Endeavour Veterinary Ecology Pty Ltd

FINAL TECHNICAL REPORT

# MORETON BAY RAIL KOALA MANAGEMENT PROGRAM

# Moreton Bay Rail

# Koala Management Program

(Koala Tagging and Monitoring Program/
Koala Translocation/AKHO-CM/GOSMP)

# Final Technical Report



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**Cover images:**

Top image: Koala *Poppy* in the free-range enclosure at Toorbul in November 2014
Bottom image: A Redcliffe Peninsula Line train passing fauna culvert F3 at Kippa-Ring

**Plate 1**: Koala *Silk* at the Amcor site after her first veterinary examination in December, 2013. She was one of the original *Chlamydia* vaccine trial animals.

# EXECUTIVE SUMMARY


## Key points

- All key objectives achieved with excellent success - no koala death or injury during vegetation clearing
- Regulatory and ethical obligations to protect and conserve koalas fulfilled
- Community stakeholder expectations met and exceeded
- Considerable collateral benefit to body of scientific knowledge on koalas
- Blueprint for future management of koalas and other significant wildlife

# Executive Summary

## Introduction

The 13km Moreton Bay Rail (MBR) (now the *Redcliffe Peninsula Line*) corridor passes through areas of significant remnant koala habitat between Petrie in the western extent and Kippa-Ring in the east. A koala management program was implemented well prior to construction works to satisfy legislative requirements and meet community expectations regarding protection of koalas. The program commenced koala captures in March 2013 some 10 months prior to the commencement of vegetation clearing, and was nominally terminated on 30th June, 2016, although some koala monitoring continued until early 2017 under another program of works. During that time, 503 koalas were captured and given veterinary examinations, with most fitted with telemetry devices and monitored after release back into the wild.

The aims of the program were to minimise the risk of death or injury to koalas during construction works, to provide scientific data to inform and support mitigation works, and to offset some of the residual impacts of the rail project on the koala population through an holistic package of measures. These included disease treatment and control, support of scientific research on koalas, and supporting the first field trial of a number of new vaccines to combat chlamydial disease in koalas. This program was referred to as the *Koala Tagging and Monitoring Program (KTMP).* A program of translocation for koalas living in severely impacted habitat remnants was conducted and resulted in a relatively small number of koalas (28) being moved to safer habitat at two sites. This program was referred to as the *Koala Translocation (KTrans)* program. An important aim of the work was to demonstrate the viability of koala translocation as a last-resort management option for koalas exposed to high-risk environments. This package of koala protection and conservation measures ensured that TMR met its obligations with respect to the various legislative and environmental agreements.

## Aims of the koala management program

The broad aims of the koala management program were:

1. To avoid harm to koalas during vegetation clearing and construction works;

2. To inform mitigation measures targeting key threats, using an adaptive management approach; and

3. To use a range of compensatory measures to offset residual impacts, and thereby provide benefits to the local koala population, as well as benefiting koala conservation and research efforts more broadly. These included:

    a) Control of chlamydial disease by treatment and vaccination
    b) Wild dog control
    c) Securing habitat offset sites
    d) Replanting degraded habitat in offset sites and at strategic corridors
    e) Contribution to scientific research programs
    f) Translocation of koalas whose displacement to, or existence in, high-risk environments in the study area was not consistent with the koala protection and conservation objectives

## Methods used

The central methods used to achieve the aims were: 1. Search and capture of most/all koalas in defined areas of habitat (koala search polygons) in and adjacent to the rail corridor; 2. Veterinary management and treatment of diseased koalas; and 3. Telemetric monitoring of all koalas using conventional radio-telemetry as well as purpose-designed remote telemetry technology. The latter technology was developed specifically for koalas by Endeavour Veterinary Ecology (EVE) in collaboration with embedded systems firm LX Solutions, and won a National Engineering Excellence award in 2015. This technology facilitated near-real-time monitoring of koalas using a web-based interface. Population viability analyses (PVAs) were used to evaluate the effectiveness of the koala management program in achieving a net benefit for the local koala population, based on the data collected during the monitoring program. This mathematical modelling method was also used to project outcomes under various hypothetical scenarios (including the scenario that no koala management occurred).

One of the objectives of the koala management program was to detect death of koalas rapidly and diagnose the causes of all deaths of monitored koalas occurring during the course of the program, which would then guide the adaptive management approach. This necessitated the frequent (almost daily) monitoring of koalas to enable rapid detection of severe illness or death. This regular monitoring also facilitated the early detection and treatment of koalas that became ill during the program, and was a necessary method used to ensure that koalas were found and protected as the vegetation clearing front progressed. Aside from providing important information to guide adaptive management and mitigation approaches, mortality data also provided valuable scientific information on the important threats to koalas in the region.

The high level of chlamydial disease as well as the intensive management of the koalas required significant effort in terms of veterinary management and captive care. There were numerous orphaning events over the nearly four-year duration of the program, necessitating hand-rearing of the orphans, as well as veterinary treatment of over 200 cases of injury and illness. Veterinary care and husbandry was mostly provided by EVE at their facilities at Toorbul, with some koalas also being treated at the Australia Zoo Wildlife Hospital and by Veterinary Specialists Services (for orthopaedic treatment). Over 3500 veterinary examinations and procedures were conducted over the course of the program by EVE.

**Plate 3**: Orphaned koala joey, *Pistachio*, shortly after rescue receiving glucose solution. His mother *Caz* had been killed by a wild dog, which had either overlooked, or not bothered to kill the little joey. *Pistachio* was successfully hand-reared and released at the TMR-owned koala habitat offset site at Griffin.

## Results of the koala management program

The objective of protecting koalas during the vegetation removal works was achieved with 100% success: no koalas were killed or injured by clearing works. Through the duration of the project, only four *untagged* koalas were detected (by wildlife spotter/catchers) at the vegetation clearing front, and these koalas were successfully captured and tagged. Disease prevalence (chlamydial disease) in the koala population was approximately 28% at the commencement of the program, and was reduced to close to 0% for most of the final 6 months of monitoring. Disease incidence (the rate of new cases per year) was similarly reduced, demonstrating unequivocal success in achieving the objective of reducing disease impacts.

The most significant cause of death in the first two years of the program was predation by wild dogs. This was reduced to insignificant levels by mid-late 2015, and continued at that low level until the termination of the program. Both disease and wild dog-related deaths were contributing significantly to the koala population suffering a rapid decline towards extinction, with some models predicting functional extinction within 1-2 decades. As a consequence of the koala management program, this decline was reversed, and the population began a growth trajectory, estimated to be approximately 6% per annum, based on data from the latter 12 months of the monitoring program. This is a remarkable and unprecedented turn-around in the fortunes of the koala population, and is an irrefutable testament to the success of the program.

The following two pages contain a series of graphs and charts showing some of the key information in a graphical form. These are:

1. Annualised mortality rate - changes over time;
2. Chlamydial disease prevalence (% koalas affected) - changes over time;
3. Causes of death pie chart showing proportionate causes - first two years of monitoring;
4. Causes of death pie chart showing proportionate causes - last 12 months of monitoring.

The graph overleaf shows the dramatic reduction in annualised mortality rate over the duration of the program. (The large peak around Sept-Oct 2014 corresponded with high activity of the “Amcor Dog” - a wild dog responsible for many koala deaths.) Note that in the last few months of 2013, the annualised mortality rate exceeds 100%. This must be viewed as a hypothetical scenario - if the rate of deaths in those windows of time had persisted over months or a year - all koalas would have been killed. In reality, this is very unlikely to happen, because, for example, as koalas become very scarce, the likelihood of wild dog predation at high rates will reduce.

**Plate 4**: Bushland view of a Redcliffe Peninsula Line train passing through Kippa-Ring

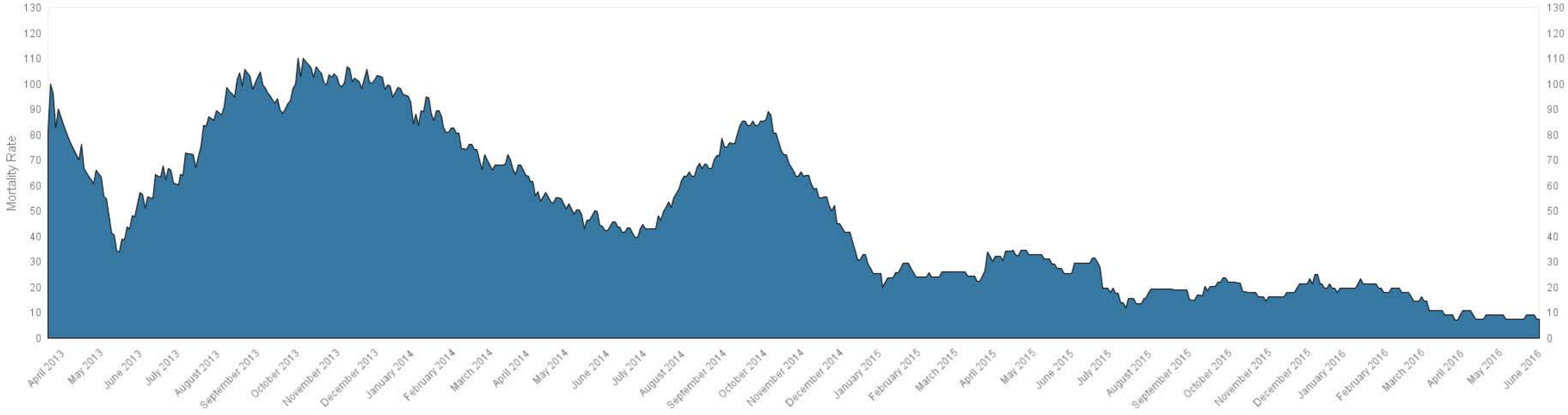


**Figure ES1:** Annualised mortality rate over the duration of the program. Note the significant decline in mortality rate over the life of the koala management program, down to a much more acceptable rate of <10% per annum.

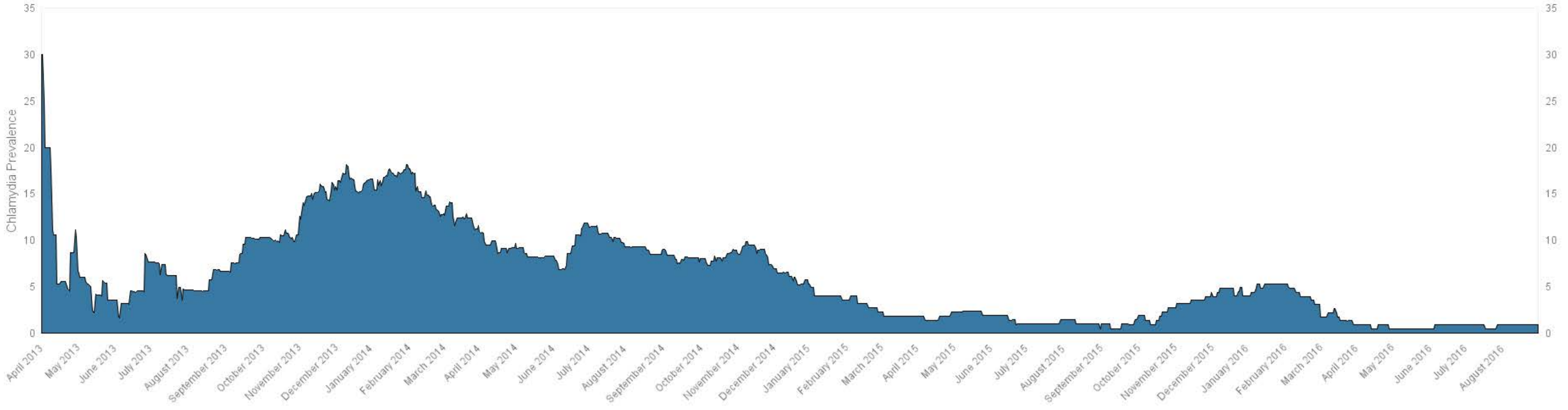


**Figure ES2:** Chlamydial disease prevalence over the life of the koala management program. Sections of the graph prior to January 2014 are less meaningful, because large numbers of "cleanskins" were still being captured. Peaks around November to January each year correspond with times of high spread of infection during the breeding season. This is the first time that population-level chlamydial prevalence has been measured over time. A significant finding is the considerable increase in prevalence and incidence in the latter stages of the breeding season - a logical, but previously undocumented, effect of critical importance to chlamydial disease management and understanding of epidemiology.

Pie chart showing the relative contributions of various causes of death in the first 2 years of the koala management program. Wild dog predation and chlamydial disease account for 80% of deaths.

**Total number of koala deaths was 224 (of 444 processed in the first two years).**

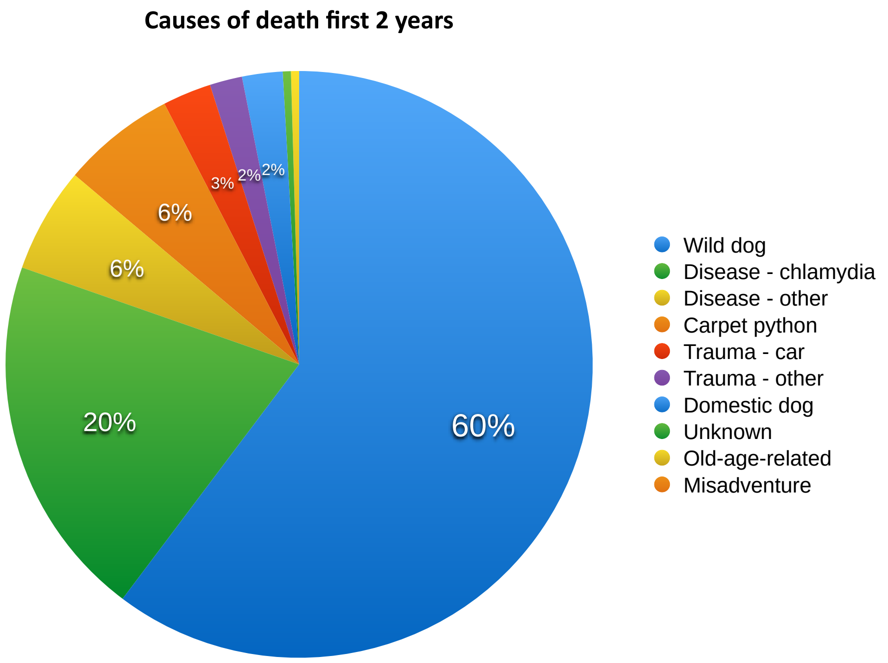


**Figure ES3:** Relative contribution of various causes of death in the first 2 years of the program. Tiny wedges indicate single koala deaths due to “unknown” and “old-age-related” causes. There were no “misadventure” deaths in the first two years. Significant causes of death were wild dog predation and disease. Legend list works clockwise from the 12 o’clock position.

Pie chart showing the relative contribution of various causes of death in the last 12 months (to 31 August, 2016) of the program. Wild dog predation and chlamydial disease accounted for only 19% of deaths. **Total number of koala deaths was 32 (of around 200 koalas being monitored in the last 12 months).**

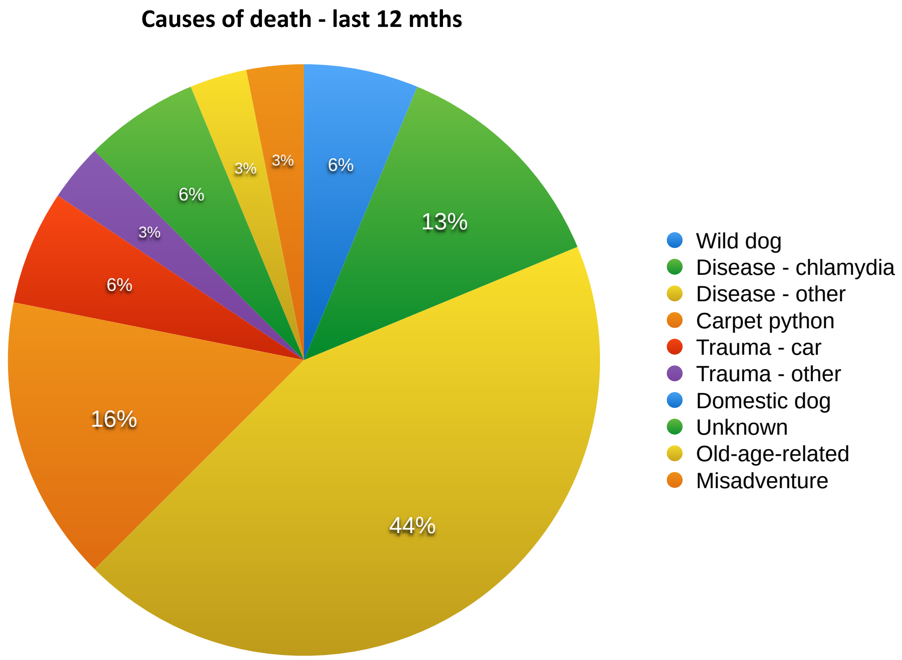


**Figure ES4:** Relative contribution of various causes of death in the last 12 months of the program. Note that “disease - other” and carpet python predation are the most significant causes of death. Control programs for chlamydial disease and wild dogs significantly reduced mortality associated with those causes. Legend list works clockwise from the 12 o’clock position.

## Koala translocations

Koalas considered to be at significant risk when assessed against comprehensive criteria were translocated to safer habitat. Twenty-eight (28) koalas were translocated to two sites determined to be suitable for receiving displaced koalas; these were the Murrenbong Scouts land situated to the north-west of the rail corridor, and the TMR-owned offset site at Griffin, to the south of the eastern extent of the rail corridor. The translocation of the koalas as part of the *KTrans* program of works was successful in that mortality rates in translocated koalas were not significantly different from those of the resident population of koalas over the approximately two years of monitoring at each site. At the time of writing, 17 of the translocated koalas were still alive.

Translocated koalas integrated into the resident population, formed stable home ranges and contributed reproductively to their respective receiving populations. The Griffin site provided particularly interesting information because it is a TMR-owned site that had been extensively replanted with koala food trees over approximately half (35ha) of its total area (the remainder being naturally vegetated). Koalas began to use the revegetated areas for both resting and as a food resource regularly from approximately mid-2015 onwards. At the time of writing, seven joeys had been born to translocated koalas (conceived and born after translocation), and the proportion of the adult population at the site that was derived from the translocation program (translocated animals and their progeny) was 63% (11/19).

## Contributions to scientific endeavours

The value of the contributions of the koala management program and its data to scientific/academic endeavours cannot be overstated. This program has provided unprecedented insights into the biology and ecology of koalas, and a huge number of data was collected over the nearly four years of the program. Many of these will not be analysed for the purposes of this technical report, but will provide opportunities for numerous research analyses of benefit to the body of scientific knowledge on koalas. In particular, the MBR project has been of crucial importance in the refinement and testing of a number of new koala anti-*Chlamydia* vaccines, which have shown great promise in reducing the impact and severity of chlamydial disease in koala populations. Many other university-based scientific projects related to koalas were supported (at minimal cost to the project) by virtue of the provision of biological samples and/or data, which otherwise would never have been available to them.

The development of the customised, koala-specific telemetry system, largely prompted by the MBR project, has revolutionised the monitoring of large numbers of koalas concurrently. The system provides near-real-time data presented in a map-based web-interface, allowing the location and activity of tagged koalas to be monitored remotely - via the desk-top. Additional firmware improvements during the course of the project allowed the system to give fine-detail data on the interaction of koalas with the rail fence - a functionality that will have high-value application on other linear infrastructure projects. The collar application method was developed for the MBR project with koala safety as a paramount design objective, and has almost completely removed risk associated with traditional telemetry collars. There were no deaths or significant injuries caused by LX *K-Tracker* telemetry collars during this program - the largest koala telemetry program ever implemented - spanning in excess of 200,000 koala-telemetry days. In addition, the telemetry system probably saved the lives of a number of koalas, whose movements into dangerous areas were detected remotely, prompting their rescues - koalas *Anna* and *MacGyver* (see ***Chapter 6 - Ranging behaviour and habitat use by koalas***).

## Community stakeholder management

One of the very successful components of the management of the MBR project with respect to koalas was the early and ongoing engagement of koala conservation and welfare stakeholders. Aside from showing good faith, transparency, and developing trust in that group of stakeholders, this engagement provided great value to them in terms of providing scientific information and knowledge, and a detailed insight into the mechanics and results of the koala program. This was greatly appreciated, and in turn, that group became one of the leading advocates for the program and defended the project and TMR on more than one occasion in the face of poorly informed, potentially adverse media attention. It also provided TMR with the opportunity to utilise local knowledge and insight into the subject koala population. In terms of reputational risk management, this was of significant value over the course of the MBR project, and is a component of project management that we highly recommend for future projects.

## Recommendations

The approach taken to koala management during construction of the MBR project has been exemplary in many respects, and its success due largely to the following factors:

1. The koala management program was carefully considered and designed well before commencement of construction works;
2. Appropriate experts were engaged to design and conduct the program;
3. The methods and approach were based on proven scientific methods and contemporary data, but applied innovative technological solutions;
4. The management program was implemented early (well before construction commenced);
5. The program was appropriately funded throughout;
6. Community stakeholders were engaged, respected and kept informed, which was crucial in building and maintaining trust in both the project owner (TMR) and the contractor tasked with delivery of the koala program.

A number of innovative technical solutions were developed and implemented during the koala management program:

1. Development of an award-winning koala telemetry system allowing remote monitoring of large numbers of animals - the LX *K-Tracker* system;
2. Development of a customised koala database using the FileMaker® platform, integrating multiple field and veterinary data streams.
3. Implementation of multi-tag telemetry methods to ensure efficient location and capture of koalas after a tag drop-off, including application of “anklet” VHF transmitters.
4. Production of weekly “where are they now?” Google Earth® kmz files to facilitate koala protection during vegetation clearing activities, complementing the near-real-time LX telemetry system.

Our primary recommendation is that the approach taken in the koala management program for the MBR is applied on future infrastructure projects if koalas or koala habitat are likely to be impacted. Given its success and the broader benefits that have accrued, the MBR koala management approach provides a suitable model for management of significant wildlife on other State-controlled community infrastructure projects. Key components of the model are the scientific approach to necessary management of fauna, and early and ongoing stakeholder engagement and management. Specific and detailed recommendations are provided later in this report.

## Summary

The koala management program, although detecting and documenting the severe impacts of wild dogs and disease and the koala population's trajectory to extinction, was effective in managing those impacts and returning the population to a positive/growth trajectory as well as achieving its stated objectives. This conclusion is validated by expert and astute mathematical analysis of mortality and reproductive data conducted by researchers at the University of Queensland as population viability analyses, and is therefore unequivocal.

The rail construction project resulted in two important and essentially permanent impacts - the loss of local koala habitat and the formation of a semi-permeable barrier to koala movement through the landscape. However, these residual impacts have been sufficiently compensated for, and/or mitigated, through an holistic package of measures, such that the local koala population has ultimately benefited. The fact that such a significant net benefit to the koala population could be achieved is evidence of the tenuous and diminished state of koala populations in SEQ.

The effectiveness of offsetting and mitigation measures is supported by early data from ongoing programs of work. Koala movements through fauna and drainage culverts indicate that the rail corridor is sufficiently permeable to allow genetic exchange between koala sub-populations living north and south of the rail line; and the 3-year-old replanted koala habitat in the Griffin offset site was (at the time of writing) already being used as a forage and shelter resource by the local koalas, and its population was on a significant growth trajectory. Investigation of koala movements across the rail corridor was ongoing at the time of writing, and monitoring at the Griffin offset site was completed in January, 2017. These programs of work formed part of the *Alternative Koala Habitat Offsets* program, some of which is reported here, other components of which will be reported separately.

It is important to note that the MBR project has provided very substantial benefits to the koala population in the short-term, but the duration of this beneficial effect is difficult to accurately predict. Ongoing monitoring and management of threats by entities other than TMR will probably be necessary to sustain the growth trajectory established by the MBR koala management program. Nevertheless, the scientific and adaptive management approach documented herein has provided valuable guidance with respect to managing the major contemporary threats to population viability in the near and medium-term future, and serves as a good model for application on future projects.

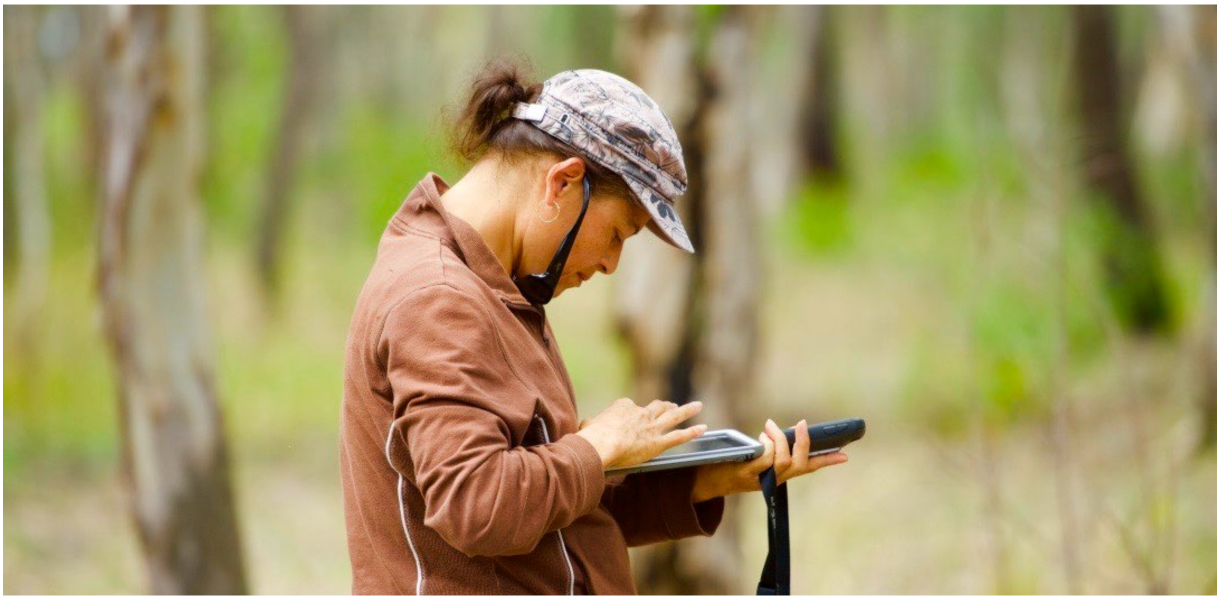

**Plate 5**: Koala ecologist Dr Deidre de Villiers enters data into the koala database during release of the hand-reared juvenile *Sammy* at the Kippa-Ring bushland.

