data is less clear on what might be the cause of this decline. A significant positive correlation was found with trapping of quenda, but no strong association was found with koomal or chuditch. Inconsistent trends were observed in the proportion of males captured at each site and the condition indices showed no significant pattern with regards to time or site. Since almost all the woylies caught were adults (95%), little could be said about trends in population structure. Similarly, no significant patterns were found in their weights or size except for the expected sex and age differences.

# Population trends – spatial patterns of woylie decline

*Adrian Wayne, Colin Ward and Julia Wayne*
*Department of Environment and Conservation*

## Abstract

Spatial characterisation of the woylie declines is considered an important form of evidence that may be particularly powerful in assisting in the identification of key agents of decline. A rigorous spatial analysis has not yet been conducted. Expert assistance in spatial analysis is being sought to assist with this.

A superficial exploration of the data reveals the potential for a striking pattern to the declines. There appears to be a spatial progression of the decline, indicative of a front progressing through the region. The rate of spread appears somewhat limited, which if substantiated, could provide evidence that the agent(s) of decline may have some limited mobility.

Three central sites (Moopinup, Yackelup and Camelar) were the first sites to repeatedly catch no woylies, where previously high capture rates had been observed. The Perup Ecology Centre is approximately central to these sites (i.e. potentially "ground zero"). The declines roughly expanded outwards from this area, first to the south and then to the north. Winnejup is the exception to this pattern, declining relatively sooner than would be expected based on a declining radiation from a single point. Based on the patterns observed, the declines at Balban were predicted to occur in 2006/2007, 6-12 month before they happened. The opportunity of the anticipated declines was realised by incorporating this site in the PCS study (Chapter 4). It is also predicted on the same basis that Keninup will undergo a similar decline in 2008.

In some cases the declines began after the capture rates of woylies were particularly high. It is, therefore, also possible that there may a density-dependency relationship associated with the declines.

A more rigorous analysis of the spatial, temporal and density characteristics of the declines are clearly needed to establish whether the speculation derived from anecdotal observations can be verified.

# Direct human interference

*Julia Wayne and Ian Wilson*
*Department of Environment and Conservation*

## Abstract

Direct human interference was recognized as one of the potential factors influencing the decline of woylies in southwestern Australia.

Direct human interference covers a wide range of activities and factors including; trapping intensity, live harvest for translocation, trapping consequences (deaths, predations and pouch young intervention), illegal killing/harvesting, and road kills. This report focuses on trapping activities.

Despite the potential for significant impact, the results indicate that, in the Upper Warren region, human interference has not been a major contributing factor in the decline of woylie populations.

It is, however, important to continue to monitor these potential impacts through adequate and comprehensive recording of monitoring events, procedures and fates of individuals.

# Fire

*Julia Wayne, Adrian Wayne and Ian Wilson*
*Department of Environment and Conservation*

## Abstract

A number of fire history attributes were analysed in relation to woylie capture rates and extent of decline along the 11 Upper Warren Fauna Monitoring transects.

Corporate fire history data and District and Science Division fauna monitoring data were used in the analyses.

No relationships were found during these or previous analyses of fire history data and woylie capture rates and declines.

These are preliminary analyses only, and more sophisticated and rigorous analysis of the data is required to verify whether any temporal patterns or relationships exist.

# Climate

*Peter Orell*
*Department of Environment and Conservation*

## Abstract

Rainfall data from Bureau of Meteorology recording stations located near *Western Shield* fauna monitoring sites in southwestern Australia were plotted as annual, monthly, winter and summer rainfall with line plots for long-term averages as a reference. Visual comparison of the data with capture rates of woylies and other medium size mammals at fauna monitoring sites suggests that there may be a weak link with decline in rainfall and population decline in the lower rainfall sites in the wheatbelt but the link is less apparent in the higher rainfall sites in the jarrah forest. The evidence suggests that climate is not a primary causative agent in the decline of woylies at least in the Upper Warren region.

# Population Comparison Study

## Population Comparison Study Overview

*Dr Adrian Wayne*
*Department of Environment and Conservation*

### Introduction

The quickest and surest means to identifying the agent(s) of decline is to use a hypothetico-deductive approach (Caughley, 1994, Caughley and Gunn, 1996). The declining-population paradigm provides a framework by which this approach can be used. Comparisons between populations at different stages of decline provide strong associative evidence that can identify putative agent(s) of decline among the countless conceivable possibilities. The 'shortlist' of putative agents that result from this exercise can then be experimentally tested to robustly determine their role in a species decline.

The Population Comparison Study (PCS) component of the Woylie Conservation Research Project (WCRP), is therefore, the principal tool in the diagnosis of woylie decline. The section provides a brief overview of the design and details of the PCS common to its various components.

### PCS investigative components

The five investigative components of the PCS, examined differences between the woylie populations and the three major categories of putative agents of decline;

Woylie components

12. Woylie demographics
13. Woylie survival and mortality

Putative agents of decline

14. Predators
15. Resources
16. Disease

Together, these components provide an extensive and integrated enquiry into some of the mechanics possibly causing the woylie declines and the possible factors that may be associated.

### PCS sites

This is a more detailed and focused study designed to complement data collected from the broad-scale regional (Upper Warren) fauna monitoring program (Chapter 2). This study focused on the Upper Warren region where moderate woylie densities still existed and where declines were current. The five PCS sites in the Upper Warren region were associated with a subset of the 11 key monitoring transects (Figure 4.1.1) and provided replicated representation of contemporary population states across the region;

- Declined populations now at low densities: Boyicup and Winnejup
- The last remnant moderate-density populations: Keninup, Warrup and Balban (i.e. sites seemingly not yet affected and which have the potential to decline)

Karakamia Wildlife Sanctuary supports the last remaining high density woylie population. Managed and owned by the Australian Wildlife Conservancy and isolated from other woylie populations, the woylies at Karakamia are contained within 275 ha of jarrah/marri forest, bounded by a predator-proof fence (i.e. cat and fox free). Having been reintroduced to Karakamia in 1996, the woylie numbers rapidly expanded and have remained at relatively stable, high densities for about the last five years

(Trish Gardner, pers. comm.). Located approximately 50 km east of Perth, Karakamia provides a particularly powerful comparative site to the Upper Warren PCS sites.

### Site descriptions

The five Upper Warren PCS sites were located adjacent to some of the key fauna monitoring transects. The PCS site at Karakamia was approximately central to the property. In contrast to the transects used for regional fauna monitoring, the PCS research was site-based, using the trapping grids associated with the demographics component as the central points of reference. The predator and resources components necessitated studying sites outside these grids but remained closely associated with the trapping grids wherever possible.