# Note to readers of this report

This report is written in a style and language that aims to be easily read and understood by the layperson. Much of the important scientific information and findings have been, or will be, written up as research papers for publication in the peer-reviewed scientific literature. We have purposely avoided referencing many of the statements made in the text, as would be usual in scientific writing, to make it more readable. One exception is ***Chapter 11 - Population viability analysis***, a chapter that is necessarily scientifically and mathematically detailed, as it provides the unequivocal evidence for the MBR project's success in appropriately managing its impacts on the koala population, as well as providing considerable benefits to population persistence in the area.

The authors intended that each chapter should be able to be read and understood without having to repeatedly reference other sections of the report. Therefore, between chapters there is some duplication of information. One of the most important components of the koala management program to benefit the koala population was the management of health and treatment of disease. Consequently, ***Chapter 4 - Veterinary management of koalas*** is one of the most detailed.

This report presents information on a number of important analyses of data that are of relevance or interest with respect to the management of koalas impacted by infrastructure development. The vast body of data collected during the koala management program provides a fertile source of information for researchers interested in further analysis on a range of ecological, health and koala management streams. We have done and presented herein, only *some* of the wide range of analyses made possible by the very valuable data-sets collected.

All conclusions drawn and reported in this document are supported by data collected and analysed by experienced ecologists and other scientists. Analysis of many of the data has been performed by Endeavour Veterinary Ecology and its subcontractors collaborating with university-based scientists. The conclusions are scientifically robust, having been based on a large and rigorously collected body of data - arguably the most comprehensive set of longitudinal ecological and veterinary data ever collected from a wild koala population.

The comprehensive raw data-sets from which the information in this report is derived and the source documents for data analysis have been lodged with the Queensland Department of Transport and Main Roads (TMR), as the project owner. These data provide a wealth of opportunity for additional analysis on topics such as epidemiology, population health and clinical parameters, and koala ecology and biology - analyses which did not form part of the scope of works for the koala management program. Persons or entities wishing to access or use data and source files for the purposes of validating conclusions or findings reported herein, or for additional analysis should apply directly to TMR.

At the time of writing, the contact details for persons wishing to make application for access to data or source files is:

Transport and Main Roads,
Program Delivery & Operations,
North Coast District Environmental Team.
P: 07 5451 7055
E: northcoast@tmr.qld.gov.au

## Table of Contents

**Plate 6**: Unusually pigmented joey of *Paula C.* Lack of pigmentation of the fur is rare, but this joey is not albino because there is normal pigmentation of the eyes and nose.

# Glossary

## An explanation of acronyms, technical terms and abbreviations

| Term | Interpretation |
|---|---|
| AEC | Animal Ethics Committee |
| Anklet | A VHF radio-telemetry device fixed to a koala's ankle, rather than around the neck. |
| AKHO | Alternative Koala Habitat Offsets program - a program of compensatory and offset measures implemented by the MBR project to satisfy regulatory requirements as well as providing an holistic package of measures aimed at benefiting koalas based on adaptive management of critical threats. |
| AOCM | Alternative Offsets - Connectivity Monitoring program - a program of works separate from the KTMP, which aimed to assess the degree of permeability of the rail corridor to the movement of koalas - a process essential for maintaining genetic health in koala populations living on either side of the rail corridor. |
| ARC | Australian Research Council - major granting body for university-based research |
| AZWH | Australia Zoo Wildlife Hospital |
| Bio-telemetry | The use of radio/microwave or other electromagnetic frequencies to transmit data collected from an animal wearing a bio-telemetry device to a remote data acquisition point (such as a laptop computer). |
| *Chlamydia* | A specialised intra-cellular bacterium, which causes a range of chronic and acute diseases in koalas, including ocular, respiratory, urinary and reproductive disease. |
| Chlamydiosis | Disease caused by the bacterium *Chlamydia* |
| Cleanskin | An untagged koala that has never been captured or tagged as part of the Koala Tagging and Monitoring Program |
| DAF/DAFF | Department of Agriculture and Fisheries (previously Dept of Agriculture, Fisheries and Forestry) |
| EHP | Department of Environment and Heritage Protection (Qld) |
| EPBC | Environmental Protection and Biodiversity Conservation Act - a Commonwealth (federal) Act that seeks to regulate activities that are likely to impact on matters of national environmental significance. |
| EVE | Endeavour Veterinary Ecology Pty Ltd |
| Flagging | The initial process of capturing a koala using an extendable pole with a "flag" or "halo" which is used to encourage the koala to move down a tree. |
| KTMP | Koala Tagging and Monitoring Program |
| KTrans | Koala Translocation Program |

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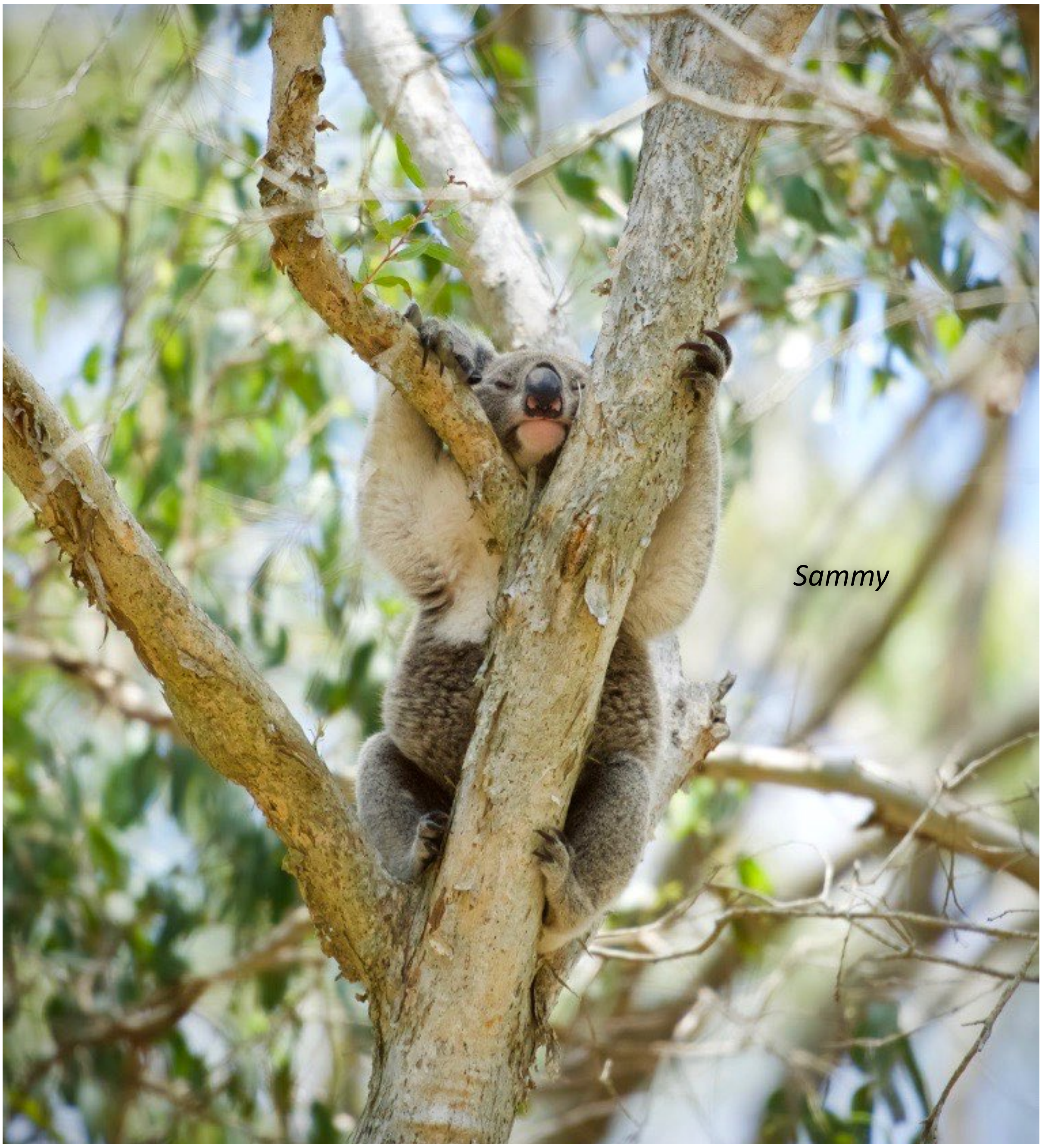
|---|---|
| LX *K-Tracker* system | An award-winning bio-telemetry system developed for the MBR KTMP which provides 12-hourly data uploads of GPS position and koala activity, using wireless communication with base stations to allow data upload to a web-based graphical user interface. |
| MBR | Moreton Bay Rail project. |
| MBRL | Moreton Bay Rail Link project - the original project title prior to addition of works to upgrade some sections south of Petrie. |
| MBRC | Moreton Bay Regional Council |
| MoA | Memorandum of agreement - contractual instrument between TMR and EHP |
| MOP | Member of the public |
| NJKHT | Non-juvenile koala habitat tree |
| OHE | Ovario-hysterectomy - a veterinary surgical treatment for untreatable bilateral reproductive tract disease which has rendered a female koala sterile (permanently unable to produce young). It is the same as the spey operation performed on domestic pets to prevent breeding and oestrous behaviour. |
| PCR | Polymerase chain reaction. A molecular tool in which minute quantities of target DNA are amplified up in an enzymatic reaction to enable detection and identification. Now a commonly-used diagnostic and research detection test for *Chlamydia.* |
| Pinger | A VHF transmitter (e.g. VHF anklet or VHF component of a collar) |
| POC | Point of capture of koalas. Koalas were usually released back at their POC |
| Program | Koala management program |
| Project | Moreton Bay Rail project |
| QUT | Queensland University of Technology |
| Radio-telemetry | The use of a VHF radio transmitter (generally a collar or anklet in koalas) and a VHF receiver to locate, a koala. |
| Redcliffe Peninsula Line | The official name of the operating rail line that was constructed in the Moreton Bay Rail project. |
| SEQ | South-East Queensland |
| SPP | Scientific Purposes Permit |
| SPRP | State Planning Regulatory Provisions |
| Tag | Other than the plastic swivel-type ear tag, the term “tag” refers to a radio-telemetry or bio-telemetry device (e.g LX collar, VHF collar pinger or VHF anklet) |
| USC | University of the Sunshine Coast |
| Velcro® Anklet Collar | A collar made of Velcro® material with a threaded-on “anklet” VHF transmitter used for telemetry of sub-3kg juvenile koalas. |
| VHF | Very high frequency – radio-frequency band used for radio-telemetry |

# CHAPTER 1: INTRODUCTION AND BACKGROUND




## Key points

- Large koala population living in the MBRL corridor
- Legislative and community obligation for MBR project to protect koalas
- Aims and objectives were clearly defined
- Holistic approach to koala protection and management proposed
- Koala translocation considered an essential component of management
- Alternative offset, management and compensatory measures implemented

# Chapter 1: Introduction and background

## 1.1 Rationale for the koala management program

Koala habitat in and adjacent to the corridor for the Moreton Bay Rail (MBR) encompasses parcels of land of varying tenures and levels of protection. Large habitat blocks at either end of the proposed rail link (the former Amcor mill in the west and low-lying blue-gum-dominated forest to the north of Hays Inlet in the east) supported significant koala populations. Remnant corridors of habitat between these two larger blocks had been protected from urban development by virtue of their existence in the rail corridor, and/or in riparian zones. The Pine Rivers region (of the Moreton Bay Regional local government area) includes priority koala assessable development areas under the SEQ Koala Conservation State Planning Regulatory Provisions (SPRP). Most notably, in respect of the MBR project, the former Amcor site contains both *high-value* and *medium-value bushland* and *rehabilitation* areas. Although the Kippa-Ring section of the rail corridor passes through equally valuable remnant koala habitat, this area is excluded from the Pine River priority koala assessable development area (see http://www.ehp.qld.gov.au/wildlife/koalas/mapping/documents/sprp-values/sprp-habitat-values-map14.pdf)

In short, the SPRP compels development proponents to minimise impacts on koalas and koala habitat. However, Queensland Government public sector entity activities, such as construction of the MBR project, are exempt (then, and at the time of writing) from the SPRP as they are subject to the *State Government Supported Community Infrastructure Koala Conservation Policy* (CI Policy). This policy largely commits community infrastructure to similar levels of koala protection using an MoA as the agreement instrument between the proponent entity and the Department of Environment and Heritage Protection (EHP).

**Plate 1.2**: Koala *Tash* from the Amcor paper mill site. One of the first *Chlamydia* vaccine trial animals, she was ultimately killed by a wild dog, presumed to be the "Amcor Dog".

In addition to the regulatory framework for koala protection, the MBR project recognised the significant community interest in protecting koalas and other natural values during construction and operation of the rail project. Stakeholder groups, including a number of local koala rescue and advocacy groups, were consulted well prior to the commencement of major construction works, and it became clear that a high level of koala protection and welfare would need to be implemented to satisfy them. TMR concerns were based on both individual animal welfare as well as negative impacts on the viability of the local koala population generally. Welfare concerns included protection of the animals from direct and indirect impacts of vegetation clearing and construction activities as well as potential welfare impacts of the scientific methods or technology used to monitor the koalas. Consequently, these concerns were of primary importance in the development of the project plan and scientific methods. Specifically, the approach had to minimise risk associated with construction activities as well as avoid risks specifically associated with the scientific and monitoring program itself (such as collar-related mortality and injury). Regular and transparent communication of progress and results was a key component of stakeholder management, which underlined the importance of robust and animal welfare-conscious methods and technologies.

Both the MBR project and the stakeholders acknowledged the recent (2012) listing of the koala as vulnerable to extinction under the *EPBC Act* and its similar status under State legislation. Stakeholders were vocal during consultation sessions in stating the inadequacy of baseline regulatory compliance in properly protecting koalas during development. Based on this feedback, and early advice from Endeavour Veterinary Ecology and other scientific consultants, a comprehensive koala management plan for the project was developed.

A draft *Koala Action Plan* was prepared by SMEC in 2012 and has since been reviewed by TMR (http://www.tmr.qld.gov.au/Projects/Featured-projects/Moreton-Bay-Rail/Publications/Moreton-Bay-Rail-Koala-Action-Plan). This document provides comprehensive background information on the rail project itself, the initial koala survey findings and the approach to development and implementation of the koala management programs (*KTMP1*, *KTMP2* and *KTrans*), as well as other koala protection and mitigation actions conducted on behalf of the project. Rather than repeat much of that information here, we refer interested readers to the *Koala Action Plan* for detailed background information and a koala management overview.

The methodological approach to the on-ground koala management works conducted by EVE was outlined in the documents entitled *Koala Disease Management Plan: A partnership with the Moreton Bay Rail Link Project, Incorporating the Koala Chlamydia Vaccine Field Trial: A research project of the Queensland University of Technology* and *Proposal to conduct a koala tagging and monitoring program for the Moreton Bay Rail Link project*, contained in Appendices 1 and 2, respectively.

At monthly intervals after commencement of the koala management program, EVE provided reports summarising key statistics and findings. Over the duration of the *KTMP1, KTMP2* and *KTrans* programs, 40 monthly reports were provided to TMR covering activities occurring between late March 2013 and 31st July, 2016. This report is the final technical report for those programs of work and contains a comprehensive analysis of data and scientific findings derived from the approximately 4-year duration of the programs. It includes an analysis of population viability, conducted by Dr. Hawthorne Beyer from the University of Queensland's *Centre for Biodiversity and Conservation Science*, for the koala population that formed the subject of the program, and a summary of the *Chlamydia* vaccine field trial by Prof. Peter Timms from the University of the Sunshine Coast.

At the time of writing, ongoing works to monitor koalas' use of crossing structures, such as culverts and bridges, using GPS telemetry tags and trail cameras was occurring, under a program of works hereinafter referred to as the *Alternative Koala Habitat Offsets - Connectivity Monitoring* (*AKHO-CM*) program. Extended monitoring of the Griffin offset site, including koala telemetry monitoring, koala use of replanted areas, and growth of replanted areas, continued until December 2016 under a program of work referred to herein as the *Griffin Offset Site Monitoring Program* (*GOSMP*). Data and findings of these two programs of work, collectively forming a part of the *Alternative Koala Habitat Offsets* program, are reported here, but ongoing works with respect to some aspects of the connectivity monitoring program were reported by others.

## 1.2 Defining the aims and objectives

Discussion and refinement of the aims and objectives of the koala management program occurred for at least 12 months prior to the commencement of the koala search and capture efforts in March 2013, and involved significant stakeholder consultation. Limited budget estimates or allocations (late 2011- early 2012) constrained proposed koala management activities to the management of disease by a limited capture and tagging program (of up to 30 koalas) and the implementation of a *Chlamydia* vaccine trial. This approach was outlined in the document *Koala Disease Management Plan: A partnership with the Moreton Bay Rail Link Project, Incorporating the Koala Chlamydia Vaccine Field Trial: A research project of the Queensland University of Technology* (*Appendix 1*). Later discussions between EVE and TMR identified the likelihood of significantly more koalas being at risk from construction activities and operation of the rail line, and a detailed koala management proposal involving capture and tagging of at-risk koalas was developed. The *Proposal to conduct a koala tagging and monitoring program for the Moreton Bay Rail Link project* is contained in *Appendix 2*.

Koala stakeholder consultation was important in developing and refining the aims and objectives of the koala management program. The value of early stakeholder engagement in developing respect and trust cannot be overstated, and enabled key stakeholder concerns - particularly regarding koala welfare and population viability - to be addressed in terms of the aims and objectives. Koala advocacy and welfare stakeholders had two primary concerns:

1. Whether, and how, impacts on individual koala welfare were to be managed, i.e. how were koalas going to be protected during vegetation clearing, construction and operational phases of the project;

2. Whether, and how, the project would avoid significant or even incremental impacts on local koala population viability.

Specific concerns were also raised about the potential welfare impacts of the koala management program itself, in respect of two components:

1. The welfare impacts and risks of capture, veterinary processing, tagging/collaring, and field tracking of the koalas; and

2. The potential welfare and survival impacts of the translocation of koalas, if translocation was to be carried out.

**Plate 1.3**: Koala *Maxwell* takes a leap following his final release at the Griffin offset site in December 2016. He was one of the resident koalas tagged and monitored at the site. He was hand-reared after being found alone and in only fair body condition at 9-10 months of age in May 2014, four months prior to the commencement of translocations to the site.

The idea of providing an holistic package of koala protection, compensatory and habitat offset measures was proposed early in discussions. This approach was considered to be far preferable to providing *only* the State koala habitat offsets based on the 5:1 replacement of non-juvenile koala habitat trees (NJKHTs) or provision of a dollar amount of approximately $920 per NJKHT. It would also allow the provision of compensatory measures based on empirical data derived from the koala tagging and monitoring program itself, and facilitate the adaptive management approach proposed by EVE. This approach appeared to be widely supported by koala stakeholders, and formed the basis of the programs implemented over the 4 years of the koala management program. Ultimately, the aspirational goal of the compensatory and offset package was to provide a demonstrable net benefit to the local koala population validated by empirical data (in the short-term) and robust modelling (for longer-term projections).

Key threats were assumed, based on previous scientific studies and anecdotal evidence, to include chlamydial disease, domestic dog attack, motor vehicle strike, anthropogenic misadventure and wild dog predation. Loss of habitat was unavoidable in construction of the rail project and this loss and associated fragmentation of habitat remnants was considered to result in both immediate and longer-term impacts on population viability. Consequently, the holistic package of measures initially proposed included the following components:

1. Conducting a koala capture, tagging and monitoring program (the *KTMP*);
2. Disease management by:
    a) Veterinary assessment of all koalas and treatment of sick koalas
    b) Field trial and evaluation of the new *Chlamydia* vaccine
3. Support of university-based koala research;
4. Translocation of koalas at significant risk (the *KTranslocation* or *KTrans* program);
5. Wild dog monitoring and control;
6. Construction of fauna crossing structures and koala fencing of the rail corridor;
7. Strategic fencing of local “black spot” roads to reduce motor vehicle mortality;
8. Acquisition and re-planting of offset sites.

Mitigation or management of emergent risks when possible (the adaptive management approach) was a key strategy, and one that would rely upon data collected during the *KTMP*.

The proposed approach to koala management was finalised in early 2013, and the program commenced with the first koala (*Ozone*) recruited in March 2013.

# CHAPTER 2: GENERAL METHODS


## Key points

- Holistic strategy to koala protection and management guided the approach
- Key drivers of the methods and approach were carefully defined aims and objectives
- Objectives based on regulatory compliance and community expectations
- Key technological components developed: *K-Tracker* system, koala database
- Partnerships with university groups to maximise broad benefits
- Scientific approach and data acquisition guided adaptive management, mitigation and offset measures
- Approach and results robustly defensible and scientifically sound
- Successful model for application on future infrastructure projects

# Chapter 2: General methods

## 2.1 Regulatory approvals

Approvals from the Department of Environment and Heritage Protection (EHP) were required to conduct the koala tagging and monitoring program and translocations. Each required prior approval from an animal ethics committee (AEC). All AEC approvals were issued by the DAF Community Access AEC. **Table 2.1** below, shows the regulatory approval numbers and summary of the specific purposes of each of the permits.

| Title/Project | SPP Approval (DEHP) | AEC Approval | Start Date | Finish Date | Summary of Purpose |
|---|---|---|---|---|---|
| Assessment, monitoring and management of disease in koalas inhabiting the proposed Moreton Bay rail corridor including an assessment of the efficacy of the koala *Chlamydia* vaccine in a wild population | WISP11525212 2.<br>WISP16125415<br>*WITK14173714 | | 14 July 2012<br>14 July 2015<br>18 Feb 2014 | 13 July 2015<br>13 July 2020<br>17 Feb 2017 | Conduct of the Koala Tagging and Monitoring program and *Chlamydia* vaccine field trial. *Protected area permit for Freshwater NP and North Pine Dam Nature Refuge |
| Assessment, monitoring and management of disease in koalas inhabiting the proposed Moreton Bay rail corridor including an assessment of the efficacy of the koala *Chlamydia* vaccine in a wild population | | CA 2012/03/597<br>CA 2015/03/852 | 1 May 2012<br>1 May 2015 | 30 April 2015<br>30 April 2018 | Conduct of the Koala Tagging and Monitoring program and *Chlamydia* vaccine field trial. |
| Investigation of *in situ* and *ex situ* management options for wild koalas impacted by loss of habitat: the Moreton Bay Link project | WISP13661313 | | 1 Nov 2013 | 31 Oct 2018 | Translocation of koalas impacted by the MBR |
| Investigation of *in situ* and *ex situ* management options for wild koalas impacted by loss of habitat: the Moreton Bay Link project | | CA 2013/09/719 | 1 Oct. 2013 | 30 Sept. 2016 | Translocation of koalas impacted by the MBR |
| Fauna egress fencing trial for transport corridors (road and rail). | WISP14791114 | | 25 July 2014 | 24 July 2016 | Trialling the efficacy of egress or escape points in koala proof fencing to mitigate the impacts of linear infrastructure |
| Fauna egress fencing trial for transport corridors (road and rail). | | CA 2014/06/777 | 30 June 2014 | 30 June 2016 | Trialling the efficacy of egress or escape points in koala proof fencing to mitigate the impacts of linear infrastructure |
| Methods for research and management of koalas in Queensland. | WISP17273716 | | 4 July 2016 | 3 July 2021 | Research and management of koalas in Queensland. |
| Methods for research and management of koalas in Queensland. | | CA 2016/03/950 | 18 May 2016 | 29 April 2019 | Research and management of koalas in Queensland. |

**Table 2.1**: Details of regulatory approvals required for components of the koala management program

**Plate 2.2**: Koala *Sammy* following final release into the bushland at Kippa-Ring. *Sammy* was subject to a “mother-swapping” event; his biological mother was *Aerona*, who either abandoned or lost him. He was adopted naturally by the koala *Karen*, who lived near *Aerona* but eventually hand-reared by EVE’s koala ecologist Dr Deidre de Villiers. More detail on this unusual event is provided in ***Chapter 10 - Koala reproductive success***.

## 2.2 General approach and methods

Detailed aims, objectives, justification, background information and methods are specified in the documents entitled *Koala Disease Management Plan: A partnership with the Moreton Bay Rail Link Project* (Appendix 1), and *Proposal to conduct a koala tagging and monitoring program for the Moreton Bay Rail Link project* (Appendix 2), which were prepared prior to the commencement of operational works for the koala program.

Over the course of the program, a number of improvements and technological advances occurred including:

1. Development of the low-impact LX Solutions/EVE *K-Tracker* koala telemetry system, which facilitated near-real-time remote monitoring of koalas using a very safe telemetry collar;

2. Development of the koala database using the Apple® subsidiary FileMaker® platform, allowing integration of all data streams.

3. Refinement of diagnostic work-up and treatments.

4. Treatment of sick/injured program koalas at the EVE veterinary facilities, rather than referral to external providers.

5. Development and testing of a one-way koala egress "valve" that would allow koalas trapped in road or rail corridors to rapidly transit corridor fences.

The following section provides a brief overview of methods and approach, with more detail on methodology provided in the following chapters dealing with specific sections of work or data analysis.

**Plate 2.3**: Koala *Jane* and joey at final release in bushland at the Griffin offset site in December 2016. Her joey *Loki* is 10 months old, 1.3 kg and nearing the age of independence. *Jane* was pregnant at the time the photo was taken. Both *Loki* and the new joey (foetus) were conceived after her translocation to the Griffin offset site.