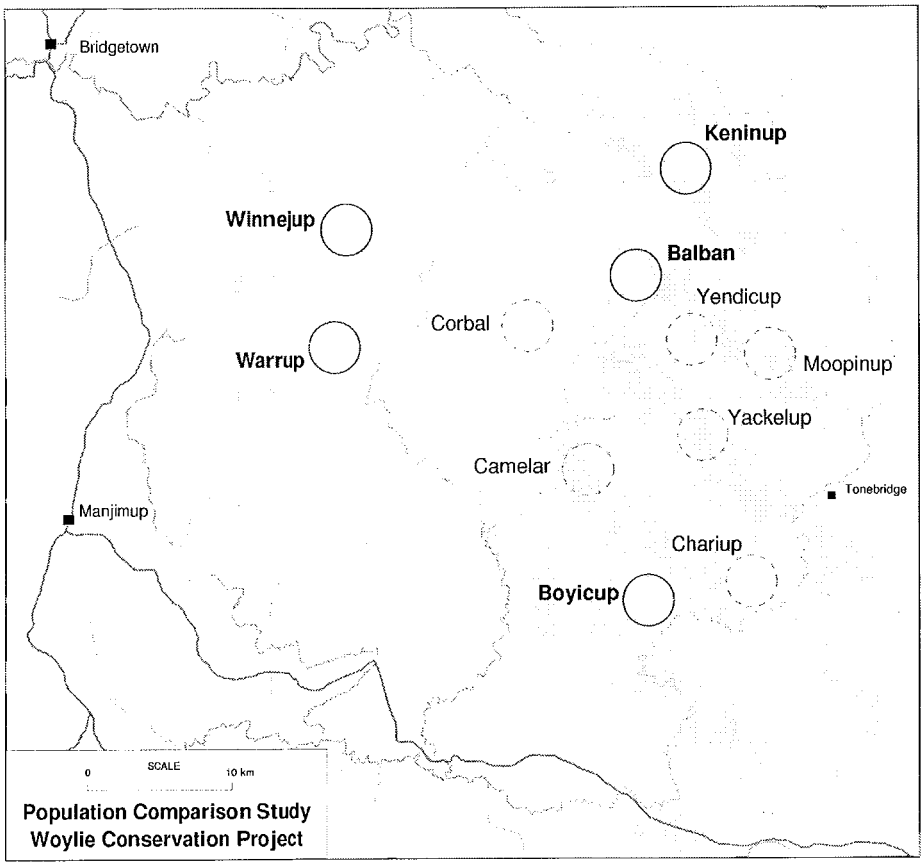



**Figure 4.1.1. The five principal Upper Warren areas (in bold) associated with the Population Comparison Study in relation to the other sites associated with the Upper Warren Fauna Monitoring program (plain text and dashed circles). The Karakamia PCS site is 50 km east of Perth, Western Australia.**

# Demographics

*Colin Ward[1], Adrian Wayne[1], Marika Maxwell[1], Chris Vellios[1], Jo Williams[2], Jacqui Richards[2], Trish Gardner[2], Brian Whittred[1], Zoe Clark[1], Bruce Ward[1], Julia Wayne[1], Marnie Swinburn[1], Jamie Flett[1], Alison Dugand[2]*
*[1]Department of Environment and Conservation, Manjimup*
*[2]Australian Wildlife Conservancy*

## Abstract

The biometric and demographic attributes of woylie populations were examined as part of the Population Comparison Study (PCS). The five PCS grids in the Upper Warren and the one PCS grid at Karakamia Wildlife Sanctuary were live cage-trapped every eight weeks for 12 months (Upper Warren sites, July 2006 - June 2007; Karakamia, September 2006 – July 2007). The capture rates of woylies declined at Balban (21% to 4%), remained relatively stable and high at Karakamia (mean 77%), stable and moderate at Keninup (mean 52%) and Warrup (mean 29%), and remained low, having declined in the preceding years at Winnejup (mean 3%) and Boyicup (mean 2%).

Preliminary exploration of the data included the temporal and spatial variation in demographic attributes of the six populations. Sex ratios differed substantially between the moderate-density sites in the Upper Warren (strongly male biased) and Karakamia (strongly female biased). The prevalence of subadults was low or absent at all sites but varied temporally at Karakamia. The proportion of adult females breeding within the Upper Warren region was similar between grids and over time (overall mean of 89%) but highly seasonal at Karakamia (4% in summer to 81% in spring). Adult woylies at Karakamia were smaller than at Upper Warren sites (means of 1070 g and 1368 g, respectively). More thorough and extensive analyses of the demographic attributes of these woylie populations are planned.

# Survival and mortality

*Colin Ward, Adrian Wayne, Bruce Ward, Marika Maxwell, Brian Whittred, Chris Vellios, Julia Wayne, Jamie Flett.*
*Department of Environment and Conservation, Manjimup*

## Abstract

A woylie 'search and rescue' exercise (June 2006) aimed to recover sick and dead woylies that might provide evidence for the recent declines. A total of 15 searches within four forest blocks in the Upper Warren (two supporting moderate woylie densities and two where woylies recently declined) involved 66 DEC personnel and volunteers and resulted in the recovery of 17 woylie bodies (all in advanced stages of decomposition) and no sick woylies, among other finds.

The survival and mortality of 58 radio-collared woylies were examined at the Upper Warren population comparison study sites, July 2006 – June 2007. Monitoring of the mortality-sensitive radio-collars was generally conducted every weekday. Radio-collars were removed from 16 individuals (two were later recollared) during the study and collars fell off another three animals (one of which was subsequently recollared). A total of 21 mortality events were observed. Forensic evidence collection included the body site, animal remains (in the field and lab), necropsy (when possible), DNA, and forensic odontology.

This study demonstrates that the woylie declines result in part, at least, from mortality and not loss through emigration. Survival was substantially reduced while the declines were occurring at Balban relative to other sites not presently declining or having previously declined. Predation/scavenging is proximately associated with 20 of the 21 mortalities observed. Preliminary evidence indicates that cats were primarily associated with 13 woylie mortalities, four with raptor and three with fox. Chuditch were implicated at nine carcasses (DNA and odontology) but were generally considered secondary scavengers based on the field evidence. Based on the available evidence it is hypothesized that the ultimate factor(s) related to woylie mortalities (and population declines) is not predator related, rather predators are exploiting a prey made more vulnerable by other factor(s).