## 2.3 Delineation of koala search and capture areas

Six koala search and capture areas were delineated as polygons encompassing areas of koala habitat along and adjacent to the rail corridor by reference to aerial imagery (Google Earth®) (**Figures 2.1 and 2.2**, below). The intention was to create search areas that maximised the likelihood of detecting all koalas that were potentially at risk from vegetation clearing for the rail project for the duration of the project, and took into account the increased ranging behaviour of koalas during the breeding and dispersal season (July-December). The polygons are shown in the following figures, and area and site characteristics listed in **Table 2.2**, below.

| Polygon name (west to east) | Area | Site characteristics/comments |
|---|---|---|
| Amcor | 285ha | Included most of the former Amcor mill site at Petrie, plus sections to the south to Lawnton Pocket Rd. |
| Bruce Hwy West | 126ha | V-shaped polygon encompassing habitat along Freshwater and Black-duck Creeks, to the west of the Bruce Highway. |
| Mango Hill | 48.2ha | Encompassing habitat to the east of the Bruce Highway along Freshwater Creek and around Freshwater Ck Rd and Halpine Drive. |
| Kinsellas Rd | 58ha | Encompassing habitat along Kinsellas Rd East and now cleared acreage properties to the south of Anzac Avenue. |
| Rothwell | 165ha | Encompassing low-lying salt flats, mangroves and some low coastal open blue-gum dominated eucalypt woodland/forest along and around Saltwater Ck. |
| Kippa-Ring | 193ha | Encompassing large block of remnant habitat south of Anzac Avenue, and incorporating the Chelsea St Conservation Area, and habitat adjacent to Hay's Inlet Conservation Park. |

**Table 2.2**: Koala search area polygon names, area and site characteristics.

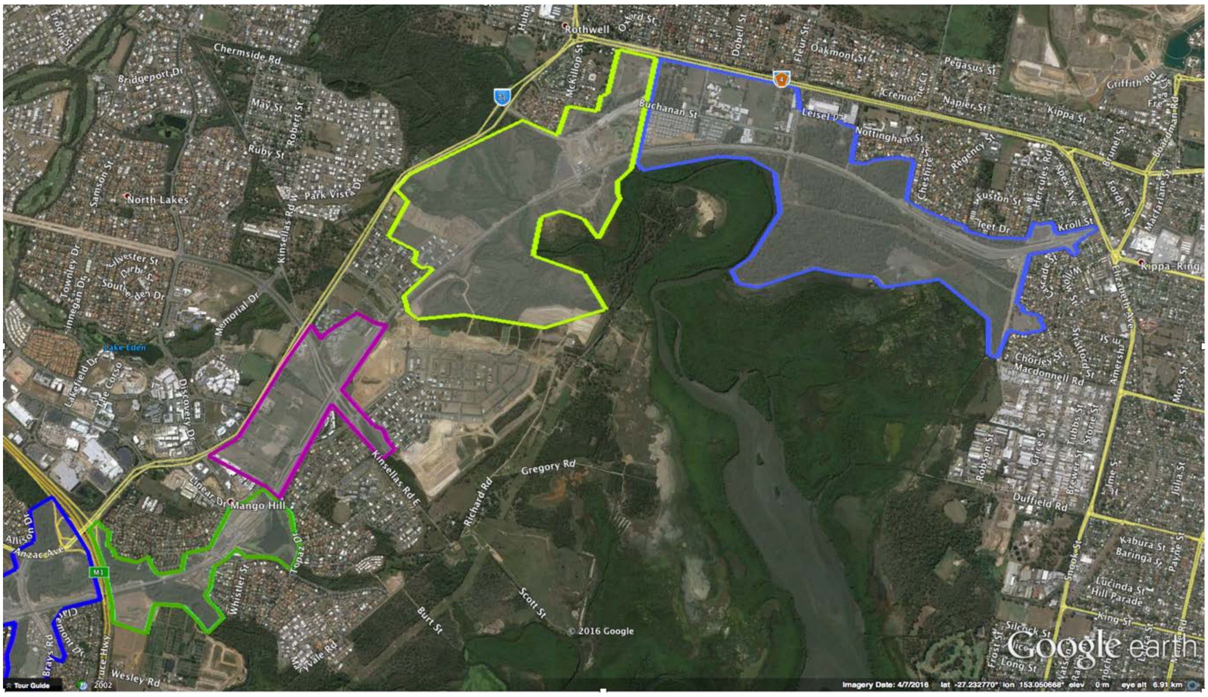



**Figure 2.1:** Koala search polygons east of the Bruce Highway: from left to right Mango Hill (green), Kinsellas Rd (mauve), Rothwell (lime), and Kippa-Ring (lavender). The curve of the Bruce Highway is just visible in the lower left corner.

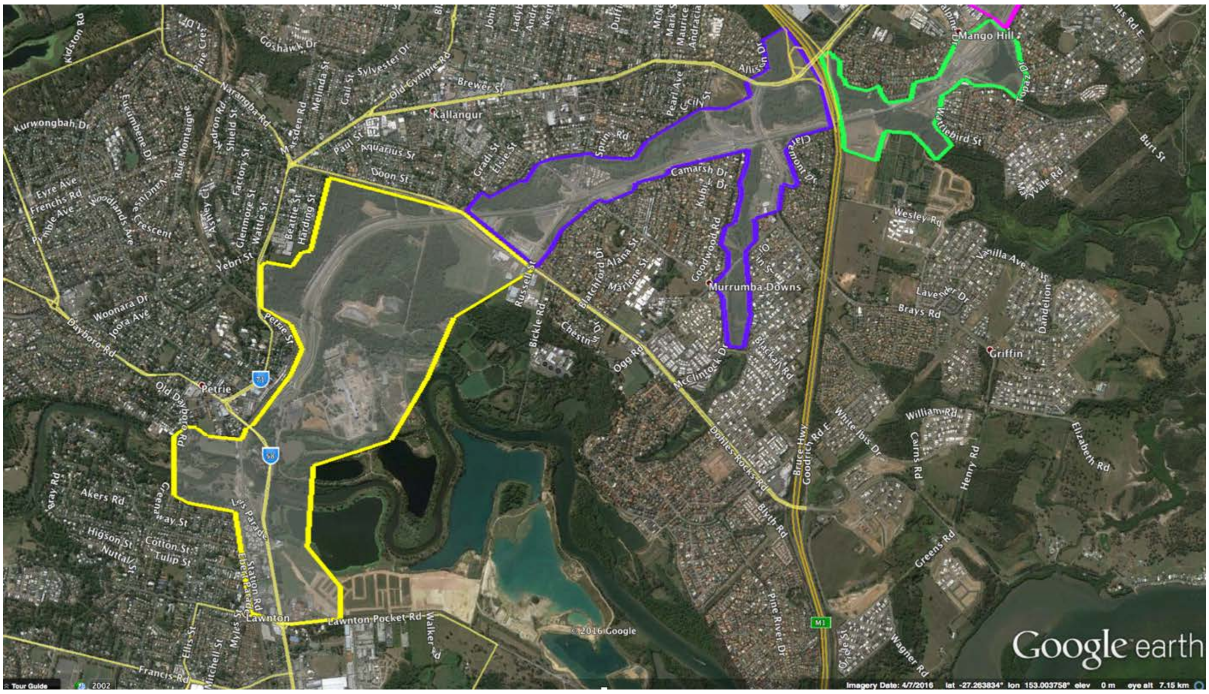



**Figure 2.2:** Koala search polygons west of the Bruce Highway: from left to right Amcor (yellow) and Bruce Hwy West (purple).

Polygon boundaries were based on logistical considerations and operational objectives rather than being entirely defined by ecological or habitat characteristics.

## 2.4 Site characteristics

Ecological characteristics along the 13km MBR corridor include vegetated areas of various age, structure, composition, habitat condition and intactness. These vegetation communities include open grassland, shrubland dominated by exotic species, and various types of wet and dry open-closed forest, generally dominated by mixed eucalypt/paperbark associations. The corridor traverses several creeks and drainage lines, with the most notable being Yebri Creek at Petrie, two crossings of Freshwater Creek at Kallangur and Mango Hill, Black Duck Creek at Murrumba Downs and Saltwater Creek at Rothwell. There are also several minor ephemeral drainage lines and tidal drains in the east of the project area that the MBR corridor traverses. A more detailed description of ecological characteristics for the various sections starting in the west at Petrie and moving east to Kippa-Ring are provided below. These sections differ from the koala search polygons areas and are more a representation of key habitat areas utilised by koalas included in the tagging and monitoring program (whose ranging was not limited to the koala search polygons). The translocation recipient sites at Griffin and the Scout's land at Kurwongbah are also included.

Several areas of *Regulated Vegetation*, as mapped by the Queensland Government, occur in some of the sections, with a total of ten different regional ecosystems (RE) mapped on the site. In general, this mapping was accurate and provides further information relating to the vegetation communities that occur within the MBR area from Petrie to Kippa-Ring and the Griffin and Scouts translocation recipient sites. The descriptions of the mapped REs are shown in **Table 2.3** below.

| Regional Ecosystem Code | Regional Ecosystem Description |
|---|---|
| RE. 12.1.1 | *Casuarina glauca* +/- mangroves woodland. Occurs on margins of Quaternary estuarine deposits. |
| RE 12.1.2 | Saltpan vegetation comprising *Sporobolus virginicus* grassland and samphire herbland. Grasses including *Zoysia macrantha* subsp. *macrantha* sometimes present in upper portions of tidal flats. Includes saline or brackish sedgelands. Occurs on Quaternary estuarine deposits. Marine plains/tidal flats. |
| RE 12.1.3 | Mangrove shrubland to low closed forest. Occurs on Quaternary estuarine deposits. |
| RE 12.3.11 | *Eucalyptus tereticornis* +/- *E. siderophloia* and *Corymbia intermedia* open forest to woodland. *Corymbia tessellaris, Lophostemon suaveolens* and *Melaleuca quinquenervia* frequently occur and often form a low tree layer. Other species present in scattered patches or low densities include *Angophora leiocarpa, E. exserta, E. grandis, C. trachyphloia, C. citriodora* subsp. *variegata, E. latisinensis, E. tindaliae, E. racemosa* and *Melaleuca sieberi. E. seeana* may be present south of Landsborough and *Livistona decora* may occur in scattered patches or low densities in the Glenbar SF and Wongi SF areas. Occurs on Quaternary alluvial plains and drainage lines along coastal lowlands. |
| RE 12.3.5 | *Melaleuca quinquenervia* open forest to woodland. Understorey depends upon duration of water logging; sedges and ferns, especially *Blechnum indicum*, in wetter microhabitats and grasses and shrubs in drier microhabitats. Ground layer species include the grasses Leersia hexandra and *Imperata cylindrica,* the sedges/rushes*, Baumea rubiginosa, Gahnia sieberiana, Lepironia articulata, Schoenus brevifolius and Schoenus scabripes* and the fern *Lygodium microphyllum.* Other tree species that may be present as scattered individuals or clumps include *Lophostemon suaveolens, Eucalyptus robusta, E. tereticornis, E. bancroftii, E. latisinensis, Corymbia intermedia, Melaleuca salicina, Livistona australis, Casuarina glauca, Endiandra sieberi. Melastoma malabathricum* subsp. *malabathricum, Glochidion sumatranum* and *Melicope elleryana* are often in understorey. Occurs on Quaternary alluvium in coastal areas. |
| RE 12.3.6 | *Melaleuca quinquenervia* +/- *Eucalyptus tereticornis, Lophostemon suaveolens, Corymbia intermedia* open forest to woodland with a grassy ground layer dominated by species such as *Imperata cylindrica. Eucalyptus tereticornis* may be present as an emergent layer. Occurs on Quaternary floodplains and fringing drainage lines in coastal areas. |
| RE 12.5.2a | *Corymbia intermedia, Eucalyptus tereticornis* woodland. Other species can include *Lophostemon suaveolens, Angophora leiocarpa, Eucalyptus acmenoides* or *E. portuensis, E. siderophloia* or *E. crebra, Corymbia tessellaris* and *Melaleuca quinquenervia* (lower slopes). *Eucalyptus exserta* is usually present in northern parts of bioregion. Occurs on complex of remnant Tertiary surfaces +/- Cainozoic and Mesozoic sediments usually in coastal areas with deep red soils. |
| RE 12.5.3 | *Eucalyptus racemosa* subsp. *racemosa* woodland with *Corymbia intermedia, E. siderophloia* +/- *E. tindaliae, E. resinifera, E. pilularis, E. microcorys, Angophora leiocarpa. Melaleuca quinquenervia* is often a prominent feature of lower slopes. Minor patches (<1ha) dominated by *Corymbia citriodora* subsp. *variegata* sometimes occur. Occurs on complex of remnant Tertiary surfaces +/- Cainozoic and Mesozoic sediments. |
| 12.11.5k | *Corymbia henryi* woodland +/- *Eucalyptus crebra, E. carnea, E. tindaliae, E. fibrosa* subsp. *fibrosa, E. siderophloia, C. citriodora* subsp. *variegata, Angophora leiocarpa, E. acmenoides, E. helidonica, E. propinqua, C. intermedia*. Includes patches of *E. dura*. Occurs on drier ridges and slopes in near coastal areas on Palaeozoic and older moderately to strongly deformed and metamorphosed sediments and interbedded volcanics. |
| 12.11.18a | *Eucalyptus moluccana, Eucalyptus tereticornis* and *Lophostemon confertus* open forest. Occurs on Palaeozoic and older moderately to strongly deformed and metamorphosed sediments and interbedded volcanics. |

**Table 2.3:** Mapped regional ecosystems within the MBR area (from Petrie to Kippa-Ring and the Griffin and Scouts sites)

## 2.4.1 Amcor Site – Petrie to Kallangur section

The Amcor site covers approximately 240 hectares with approximately half of the site (121 hectares) providing (vegetated) habitat for koalas. This site and the koala habitat it contains is extremely important for the local koala population as it represents one of the largest remaining vegetated areas. It is surrounded by intensive urban development dominated by residential dwellings. The site was purchased by the Moreton Bay Regional Council in 2015 and, at the time of writing, was being developed as a university precinct.

The Amcor site is bounded to the south by the North Pine River, to the west and north respectively by Gympie Road and Dohles Rocks Roads in addition to residential and industrial development, and to the east by the Murrumba Downs Sewerage Treatment Plant operated by Unitywater. Yebri Creek flows in an easterly direction through the middle of the site with the southern half of the site originally used for the Petrie Paper Mill until its recent demolition. As a result of this infrastructure, the southern half of the site generally contains only clumps and several strips of vegetation that, while mostly native, are dominated by regrowth, with only occasional scattered mature trees present.

The site north of Yebri Creek is also highly disturbed with approximately seven hectares of land historically used as waste landfill, and 24ha of disused treatment ponds dominating the eastern portion of the site. The vegetation north of Yebri Creek is a mosaic of remnant vegetation, regrowth native open eucalypt forest, sometimes with stands or scattered individual exotic species such as camphor laurel (*Cinnamomum camphora*) or slash pine (*Pinus elliottii*), and open grassland/dense low shrubland dominated by numerous exotic species. The open eucalypt forest is dominated by blackbutt (*Eucalyptus pilularis*), flooded gum (*E. grandis*) and scribbly gum (*E. racemosa*) with the most mature stands occurring west of the rail alignment. However other species such as Queensland blue gum (*E. tereticornis*), old grey ironbark (*E. siderophloia*) and brushbox (*Lophostemon confertus*) are also present. The site contains several areas of Regulated Vegetation as mapped by the Queensland Government, with four different REs mapped on the site. These include a 15ha area of 'endangered' RE 12.5.3 in the north of the site, 'of concern' RE 12.3.11 and another area of RE 12.5.3 associated with Yebri Creek. (The latter appears to be incorrectly mapped, however.) There is 'least concern' RE 12.1.3 associated with the northern bank of the North Pine River in the south of the site. The descriptions for these REs are shown in **Table 2.3** above.

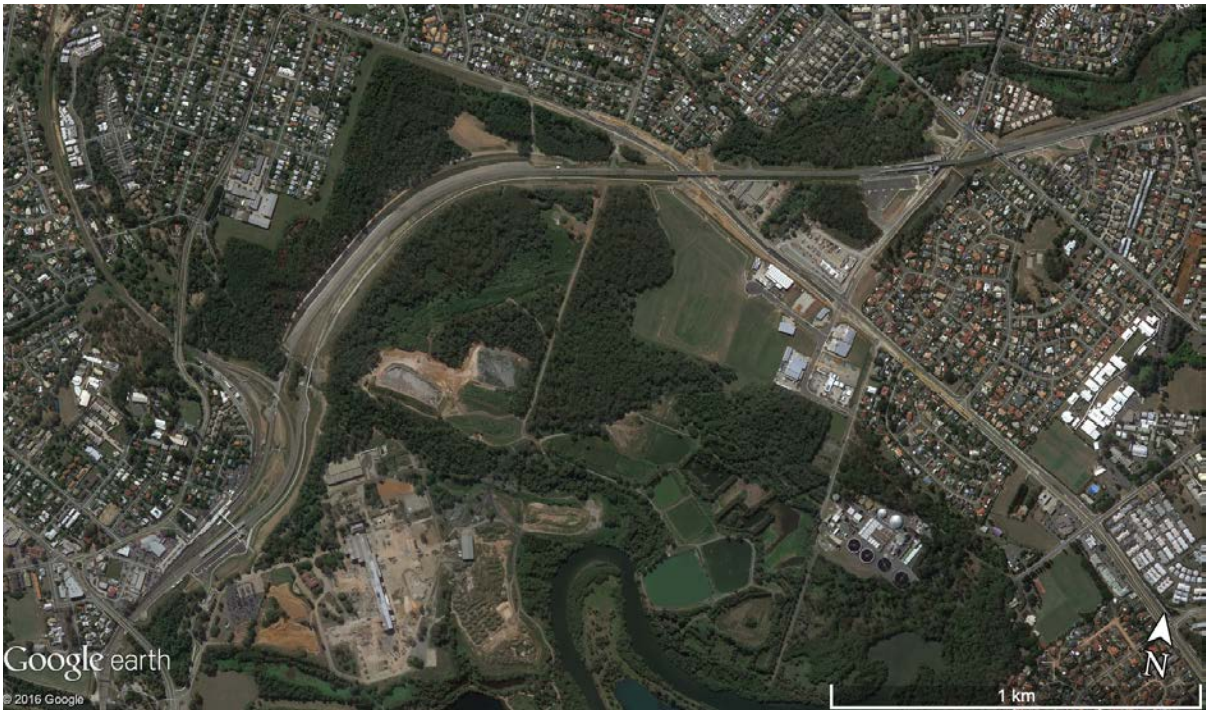



**Figure 2.3**: Aerial photograph showing vegetation in and around the Amcor site at Petrie

## 2.4.2 Kallangur to Murrumba Downs section

This section covers an area of approximately 60ha and is predominantly characterised by a section of the Freshwater Creek corridor that is transected by Dohles Rocks Road in the west, and the Bruce Highway in the east. The rail corridor and new Kallangur Station bisects an area of predominantly terrestrial open eucalypt forest dominated by scribbly gum (*E. racemosa*), while four local roads traverse the linear Freshwater Creek habitat – Goodfellows Road, Duffield Road, Cecily Street and Brays Road. Another small waterway, Black Duck Creek passes north-south under the new rail corridor and joins Freshwater Creek just west of Brays Road. The new Murrumba Downs station is located along the southern edge of the Freshwater Creek corridor accessed by Cecily Street.

Vegetation in the Freshwater Creek corridor is dominated by disturbed broad-leaved paperbark (*Melaleuca quinquenervia*) forest on the margins and within the creek channel, fringed in some areas by Queensland blue gum (*E. tereticornis*). Extensive areas of weeds and exotic grasses dominate areas that have been historically cleared and a stand of slash pines (*P. elliottii*) occurs on the southern bank of Freshwater Creek north of the new Murrumba Downs station. Despite the overall disturbed nature of this section and the four road crossings, the habitat still supports several koalas. It functions as an important corridor linking the Black Duck Creek corridor to the south, another section of Freshwater Creek that flows from the NNW, the main Freshwater Creek corridor as it continues east under the Bruce Highway and a more tenuous westerly link (across Dohles Rocks road) to habitat on the Amcor site. There are already several records of koalas utilising this corridor to move west-east/east-west under the highway. The presence of heavily urbanised areas that surround these creeks highlights the significance of the habitat in these corridors. Furthermore, the habitat quality and ecosystem function could be significantly increased if rehabilitation were conducted in suitable areas.

The scribbly gum (*E. racemosa*)-dominated forest associated with the new Kallangur Station is generally in good condition and intact, with only some areas containing lantana (*Lantana camara*). This area of scribbly gum forest appears to be consistent with RE 12.5.3 but has not been identified as *Regulated Vegetation* or mapped as such on the RE mapping. Only one area of *Regulated Vegetation* is mapped in the east of this section as 'least concern' RE 12.3.6 over part of Freshwater Creek. The descriptions for these REs are shown in **Table 2.3**.


**Figure 2.4**: Aerial photograph showing vegetation between Kallangur Station and Murrumba Downs Station

### 2.4.3 Mango Hill section – Bruce Highway to Kinsellas Road

This section covers an area of approximately 15ha with the only viable habitat occurring in the western portion of the section along the Freshwater Creek corridor. The vegetation in this section is dominated by broad-leaved paperbark (*M. quinquenervia*) with fringing Queensland blue gum (*E. tereticornis*) not dissimilar to the previous Kallangur-Murrumba Downs section. Although supporting good stands of paperbark, this creek corridor has previously been disturbed, with both terrestrial and aquatic weeds abundant in some areas.

The rail corridors traverses the Freshwater Creek corridor 250m east of the Bruce Highway in the form of a high concrete bridge allowing some ecological connectivity across the corridor. This has been evidenced by multiple crossings under the bridge by at least two different koalas detected using remote bio-telemetry (LX *K-Tracker* telemetry system) and trail cameras (see ***Chapter 12 - AKHO-CM and GOSM Programs***. Due to the surrounding intensive residential development and the construction of the Mango Hill train station, no other areas of viable habitat occur in this section.

*Regulated Vegetation* is mapped along the Freshwater Creek corridor as 'least concern' RE 12.3.5 and immediately east of the Freshwater Creek bridge an area of 'endangered RE 12.5.3 is mapped, however this vegetation appears to have been removed during the construction phase of the MBR project. The descriptions for these REs are shown in **Table 2.3**.


**Figure 2.5**: Aerial photograph showing limited vegetation between the Bruce Highway and Kinsellas Rd. Significant vegetation exists mainly along the Freshwater Creek habitat corridor.

## 2.4.4 Rothwell section – Kinsellas Road to Gynther Road

With the exception of the Saltwater Creek corridor, all viable habitat and connectivity between nearby habitat fragments has been obliterated by residential development in this 15ha section. The majority of remaining vegetation in this section is associated with Saltwater Creek and is mostly below the Highest Astronomical Tide (HAT). It consists mostly of mangrove forest and other marine plants. Limited terrestrial vegetation, consisting of paperbark/eucalypt open forest, occurs on the eastern side of Saltwater Creek and to a lesser extent on the western side of Saltwater Creek. Although relatively sparse, these areas provide habitat for koalas. A 600m linear patch of eucalypt-dominated vegetation occurs immediately west of Gynther Road. This has been utilised by koalas previously, however the long term viability of this area is uncertain due to continuing urban encroachment and increasing local traffic volumes around Rothwell Station.

*Regulated Vegetatio*n is mapped in the form of five different REs – all associated with the Saltwater Creek corridor and includes 'least concern' REs 12.1.2, 12.1.3 and 12.3.6, 'of concern' RE 12.1.1 and 'endangered' RE 12.5.2a. The descriptions for these REs are shown in **Table 2.3**.


**Figure 2.6**: Aerial photograph showing limited vegetation between Kinsellas Rd and Gynther Road, dominated by marine vegetation types along Saltwater Creek, with patchy eucalypti-dominated forest on either side of the creek.

## 2.4.5 Kippa-Ring section – Gynther Road to Hercules Road

This section contains the largest area of intact koala habitat along the MBR alignment, covering approximately 130ha. It is the largest remaining patch of vegetation in the Kippa-Ring locality. This area is largely an MBRC conservation reserve and is bounded to the north and west by a combination of residential, light commercial, retail and retirement village development, including two schools which still contain small stands of trees utilised by koalas. It is bounded to the east by high-density residential development and to the south by the Hays Inlet Conservation Area.

The vegetation in this section is dominated by open mixed eucalypt forest that is largely intact and has few weed species present. Towards the south, this community then grades into paperbark (*Melaleuca quinquenervia*) and swamp she-oak (*Casuarina glauca*) forest before mangrove forest becomes dominant in the inter-tidal zone. Prior to the MBR corridor bisecting the northern third of this patch, other existing disturbance included a 30m wide power-line easement that ran essentially parallel to, but south of the rail corridor, and several tidal drainage channels.

This area is of critical importance to the local koala population. Due to the generally high density of the residential areas and lack of nearby habitat to the north and south, safe koala movement corridors are very limited. Some movement opportunities exist to the west through a very narrow but functioning corridor while the best movement opportunities are from the eastern edge of this area where other habitat occurs to the south at Clontarf. There have been numerous instances of MBR-monitored koalas utilising this corridor and habitat to the south.

The majority of vegetation in the Kippa-Ring section is mapped as *Regulated Vegetation* in the form of six different REs which were 'least concern' REs 12.1.2, 12.3.5 and 12.3.6, 'of concern' REs 12.1.1 and 12.3.11 and 'endangered' RE 12.3.5a. The descriptions for these REs are shown in **Table 2.3**.


**Figure 2.7**: Aerial photograph showing vegetation at Kippa-Ring, between Gynther Rd and Hercules Rd. The marine areas of Hays Inlet and Saltwater Creek border the south of this important koala habitat remnant.

## 2.4.6 Translocation and offset sites

### Griffin offset site

In partial fulfilment of offset requirements for the project, a TMR-owned site at Griffin was designated as a koala habitat offset for the MBR project. Approximately 35ha of open grassland on the site was replanted with koala habitat trees between 2013 and 2015. The 65ha site (55ha delineated by lots, and approximately 10ha of marine reserve area) had been used for cattle grazing and consisted of open grassland in the eastern half and forested vegetation communities in the north and western portions of the site. Existing forest communities are mostly open to closed mixed eucalypt-paperbark forest that includes Queensland blue gum (*E. tereticornis*), old grey ironbark (*E. siderophloia*), spotted gum (*Corymbia citriodora*), scribbly gum (*E. racemosa*), pink bloodwood (*C. intermedia*) and Moreton Bay ash (*C. tessellaris*). The site also contains several man-made dams in the low-lying areas in the western half, which are continuous with natural wetland and swamp areas to the north. The majority of clumps and scattered trees in the northeast of the site consist of Queensland blue gum (*E. tereticornis*) and Moreton Bay ash (*C. tessellaris*). The northern portion of the site is dominated by broad-leaved paperbark (*M. quinquenervia*) associated with a drainage line that flows to the north-east.

The site is bounded by the Bruce Highway (to the west), the North Pine River (to the south) and a residential development (to the north), so habitat corridors linking habitat on the site to other nearby habitat areas are somewhat limited. The paperbark-dominated drainage line that occurs in the north of the site continues to the north of the site boundary for approximately 600m until the habitat is reduced to scattered trees and is transected by two local roads. This corridor is utilised by koalas and some of the MBR-monitored koalas established home ranges and/or dispersed through the corridor. The south-west corner of the site is tenuously connected to a narrow riparian corridor along the northern bank of the Pine River west of the Bruce Highway. This corridor was utilised by a MBR-monitored female koala from the Griffin site (*Anna* - see ***Chapter 6 - Ranging behaviour and habitat use by koalas***).