# Predators

*Marika Maxwell[1], Adrian Wayne[1], Matthew Williams[2], Brian Whittred[1], Bruce Ward[1], Graeme Liddelow[1], Julia Wayne and Ian Wilson.*
*[1]Department of Environment and Conservation, Manjimup*
*[2]Department of Environment and Conservation, Kensington*

## Abstract

Predator activity and fox control operations in the Upper Warren region were investigated in relation to their possible association with recent woylie declines. Predator activity surveys, using sandpads, were conducted at the five Upper Warren Population Comparison Study sites during the 12 months commencing August 2006. The surveys were conducted immediately prior to and after the quarterly fox-baiting events performed by DEC as part of the '*Western Shield*' program and Donnelly District conservation management.

Cat activity was least at sites with stable and high woylie abundance and greatest at Balban where woylies were currently declining, however, overall there was no statistically significant difference between sites. The preliminary evidence remains consistent with cats potentially having a role in the decline of woylies, however, it is premature and there is insufficient data to determine the strength or nature of this association.

Fox activity was significantly different between sites and generally increased overtime, particularly from February 2007. Fox activity did not differ significantly between pre and post fox-baiting and whether this is related to baiting effectiveness is uncertain due to limitations in the data and statistical power. Fox control activities have been highly variable in the Upper Warren region since 1996. Although generally within the *Western Shield* baiting framework, intervals in the fox control program have frequently occurred. More strategic spatial and temporal considerations of fox control, particularly in relation to fox biology, would be expected to substantially improve effectiveness with negligible impact on existing resources.

Methodological considerations of sandpad monitoring are also addressed. Sandpads across the full length of forest tracks are preferable to the 1 $m^2$ plots previously used in the region and passive sandpads were found sufficient for measuring fox and cat activity. The activity indices (AI) derived from the sandpads closely matched the capture rates for other fauna species.

Ongoing monitoring of predator activity and/or abundance would be extremely valuable and highly recommended for the Upper Warren and elsewhere where predator control is conducted and fauna conservation is considered a high priority.

# Resources

*Kerry Rodda[1], Adrian Wayne[2], Marika Maxwell[2], Richard Robinson[2], Julie Fielder[2], Neale Bougher[2], Wendy Sicard[2]*
*[1]Murdoch University*
*[2]Department of Environment and Conservation*

## Abstract

The availability, abundance and suitability of resources such as food have been identified as a potential factor in woylie declines. While the woylie is known to be mycophagous (i.e. hypogeal and epigeal fungi are a major component of the diet), no comprehensive studies have been undertaken examining temporal and spatial variation in diet and food resource availability. The food resources component of the Woylie Conservation Research Project (WCRP) is being addressed through a collaborative PhD research project between Murdoch University and the Department of Environment and Conservation. Preliminary surveys investigating fungi availability and the methods for assessing sporocarp abundance have been conducted. Overall the preliminary results indicate that hypogeal fungi are not limiting at any of the Population Comparison Study sites where woylies have declined. However, more information regarding diet and feeding preferences is required. The aims, results so far and proposed future work are outlined in this report.

# Disease

## Rationale to the approach to disease investigation

*Adrian Wayne[1], Andrew Thompson[2], Keith Morris[1]*

*[1]Department of Environment and Conservation*

*[2]Murdoch University*

### Abstract

The Woylie Disease Reference Council (WDRC) was established to provide a rapid response to the need to identify the possible role(s) of disease in recent woylie declines. The WDRC was designed to efficiently and effectively co-ordinate the complexity of a multidisciplinary and highly collaborative disease investigation including haematology, bacteriology, parisitology virology, toxicology, pathology, nutrition and clinical investigations, epidemiology, and genetics. The broad objectives of the disease investigations associated with the Woylie Conservation Research Project (WCRP) are outlined. The rationale for the WCRP approach, its charter and membership are provided. The general strategies for the disease investigations are listed. In addition to successfully addressing the needs of the WCRP, this approach provides a valuable model for future investigations on disease-related wildlife issues in Western Australia.

## Field health and disease sampling

*Adrian Wayne, Marnie Swinburn, Colin Ward, Julia Wayne, Brian Whittred, Marika Maxwell, Chris Vellios*

*Department of Environment and Conservation, Manjimup'*

### Abstract

Routine health checks and sampling for disease analyses were conducted on all woylies on Upper Warren fauna monitoring transects and Population Comparison Study sites. The principal benefit of the health checks is the increased likelihood of the detection of individuals displaying clinical symptoms that may provide clues or direct evidence of factors associated with recent woylie declines. Preliminary exploration indicates substantial differences in the prevalence of eye and skin conditions. Whether these differences are related to observer differences or associated with woylie declines remains to be investigated.