*Regulated Vegetation* is mapped in several areas in the central portions and small marine areas in the south of the site. However the RE mapping in the central portions appears to be erroneous as it corresponds with the areas that were open grassland prior to the offset replanting, and would therefore not be consistent with remnant status. The mapped REs were 'least concern' 12.1.2 and 12.1.3, mixed polygon of 'of concern' 12.3.5, 12.3.6 and 12.3.11 and 'endangered' 12.5.3, and are described in **Table 2.3**.

**Plate 2.4**: The Griffin offset site contained a mix of replanted koala habitat trees and established habitat. Re-planting of old grazing land commenced in early 2013, with most grassed expanses on the site completely replanted by 2015, comprising approximate half of the 65ha site. These areas were regularly used by koalas by 2016.


**Figure 2.8**: Griffin offset site purchased by TMR in partial fulfilment of koala habitat offset obligations.


**Figure 2.9**: "Scouts" translocation recipient site, situated approximately 5km to the west of the MBR project. The "Murrenbong Campsite" site is owned by the Scout Association Australia Queensland Branch, and has broad habitat continuity on all boundaries.

### Scouts' Land

The Murrenbong Scouts' site is located at Kurwongbah approximately 5km to the north-west of the MBR corridor, and covers an area of approximately 150ha. This and the Griffin offset site were used as recipient sites for at-risk koalas translocated from habitat in and around the MBR corridor. The southern half of the eastern site boundary is bordered by Scout Road, however the remaining site boundary is contiguous with a large expanse of vegetation stretching to the north and west. Vegetation is dominated by dry, open mixed eucalypt forest with occasional narrow gullies and drainage lines that support wetter communities. Dominant species in the drier forest include spotted gum (*C. citriodora*), gum-topped box (*E. moluccana*), grey gum (*E. propinqua*), old grey ironbark (*E. siderophloia*), white mahogany (*E. acmenoides*) and Queensland blue gum (*E. tereticornis*), while broad-leaved paperbark (*M. quinquenervia*), swamp box (*L. suaveolens*) and umbrella cheese tree (*Glochidion sumatranum*) are common in the gullies and drainage lines.

Overall, the site vegetation was in good condition with minimal weed cover. However, few hollow-bearing trees and a somewhat uniform age-class structure may indicate prior widespread disturbance, such as historical logging. Presently though, vegetation cover across the site is generally intact with the exception of a man-made dam and an electrical transmission line corridor through the middle of the site in a north-west/south-east direction. The site vegetation is contiguous with surrounding vegetation on all sides, so connectivity to surrounding habitat is high, with koala movement and dispersal opportunities in any direction from the site.

Reflecting the essentially continuous vegetation cover over the site, *Regulated Vegetation* is mapped over nearly the entire site with three different REs identified. These were 'of concern' RE 12.3.11 and 'least concern' REs 12.11.5k and 12.11.18a which are described in **Table 2.3**.

The total area of each of the translocation recipient sites is shown in **Table 2.4** below.

| Translocation polygon name | Area | Site characteristics/comments |
|---|---|---|
| **Griffin** | 65 ha | Old cattle grazing property with large areas of grassed paddocks occupying approximately one half of the site. These were replanted with koala habitat trees. Site includes approximately 55ha on four lots, plus approximately 10ha of other-tenure land, including tidal flats. |
| **Scouts** | 157 ha | Almost completely vegetated site owned by the Scout Association Australia Queensland Branch. |

**Table 2.4**: Area and site characteristics of the koala translocation recipient sites.

## 2.5 Koala search and capture approach

A primary objective of the *Koala Tagging and Monitoring Program* was to protect koalas during vegetation clearing and construction works. This required all at-risk koalas to be captured and protected from harm prior to commencement of vegetation clearing works. This objective was achieved using telemetry devices to locate animals on each day of vegetation clearing. All koalas living in and around the MBR project were considered to be at risk due to normal ranging behaviour, and therefore considerable effort was expended to capture all koalas, rather than just a sample. At each koala search area (polygon), a number of days or weeks of intensive and systematic search effort was applied (consistent with the habitat type, density and area), and thereafter opportunistic captures were conducted when "cleanskin" (untagged) koalas were located during field work.

**Plate 2.5**: Koalas can be very difficult to spot, even when the vegetation is not dense. The three images above show the same tree at increasing magnification, showing how well camouflaged koalas can be. The red arrow in the top image shows the approximate location of the koalas. This demonstrates the value of telemetry devices in efforts to locate and protect koalas during vegetation clearing. This is koala *Jane* and her near-independent joey at the offset site at Griffin.

Koalas were entered into the program in one of two general ways:

1. By search and capture (or opportunistic capture) in the habitat defined by the koala search polygons; or
2. Via koala rescue groups or wildlife hospitals.

In the case of 2 (above), the criterion for acceptance of a koala from a wildlife rescue group or hospital was that there was an intention by the group to release that koala into habitat *encompassed by one of the koala search polygons* (irrespective of its original point of capture/rescue). In other words, if the koala was going to be released into habitat in the MBR koala search polygons, then it would be tagged and included in the program.

Transect searches were conducted over a number of days or weeks in habitat encompassed by each of the koala search polygons, generally using a team of four to six experienced koala biologists, including experienced koala capture personnel. Search times were allocated somewhat arbitrarily, and often additional search effort was applied if on-ground personnel deemed that additional effort was necessary to thoroughly search all habitat. Search effort was approximately 1 day per 25ha. Data collected when koalas were located during searches included date, time, weather conditions, tree species, height in tree, tree height and diameter at breast height (DBH) and GPS position. An assessment of the suitability of the koala/tree for a capture attempt was made at the time, and one of three outcomes ensued:

1. A capture attempt by traditional methods (flagging with/without tree climb) was attempted;
2. A koala trap was set;
3. No capture was attempted due to unsuitability of tree or circumstances.

Koala capture and handling methods are contained in *Appendix 3 -Koala Capture and Handling*, and a pre-capture tree assessment check sheet is shown in *Appendix 4 - Tree-climbing checklist*.

**Plate 2.6**: Images showing conventional climbing flag capture (above) and koala trap capture (below). Top images are the capture of the koala *Lexi;* lower images are a double-trap set-up for koala *Raylee* and her near-independent joey *Tash.* Right lower image shows both mother and joey captured in the left trap.

## 2.6 Subsequent captures

As part of the population health management program, all koalas were scheduled for capture at 6-monthly intervals following their date of initial capture and entry in to the KTMP. At their initial capture all koalas received a comprehensive veterinary examination, which was repeated at their 6-monthly captures. In addition, koalas were captured sooner than 6-monthly for the following reasons:

1. When injury or illness was detected;
2. In growing animals for the purposes of resizing collars or anklets;
3. When follow-up veterinary checks or treatment were required for previously treated koalas;
4. At scheduled re-vaccination time-points for koalas included in the vaccine trial;
5. When koalas dropped telemetry tags and required re-application of the tags;
6. If the koala was deemed to be in immediate danger.

An analysis of data relating to koala capture intervals showed an average capture interval of 80 days for all koalas across the whole koala management program.

**Plate 2.7**: Koalas that have been caught a number of times are generally quite relaxed, and will often readily eat before and after veterinary examinations. This is koala *Tait* who seems to have found a comfortable spot on the kidney dish after recovery from anaesthesia for his scheduled veterinary check in December, 2014.

## 2.7 Transport of koalas

After capture, koalas were transported in purpose-built koala transport cages with browse provided. The transport cages consisted of a durable plastic base and upper weld-mesh wire section, with a top-opening lid or gate. The cages were covered with a light cotton fabric cage cover to minimise exposure to visual stimuli when koalas were contained within. Koalas were transported in air-conditioned vehicles back to the EVE veterinary facilities at Toorbul. If transport to Toorbul was delayed (for example, while another capture was occurring), contained koalas were placed into an air-conditioned demountable on site.

**Plate 2.8**: Koala *Maxwell* contemplating freedom at his final release at the offset site at Griffin. Top-opening wire-topped cages are the most suitable for koala transport.

**Plate 2.9**: Hand-reared koala *Sammy* says his final farewell to foster mother and koala ecologist Dr Deidre de Villiers at the time of his final release into bushland at Kippa-Ring at the end of the koala management program.

## 2.8 Release of koalas

After recovery from anaesthesia for veterinary examination, koalas that were suitable for release (that is, they were not sick or otherwise required admission for treatment) were placed back into a koala transport cage and returned to their point of capture. In most cases, koalas were released at their exact point of capture (POC). If the tree or circumstances around the capture tree were unsuitable (for example, if the capture occurred on the edge of a busy road), the koala was released into another tree in its home range near the point of capture. The release of koalas outside of their usual home range only occurred for koalas meeting the criteria for translocation (see ***Chapter 7 - Koala translocation***).

Vocalisation immediately after release occurred in a small proportion of koalas, and is considered to be a normal behaviour. It occurs in a subset of koalas that become quite stressed by the capture/ captivity events, and their release back into the wild causes an overwhelming release of emotion. It was observed in less than 10% of koalas (see **Plate 2.10**, below - koala *Mali*).

**Plate 2.10**: Final release of the koala *Mali* near the new Kallangur Station. *Mali* is an aged female koala who was rendered sterile by chlamydial infection. She was successfully treated with antibiotics and surgical ovario-hysterectomy. She remained healthy for the remainder of the program, and was not translocated due to her age, well established home range and sterility.

**Plate 2.11**: Koalas *Johnny K* (left image) and *Kylie* (right image) immediately following release after scheduled veterinary health checks. Both koalas were resident in bushland in the *Bruce Hwy West* koala search polygon.

## 2.9 Veterinary assessment and management

All initial and scheduled veterinary examinations were conducted at the EVE veterinary clinic at Toorbul. Veterinary examinations were comprehensive and standardised to ensure effective diagnostic work-up and consistency of data collection. The approach to examination essentially followed the procedure outlined in the document entitled *A standardised approach to the veterinary clinical examination of wild koalas for population health assessment* contained in *Appendix 5*. Veterinary examinations were conducted under general anaesthesia/sedation induced by intramuscular injection of alfaxalone (Alfaxan® Jurox). Data were recorded initially on paper forms, then using the Apple Numbers® program, then, from May 2015, using a custom-designed FileMaker® database. All early records were ultimately duplicated in the database.

Koalas determined to be ill or injured on veterinary examination were treated at the EVE facilities or at other wildlife veterinary facilities. Poor outcomes associated with referral of koalas to other facilities prompted the construction of koala rehabilitation enclosures at the EVE veterinary clinic at Toorbul, and rehabilitation of most sick and injured koalas was performed by EVE thereafter.

Surgical procedures, other than orthopaedic repairs (of fractured bones), were conducted at the EVE veterinary facilities. Orthopaedic procedures were generally conducted at the Veterinary Specialist Services hospital at Underwood, by Dr Phil Moses. Program budgets allowed for an appropriate standard of veterinary diagnostic work-up and care to be applied to all koalas requiring veterinary care. This approach was essential to maintaining trust among the koala stakeholders that the project was treating the koalas with respect and compassion.

**Plate 2.12**: EVE veterinarian Dr Amy Robbins performing a mid-treatment veterinary examination on anaesthetised koala *Tanja* during in-patient care for chlamydial infection of the urogenital tract in September 2016. She was later released back into the wild.

## 2.10 Necropsy examination

One of the most important objectives of the koala management program was to determine causes of death in monitored koalas. This was an essential dataset to inform conservation management actions and avoid or mitigate project-caused mortality; that is, it was a critical input into the adaptive management process.

Conducting diagnostic necropsy examination requires rapid detection of death and early recovery of a carcass - prior to significant decomposition. This, in turn, requires that monitoring of tagged koalas occurs with sufficient frequency to detect death quickly after a mortality event. Consequently, conventional radio-tracking frequency was at least once every 3-4 days. In koalas bearing the LX *K-Tracker* tags, 12-hourly GPS and activity data uploads allowed for detection of death within 24 hours.

Necropsy examination of deceased koalas was conducted as soon as possible after death, whether death occurred naturally or euthanasia was performed. The examination consisted of thorough gross dissection of the carcass and observation of gross lesions. In cases in which the diagnosis relied upon or was strengthened by examination of histology specimens, tissues samples were collected into formalin, sent to Queensland Medical Laboratories (QML) for processing, and returned to EVE as histology slides for examination by Dr Jon Hanger. Additional diagnostic testing, such as microbial culture and sensitivity was occasionally performed as necessary to support or refine a diagnosis of cause of death. These samples were tested by QML.

Comprehensive reports of necropsy findings, including diagnosis, contributing circumstances, predisposing factors, explanatory comments and expert opinions regarding cause of death were recorded as stand-alone documents in the early phase of the project or in the FileMaker® database in the last 18 months of the program. Paper and digital records were ultimately duplicated in the database. A detailed overview of koala mortality over the course of the program is contained in ***Chapter 8 - Causes of death of koalas***. Necropsy summaries are contained in *Appendix 6*.

**Plate 2.13**: Initial stages of necropsy examination of koala *Caz*, showing findings typical of the "Amcor Dog" - punctures on the rump consistent with a "positioning" bite (bottom right image), with the accurate and consistent "kill bite" to the neck (bottom left image). Astute and thorough necropsy technique and experience is essential to building the case for a diagnosis, and elucidating the circumstances and most like scenario(s) resulting in the death of each koala. *Caz's* joey *Pistachio* was successfully hand-reared after this orphaning event.

## 2.11 Monitoring and telemetry

### 2.11.1 Monitoring methods

Radio-collaring of koalas has been a standard ecological method for many decades. However, telemetry collars can cause mortality and severe injury in koalas due to hang-ups, severe collar rub, severe skin infections and other incidents. For both animal welfare, koala stakeholder confidence and PR risk management reasons, the use of very safe and low-impact devices and attachment methods was of paramount importance.

**Plate 2.14:** Trauma caused by a radio-telemetry collars (Note: these koalas are not MBR koalas). Left image shows significant rub injury on the shoulder caused by a bulky GPS-logging collar. Right image shows a more severe lesion caused by a telemetry collar. Much more severe injuries occur occasionally and often lead to the death of the koala.

Monitoring of koalas by telemetry was an essential and central method of the koala management program. It enabled the following objectives to be achieved:

1. Location and protection of tagged koalas during vegetation clearing;
2. Determination of ranging behaviour and habitat usage - inform rail design;
3. Detection of death and recovery of carcasses for necropsy examination;
4. Monitoring of individual koala health, and capture and veterinary management when required;
5. Implementation of the *Chlamydia* vaccine trial;
6. Monitor responses of koalas to construction activities and during operational phase of rail project;
7. Monitor use of crossing structures (culverts and under-bridge corridors) by koalas - habitat connectivity monitoring.
8. Intervention when koalas were in high-risk situations.

These objectives required the telemetry monitoring method to provide information at least every day during vegetation clearing in respect of objective 1 above, and every 3-4 days in respect of objective 3 above. Had the telemetry and monitoring methods not been as they were, those two objectives would not have been achieved.

Currently available telemetry devices for wildlife fall into three broad categories:

1. Standard radio-telemetry transmitters: these are simple VHF radio transmitters that emit a "ping" at around 1-second intervals on a specific frequency in the 148-153 MHz range, allowing location of a koala in the field using a directional antenna and special telemetry receiver. Transmitters may be in the form of a collar or anklet - a low-impact design developed by EVE. These transmitters do not store data "on-board", but instead the field operator locates the koala and collects data at the site. This method was used to track koalas each day during vegetation clearing, at scheduled field tracking events, and if health or situational concerns occurred.

2. Data-logging GPS collars: these collars incorporate a GPS antenna and simple electronics that allow GPS positions to be collected at pre-programmed times and intervals and stored "on-board". These collars incorporate a VHF transmitter as well to allow standard radio-tracking of the tagged animal. However, GPS data are not available until the collar is recovered and data downloaded. These collars did not sufficiently achieve the objectives required of the MBR koala program and so were not used.

3. Data-logging GPS collars with remote data download/upload: these collars are similar to data-logging GPS collars, but have additional electronics to allow data to be accessed remotely in near-real-time. At the time of commencement of the MBR koala program none of the commercially available wildlife telemetry collars were suitable for koalas due to form factor, safety issues and/or functionality. Commercially available GPS collars were available that provided some remote data interrogability, but their form factor was not suitable for koalas for safety and comfort reasons. Other tags marketed as suitable for koalas, such as satellite and remote UHF download options had similar limitations.

The most suitable telemetry technology in terms of meeting the objectives of the KTMP and broader koala management program, was the data-logging GPS collars with remote data access functionality. Ultimately, the LX/EVE *K-tracker* provided the following benefits to the project:

1. Significant improvement in koala monitoring frequency and quality;
2. Net cost savings after 9-12 months of deployment, compared with standard radio-telemetry (field tracking);
3. More rapid detection of severe illness and mortality of tagged koalas;
4. Desk-top graphical user interface accessible by mobile devices, such as tablets and laptops, by anyone with login permissions;
5. Near-real-time monitoring of koala GPS positions and activity levels.

**Plate 2.15**: Koala *Maya* after release back into her home range in February, 2014. She is fitted with a standard VHF anklet and one of the early versions of the low-impact LX *K-Tracker* collars. These collars never caused serious injury.

## 2.11.2 Bio-telemetry and development of the LX *K-Tracker* system

Bio-telemetry systems allow the collection of biological data and usually GPS position for either remote download/upload or store-on-board access. EVE commissioned the development of a bio-telemetry collar specifically for koalas from Bio-Trace Telemetry Pty Ltd in 2011. Although these collars showed great promise and were functionally the most suitable, significant in-field failures in the early stages of the MBR program caused the system to be abandoned and an alternative system developed. EVE then commissioned the development of a koala-specific telemetry system by *LX Solutions* in mid-late 2013 and field trials of the new "K-Tracker" tags occurred in early 2014. This system allowed near-real-time access to 12-hourly GPS and activity data via a custom-designed web-based user interface. EVE designed the innovative attachment collar, and refined the attachment system with the assistance of *Design + Industry*, based in Sydney. The resulting collar is a refined, elegant, safe and very low impact telemetry solution for koalas. An integral break-point is incorporated into the collar to ensure the collar snaps off in the event of a hang-up or entanglement. The system won a National Engineering Excellence award in 2015, and became the central telemetry technology for the MBR koala program in the last 2-3 years of the program. Additional geo-fencing firmware functionality, added in 2016, allowed for an automatic and scaled increase in GPS fix-rate when koalas were close to, or interacting with, the koala fence and crossing structures along the new rail line. This function allowed for finer detail data acquisition when koalas were interacting with the rail fence or culverts and better interpretation of behavioural responses. Examples of this functionality are shown in ***Chapter 6 - Ranging behaviour and habitat use by koalas***.


**Figure 2.5:** Data outputs from the *K-Tracker* collars are relayed to the LX Solutions-hosted website via solar-powered base stations. Data are displayed graphically on a Google-Earth map overlay on the website (bottom image), and are downloadable as CSV files for more detailed data processing and analysis. Top left plate shows installation of a base station at the Kippa-Ring bushland. Top right figure shows a graphical representation of the *K-Tracker* communications system.

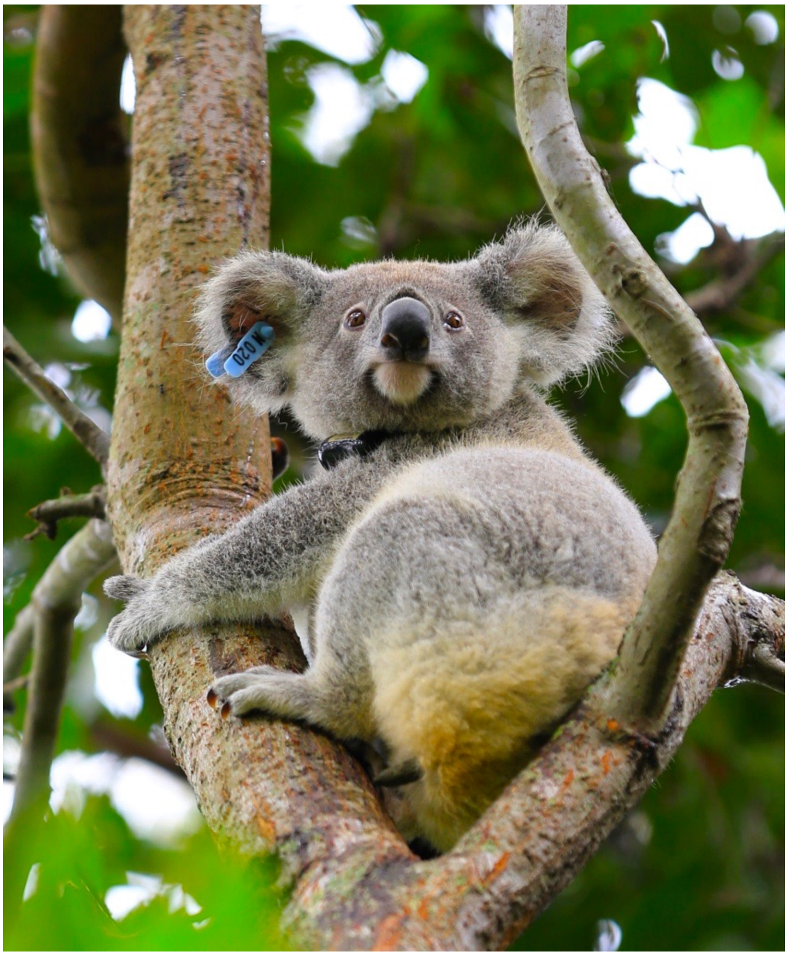


**Plate 2.16**: Koala *Tash* as a near-independent joey (May 2013 - Amcor site), fitted with a juvenile VHF koala collar. (Top image). Bottom image shows a slightly older *Tash* (February 2014), wearing an early version of the *K-Tracker* collar and a VHF "anklet". The *K-Tracker* collects a GPS position and activity data every 12 hours, and transmits that to the local base station, which then uploads the data to the website. The VHF anklet is used for conventional field radio-tracking.

## 2.11.3 Standard radio-telemetry

All koalas bearing *K-Tracker* tags were also tagged with a VHF transmitter anklet as a back-up tracking device in the event of collar drop-off or malfunction. The collars themselves were also fitted with a VHF transmitter (enclosed in the lower collar weight enclosure), to enable collar retrieval in the event of drop-off and as a back-up koala tracking device.

Koalas less than 3kg in bodyweight (near-independent or newly independent young) were fitted with a "Velcro® anklet collar". This is a collar constructed of Velcro® material on which an "anklet" VHF transmitter has been fitted. This is a very safe and simple, low-impact solution for small koalas that are around the age of independence from their mother, but are under the 3kg+ bodyweight criterion for fitting of the *K-Tracker* collars.

**Plate 2.17**: Hand-reared orphaned koala *Rocket* at time of release back into the wild. *Rocket* has a "Velcro® anklet collar" fitted, which is a safe tracking solution for recently independent juvenile koalas.

**Plate 2.18**: Near-independent joey *Ian* (joey of *Panda*) fitted with a juvenile koala VHF collar and a VHF anklet.

## 2.11.4 Monitoring schedules

Telemetry monitoring and field tracking schedules are provided in detail in ***Chapter 6 - Ranging behaviour and habitat use by koalas***.

In brief: koalas were required to be monitored at a frequency of twice weekly *as a minimum* in order to achieve key objectives and meet the conditions of the regulatory approvals. Higher frequency in the first two weeks was required in koalas that were collared for the first time. The *K-Tracker* system allowed for monitoring of koalas daily, using remote (desk-top) access to both GPS and activity data streams. When the *K-Tracker* system was functioning normally, koalas bearing these tags were field-tracked once every 2 weeks. Koalas bearing only a VHF transmitter(s), or when the *K-Tracker* was non-functional or out-of-range, were tracked twice weekly (at 3 or 4-day intervals).

Monitoring frequency was increased during periods of vegetation clearing: koalas in at-risk areas were tracked daily; each morning prior to the commencement of vegetation clearing in their area, and occasionally more frequently if required.

**Plate 2.19**: Koala *Matt* from Kippa-Ring, wearing one of the original VHF transmitter collars used early in the project.

## 2.12 Translocation

At the time of writing, translocation of koalas in response to development pressure was prohibited under the *Nature Conservation Act, 1992* except when permitted under the provisions of a Scientific Purposes Permit (SPP) issued by the Queensland Department of Environment and Heritage Protection (EHP). Translocation of some koalas was considered to be necessary during construction of the Moreton Bay Rail to avoid leaving koalas in high-risk situations, and consequently an application for an SPP allowing the translocation koalas was made in October 2013, and granted (WISP13661313). The primary scientific purpose for which the permit was granted was to investigate the effectiveness of translocation as a management tool for displaced or at-risk koalas.

The permit applied to both translocated koalas and also resident koalas living in the recipient site habitat. The approval conditions allowed for up to 40 koalas at each of four potential recipient sites to be captured and monitored for a minimum of three months prior to the translocation of any koala into the site. Up to 150 koalas were estimated in the SPP application to possibly be suitable for translocation. Resident koalas in the two selected recipient sites were radiotracked for a minimum of 3 months prior to the commencement of translocations. Each translocated koala was required to be monitored for a minimum period of 12 months following translocation. (Twenty-eight koalas were eventually translocated to two receive sites - see ***Chapter 7 - Koala translocation***).

Translocation was determined to be an option of last resort for koalas that were in circumstances of high risk, either because of works associated with the Moreton Bay Rail project and/or other development projects or present circumstances. Comprehensive criteria were developed against which each koala was assessed for suitability for translocation, and these included both site/habitat and individual characteristics, as well as consideration of future circumstances and risks. The assessment criteria and assessment results are contained in *Appendix 7*.

Prior to translocation of koalas, each was subjected to a comprehensive veterinary examination and determined to be free of significant disease or infection. The duration of monitoring of resident koalas in the proposed recipient sites exceeded 3 months, because captures of those koalas were spread over a number of weeks, and monitoring continued for at least three months after the final koala was captured and released. Similarly, monitoring of most translocated koalas exceeded 12 months, because monitoring continued for *all* translocated koalas until after the *final* translocated koala had received a full 12 months of monitoring. Due to the special consideration of the Griffin receive site as a TMR-owned offset site that had been extensively replanted with koala food trees, monitoring of all koalas at that site for the MBR project continued until December 2016 as a component of the *AKHO* program of works.