The routine sampling in the field of blood, faeces and ectoparasites from woylies for disease investigations is summarized. The history of sampling of radio-collared individuals associated with the 'Population Comparison Study' of woylie survivorship and mortality is also briefly summarized. Samples from radio-collared cohorts include biometrics, health checks and disease samples.

# Clinical and Pathological Investigations into Woylie Declines in WA

*Paul Eden[1], Graeme Knowlws[2], Phil Clark[2]*
*[1]Perth Zoo*
*[2]Murdoch University*

## Abstract

Perth Zoo Veterinary Department has been contributing to investigations into disease aspects of population declines in woylies (*Bettongia pencillata ogilbyi*) since April 2006. This has involved contribution at a number of levels, including development and co-ordination of clinical sampling protocols, acting as a responder for veterinary management of sick or injured woylies found in the field, on-site participation in trapping programs including collection of diagnostic samples, and contribution of clinical knowledge and expertise to research programs investigating health and disease of woylies. Since becoming involved in this program, nine woylies have been presented to Perth Zoo Veterinary Department with various injuries. Five of these animals were euthanased and sent to Murdoch University for necropsy examination. Four animals were rehabilitated and returned to their original location. Three orphaned woylies were also reported to have developed Metabolic Bone Disease, two of which were euthanased. Perth Zoo veterinarians have also participated in examination of over 150 woylies from field sites in the Upper Warren region and at Karakamia sanctuary, including undertaking investigations into a chronic skin condition observed in woylies from the Upper Warren region. There has not been any conclusive evidence to indicate a particular underlying disease process based on findings of these examinations to date, however this process has contributed valuable information in regards to captive management and rehabilitation of woylies as well as providing relevant samples for other investigation projects in this research program.

Haematological investigations have been undertaken through the Murdoch University Clinical Pathology Laboratory, overseen by Dr Phil Clark. Preliminary data analysis has established a reference range for haematological parameters for woylies, and has identified two haemoparasites (Trypanosomes and Piroplasms), which have been investigated further and will be discussed later in this symposium. There have not been any indications of a primary haematological disease in samples analysed to date, however further data analysis, including incorporation of more recent data and analysis of data to investigate possible subclinical effects of other disease entities, is recommended.

From September 2005 to May 2007 officers from Department of Environment and Conservation and staff from Australian Wildlife Conservancy, submitted woylies found dead in monitored wild populations in south western Australia and Karakamia Sanctuary (Chidlow, WA), respectively, to the Murdoch University pathology department. Moribund animals were sent to Perth Zoo. Field data associated with each animal submitted, for example site description, weather, evidence of predators (scats, tracks, etc), and state of the remains, was recorded by the submitters.

Thirty one woylies were submitted for necropsy at Murdoch University. Thirteen were males, 16 female and two were unknown (because only limited body parts were found in the field). All animals submitted were adults. One female adult had a pouch young.
Veterinary pathologists from School of Veterinary and Biomedical Sciences, Murdoch University conducted all necropsies. The causes of death included

- skeletal fractures/ marked haemorrhage (7) (mostly suspected road accidents)
- skeletal fractures/haemorrhage with puncture (bite) wounds (6) (predation)
- cardiomyopathy / skeletal muscle myopathy (2)

In 11 cases the cause of death could not be determined grossly or by histopathology. All but one of the animals, whose cause of death was unknown, was in good body condition. For this reason, in conjunction with the unremarkable gross and microscopic findings, an acute process rather than chronic disease was the likely cause for the unknown mortalities.

Four animals presented moribund with marked focal dermal lesions and one had septic arthritis. Culture results indicated these were isolated cases of non-transmissible diseases.

# Trypanosomes

*Andrew Smith and Susana Averis*
*Murdoch University*

## Abstract

Trypanosomes of the order Kinetoplastida are introduced within a framework of their biological diversity and ecological impact. A morphologically distinct trypanosome species was detected by light microscopy at relatively high prevalence level of ~ 40% within the declining woylie population of the Upper Warren region. Initial investigation by light microscopy revealed no trypanosomes within the stable and fenced woylie population within the Karakamia Wildlife Sanctuary (operated by Australian Wildlife Conservancy). Further investigation employing molecular techniques revealed the trypanosome within the Upper Warren area to be novel based on analysis of the 18SrRNA gene, and also to be present within the Karakamia population regardless of initial microscopy results. The potential for trypanosomes to negatively impact on host fitness, either as a singular infection whilst the host experiences additional environmental stress, or as part of a concomitant infection together with *Toxoplasma gondii*, is discussed.