**Plate 2.20**: Translocated koala *Jane* and her 10-month-old male koala joey *Loki* at their final release at the Griffin offset site in December 2016. *Jane* was pregnant at the time, and both *Loki* and the new foetus were conceived after translocation to the site.

## 2.13 Data recording and GIS

Comprehensive data were recorded for all significant events, including, but not limited to, koala search and capture, veterinary examination and findings, koala release events, veterinary treatment and management, necropsy examination, tracking events, and other field events. Data were collected using a variety of media in the early stages of the program, but essentially all streams with the exception of *K-Tracker* data, were stored the FileMaker® database in the last two years of the program. This represented a significant saving of time as data were no longer being "double-handled" and could be accessed, analysed and discussed amongst team members immediately. It also considerably reduced the time taken to collate and analyse datasets.

The table below shows the data collection media for various streams and date of transition to the FileMaker® database.

| Data Stream | Initial data storage media | Date of transition to FileMaker® database | Comment |
|---|---|---|---|
| **Field events (koala capture, release, other non-tracking field events or incidents)** | Numbers® spreadsheet. Summary data included in Excel spreadsheet "Koala Data Records" | 5 May 2015 | Used from commencement for all field events (one spreadsheet) and initial monitoring |
| **Koala scheduled tracking events** | Numbers® Spreadsheet, then transition to TerraFlex (Trimble) | 5 May 2015 | TerraFlex provided a useful interim proprietary solution for data capture including GPS position derived from iPad GPS |
| **Koala veterinary examination records** | Paper records, then transitioned to Numbers® spreadsheet. Summary data included in Excel spreadsheet "Koala Data Records" which included field event summaries | 5 May 2015 | All essential data streams from veterinary examinations originally recorded on paper records duplicated in FileMaker. |
| **Necropsy examination records** | Originally digital document records, then transitioned to Numbers® database. | 5 May 2015 | Historical document records duplicated in FileMaker. |
| **Summary data for TMR provided monthly** | Arc-GIS | N/A | Field events and scheduled tracking events duplicated in ArcGIS file by Acorns Consulting (GIS specialist). |
| **LX *K-Tracker* data** | LX-Solutions hosted website + CSV files | N/A | Currently all *K-Tracker* data remains on the website hosted by LX Solutions. Future transfer of data to FileMaker® may require use of "zombie" database copy due to massive volume of telemetry data. |
| **Photographs** | EVE and TMR digital storage media | N/A | Images not stored in FM at time of writing due to volume/size of files. |

**Table 2.5**: Summary of data collection methods and transition to FileMaker® database.

## 2.14 Research collaboration and sampling

One of the important secondary aims of the koala management program was to support, as much as possible, the research endeavours of potential and existing university-based research programs and projects. The rationale included the following considerations:

1. The capture and monitoring of koalas on such a scale as was proposed, provided an unprecedented opportunity to collect data and samples from a large cross-section of the local koala population as well as longitudinally (over time). Such opportunities are generally well beyond the budgetary capacities of university project funding for wildlife research;

2. The collaboration of the program with university-based research groups provided the opportunity to "value-add" to the scientific work being conducted by the contractors (EVE), but at relatively low cost.

3. Some of the collaborating projects (specifically, the koala *Chlamydia* vaccine trial), were entirely consistent with, and potentially facilitated, one of the primary objectives of the koala management program - to reduce disease impacts in the koala population.

4. Biological samples and data could be collected and distributed to interested research groups at low or negligible cost to the project, but had great value to the beneficiary research projects, hence contributing to the "public good" contributed by the project.

5. The contribution to scientific endeavours that could support koala conservation in the wild was an identified aim of the holistic package of compensatory and offset measures considered before commencement of operational works.

Consequently, TMR welcomed and supported the sharing of data, biological samples and general collaborative/logistic assistance with *bona fide* research groups contributing to koala research

In addition, as part of the alternative koala habitat offsets package, TMR provided cash contributions to two successful ARC-Linkage grant applications supporting research into the development of vaccines to reduce the impacts of two significant infections in koalas - *Chlamydia* and the koala retrovirus (KoRV). The programs of work supported by these two ARC grants were ongoing at the time of writing, but had resulted in a number of publications in peer-reviewed scientific journals (*Appendix 8 - List of publications in peer-reviewed scientific journals*).

The support of ARC-Linkage grants provides a mechanism for leveraging cash from other sources (other collaborators and the ARC) to improve funding of worthy research, and value-adds to the primary project - in this case the MBR project and the koala management program.

A list of supported projects is contained in *Appendix 9 - List of research/miscellaneous projects that benefitted from data and biological samples derived from the koala management program*.

## 2.15 Data-sharing agreements and publication by external parties

Data-sharing agreements were established with the following universities: Queensland University of Technology (QUT), University of Queensland (UQ), the University of Sydney (US) and University of the Sunshine Coast (USC). Data and/or samples were also used by the QIMR Berghofer Medical Research Institute.

**Plate 2.21**: "Look! - No hands!" - Release of the koala *Martin* at the Amcor site in February 2014. He is fitted with a VHF anklet and early version of the LX *K-Tracker* collar.

# CHAPTER 3: KOALA CONSERVATION, MITIGATION AND OFFSET MEASURES


## Key points

- Holistic strategy for koala management considered the best option
- Success of koala management programs based on well-established methods combined with innovative technology
- Baseline regulatory compliance with koala habitat offsets alone would not have achieved koala protection intent
- Key offsets delivered measurable benefits - revegetation areas used by koalas, culverts used by koalas to cross rail corridor
- Treatment and management of koalas delivered profound benefits in terms of reduction of disease prevalence to nearly zero
- Scientific approach provided critical guidance for offset measures
- Innovative technology - LX *K-Tracker* telemetry system a central component - designed for the *KTMP* program to achieve key objectives
- Koala *Chlamydia* vaccine developed and field-trialled
- Demonstrable net benefit to koala population viability achieved - aspirational goal in project planning

# Chapter 3: Koala conservation, mitigation and offset measures

**Plate 3.1**: Fauna fence along the rail corridor at Kippa-Ring

## 3.1 Introduction

In an innovative approach to koala habitat offsets, the MBR project sought to deliver an holistic package of measures to compensate for the unavoidable impacts of the project on koalas. Rather than the usual five-for-one replacement of non-juvenile koala habitat trees (NJKHTs) or an equivalent cash contribution, the project aimed to provide more tangible, measurable, immediate and local benefits for koalas impacted by the rail project.  Consequently, the following measures were proposed as offset or compensatory measures, based on presumed threats to population health and viability:

1. Implementation of a koala tagging and monitoring program for the purposes of:

    a) Determining habitat use and ranging behaviour of koalas;
    b) Protecting koalas during vegetation clearing and construction works;
    c) Informing mitigation measures;
    d) Adaptively managing current and emergent threats to the koalas.

2. Management of chlamydial disease by:

    a) Treatment of koalas affected by the disease or with significant infections detected during veterinary examinations; and
    b) Conducting the first field trial of new *Chlamydia* vaccines developed by researchers at QUT and USC.

3. Opportunistically supporting other scientific research on koalas through access to biological samples and/or data derived from the koala management activities;

4. Translocation of koalas deemed to be at unacceptable risk due to construction of the rail project and/or current or future local land use intent.

5. Management of wild dogs if wild dog predation was determined to be a significant impact on koala population viability;

6. Provision of crossing structures and koala fencing to facilitate safe movement of koalas across the rail corridor;

7. Purchase of, and koala habitat restoration at offset sites;

Measures 1 - 4 (above) were delivered by EVE over the course of the koala management program; monitoring and management of wild dogs (measure 5, above) was contracted to the Moreton Bay Regional Council (MBRC), and measures 6 and 7 were delivered by TMR. This section will be limited to discussion of those measures delivered by EVE.

### Assessment of the connectivity of habitat and permeability of the rail corridor for koalas

At the time of writing, data collection and analysis of the effectiveness of crossing structures (culverts and bridges) formed the basis of an ongoing program of works (the *AKHO-CM* program) which commenced in March 2016. A related body of work which included an assessment of the growth of koala food trees planted at the Griffin offset site, and an analysis of the use of those trees by koalas resident at the site (including translocated koalas) is referred to herein as the *Griffin Offset Site Monitoring Program. (GOSMP).* Early results of data analysis from those programs are presented in ***Chapter 12 - AKHO-CM and GOSM Programs***.


**Plate 3.2**: Translocated koalas *Andrew* (top image) and *Michael* (bottom image) captured on one of three trail cameras installed in the revegetated area of the Griffin offset site. The ongoing monitoring of the Griffin site, including monitoring of tree growth in replanted areas and monitoring of koalas, continued until December 2016, some 6 months after the nominal cessation of the *KTMP* koala monitoring program in June 2016. A number of koalas frequently used replanted areas for both feeding and resting. This program was a component of the *Alternative Koala Habitat Offsets* program of works, which was ongoing at the time of writing.

## 3.2 Rationale for the alternative koala habitat offsets program

The rationale for deviating from the usual koala habitat offset requirements under the *State Government Supported Community Infrastructure Koala Conservation Policy* (CI Policy) was that greater benefits for koala population welfare, health and viability could be achieved with an holistic package of measures that were more targeted to critical threats. Part of the logical argument for this was that koala populations are considered to be in decline in many areas, not due to a lack of trees *per se*, but due to a handful of key threats whose contribution was likely to vary both spatially and over time. Hence, the collection of comprehensive population data on health and mortality would inform the mitigation and offset plan and allow targeted and adaptive management of current and emergent threats. The superiority of that approach over delivery of the usual regulatory offsets (or worse still, simply providing an equivalent cash amount to EHP) is resoundingly supported by our analyses of the data, including the population viability analyses, which are detailed in ***Chapter 11 - Population viability analysis.***

This is not to suggest that the acquisition of land, restoration of habitat and protective covenants have little benefit - they certainly do for koalas and a range of other native species - and should continue to be required as a component of offsets packages. However, the benefits that arise from providing that solely, when a lack of trees is not the key threat to koalas, are very limited compared with a targeted and holistic package of measures based on comprehensive data analysis and an adaptive management approach.

The other significant benefit of providing an holistic package with components targeting animal welfare, population health, and population viability, was that the strategy addressed issues of concern to a broad range of koala advocacy and conservation stakeholders.

**Plate 3.3**: Koala *Pistachio* was orphaned when a wild dog killed his mother *Caz* at the old Amcor mill site. *Pistachio* was successfully hand-raised by EVE ecologist Dr Deidre de Villiers, and eventually released at the Griffin offset site.

## 3.3 Implementation of mitigation, compensatory and offset measures

Some of the compensatory and offset measures were implemented by Endeavour Veterinary Ecology - specifically those dealing with direct management of koalas and the monitoring of koala movement through culverts using GPS collars and trail cameras. Other components of the mitigation measures and offsets package were implemented by TMR or others, such as habitat restoration and some aspects of habitat connectivity assessment and monitoring. This section deals mainly with items delivered by EVE and our collaborating research partners.

A summary of the implementation of compensatory and offset measures is contained in the table below:

| Management/mitigation measure | Provider | Commencement date | Completion date |
|---|---|---|---|
| 1. KTMP | EVE | 18 March 2013 | 30 June 2016 |
| 2. (a) Disease management | EVE | 18 March 2013 | 31 Jan 2017 |
| (b) Vaccine trial | EVE/QUT/USC | March 2013 | Ongoing at time of writing |
| 3. Support research | EVE/collaborating research group | 18 March 2013 | Ongoing at time of writing under AKHO program |
| 4. Koala translocation | EVE | March 2014 | 30 June 2016 |
| 5. Wild dog management | MBRC | November 2013 | Ongoing at time of writing under AKHO program |
| 6. Rail corridor crossings and koala fencing | TMR | 2015 | 2016 |
| 7. Offset site purchase and revegetation | TMR | 2013 | 2017 |

**Table 3.1**: Summary of key offset/compensatory or mitigation measures implemented on the MBR project.

**Plate 3.4**: The proper design, installation and maintenance of fauna exclusion fencing and effective barrier-crossing structures, can very significantly reduce mortality and other adverse ecological impacts of linear infrastructure. This image shows properly installed mammal exclusion fencing, and two effective crossing structures - a drainage culvert (M29) and a dedicated fauna culvert (F3) in a section of the Redcliffe Peninsula Line transecting wildlife habitat at Kippa-Ring.

## 3.4 Components of the koala management program, mitigation and offsets package

The following section gives additional detail on some components of the koala management, protection and conservation measures implemented for the MBR project (see the previous table). Those that were not implemented by EVE are described briefly and from the perspective of their effectiveness in achieving their primary objective(s). Those measures implemented by EVE are described in more detail, and many are the subject of additional dedicated chapters, such as chapters on koala translocation, the *Chlamydia* vaccine project and monitoring the use of crossing structures by koalas.


**Plate 3.5**: Koala *Ali* using drainage culvert M31 at Kippa-Ring in May 2016.

**Plate 3.6**: Partly hand-reared youngster *Keanu* is released into the pre-release enclosure at Toorbul, in April 2016. His mother *Karen* had adopted *Aerona's* much younger joey (*Sammy)*. (See ***Chapter 10 - Koala reproductive success***.) He was eventually released back into bushland at Kippa-Ring.

## 3.4.1 Koala Tagging and Monitoring Program

The *Koala Tagging and Monitoring Program* (*KTMP*) was designed and implemented to achieve or facilitate a number of key objectives, which included:

a. To fulfil TMR's legislative obligations with respect to koalas;
b. To avoid harm to koalas during construction and operation of the rail project;
c. To meet legislative obligations and improve the efficiency of operational (construction works) with respect to koala-caused delays;
d. To inform alternative mechanisms for delivering benefits to koalas instead of the usual statutory offsets requirements (adaptive management and the *AKHO* programs);
e. To satisfy the general community, and particularly koala stakeholder groups that koalas were being properly protected.

As described in other sections of this report, the *KTMP* required thorough searches of target habitat blocks and capture of all koalas encountered during searches. Intensive searches were conducted during the first 8 weeks of the program during which a significant proportion of koalas occupying target areas were captured. Opportunistic capture of "clean-skin" koalas encountered during field work occurred throughout the duration of the program up until December 2015. This ensured that nearly all of the koalas deemed to be at risk from vegetation clearing activities were captured, radio-tagged and monitored for the duration of the risk period. Subsequent monitoring of ranging behaviour, health, causes of death, reproduction and habitat usage provided data used to inform adaptive management and other mitigation and compensatory measures. Total koalas in the program over time is shown in Figure 3.1, below.

The *KTMP* was entirely successful in achieving its primary objective of avoiding harm to koalas caused by vegetation clearing. It was also successful in facilitating the management of chlamydial disease in the target population, which reduced disease prevalence from an overall population prevalence of around 28% down to close to zero for much of the last 12 months of the monitoring period. Incidence (rate of new infections) was dramatically reduced after commencement of capture and treatment of sick koalas.

Community koala rescue/conservation groups seemed generally very satisfied with the measures implemented to protect and manage koalas by the MBR project. Important factors in their satisfaction and ongoing support of the program were that they were engaged early (long before the commencement of vegetation clearing), their opinions and perspectives were acknowledged and respected, and they were kept well informed of program results and outcomes (both good and bad) regularly and comprehensively. They found the compassionate approach admirable and the scientific results fascinating and informative.

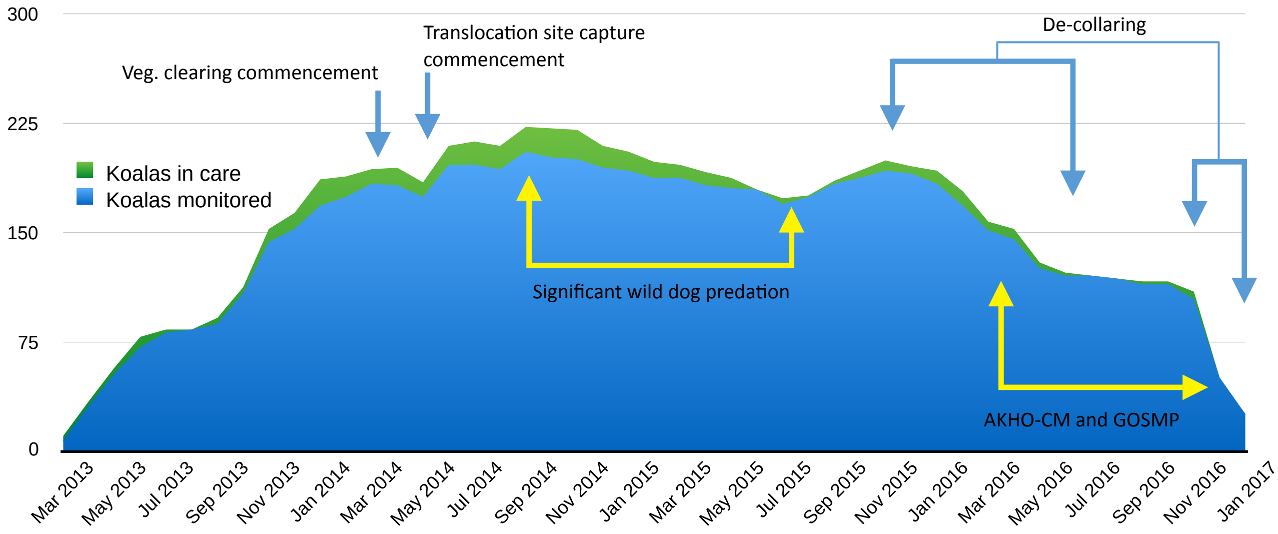



**Figure 3.1**: Graph showing total number of koalas in the *KTMP* from commencement in March, 2013 to completion in January 2017.

## 3.4.2 Management of chlamydial disease

Capture of essentially all koalas in the target populations allowed a high degree of chlamydial disease suppression. Koalas were originally referred for treatment to the Australia Zoo Wildlife Hospital. Later, dedicated treatment facilities were constructed at the EVE veterinary clinic at Toorbul, and from around mid-2014 onwards, most koalas were treated there, facilitating a higher level of veterinary oversight and more satisfactory outcomes. Veterinary management and chlamydial disease treatment are discussed more fully in ***Chapter 4 - Veterinary management of koalas***.

The following graphs, created by the FileMaker® database, show the reduction in chlamydial disease prevalence (top graph) and incidence (lower graph). As incidence is shown as an annualised rate (of new disease in previously healthy koalas), each data point represents annualised incidence based on a 90-day window, and is separated from adjacent data-points by a 2-day frame-shift. Peaks in both graphs in the right-hand half are a result of the increased prevalence and spread of chlamydial disease in the latter stages of the breeding season. (Which is consistent with one of its primary mechanisms of spread being by sexual transmission.)

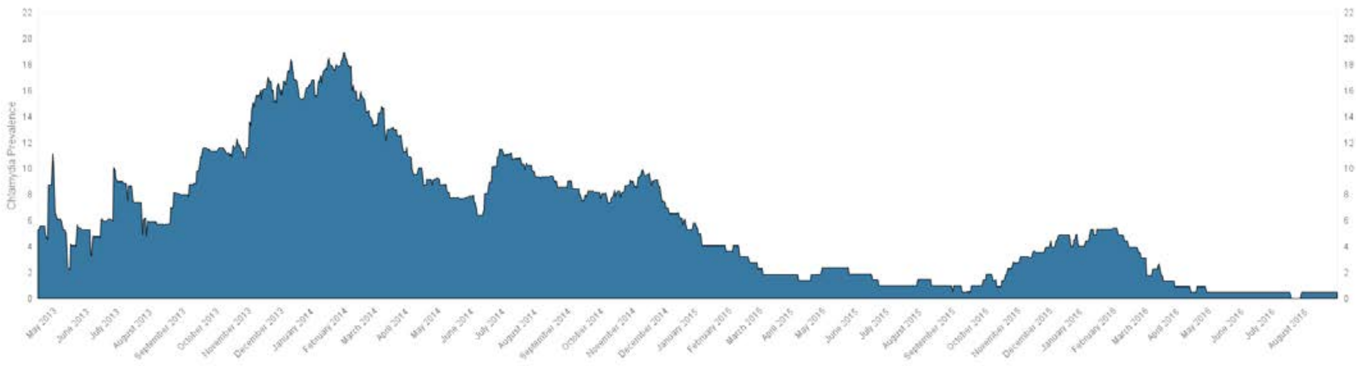



**Figure 3.2a**: Graph showing trends in chlamydial disease ***prevalence*** over the duration of the koala management program. Broad peaks correspond with the latter stages of the breeding season, when transmission rates are likely to be significantly higher, and hormonal changes associated with breeding may favour shedding of chlamydial organisms and development of disease.

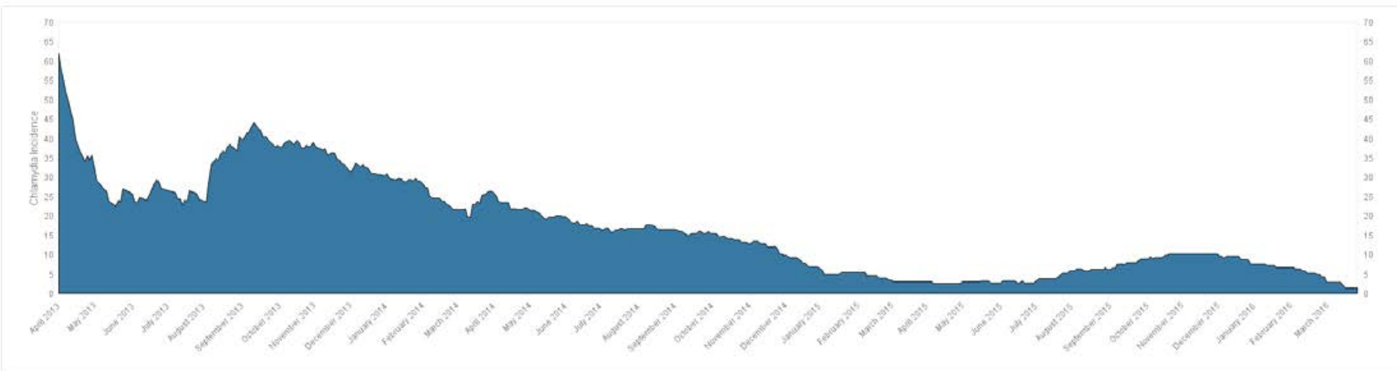



**Figure 3.2b**: Graph showing general trends in chlamydial disease ***incidence*** (rate of new cases) over the duration of the koala management program.

It is important to note that chlamydial disease was not entirely eliminated from the study populations. This is because the koala population is not a "closed" population, so infected and diseased individuals could immigrate into the study area; also, many koalas are infected, but do not show clinical signs of illness, and may spread their infections to previously uninfected animals. In the case of the Scouts study population, the koalas that were captured and tagged were a sub-group of a much larger population that was occupying habitat with broad continuity through the hinterland. Consequently, population-level control of chlamydial disease, particularly at the Scouts site, was well beyond the scope of the MBR koala management program.

Even within the more "closed" populations, such as those at the Kippa-Ring and Griffin sites, elimination of chlamydial disease entirely would have required concurrent treatment of all koalas, including apparently healthy animals. This was not a practical solution, and, even if it were, the advisability of complete elimination of *Chlamydia* from a wild koala population is fraught, as it could lead to immune-naivety, and therefore increased susceptibility to future epidemics (hypothetically). In any case, there is insufficient scientific support for that approach currently, even if it were practically possible.

The benefit that arises from treatment of chlamydial disease is two-fold:

1. It relieves affected koalas of debilitating and very painful medical conditions, which can lead to death. As such, it provides significant benefits to individual animal welfare; and

2. It mitigates the population-level effect of reduced fecundity due to sterility, as well as improving overall population health.

The duration of these benefits is difficult to predict because such an approach has not been documented before. With respect to individual koalas, the benefit persists indefinitely until such time as they are reinfected and develop new disease. Our observations are that the rate of recurrence of existing disease (after treatment) is very low. This metric is best measured in the female koalas desexed due to sterility caused by chlamydial infection, in which the confounding factor of repeat exposure to infection by sexual transmission during coitus is removed entirely. Of the 29 sterile female koalas in which surgical ovario-hysterectomy (OHE) was performed, none developed new or recurrent chlamydial disease after treatment and release. This finding supports the conclusions that:

1. The veterinary treatment regimen during the MBR koala management program was effective at achieving a microbiological and clinical cure; and

2. Repeated infections in adults are likely to be a result of new infections contracted mostly by sexual transmission - the risk of which is extinguished by OHE of sterile female koalas.

In summary, in the koala sub-populations at the Amcor, Bruce Hwy West, Mango Hill, Rothwell, Kippa-Ring and Griffin sites, the duration of benefit arising from treatment of *Chlamydia*-affected koalas will probably persist for a number of years, due to the relatively low level of outside immigration (of untreated koalas) into those areas of habitat. In contrast, at the Scouts site, where there is broad continuity of habitat, and treatment was only applied to a small subset of local koalas, the duration of benefit will probably be quite fleeting.

**Field trial of the *Chlamydia* vaccine:**

A number of versions of the vaccine developed by Prof. Peter Timms' research group was trialled over the course of the koala management program. Initially, a three-dose vaccine using the Iscomatrix® adjuvant was trialled, followed by two different single-dose vaccines using the MOMP and PMPG antigens. A summary of results to date is provided in ***Chapter 5 - Field trial of a chlamydial vaccine for koalas***. Papers resulting from the work had been published in the scientific literature (*Appendix 8*), and more were in preparation, at the time of writing of this report.

### 3.4.3 Support of university-based research

A considerable number of research projects benefited from data and biological samples derived from the koala management program. Some of these "value-added" to the koala management program by benefiting koala conservation knowledge, others provided benefits more broadly than for koalas, such as work by the QIMR Berghofer Medical Research Institute investigating arbovirus carriage by koalas.

There is a strong moral imperative to derive the maximum benefit from koala capture and monitoring:

1. It is consistent with, and supports a key objective of animal ethics oversight to reduce the use of animals in research - by deriving the most benefit from each animal capture or handling event;

2. The cost of koala capture, veterinary assessment and monitoring is generally beyond the budgets of most wildlife research projects on the scale at which the MBR koala management program was conducted;

3. The MBR *KTMP* program of works is the largest and most intensive koala monitoring and health management program ever conducted. The opportunity to collect such a valuable and voluminous set of data and biological samples, particularly in a longitudinal study, has never occurred before - hence creating a strong ethical argument for maximising its beneficial outcomes.

The fact that the MBR koala management program was designed and conducted by a non-university entity (EVE) may have facilitated the broad and diverse collaborations that ensued with respect to provision of data and biological samples. Had the program been run by a university-based research group, it is possible that broad collaborations may not have occurred due to perceived competition and research overlap.

**Plate 3.7**: EVE veterinarian, Dr Amy Robbins performs a mid-treatment veterinary examination on koala *Tanja*, a resident of bushland in Rothwell. All koalas were sampled for clinical diagnostic and research purposes, resulting in more than 12,000 samples being provided to research collaborators over the duration of the koala management program.

### 3.4.4 Translocation of koalas

The active translocation of koalas in response to development pressure and displacement by vegetation clearing is currently prohibited under State legislation (*NCA, 1992*). Paradoxically, it is also prohibited as a risk mitigation measure to protect koalas during vegetation clearing. Instead, "koala spotters" are engaged by a development proponent or vegetation clearing contractor to spot koalas in vegetation prior to clearing. If a koala is spotted, the tree is marked using flagging tape and retained until the koala moves away of its own volition, whereupon the tree can be cleared. The dangers inherent in this approach are apparent even to the layperson, however attempts to correct this in current policy have been unsuccessful, to date.

The following points give some explanation for why the policy is flawed, results in unacceptable outcomes for koala welfare and conservation, and is why, ultimately, the MBR project chose to manage koalas more appropriately:

1. The spotting rate of koalas, even by experienced koala spotters is, on average, less than 50%, and much worse than that in dense vegetation. (See results of a koala detection survey in ***Chapter 6 - Ranging behaviour and habitat use by koalas***);
2. If there is little or no safe habitat for the koala to move into (of its own volition), then it remains at significant risk.
3. The current policy seems to assume that the koala will navigate the landscape and avoid risks in its attempt to find new habitat - highly unlikely in a high-risk landscape.
4. The regulatory framework does not require a development proponent to leave any habitat at all for the displaced koala to move into.
5. Displaced koalas cannot be translocated into sites that have been purchased and planted to offset a development impact, reducing the immediate or short-term value of that mitigation measure.

State legislation with respect to wildlife management currently allows all other species of protected fauna to be moved by wildlife spotter/catchers in the face of vegetation clearing, but koalas have been inadvisedly excluded from this allowance. The only lawful mechanism in the current context that facilitates the translocation of koalas away from high-risk situations, is under the provisions of a scientific purposes permit (SPP) issued by the Qld Dept of Environment and Heritage Protection (EHP). Issuance of the permit is provisional upon the project having received approval from an animal ethics committee (AEC). Hence, such a proposal must be a part of a *bono fide* scientific research program, rather than a management response to minimise risk to koalas.

As a consequence of the regulatory constraints outlined above, and in an effort to provide evidence-based arguments for translocation as a mitigation measure in the future, EVE applied for an SPP to allow for the translocation of koalas deemed to be at high risk due to current or future development of habitat. A detailed assessment framework was developed and included criteria related to habitat and individual koala characteristics against which each koala was assessed. Several potential recipient sites were examined, and finally two were settled on to serve as receiving sites for translocated koalas. These were the Murrenbong Scouts land at Kurwongbah, and the koala habitat offset site owned by TMR in Griffin, which lies just north of the Pine River, and to the east of the Bruce Highway. The latter site had been extensively replanted with koala food trees as part of the conventional koala habitat offset requirements for the MBR project.

Koala search and capture operations occurred at both sites so that at least 3 months of telemetry data were collected on each captured resident koala prior to commencement of translocations into that site. Up to 25 koalas were permitted to be monitored using conventional or remote telemetry at each site, plus a further 15 to allow for tracking of joeys of resident animals when they reached independence, and to account for losses (deaths or dropped tags).

The table below summarises the key dates and statistics with respect to each site:

| Event | Scouts | Griffin | Total |
|---|---|---|---|
| Commencement of koala search and capture | 13/05/14 | 31/03/14 | |
| Date of first resident koala capture | 13/05/14 | 31/03/14 | |
| Date of last resident koala capture | 27/10/15 | 24/03/16 | |
| Date of last resident capture for 3-month monitoring prior to first translocation | 26/06/14 | 08/04/14 | |
| Total resident koalas captured | 36 | 18 | 54 |
| Date of first translocation | 3/10/14* | 12/09/14 | |
| Date of final koala translocation | 18/02/15 | 16/10/15 | |
| Total koalas translocated | 12 | 16 | 28 |
| Date of commencement of de-collaring of koalas | 10/02/16 | 9/12/16 | |
| Date of de-collaring of final koala | 8/04/16 | 20/01/17 | |
| Total resident koalas died/euthanased during monitoring | 15 | 9 | 24 |
| Total translocated koalas died/euthanased during monitoring | 4 | 7 | 11 |
| Total joeys produced (conceived during monitoring period) - resident females | 15 | 11 | 26 |
| Total joeys produced (conceived during monitoring period) - translocated females | 11 | 8 | 19 |

**Table 3.2**: Summary of key dates and statistics relating to the translocation program (*KTrans*). * Note that "relocation" of hand-reared orphans to habitat within 5km of their natal home range occurred prior to the official first translocations of displaced koalas to the translocation sites, but relocated koalas (hand-reared orphans) are otherwise included in translocation statistical analyses. Note also that many of the deaths/euthanasia of resident koalas occurred prior to the commencement of translocations.

**Plate 3.8**: Joey *Athena* on mother koala *Eva* during a veterinary examination. They were resident koalas at the Scouts translocation site.

## 3.4.5 Wild dog monitoring and management

The MBR project contracted the Moreton Bay Regional Council to conduct wild dog monitoring and control activities throughout most of the duration of the project. Increased resources and efforts were applied as the magnitude of the wild dog impact on the koala population was revealed. EVE established a number of trail cameras at the Amcor site and Kippa-Ring bushland early in the program, and at the Griffin offset site in the latter stages. These cameras regularly detected the "Amcor Dog" during the periods of his activity in the Amcor site. Subsequently, all wild dog monitoring was performed by MBRC, and monitoring and control activities are not reported further here.


**Plate 3.9**: Wild dogs in bushland at Kippa-Ring in early 2014 captured on an EVE trail camera placed near the carcass of an eastern grey kangaroo.


**Plate 3.10**: Wild dog detected on a trail camera monitoring replanting areas for koala use at the Griffin offset site, in November and December, 2016.

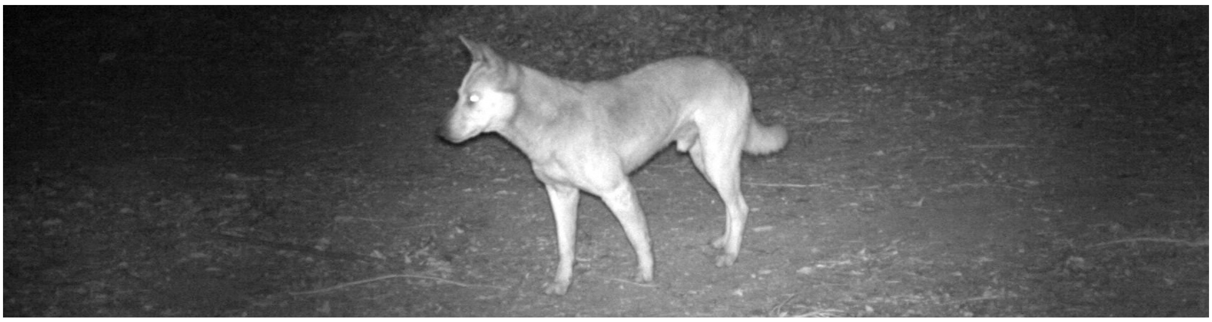


**Plate 3.11**: The infamous "Amcor Dog" (See ***Chapter 8 - Causes of death of koalas*** and ***Chapter 9 - Wild dogs***). Photo taken on a trail camera at the Amcor site in September 2014.

### 3.4.6 Rail corridor fauna crossing structures and fauna fencing

One of the permanent impacts of the rail line on koalas and other wildlife populations is the effect of creating a barrier to movement. If unmitigated, and particularly if the barrier is completely impermeable to some species of wildlife, this causes significant fragmentation of habitat along with loss of functional ecological connectivity, and isolates wildlife populations. In turn, this can limit or prevent access to important resources or resource areas, and cause genetic isolation and in-breeding. Isolated wildlife populations are also more susceptible to extinction and have lower resilience to adverse stochastic events, such as bushfire.

To mitigate the barrier effect of the MBR rail line, several dedicated fauna crossing culverts were constructed. Wildlife overpasses and overhead crossing structures, such as rope bridges, were not constructed due to Queensland Rail requirements for avoiding risks associated with the high-voltage power lines. In addition to dedicated fauna crossing culverts, numerous storm-water drainage culverts, and creek-crossing bridges were constructed, which provided opportunities for wildlife to cross the rail corridor.

**Table 3.3** (overleaf) summarises the crossing structures likely to be used by, or providing opportunities for, koalas to cross the rail corridor, and in which trail cameras were installed for the purposes of monitoring koala movements. The final column indicates whether the structures had been used by koalas to cross the rail corridor, to date. (See also ***Chapter 12 - AKHO-CM and GOSM Programs***.) All structures listed below have been used to varying degrees by a variety of fauna transiting the rail corridor, and most are confirmed to have been used by koalas, or are highly likely to have been used by koalas, based on GPS tag data.

**Plate 3.12**: Fauna culvert F3 at Kippa-Ring with fauna furniture and entry landscaping. Fauna fencing can be seen in the background with the black anti-climb sheeting. Drainage culvert M29 is just visible in the far right of the photograph. Both culverts were used by koalas and a variety of other fauna to transit the rail corridor.

| Structure name | General location | Type of structure | Used by koalas |
|---|---|---|---|
| **M31** | Kippa-Ring | Drainage culvert (generally dry) | Yes |
| **F5** | Kippa-Ring | Fauna culvert (with fauna furniture) | Yes |
| **F6** | Kippa-Ring | Fauna culvert (no fauna furniture) | Yes |
| **M30** | Kippa-Ring | Drainage culvert (generally wet) | Not detected |
| **F4** | Kippa-Ring | Fauna culvert (with fauna furniture) | Yes |
| **F3** | Kippa-Ring | Fauna culvert (with fauna furniture) | Yes |
| **M29** | Kippa-Ring | Drainage culvert (generally dry) | Yes |
| **V2** | Kippa-Ring | Vehicular access culvert | Not detected by camera, but likely based on GPS data |
| **M28** | Kippa-Ring | Drainage culvert (generally wet) | Not detected |
| **M27** | Kippa-Ring | Drainage culvert (occasionally wet) | Not detected by camera, but likely based on GPS data |
| **V1** | Rothwell | Vehicular access culvert | Not detected by camera, but likely based on GPS data |
| **Saltwater Ck rail bridge** | Rothwell | Rail bridge over Saltwater Ck | Not detected by camera, but likely based on GPS data |
| **Freshwater Ck rail bridge** | Mango Hill | Rail bridge over Freshwater Ck | Yes |
| **Black Duck Ck rail bridge/T7** | Murrumba Downs | Rail bridge over Black Duck Ck and drainage culvert T7 with fauna ledge and entry fauna furniture treatments | Not detected by camera, but likely based on GPS data |
| **M15** | Kallangur | Drainage culvert (round), generally dry. | Not detected |
| **F1** | Kallangur | Fauna (and nearby drainage) culverts under-passing both the rail bridge over Dohles Rocks Rd and Dohles Rocks Rd itself. | Not detected |
| **M12** | Amcor site | Drainage culvert (generally wet) | Not detected, but possible based on GPS data |
| **Yebri Ck rail bridges** | Amcor site | Rail bridge over Yebri Creek. | Yes |

**Table 3.3**: Summary of monitored structures potentially used by koalas to cross the rail corridor.

**Plate 3.13**: Rail bridges over Yebri Creek at the Amcor site provide good opportunities for wildlife to cross the rail corridor.

In addition, two other nearby structures not directly crossing the rail corridor were monitored for koala passage. These are summarised in **Table 3.4**, below.

| Structure name | General location | Type of structure | Used by koalas |
|---|---|---|---|
| **Bruce Highway bridge** | Mango Hill | Road bridge over Freshwater Ck just to the north of the rail bridge | Yes |
| **Cecily St bridge** | Murrumba Downs | Road bridge over Freshwater Creek | Yes |

**Table 3.4**: Summary of camera-monitored non-rail infrastructure used by fauna to transit linear infrastructure.

Upgrade works to Brays Road, near its intersection with Anzac Avenue at Murrumba Downs, involved upgrading the culvert allowing Freshwater Creek to flow under Brays Road. Brays Road creates a significant impediment to the safe passage of wildlife east-west along Freshwater Creek, and therefore the culvert should help to mitigate this adverse effect. To that end, a fauna shelf and some fauna-friendly treatments of the culvert (fencing) were constructed. However, at the time of writing, the eastern half of the fauna shelf was submerged, such that at its eastern extent it was in excess of 400mm under water, significantly reducing its value as a wildlife mitigation measure. The submersion was due to two things:

1. The significant slope of the fauna ledge as it coursed eastward through the culvert; and
2. The construction of a weir (that dams water) downstream of the culvert.

Consequently, this structure had not been monitored for fauna use at the time of writing, and ameliorative works would be required to reduce the water level, or alternatively raise the submerged fauna ledge, to ensure that this potential wildlife crossing structure functions as it should.

**Plate 3.14**: (Clockwise from top left) View through M31 (Kippa-Ring) showing outward-facing trail cameras installed at either end (Trail cameras are Reconyx® PC900 professional series cameras with heavy duty anti-theft security boxes and brackets.); V2 at Kippa-Ring with M28 wet culvert on the far right; view of the northern opening of F3 (Kippa-Ring) showing landscaping and fauna furniture; F5 southern opening, showing fauna furniture and data-logger.

### Fauna fencing and egress poles

Fauna exclusion fencing has been installed along much of the length of the rail line, with interruptions at the new stations due to public access and visibility/safety reasons. The fencing consists of an approximately 1800mm high chain-mesh fencing with a continuous concrete base plinth, and a 600mm continuous anti-climb sheeting component at its top edge. A number of koala escape poles have been installed to allow egress of koalas and other arboreal fauna to exit the rail corridor in the event that they enter it.

**Plate 3.15:** Fauna exclusion fencing along the rail corridor at the Amcor site, with escape-pole egress device. Egress poles are probably less effective for koalas than ground-installed egress valves (see below) due to the cognitive processes of a koala traversing the ground.

**Plate 3.16**: Fauna fencing along the rail boundary at the large cut through the Amcor site. This section has limited crossing opportunities for wildlife, with an approximately 1km span between crossing structures at Yebri Ck and the drainage culvert M12 near Dohle's Rocks Road. The barrier-effect of this section of the rail line remains relatively unmitigated.

### Effectiveness of fauna exclusion fencing and escape poles:

There were a number of incursions of koalas into the rail corridor after installation of the fauna fence, indicating that the fence is not entirely effective. In addition, there are designed breaches in the fence at rail stations due to operational and safety reasons - and these provide a route of entry of koalas into the rail corridor. The following table summarises some of the incursions of koalas into the rail corridor after establishment of the fauna fence.

| Koala name | Date of incursion | Circumstances | Outcome |
|---|---|---|---|
| James | 3/12/15 | Found by construction worker in the rail corridor. | Captured and assessed at clinic on 7/12/15. Released near POC 8/12/15 |
| Mali | 13/2/16 to 16/2/16 | Last LX tag upload was at 10pm on 13/2/16 on the NW side of corridor, then the next LX upload was at 10pm on 16/2/16 on the SE side of the corridor. Video captured by security cameras at Kallangur Station. | Koala navigated through Kallangur Station to bushland on the other side of the rail corridor. |
| Cowboy | 27/07/16 | Found by MOP inside the fencing of the rail corridor at Leis Parade. Cowboy was untagged, so there is no LX *K-Tracker* data to show movements or where he entered the fenced area. He was found sitting in a recently dead blue gum just within the fenced off rail corridor. | Left in the tree and had moved on by the next morning. |
| MacGyver | 14/08/16 | Crossed from southern side of corridor near School Rd and likely under a gap in the fence to enter the rail corridor. LX geofencing feature tracked his movements along the north and south fence-lines within the rail corridor. | Rescued at 8pm on Sunday night 14/8/16. Assessed on site by veterinarian and released on southern side of rail corridor near previous tracking locations. |

**Table 3.5**: Summary of incursions of koalas into the rail corridor after establishment of the fauna fence.

Of some concern, is the failure of the koala *MacGyver* to either detect and/or use the egress poles installed along the northern sweep of the rail corridor fauna fence. The geofence GPS data indicate clearly that the koala passed egress poles a number of times during his entrapment in the corridor, but failed to make use of them. One possible explanation for this is that, in our experience, koalas on the ground, faced with a see-through barrier, such as a chain-mesh fence, are in the "mind-set" to push through the barrier (as they would through grass or ground vegetation) rather than immediately making the cognitive assessment of the need to climb over the fence. We observed this during controlled trials of various ground-installed egress valves.

**Figure 3.3** (overleaf) shows the GPS positions of *MacGyver* logged during his entrapment in the rail corridor. His point of entry to the corridor is in the upper right of the figure where he presumably went over or under the fauna fencing. He was rescued around 12 hours after his estimated time of entry into the corridor, having failed to successfully exit, despite passing several egress poles.

The cases mentioned above highlight the importance of understanding the behaviour and cognitive processes of koalas travelling along the ground. They will take advantage of breaches in the fence at ground level, but may not detect or use egress devices that seem obvious to us. See photos below showing a significant gap under the fauna fencing near the location that *MacGyver* breached the fence; and a photo of a section of grill used to obstruct a small swale drain transecting the fauna fence, which koala *Saba* may have taken advantage of on number of occasions. Although quite capable of climbing chain-mesh fence, koalas may not immediately climb a fence; instead continuing to search for ground-level breaches or gaps to push under, or through. Similarly, although entirely *capable* of traversing a fence using an egress pole, they may ignore it in favour of continuing to seek a ground-level portal of egress.

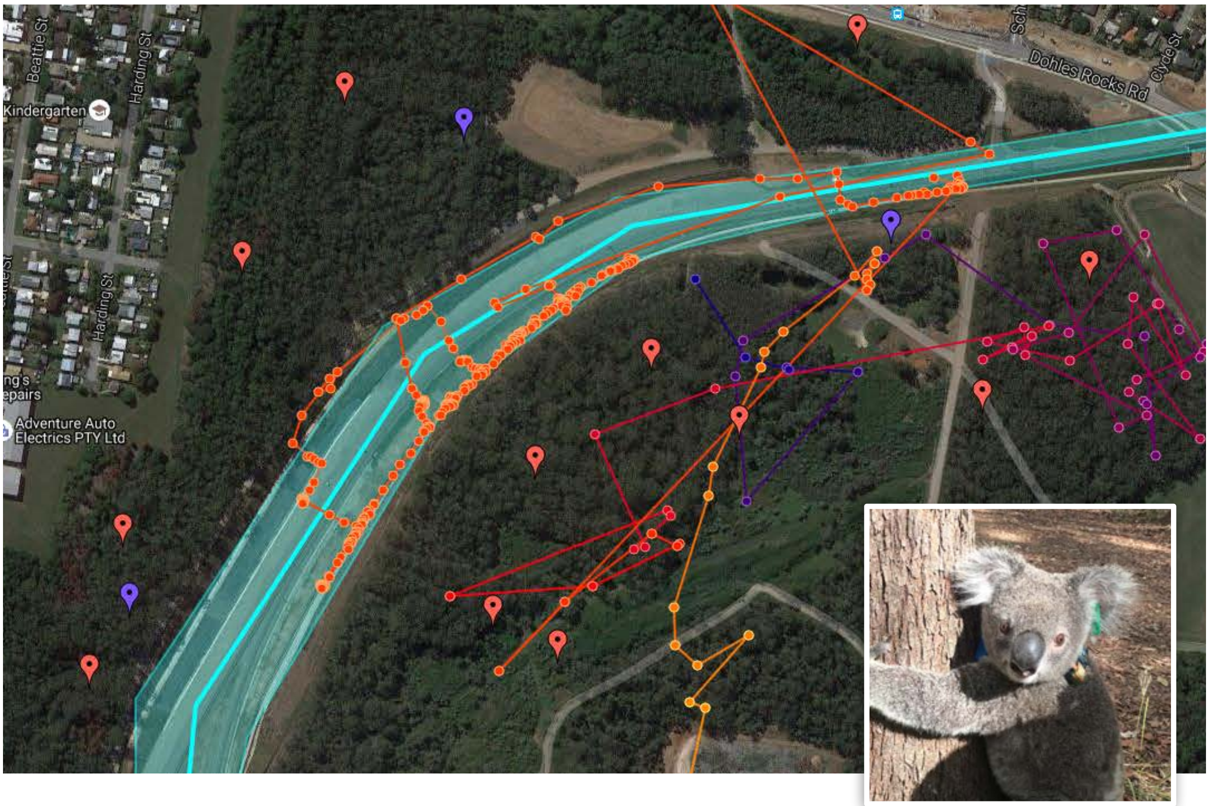



**Figure 3.3**: GPS positions of the koala *MacGyver* around the time of his incursion into the fenced rail corridor. The aqua-blue outline and shading shows the trigger area for the *K-Tracker* geofencing function, resulting in a higher GPS fix rate.

**Plate 3.17**: Demonstration of a 100mm+ gap between the lower edge of the chain-mesh fence and the base-plinth (left image). This gap is sufficient for most koalas to push under, which they will readily do if motivated; Vertical grate blocking a swale drain that crosses the fence-line east of drainage culvert M31 (right image). The gap is sufficient to allow most koalas to easily pass through into the rail corridor, and may have been the route by which the koala *Saba* traversed the corridor on a number of occasions. Our recommendation is that gaps, either vertical or horizontal are no more than 50mm if koalas are to be prevented from taking advantage of them.

## Testing of an alternative egress device - a ground-installed “koala egress valve”

EVE designed and tested an alternative device to the egress pole - the koala egress valve. (See video and photographs below.) This device used very lightly sprung Perspex® one-way swinging doors, and is installed at an angle to the fence line, and with an adjacent “wing” of fencing at approximately a 45 degree angle to the line of the fence, which acts as a funnel. The construction plans and installation instructions for the EVE fauna egress valve prototype are contained in *Appendix 10*

**Video 3.1**: Use of a prototype of the EVE koala egress valve by the koala *Venom.* The valve provides a more usable egress structure with higher likelihood of use by koalas when travelling along a fence-line on the ground. The short wing-wall section of fencing at an angle of around 45 degrees to the fence-line, tends to funnel fauna that are fence-line walking into the egress valve.



**Plate 3.18**: Koala *Carlos* entering the koala valve during trials at EVE (left image), and koala *Rhubarb* attempting to exit the one-way valve during overnight monitoring with a trail camera (right image). She attempted to exit (unsuccessfully) approximately 77 times during the night, demonstrating the device’s efficacy at preventing retrograde movement.

### 3.4.7 Offset site purchase and revegetation

TMR designated two sites in partial fulfilment of koala habitat offset regulatory requirements: these were at Lacey's Creek in the eastern foothills of the D'Aguilar ranges and at Griffin, approximately 5km south of the rail line. EVE had no role in assessment, monitoring or operational works at the Lacey's Creek site, and it is not discussed further. The Griffin offset site was used as a translocation recipient site for koalas, and both resident and translocated koalas were monitored at the site until December 2016.

Vegetation growth in replanted areas and koala use of those areas was monitored by EVE between March and December 2016 as a component of the *Alternative Koala Habitat Offsets* program of works, which is reported and discussed in ***Chapter 12 - AKHO-CM and GOSM Programs***.

**Plate 3.19**: Koala *Maxwell*, an original resident of the Griffin offset site after his final release in December 2016. He was put into foster-care for 6 months after being found in fair body condition as a 10-month-old joey in May 2014, possibly the joey of *Fozzie*.

## 3.5 Recommendations

The MBR koala management program represented one of the biggest commitments to protection and conservation of a wildlife species during construction of a linear infrastructure project in Australia. This report endeavours to demonstrate and document the success of that commitment in terms of measurable beneficial outcomes for the local koala population, as well as the broader benefits that have flowed from the work.

An important reason for the success of the program is that it was based on rigorous and thorough scientific investigation, an holistic approach to known and emergent threats (to koalas) and an adaptive management approach. This not only ensured that koala protection, mitigation and management decisions were robustly supported by data (or at the very least well-informed expert opinion), but also provided a solid base upon which to refute spurious allegations or criticism of aspects of the program or its outcomes.

Arguably, the most important thing, is that the program was successful in protecting koalas, and, at least for a time, leaving the local population somewhat better off than it had been. Had the usual base-line regulatory obligations been followed without the koala management program, the project would not have been able to reliably detect koalas and avoid clearing the trees in which they were residing. This approach would have been entirely inadequate. Conversely, the *KTMP* protected koalas, improved their health and contributed significantly to scientific knowledge.

Consequently, we make the following recommendations:

1. That TMR use the approach taken on the MBR project to protect and conserve koalas in accordance with TMR's strategic plan, as a model that is applied on future projects likely to impact on native wildlife and their habitats.

2. That future projects carefully consider all possible project impacts *as well as* non-project related threats (such as chlamydiosis and predation) as subjects for which protective, mitigation and conservation measures could be applied in an holistic package to offset residual impacts of the project.

3. That translocation of koalas, as a last resort option for unviable sub-populations or individuals isolated from effective ecological connection with viable populations, is a scientifically valid and appropriate tool for koala management associated with development.

4. That mitigation measures, such as fauna fencing, egress devices, barrier crossings and the like, are critically assessed for effectiveness, and subject to constant review and improvement when necessary.

5. That fauna risk mitigation devices (fences, egress devices, and the like) are constructed with very careful attention to detail, and inspected by suitably qualified experts prior to sign-off of contractual obligations having been met; also, that such devices are maintained appropriately to ensure ongoing effectiveness and functionality.

6. That early consultation and engagement of experts with strong scientific credentials are critical to effective project planning and successful implementation.

7. That early consultation and engagement with community stakeholders is crucial in ensuring that approaches to wildlife protection will be generally well accepted, in turn, minimising risk to the project through delays, adverse PR and political interference.