# *Toxoplasma*

*Nevi Parameswaran[1], Adrian Wayne[1], RC Andrew Thompson[1]*
*[1]Murdoch University*
*[2]Department of Environment and Conservation*

## Abstract

In response to the dramatic declines in woylie numbers, a number of woylies in the Upper Warren and in control populations outside of the Upper Warren were tested for *Toxoplasma* infection. Australian marsupials are susceptible to disease when infected with *Toxoplasma* and this protozoan parasite has been documented as being responsible for numerous deaths in captive marsupials. The commercially available modified agglutination test (MAT) was used to detect *Toxoplasma* antibodies in woylie sera. A number of variables were analyzed to determine if *Toxoplasma* infection is contributing to the decline in woylie numbers in the Upper Warren. The retrap rates of *Toxoplasma* seropositive woylies was observed to determine if *Toxoplasma* seropositive woylies survive. In addition, the *Toxoplasma* seroprevalence of woylies in the Upper Warren was compared with woylies located elsewhere, where populations were not declining. In March 2006, 153 woylies from the Upper Warren were tested for *Toxoplasma* antibodies, 9 were seropositive for *Toxoplasma*. In July to December of the same year, 143 more woylies from the Upper Warren were tested for *Toxoplasma*, 0 were seropositive. Although 6 out of the 9 seropositive woylies were retrapped none of these woylies were re-bled in July to December 2007. All sera samples from outside of the Upper Warren, including Karakamia and Dryandra, showed a zero seroprevalence of *Toxoplasma* in woylies. In addition to serology, tissues from dead woylies submitted for necropsy have been opportunistically tested for *Toxoplasma* DNA. Preliminary testing has found *Toxoplasma* DNA in the mammary gland of one woylie and in the brain of its pouch young. Combined data to date suggests *Toxoplasma* contributes to woylie deaths, however this is not conclusive. Future studies include further testing of tissues for *Toxoplasma* DNA from dead woylies.

# Endoparasites

*Unaiza Parkar[1], Alan Lymbery[1], Andy Smith[1], Aileen Elliot[1], Adrian Wayne[2] and Andrew Thompson[1]*
[1]*Murdoch University*
[2]*Department of Environment and Conservation, Manjimup*

## Abstract

Very little research has been published regarding the prevalence and the effects of gastrointestinal parasites on native wildlife in southwestern Australia. Faecal samples from woylie populations in the Upper Warren and Karakamia were screened using microscopy for the presence of gastro-intestinal parasites. Information regarding general condition was also collected. In the Upper Warren, over 80% of all animals sampled over a ten year period were infected with at least one parasite species, and there was little difference over time in either parasite prevalence or parasite diversity. For faecal samples collected from the Upper Warren and Karakamia populations in 2006, prevalence of parasitic infection was significantly greater in Upper Warren (100%) than in Karakamia (92%), due principally to a greater prevalence of nematode larvae in the faecal samples. Preliminary data found no significant correlation between the presence of gastro-intestinal parasites and the general condition of the woylies, although the analyses were hampered by a lack of resolving power in discriminating among parasite species.

# Ectoparasites

*Halina Burmej[1], Andrew Smith[1], Stan Fenwick[1], Keith Morris[2], Andrew Thompson[1] and Adrian Wayne[3]*
[1]*Murdoch University*
[2]*Department of Environment and Conservation, Woodvale*
[3]*Department of Environment and Conservation, Manjimup*

## Abstract

Ectoparasite burden has been correlated with a variety of negative effects in animals including low fecundity, poor juvenile growth rates and poor body condition. Outbreaks of vector-borne disease including trypanosomes have been implicated in the decline or extinction of endangered species elsewhere. There is little information about the importance of ectoparasites in Australian wildlife and the prevalence and impact of vector-borne pathogens. This presentation reports preliminary findings regarding the biodiversity of ectoparasites of the woylie and sympatric species. Future work will examine host-parasite dynamics and some of the potentially pathogenic organisms carried by woylie ectoparasites such as trypanosomes, and their mode of transmission.