# CHAPTER 4: VETERINARY MANAGEMENT OF KOALAS


## Key points

- Veterinary input was an essential component of the *KTMP* to achieve objectives and regulatory compliance
- All koalas received a high standard of veterinary care - 205 cases of illness and injury treated
- Chlamydial disease prevalence dropped from around 28% to less than 1% by the end of the *KTMP* due to veterinary management of sick koalas
- The Scouts translocation site had the highest disease prevalence prior to management
- Immense benefit for both research collaborators and scientific body of knowledge on koalas
- Over 12,000 biological samples provided to various scientific research projects, including *Chlamydia* vaccine research.

# Chapter 4: Veterinary management of koalas

## 4.1 Introduction

Habitat loss and premature mortality caused by domestic dogs, vehicle strike and disease, particularly chlamydiosis, are well acknowledged causes of decline of SEQ koala populations. Aside from the mortality and welfare implications that these threats pose, chlamydial disease also results in reduced reproductive output, further diminishing population viability.

Although the aforementioned threats are the most common reasons for koala admissions to Queensland wildlife hospitals, the relative contribution of each threat at the population level has not been quantified. However, since very few population studies have been conducted, particularly where causes of morbidity and mortality have been accurately ascertained, there is a paucity of information on the nature and importance of other less well-recognised impacts that may also be adversely affecting wild populations. Quantitative analysis of premature causes of death and reproductive loss is necessary if conservation and mitigation measures are to be efficiently and effectively targeted.

Chlamydial disease has been chronicled as affecting koalas from early after European settlement. However, given the dearth of comparative data, it is not known whether the prevalence, incidence and nature of disease has changed over time. Currently, the high prevalence and atypical severity of chlamydiosis in koalas (compared with other species) and its consequences for fertility and fecundity are contributing to local population extinctions. The importance of controlling chlamydial disease was highlighted in a modelling study reported in 2011, which found that recovery efforts focused on reducing single causes of mortality, other than disease, would be unsuccessful at reversing population declines. Conversely, population-level management of chlamydial disease would significantly improve resilience to extinction.

Traditionally, disease surveys of wild koala populations have been based on overt signs of illness, but without comprehensive veterinary examinations chlamydial disease prevalence will be substantially underestimated. Although proliferation and inflammation of the conjunctiva (indicative of conjunctivitis) and a stained, wet rump (indicative of cystitis) are well-recognised manifestations of chlamydiosis, disease is often subclinical and only detected using veterinary diagnostic techniques such as ultrasonography and cystocentesis. Enhancing detection of chlamydiosis using these methods not only facilitates prompt treatment of disease, often before major organ and tissue damage occurs, but also improves treatment success. In addition, early detection and treatment reduces the likelihood of disease spread by minimising the exposure time of the infected koala to other vulnerable individuals. Effective treatment of more severe and chronic (long-term) chlamydiosis can be problematic and sometimes pointless because of irreversible damage to the affected tissues and loss of organ function, emphasising the importance of early detection. If left untreated, chlamydial disease may result in death.

In recognition of the impacts that illness and trauma can have on koala population viability and the welfare of individual animals, veterinary management of sick and injured koalas, including measures, such as a *Chlamydia* vaccine field trial, were clearly-defined objectives of the MBR koala management program. Intensive monitoring using radio-telemetric and bio-telemetric methods facilitated the early detection of morbidity and mortality in koalas and determination of cause (in most cases). Data derived from the *KTMP* informed the adaptive management approach recommended in the program's early planning documents, of which veterinary treatment and disease management was a key component.

This chapter details the approach to the veterinary management of individual and population health. Additional findings and analysis relating to causes of death are presented in ***Chapter 8 - Causes of death of koalas.***

## 4.2 Objectives

The objectives of the MBR *KTMP* specifically relating to the health and welfare of the koalas and koala population health management were to:

1. Investigate the prevalence, incidence and nature of disease affecting the koala population living in, or near, the MBR corridor;

2. Reduce morbidity and mortality associated with disease by:

    a) Treatment of sick koalas.
    b) Reducing the spread of infectious diseases.
    c) Improving fecundity/fertility (reproductive rates).
    d) Implementing a field trial of the *Chlamydia* vaccine in collaboration with USC.

4. Provide high-quality veterinary care and treatment to koalas in the program affected by illness and/or trauma (including foster care of orphaned joeys).

5. Conduct a scientific field trial to assess the efficacy of a *Chlamydia* vaccine in reducing the impacts of chlamydial infection, using koalas living in, or near, the MBR corridor.

6. Determine the causes of mortality and the relative importance of each threatening process contributing to premature koala death, to inform and guide adaptive management.

These objectives were achieved by:

1. Capturing most/all of the koalas living in, or near the MBR corridor, in addition to resident koalas from two designated translocation sites.

2. Intensively monitoring tagged koalas using conventional and innovative telemetry techniques.

3. Performing comprehensive and standardised veterinary examinations of tagged koalas every six months (or earlier if required) to monitor koala health and welfare.

4. Contributing biological samples, clinical and ecological data to research projects investigating or addressing issues of koala conservation.

5. Adaptively managing koalas and threats to their welfare and survival guided by veterinary and ecological data collected over the duration of the program.

**Plate 4.2**: Partly hand-reared sub-adult *Sammy* relaxing in the pre-release enclosure at Toorbul prior to his release at Kippa-Ring. The pre-release enclosure was an important facility to benefit hand-reared youngsters in their transition to life in the wild.

## 4.3 Methods

### 4.3.1 Veterinary examinations

Koalas captured as part of the *KTMP* were recaptured every six months for a comprehensive and standardised veterinary examination to assess their health, and to ensure the correct fitting of their telemetry devices. Examinations were conducted under general anaesthesia to minimise stress and to facilitate diagnostic and biological sampling. Koalas were anaesthetised with alfaxalone 10mg/ml (Alfaxan CD-RTU®, Jurox Pty Ltd) injected intramuscularly into the quadriceps muscle at a dose rate of 3-5mg/kg. Anaesthesia was maintained as required with additional doses of Alfaxan injected either intramuscularly or intravenously, or inhalation of a combination of isoflurane (Isoflo™, Abbott) and medical oxygen via mask or endotracheal tube. Intubation was only performed for certain medical and surgical procedures (such as exploratory laparotomy) or if the koala experienced breathing difficulties and ventilatory support was required.

In order to detect most known conditions in koalas, the veterinary examinations consisted of a:

- Distant examination: the initial assessment of a koala conducted prior to anaesthesia, which included observations of overt signs of illness, symmetry, gait, neurological state, coat quality, general demeanour, presence of a joey, behavioural abnormalities, breathing abnormalities, and other lesions, such as wounds, lumps and injuries;
- Assessment of sex, weight, tooth wear, hydration and body condition score;
- Vital sign assessment and monitoring;

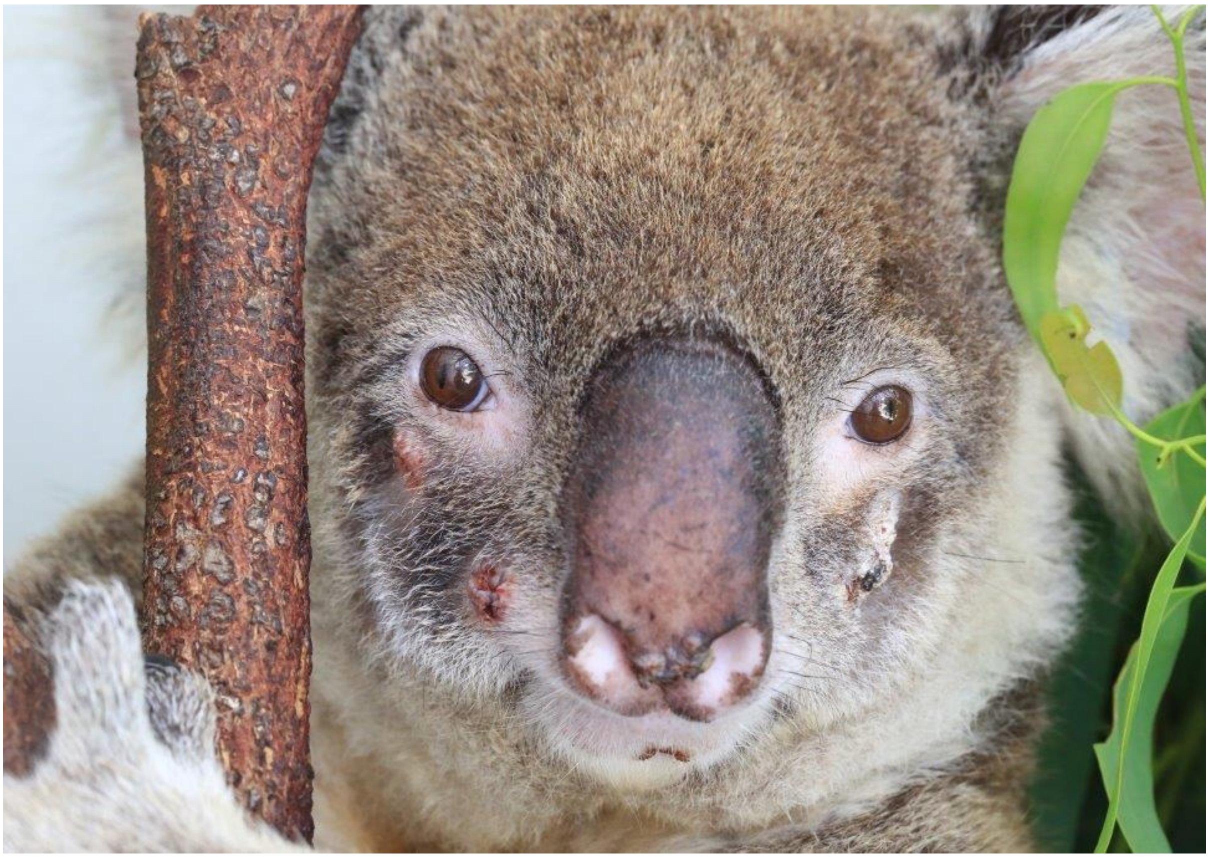


**Plate 4.3:** Distant examination of koala *Benny B* showed multifocal, raised, ulcerative dermatitic lesions. The lesions failed to respond to a variety of treatments, and the koala was eventually euthanased on humane grounds. The lesions may be a consequence of koala retrovirus-associated immune system disease, but this pathogenic mechanism has not been proven.

- General physical examination, including assessment of:
  - Musculoskeletal (palpation of muscles, bones and joints) system;
  - Skin and coat condition;
  - Peripheral lymph nodes (facial, rostral mandibular, mandibular, superficial cervical, axillary and inguinal lymph nodes);
  - Head (eyes, ears, nose);
  - Oral cavity (lips, teeth, gingiva, tongue, cheek pouches, palate, pharynx, larynx)
  - Stomach and abdomen fill and consistency;
  - Inspection of the pouch (presence/absence of a joey), mammary glands, sternal gland, scrotum, penis, clitoris and cloaca;
  - Presence of ectoparasites (e.g. presence of ticks, mites) or endoparasites (e.g. tapeworm segments with faecal pellets) (**Plate 4.4**).

**Plate 4.4:** Koala *Satyam* with an engorged female paralysis tick (*Ixodes holocyclus*) attached to the right side of his face (left image). Paralysis ticks are commonly found attached to koalas and appear to cause few health issues other than localised inflammation and ulceration at the attachment site. Image on the right shows a segment of the koala tapeworm (*Bertiella obesa*) (off-white, ribbed object) that has been passed out with a faecal pellet (top object). These tapeworms are very common in koalas and appear not to be associated with significant lesions or ill-health.

- Diagnostic techniques, including:
  - Ultrasound of the bladder, kidneys, ureters, male reproductive tract (prostate) and female reproductive tract;
  - Urinalysis (for dipstick urinalysis, urine specific gravity and cytological assessment of urine sediment);
  - Clearview® *Chlamydia* MF testing of swabs from various anatomical sites (ocular, urogenital tract (prostatic urethra in males) and urine sediment) (Note: manufacture of the Clearview *Chlamydia* MF test ceased in late 2015);
  - Blood collection for analysis of a smear, packed cell volume and total plasma protein;
  - Bone marrow collection for cytological assessment (Note: analysis of a bone marrow sample can aid in the diagnosis of conditions including leukaemia, and myelodysplasia);
  - Abdominal aspirate for cytological assessment (Note: analysis of abdominal fluid can aid in the detection of conditions including peritonitis, ascites, neoplasia (e.g. mesothelioma, lymphoma) and presence of blood in the peritoneal cavity (often the result of trauma)).

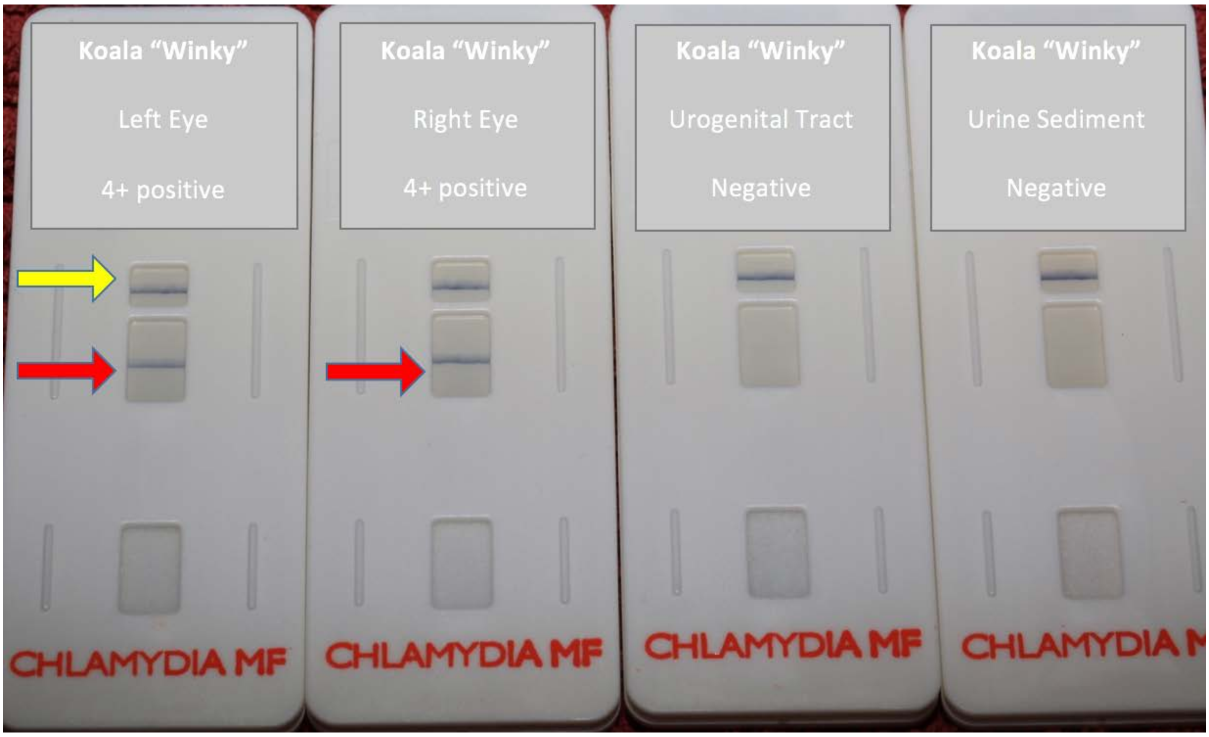



**Plate 4.5:** Clearview *Chlamydia* MF test results of koala *Winky* (a koala with acute-subacute bilateral conjunctivitis)- red arrows indicate a strong positive result (4+) in the results window (Scoring system 0-4: 0 (negative)= no line in the results window, 4+ positive = line in results window is equal to or greater than the intensity of the line in the control window (yellow arrow)). (Note: at the time of writing the Clearview *Chlamydia* MF test was no longer being manufactured, and therefore no rapid "bed-side" diagnostic test for chlamydial infection was readily available).

Additional diagnostic techniques were utilised if indicated. These included:

- radiography (x-rays);
- faecal analysis;
- exploratory laparotomy;
- collection of biological samples for culture and sensitivity;
- biopsies;
- blood collection for haematology/biochemistry;
- cytology (e.g. of lumps/growths, skin lesions and the like).

For identification purposes, koalas were ear-tagged with a numbered plastic swivel tag (left ear in males, right ear in females) and microchipped. Prior to their release, koalas were fitted with either a bio-telemetry and/or radio-telemetry device to enable their ongoing monitoring in the program. Pigmentation patterns in fur and skin of the nose were frequently used to assist in the identification of koalas in photographs.

**Plate 4.6**: Distinctive pigmentation patterns on the nose can sometimes assist in the identification of koalas from photos. Left image is koala *Ali*, middle image is *Sammy*, and right image is *Tanja*.

### Abridged Veterinary Examinations (including attachment of telemetry devices)

Although 6-monthly capture and veterinary examination was suitable for most adult koalas, growing koalas had to be recaptured more frequently to avoid tag-related issues (such as constrictive injuries and rub lesions). These veterinary examinations were known as "tag sizing checks". For example:

- Dependent (still with mother) joeys: joey of 1kg bodyweight or above (around 9-10 months of age), were fitted with a lightweight Velcro® anklet collar (a VHF pinger with a Velcro® attachment) (**Plate 4.7** below). At this age, joeys experience a rapid phase of growth and are at risk of tag-related injuries, particularly constrictive injuries, if the device is not checked/ refitted at regular intervals. EVE's protocol for recapture of dependent koala joeys was for a capture and check every 45 days. Monitoring/adjusting the fit of a Velcro® anklet collar was generally performed while the joey was conscious. Hang-ups were avoided by incorporating a Velcro® "break-point".

**Plate 4.7**: Approx. 12-month-old koala joey *O'Connor* wearing a Velcro® anklet collar (March 2016)

- Sub-adult koalas: once a koala had reached 3kg or above, it was fitted with an LX *K-Tracker* bio-telemetry collar and a VHF anklet (**Plate 4.8**). Recapture frequency was based on each individual's history of weight gain and how firmly the tags were fitting after the period following the last capture. As a general rule, sub-adult koalas were recaptured every 2-3 months to assess the fitting of their telemetry devices. Koalas only reverted to recapture every 6 months once they had reached a stable weight, when it was not expected that their weight gain in that period would create a risk of constrictive injury.

**Plate 4.8:** Koala *Billy Ray* (October 2015) wearing an LX *K-Tracker* bio-telemetry collar and VHF anklet. As a rapidly growing young koala, she had to be captured frequently to adjust the fit of both the anklet and the *K-Tracker* collar.

Other reasons for more frequent capture intervals are as follows:

1. Sick and/or injured: if a tagged koala or their dependent joey was reported by field personnel or a member of the public to be showing signs of illness or injury, they were recaptured promptly for a veterinary examination. If there was uncertainty as to whether or not the koala was unwell (this may have been due to limited visibility of a koala in the tree), the frequency of tracking was increased to allow for daily observations until it was determined whether or not there was cause for concern and if the koala required recapture.

2. Misadventure: occasionally koalas would find themselves in high-risk situations requiring their immediate recapture. Some examples include: venturing onto properties with domestic dogs, climbing signposts adjacent to busy roads (koala *Taryn*), moving over/through breaches in road-side fauna exclusion fencing (see discussion of koala *Anna* in ***Chapter 6 - Ranging behaviour and habitat use by koalas***).

3. Recheck of a previous health issue: a koala that had received veterinary treatment or had a health issue that required close monitoring, but not necessarily intervention, was recaptured as deemed necessary by the veterinarian, for example to assess response to treatment.

4. Dropped tags: for the duration of operational works involving vegetation clearing, if a koala dropped one of their tags (e.g. collar or anklet), they would be immediately recaptured. This was to minimise the chance of losing the koala in the event that their second telemetry tag was also dropped or malfunctioned. A koala without telemetry tags could not be easily located and protected during vegetation clearing, a primary objective of the program. Later, if a koala dropped one of their tags, they would generally be recaptured a minimum of 45 days after their last capture. This was to avoid catching koalas too frequently, as some koalas had a propensity to slip their tags more than others (e.g. fighting males). If a koala was successful at dropping all of their tags, intensive targeted searches were conducted to find the koala for recapture (if the koala was relevant to ongoing monitoring programs).

5. Koalas that were part of the *Chlamydia* vaccine trial: *control group* koalas were recaptured for a full veterinary examination/biological sampling two months after their initial capture, then at 6-monthly intervals thereafter; *multi-dose vaccine* koalas were recaptured at one month (for a vaccine booster) and two months (for a vaccine booster and full veterinary examination/ biological sampling) after their initial capture, then at 6-monthly intervals thereafter. Subsequent field trials of a single-dose vaccine did not require additional recapture of koalas. Vaccine koalas were sampled at their routine 6-monthly veterinary examinations or opportunistically if they were recaptured for any of the reasons outlined above.

**Plate 4.9**: Koala joeys were often kept with their mothers during veterinary examinations. Koala *Indigo's* 9-month-old joey *Carmin* found a comfy spot on her mother's head, during a scheduled vet check in July 2014.

## 4.3.2 Necropsy (*post mortem*) examinations

An important objective of the *KTMP* was to determine causes of koala mortality occurring during the monitoring period. Many previous field studies have made assumptions about the causes of death in koalas because thorough necropsy examinations were not conducted on deceased koalas, or monitoring frequency was not sufficient to detect mortality events in a sufficiently timely interval to permit diagnostic necropsy examination. Successful identification and management of important threats to koala population viability requires frequent (daily, or nearly daily) monitoring of many individuals (either remotely or using conventional field monitoring) and diagnostic necropsy examination of deceased koalas soon after death. Cause-of-death and other mortality data are essential inputs for population viability analysis and to guide conservation and mitigation planning.

To maximise the likelihood of obtaining an accurate cause-of-death diagnosis, the majority of koalas were closely monitored using the LX *K-Tracker* telemetry system. This system provided 12-hourly GPS and activity data uploads from each collared koala, allowing daily remote monitoring. If a koala had a low or zero activity datum, it was immediately field-tracked using conventional radio-telemetry to determine if it had dropped its tag (a common cause of zero or low activity data), was unwell or recently deceased. If a bio-telemetry collar became non-functional or uploaded unreliably, monitoring reverted back to a twice-weekly tracking schedule (every three to four days), which was as for koalas wearing a conventional VHF radio-telemetry device only.

Post-mortem decomposition of carcasses begins almost immediately after death. In some cases, for example in koalas affected by some bacterial infections and in very warm and humid/wet weather, the rate of decomposition is very rapid, with early skeletonisation occurring within 2-3 days. Hence, the monitoring of koalas either remotely or by conventional radio-tracking, on a daily or near daily basis, was essential to achieving the objective of accurately identifying cause of death. To minimise degradation of tissues after a deceased koala was found, carcasses were placed on ice and transferred promptly to the EVE veterinary facilities for necropsy examination.

Further details on causes of mortality and necropsy findings are presented in ***Chapter 8 - Causes of death of koalas.*** *Appendix 6* contains summary information on the necropsy findings and probable cause of death of all koalas that died during the koala management program, up until program completion (De-collaring of koalas was essentially complete by January 2017).

**Plate 4.10:** Koala *Red Baron* found dead in December 2013. Frequent monitoring of koalas makes the recovery a fresh carcass more likely, allowing for subtle lesions to be detected and in most cases, an accurate diagnosis of cause of death to be achieved. (In this case the cause of death was *carpet python predation- not ingested*. Nearly two-thirds of all koalas killed by pythons were not ingested).

## 4.3.3 EVE veterinary facilities

EVE veterinary facilities at Toorbul provided for all veterinary procedures required for MBR koalas except for radiography and orthopaedic surgery. In the initial phase of the *KTMP*, EVE had limited koala rehabilitation enclosures, and koalas requiring prolonged in-patient care were sent to the Australia Zoo Wildlife Hospital (AZWH). As the program progressed, it became apparent that the capture of large numbers of koalas (many of which required medical attention), placed a significant burden on the AZWH - a charity-funded facility. TMR acknowledged the extra encumbrance the *KTMP* had placed on the AZWH and approved the construction of six koala enclosures at the EVE facilities at Toorbul for the ongoing treatment of MBR koalas. Treatment and rehabilitation of MBR koalas at EVE resulted in closer monitoring and better care of sick koalas, and improved treatment outcomes, compared with external care providers/facilities.

The facilities at EVE include the following:

- Veterinary examination room;
- Surgical theatre;
- Diagnostic laboratory;
- Seven outdoor rehabilitation enclosures for in-patient care of koalas;
- Two “free-range” pre-release enclosures for hand-raised koalas;
- Two indoor intensive care enclosures.

**Plate 4.11:** Veterinary examination area with laboratory in the background and ICU enclosures to the rear far left. Anaesthetised koala *Carlos* is on the examination table during a scheduled veterinary examination.


**Plate 4.12**: Outdoor koala rehabilitation enclosures at the EVE facilities at Toorbul. The purpose-built enclosures can house six koalas individually, and provide good protection from cross infection.

**Plate 4.13:** EVE's surgical theatre. Veterinarian Dr Amy Robbins (left) and veterinary nurse Natasha Banville (right) performing an exploratory laparotomy on koala *Barnacles* to diagnose the cause of a peritoneal effusion (excessive fluid in the abdominal cavity). He was euthanased intra-operatively after surgery enabled a definitive diagnosis of lymphoma -the most common malignant cancer of koalas.

**Plate 4.14:** Inside an EVE koala enclosure- koala *Deb* with her 10-month-old joey *Rocket.* Each enclosure contains two up-right perches connected by a cross-perch, and freshly cut browse is provided twice daily.

**Plate 4.15:** Hand-reared koala *Bobby* shortly after release into the pre-release enclosure (April 2016). He was placed into foster-care as a juvenile after losing weight following early weaning by his mother *Robyn.* The pre-release enclosure is a free-range enclosure around a group of trees and shrubs, including one large blue-gum tree. This allowed hand-reared orphans and long-term in-patients to develop climbing strength before release back into the wild.

**Plate 4.16:** Intensive care enclosures at EVE veterinary facilities at Toorbul. These enclosures facilitate closer monitoring by veterinary staff, and treatments such as IV fluids. Environmental control is important in critically ill patients, for which outside enclosures would be inappropriate in both excessively hot and cold weather.