# Bacteriology

*Yazid Abdad[1], Peter Adams[1], L. Pallant[1], Adrian Wayne[2], Halina Burmej[1], Stan Fenwick[1]*
[1]*Murdoch University*
[2]*Department of Environment and Conservation*

## Abstract

Faecal and ectoparasite samples from woylies and other co-habiting native species were analysed for the presence of the potential bacterial pathogens *Salmonella* and *Rickettsia.* This work constitutes a component of the disease investigations within the Woylie Conservation Research Project (WCRP) - diagnosing recent declines in woylie populations in southwestern Australia. The significance of the bacterial isolates will be discussed in relation to declining woylie populations and zoonotic infections.

# Identification of potential diseases and risk assessment in relation to recent woylie declines

*Carlo Pacioni[1], Trevor Ellis[1], Graeme Knowles[1] and Paul Eden[2].*

*[1]Murdoch University, Veterinary and biomedical sciences.*

*[2]Perth zoo.*

## Abstract

A qualitative approach has been used in order to assess disease risks related to declines in woylie populations in southwestern Australia. Certain disease agents have been recognised as critical to this risk assessment including: Chlamydiales, Macropod Herpesvirus, Orbivirus, Encephalomyocarditis virus and *Neospora caninum*.

Arrangements for the analysis of these diseases are in progress. The outcomes of this investigation are expected to assist the understanding of the woylie decline dynamics.

# Disease synthesis

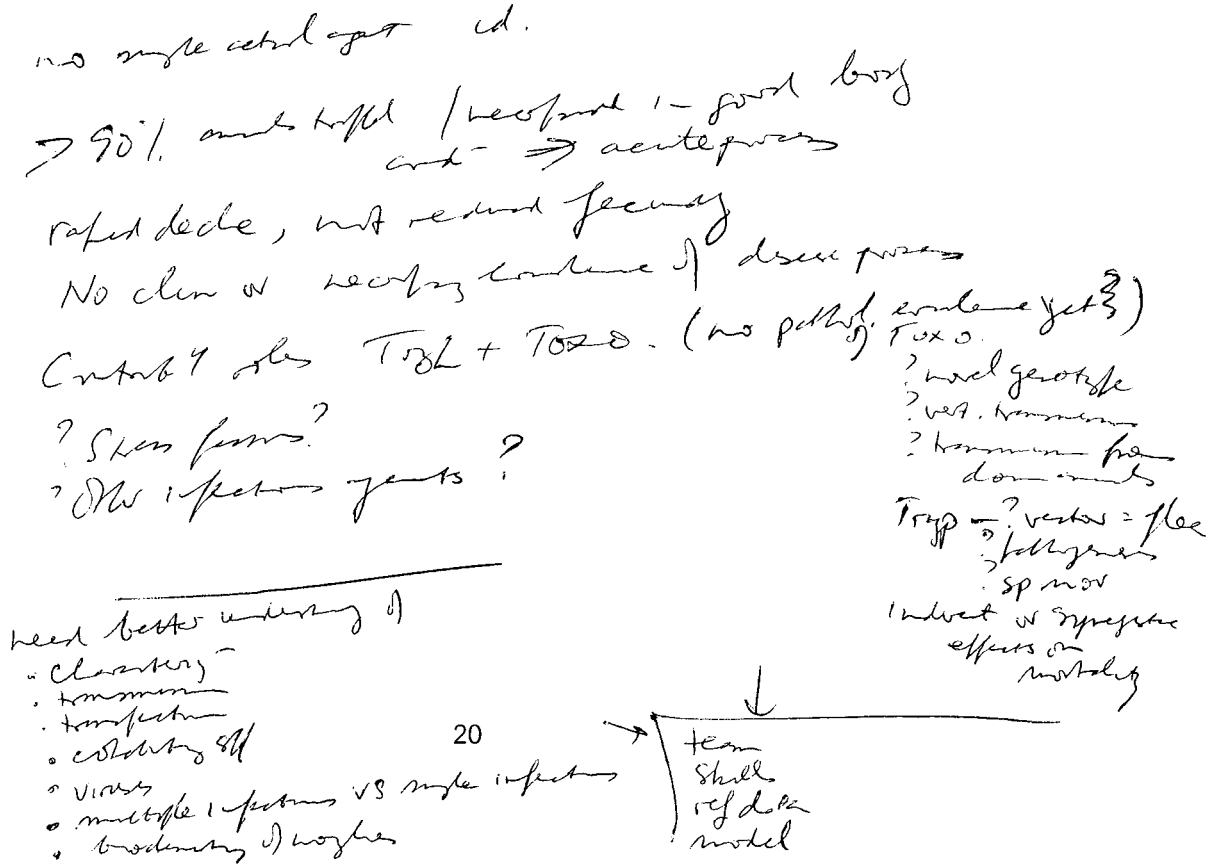
*Andrew Thompson[1], Graeme Knowles[1], Paul Eden[2]*

*[1]Murdoch University*

*[2]Perth Zoo*

## Abstract

The Woylie Disease Reference Council (WDRC) has made a number of key contributions relating to diagnosing the decline in the woylie populations of southwestern Australia. These have included the identification of possible pathogenic organisms from woylies sampled from the Upper Warren and Karakamia Wildlife Sanctuary, the development of an extensive range of databases and reference materials, and furthering the knowledge of the health and diseases of this species as a whole. A summary of the disease investigations thus far is presented, and suggestions made as to what further investigations are recommended.



# Conservation Genetics

## Conservation Genetics

*Carlo Pacioni[1], Peter Spencer[1] and Adrian Wayne[2]*
*[1]Murdoch University*
*[2]Department of Environment and Conservation, Manjimup*

### Abstract

A crucial component of the Woylie Conservation and Research Project (WCRP) is a sound understanding of the genetics of this species.

Our aims were to characterise woylie genetics and use this information to focus on outcomes that will be directly relevant to conservation and recovery of the species and to incorporate these findings into the demographic management of declining populations.

# Summary of Preliminary Findings

## Summary of Progress and Interim Findings

*Adrian Wayne*

*Department of Environment and Conservation*

### Abstract

The responses to the report of woylie declines in the Upper Warren included an initial situation assessment of woylie populations throughout the southwest, an early-response workshop, the establishment of the Woylie Conservation Steering Group and the development of the Woylie Conservation Research Project (WCRP). Using a decline diagnosis framework broadly based on the 'declining-population paradigm, the WCRP consists of three major components; I) Upper Warren fauna monitoring that built on, enhanced and co-ordinated previously independent existing activities, II) Meta-analysis of existing datasets that were aggregated into a single database, and III) a population comparison study (PCS) designed to discriminate factors and attributes associated with contemporary declines. The PCS has five main lines of enquiry; a) woylie density and demographics, b) woylie survival and mortality, and investigations into the key putative agents of decline, c) predators, d) resources, and e) disease.

Although it remains premature to identify the possible cause(s) of the woylie declines, the preliminary results can provide some early hints regarding what ongoing work is likely to suggest might be the likely agents of decline. Factors that are not probably the primary agents of decline include habitat loss / modification, fire, direct human interference from trapping and resources including food. Climate may be associated with woylie declines at Venus Bay Peninsula (VBP), South Australia and cannot be ruled out as a factor in Western Australia, but seems unlikely for the Upper Warren populations at least. Given the lack of fox activity or density monitoring data associated with most of the observed woylie declines it is not possible to determine whether they may be a major agent of decline. This is, however, considered unlikely for the Upper Warren region given that during the WCRP, foxes only accounted for 15% of the implicated primary predators/scavengers associated with observed mortalities and none of the mortalities at the Balban PCS site (which underwent a >80% decline in 12 months) were attributed to foxes.

The rapid and substantial woylie declines are driven at least by increased adult mortality. Emigration of animals elsewhere is not supported by the evidence. Whether recruitment into the adult (breeding) population is involved in the declines can not yet be established, however, the preliminary exploration of the data suggests breeding rates (prevalence of pouch-young) are not associated with the declines.

The leading speculative hypothesis (i.e. untested) for the cause(s) of the declines is presented. In summary, multiple interactive factors are expected responsible, with disease considered the most likely primary and ultimate agent of decline. The symptoms and unequivocal confirmation of the disease and the related interacting factors remain elusive at this stage, although some key suspects have been identified including *Toxoplasma*, *Trypanosoma sp. nov.*, possible synergistic effects between the two parasites and the involvement of stressors that may trigger the disease. Other infective agents may also be involved. As a consequence of the disease(s), opportunistic and exploitative predation/scavenging, predominantly by cats, are likely the most proximately-related factor associated with the deaths of the woylies. Whether the predation/scavenging occurs on moribund or dead animals that would die regardless, or whether in the absence of predation in general, the woylies would otherwise recover and survive remains unknown.