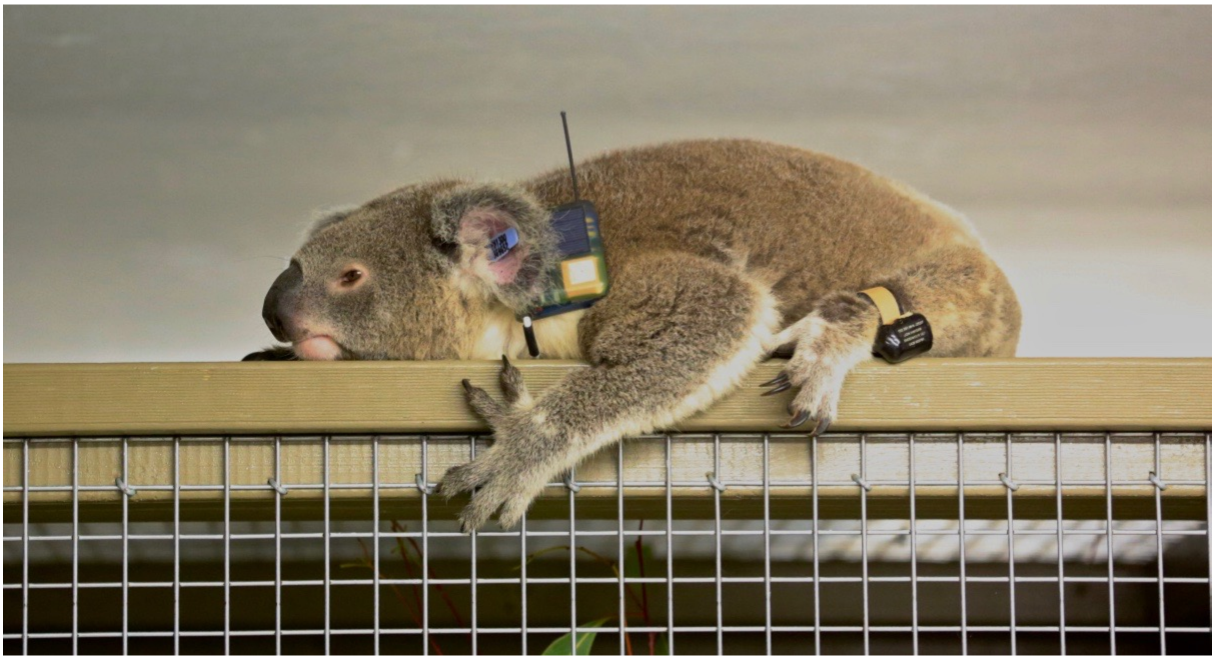


**Plate 4.17**: Some koalas found it more comfortable to sleep *on* the enclosures, rather than *in* them. This is koala *Button* resting on one of the newly-constructed ICU enclosures in February 2014. The construction flaw (an 80mm gap at the bottom) was fixed and prevented any future excursions.

## 4.3.4 Veterinary treatment of koalas

### Treatment regimen for koalas with chlamydial infection/disease

Koalas with chlamydial disease or a strong positive result on their Clearview® *Chlamydia* test (but no obvious chlamydial lesions) (**Plate 4.18**, below) were admitted to EVE facilities for treatment. The standard treatment regimen was a 28-day course of chloramphenicol injection (Chloramphenicol 150 (150 mg/ml), CEVA Animal Health Pty Ltd.) (**Plate 4.19**) administered at a dose rate of 60mg/kg by subcutaneous injection once daily. In some cases, the antibiotic course was shorter than the preferred 28-day course due to: the temporary unavailability of chloramphenicol in the early stages of the program; if a koala coped poorly in care; and in some cases, to reduce the risk of the koala developing further health complications (e.g. oxalate nephrosis) associated with captive care. These considerations are outlined in more detail below.


**Plate 4.18:** Koala *Taryn’s* strong positive Clearview® *Chlamydia* test result (3+ positive - urogenital tract) (left image). The arrow indicates the positive indicator line. She had no obvious disease lesions detected at her veterinary examination. Koalas with strong Clearview® positive results were treated as a precautionary measure to reduce the likelihood of developing disease and to prevent contributing to the spread of infection. Image on the right shows koala *Taryn* and her near-independent joey *Trent* in care at EVE for treatment of chlamydial infection. *Taryn* was pregnant at the time of her treatment and gave birth while in care. Mother and joey were released in December 2015 and then recaptured approximately 4 months later for de-collaring and removal from the *KTMP*. The new joey was still alive.


**Plate 4.19:** Chloramphenicol 150, the antibiotic used to treat chlamydiosis in koalas. The drug was temporarily discontinued by the manufacturer due to its low rate of use in general veterinary practice, causing major issues for treatment of koalas. Eventually the manufacturer agreed to manufacture periodic batches to supply koala hospitals.

In addition to systemic antibiotics, koalas with chlamydial conjunctivitis were treated with two topical eye preparations including: drops containing dexamethasone 1mg/ml (Maxidex® 0.1% eye drops; Alcon Laboratories) and an ointment containing chloramphenicol 10mg/g and hydrocortisone acetate 5mg/g (Chloroptsone®; CEVA Animal Health Pty Ltd.). In severe chlamydial cases (particularly koalas with cystitis), to relieve pain associated with severe bladder inflammation and ulceration, steroidal or non-steroidal anti-inflammatory and other analgesics were administered.

**Plate 4.20**: Koalas frequently eat dirt and termite mound material, presumably to provide trace elements and minerals, or perhaps grit, not available in their usual foliage diet. In-patients are provided with soil or termite mound material to enable *ad lib* access to this component of their diet. The photograph on the left shows koala *Susan* eating dirt at the Griffin offset site, and the photograph on the right shows joey *Baratheon* being hand-fed a portion of termite mound during the in-patient treatment of his mother *Red Queen* for fungal skin and claw infections.

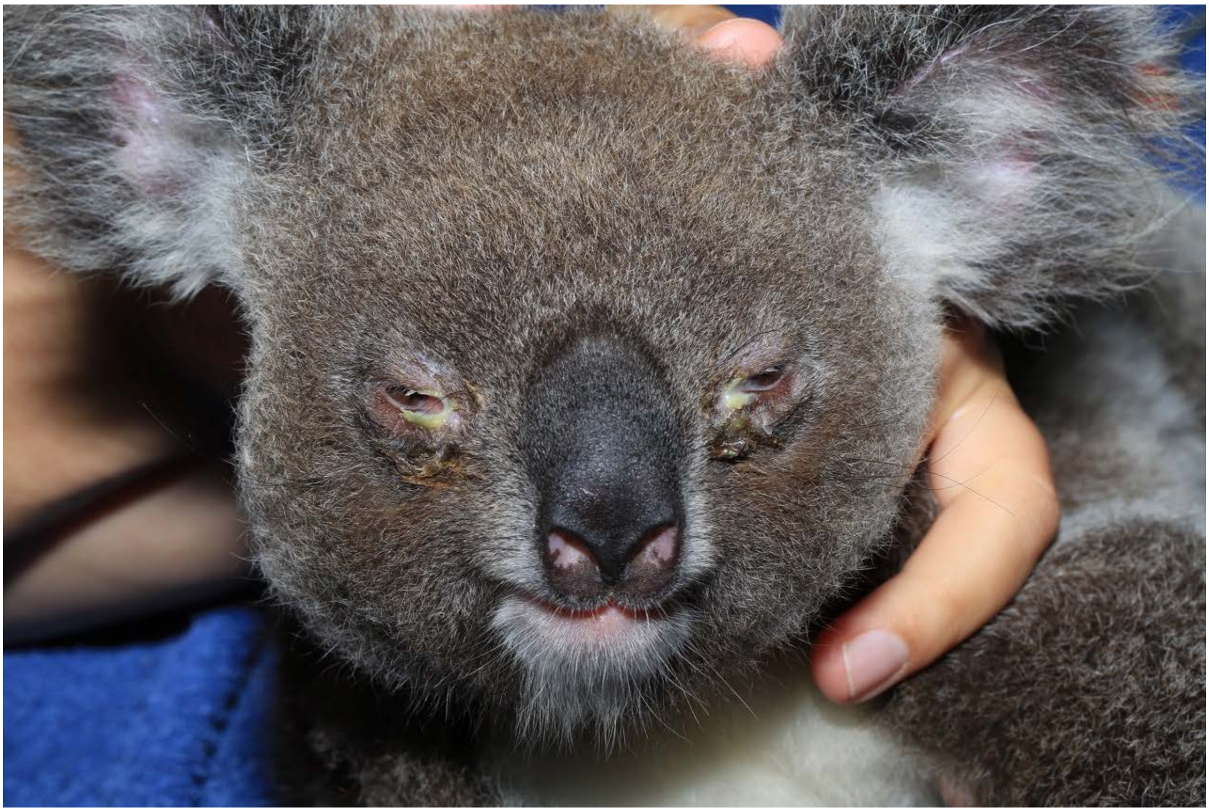


**Plate 4.21a**: Koala *Winky* with severe, acute-subacute bilateral kerato-conjunctivitis caused by *Chlamydia* infection in January 2014, (image above). She was successfully treated and released back into the wild. The photograph below shows her 20 months later, with her nearly independent back-rider joey *Willie* at the time of their release at Kippa-Ring following scheduled veterinary checks in September 2015. There had been no recurrence of disease following treatment.

**Plate 4.21b**: Koala *Winky* and her joey *Willie* approximately 20 months after her treatment for kerato-conjunctivitis.

## Treatment and management of female koalas with reproductive tract disease

The management of female koalas that are sterile as a result of chlamydial infection is a contentious issue, and, because of that, the topic is worthy of some explanation and discussion. EVE's standard approach is not to euthanase sterile female koalas if their quality of life and prognosis are good (following treatment). This approach is in conflict with the views of some koala ecologists and veterinarians who argue that these animals should be euthanased, or at least removed from wild populations. It is also at odds with the current EHP policy on the management of koalas found to be sterile (generally as a result of chlamydial disease) under most circumstances, but was permitted under the SPPs issued for the various MBR koala management programs. Our approach to management of this subset of koalas is based on robust scientific, ethical and philosophical foundations, which are presented below.

There are three broad principles or issues that should be considered in this discussion:

1. The intrinsic value of a life;
2. The welfare of the animal (the "animal welfare issue");
3. The health, sustainability and viability of the koala population (the "ecological issue")

Often the issue is discussed with reference to point 3 alone.

**With respect to point 1 above, *the intrinsic value of a life:***

Most people would argue that the life of an animal has some intrinsic value, and should therefore not be subject to arbitrary destruction, or destruction without good cause. In other words, some compelling reason should exist to justify the killing of an animal. In the context of sterile female koalas, that reason should be justified by circumstances associated with either or both of points 2 and 3 (above). Because ethically, extinguishment of a life should not be arbitrary, the onus is on the proponents of euthanasia to provide compelling justification for that course of action.

**Regarding point 2 above, *the welfare of the animal:***

A female koala affected by sterility and also severe or multifocal disease, old age, or another concurrent condition that results in a poor prognosis, should be euthanased. The justification for this is that the prognosis is poor, and/or the stress of treatment and captivity for the prolonged treatment course and surgery, cannot be justified in an aged animal. The euthanasia of these cases is not contentious, and therefore not worthy of further discussion. However, a significant proportion of female koalas that are examined have sonographic changes indicating sterility, but are otherwise healthy. This can occur in female koalas as young as 14-15 months (e.g. koala *Jud*) since many young female koalas are known to begin breeding shortly after independence from their mother. It is the management of this subgroup of koalas that causes the most controversy.

EVE's standard therapeutic approach to these koalas is to administer chloramphenicol for an appropriate period of time to achieve microbiological cure of the chlamydial infection prior to surgery to perform an ovario-hysterectomy (OHE - spey or desexing surgical operation). Essentially then, the infection has been cured (prior to the stress of surgery) and the damaged and non-functional reproductive tract removed surgically in an operation similar to the desexing or speying of a domestic pet dog.

An ovario-hysterectomy has two important objectives:

1. To remove the diseased tissue so that it causes no further discomfort or illness in the koala; and
2. To obviate reproductive cycling in the sterile koala. This has two important consequences:
    a) OHE females do not cycle, therefore preventing mating and the risk of new or repeated infection and contributing to spread of infection within the koala population; and
    b) It prevents the female koala from being excessively harassed by male koalas seeking to mate, which could occur if the female were cycling repeatedly without falling pregnant.

**Regarding point 3 above, the health, sustainability and viability of the koala population:**

It is important to explain the distinction between the various sterilisation operations that can be performed. The surgical operation performed on sterile female koalas with reproductive tract disease is an ovario-hysterectomy. This involves the surgical removal of both ovaries, both oviducts and both uteri (**Plate 4.22**, below). The result is a sterile female koala that does not reproductively cycle, and neither seeks out males for mating, nor is attractive to males seeking a mate.

In contrast, *tubal ligation* of females (similar to vasectomy in males), prevents movement of the ovum down the tract after ovulation - thereby preventing pregnancy, but it does <u>not</u> prevent reproductive cycling. Therefore, a tubally-ligated female is still able to reproductively cycle and be attractive to, and receptive to males. Tubal ligation has been performed on many koalas in southern populations as a means of reducing population fecundity. That technique has no relevance to this discussion, because it has an entirely different objective. The objective of the OHE is to remove diseased tissue in an already-sterile koala and prevent reproductive cycling, thereby improving individual animal welfare (of the affected female) and eliminating the risk of her contributing to disease spread in the population. Tubal ligation would do neither of those things. When OHE is performed on already-sterile female koalas, it has no impact on the fecundity or reproductive output of the population - because that female is already sterile.

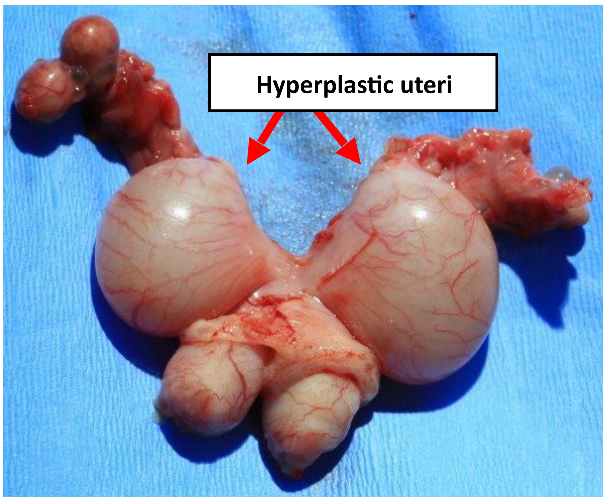



**Plate 4.22:** Intubated koala *Venom* recovering from surgery to removed her disease reproductive tract - ovario-hysterectomy (left image). The surgically removed tissue is shown in the right image and includes both ovaries, both oviducts and both uteri. *Venom* did not have the typical ovarian bursal cysts that are seen in many females with reproductive disease. Sonographically, her reproductive tract always had a “moth-eaten” appearance and she never produced a joey. At the time of surgery, *Venom* had moderate fibrosis of the reproductive tract with adhesions between her left uterus and rectum. There was a corpus luteum present on the right ovary and bilateral physiological hyperplasia of the uteri (i.e. she was reproductively cycling). One of the issues with “entire” females with reproductive disease is that they continue to cycle, and so are still attractive to males, mate, and may contribute significantly to disease spread in the population.

## Habitat carrying capacity

If one agrees that the lives of these koalas have intrinsic value, and that the animal welfare issue has been satisfactorily resolved with appropriate veterinary treatment, then arguments in favour of euthanasia or removal of these koalas from their wild populations must be based on point 3 (above) *the health, sustainability and viability of the koala population*. This compels a proponent of euthanasia/removal to present logical reasons why a desexed female koala would have a negative effect on population health or viability. The most commonly presented argument is that these koalas occupy habitat that would/might otherwise be used by healthy, reproductively viable koalas. The assumed corollary of this is that these fecund koalas would then die, or be somehow unable to contribute to the population because of the occupation of habitat by sterile females, therefore having a negative effect on population viability.

This argument is only logical and supported if the habitat in question is considered to be at or beyond its koala carrying capacity, otherwise there is no practical and logical mechanism by which the sterile (desexed) female koalas could prevent reproductively viable koalas from occupying habitat and contributing normally to the koala population. In SEQ, there is ample and well publicised evidence of koala population declines that are disproportionately high in comparison with habitat loss rates. In Queensland (in marked contrast with some Victorian koala populations) there are only rare instances of local koala populations appearing to exceed the carrying capacity of their habitat. (Koalas living in habitat remnants south of the Pine River at Lawnton are a contemporary example.)

Logically then, on average, remaining habitat is likely to currently sustain koala populations at well below carrying capacity; this is supported by scientific surveys and anecdotal observations in many areas of SEQ. If this were not the case, and remnant habitat was demonstrably at or exceeding koala carrying capacity, then removal of koalas from those habitats would be desirable, and an argument for removal of sterile koalas might then have some foundation. As this is not the case, the argument that sterile female koalas "take" habitat from, or displace healthy fecund koalas has no logical or practical support with respect to most koala habitats in SEQ. Certainly, we did not observe negative impacts in the koala population caused by the re-release of sterile female koalas (after their sterility was detected), neither did it result in higher numbers of koalas requiring translocation in the *KTrans* program.

## The "ecological value of a koala"

There is some theoretical support for the positive ecological value (rather than null value) of desexed female koalas that are returned to their native populations after appropriate treatment. This argument is based on the fact that a native animal, living in its usual native habitat has some intrinsic ecological value by virtue of its evolution and place in that ecosystem - it is an intrinsic component of its ecosystem. Certainly, reproductive viability is an important value because it is necessary for perpetuation of the species, but it is illogical to contend that the <u>only</u> value of an organism resides in its reproductive capability. To apply that to the issue of sterile female koalas; if a fecund female koala has an ecological value, then logically a sterile female koala must have *some* ecological value, albeit less on account of her inability to produce offspring. One simple example of how a sterile female koala might provide an ecological value as well as contributing positively to the viability or sustainability of her native population is through predator risk dilution. In other words, her presence in the population ostensibly dilutes the risk of predation of fecund animals. Hence, in spite of their sterility, these koalas provide some ecological value.

## Social cohesion

It has also been hypothesised that in low-density koala populations, simply having koalas - any koalas - may serve to have a cohesive effect on the population. Expert opinions have also been expressed about the existence of structured social networks and interactions within koala populations, and the undesirability of unnecessarily interfering with those. Hence, sterile koalas, even though not contributing progeny to the population may nevertheless provide some benefit, by contributing to social cohesion and networks. While this is an untested hypothesis only, it favours a position of caution in removing any individuals from a low-density population - such as sterile females - particularly if they have been appropriately treated with antimicrobials and surgery.

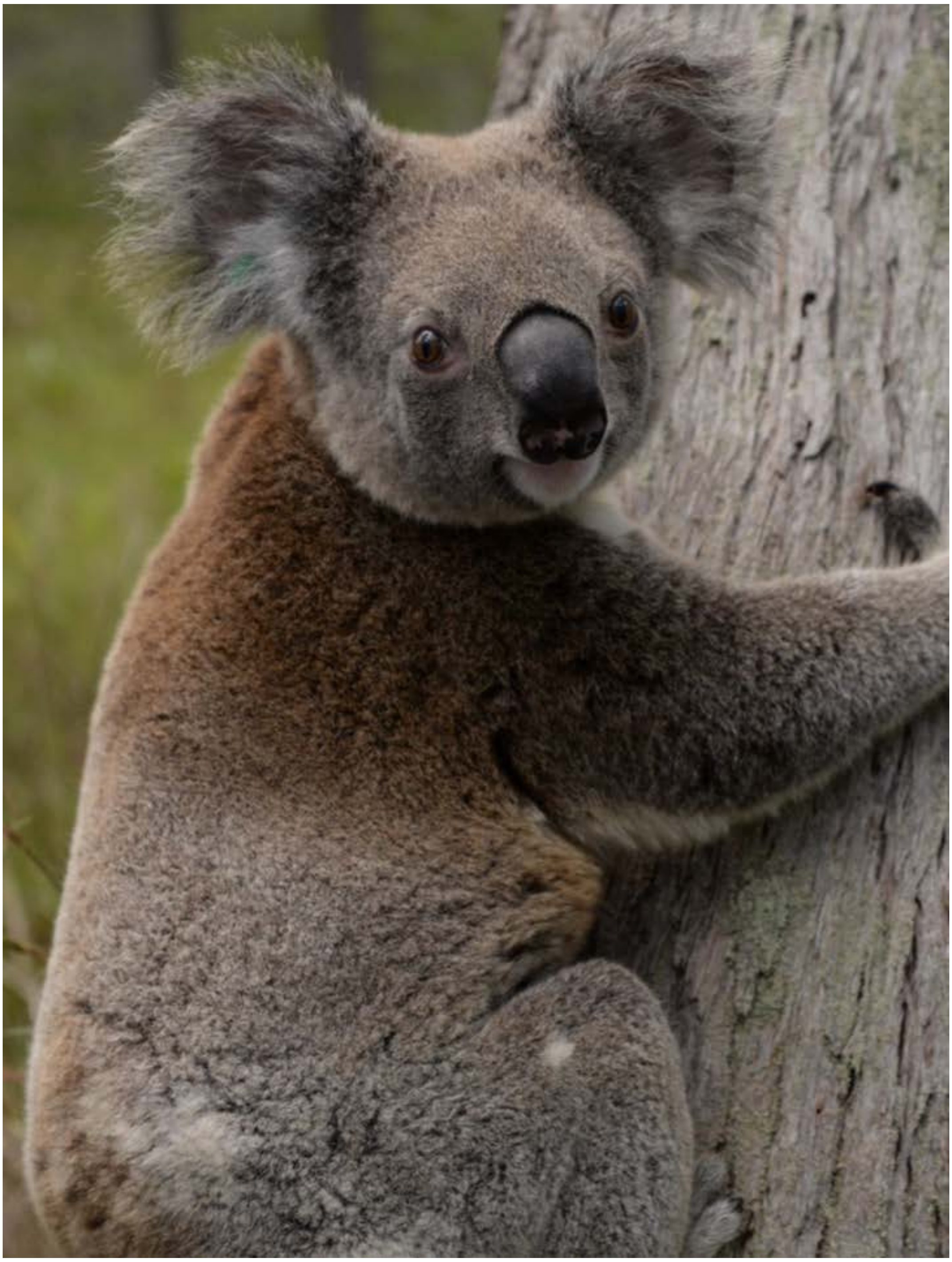


**Plate 4.23**: Koala *Chris* was found to have reproductive disease causing sterility in 2014 but always appeared overtly healthy (She was ovario-hysterectomised in December 2014). In most populations of koalas in south-east Queensland, a significant proportion of female koalas are quite healthy, but incapable of breeding due to past *Chlamydia* infections.

### Removal and placement into captivity

Current EHP policy allows for the placement of some unreleasable wildlife into captive institutions (zoos and the like) under Species Management Plans (SMPs). While some koalas appear to tolerate captivity relatively well, many do not; and for these, permanent captivity is a poor welfare outcome. Given the lack of justification for removing these animals from the wild (assuming appropriate veterinary treatment has occurred) and the potential for poor animal welfare outcomes, the project did not support the placement of sterile MBR koalas into captive institutions.

In summary: the euthanasia of otherwise healthy, but sterile koalas in the current circumstances in SEQ is unjustified when appropriate veterinary treatment is applied. Intrinsic value-of-life and animal welfare issues are addressed by appropriately treating these patients. There is no logical argument from an ecological perspective in support of euthanasia in the current circumstances in SEQ, in our view, and sufficient justification for returning appropriately treated sterile koalas back to their habitat of origin.

**Plate 4.24:** Koala *Savannah* had reproductive disease (bilateral ovarian bursal cysts) but was otherwise healthy. She was ovario-hysterectomised in April 2014 and was subsequently released back into the wild. She disappeared from the Amcor site in September that year, in circumstances suggestive of wild dog predation, although her remains were never found. This was during one of the most active periods of the "Amcor Dog" during which time dozens of koalas were killed. (See ***Chapter 8 - Causes of death of koalas*** and ***Chapter 9 - Wild dogs***.)

### 4.3.5 Difficulties relating to veterinary treatment of koalas

The following section details some of the challenges associated with treatment of koalas during the course of the program.

#### Unavailability of chloramphenicol

Since 2012, the supply of chloramphenicol by CEVA Animal Health, the manufacturer of the antibiotic, has been unpredictable due to poor demand from the veterinary industry. Given that chloramphenicol is the anti-chlamydial antibiotic of choice by many koala treatment facilities, there was widespread concern about the future prospects for chlamydial treatment in koalas. (Note: other antibiotics known to be successful at treating chlamydial infection in other species (e.g. tetracyclines) are not generally used in koalas due to their adverse and often fatal gastrointestinal side effects.) Due to difficulties in sourcing chloramphenicol, compounding pharmacies were used to manufacture the injectable drug, but these formulations were less efficacious, difficult to inject, and occasionally caused skin necrosis and injection site reactions. Although the original formulation was intermittently available, production of the CEVA product eventually ceased in 2013.

Fortunately, in response to requests from a number of koala treatment facilities, CEVA agreed to manufacture occasional bulk batches of the drug to enable the ongoing treatment of affected koalas. Supply of the drug resumed in late July 2014, permitting treatment of koalas using the preferred treatment regimen. However, in the intervening period a number of MBR koalas that required treatment for chlamydiosis were not treated for a sufficient period, or at all with chloramphenicol. The following section details some of the issues that were consequent to the unavailability of chloramphenicol injection.

#### Use of antibiotics (other than chloramphenicol)

During the chloramphenicol shortage in 2013-2014, the antibiotic florfenicol (Nuflor®), a synthetic analogue of chloramphenicol, was used as an alternative systemic therapy to treat koalas affected by chlamydiosis. It was being trialled by at least two other koala facilities as an alternative treatment for chlamydiosis, but was discovered to be largely ineffective at treating infection and in some cases led to fatal caeco-colic dysbiosis. Furthermore, of the 23 MBR koalas that were treated with florfenicol at EVE, 10 had to have follow-up treatment with chloramphenicol when it became available again. The remaining 13 koalas had the following outcomes:

- 3 koalas were euthanased due to the progression of disease following florfenicol treatment (chloramphenicol was still unavailable at the time) or had severe disease detected at veterinary rechecks at which time it was considered that no antibiotic would have been efficacious;
- 1 koala died from wild dog predation prior to being re-assessed for treatment success at a follow-up veterinary examination;
- 4 koalas died or were euthanased following treatment with florfenicol due to gastrointestinal complications caused by the drug (caeco-colic dysbiosis/typhlo-colitis);
- 4 koalas had no additional treatment (their infection/disease either resolved or was considered inactive following treatment);
- 1 koala slipped its telemetry tags, so an outcome following florfenicol administration was unknown.

Enrofloxacin (Baytril®, Bayer Animal Health, Pymble, N.S.W, Australia), a fluoroquinolone antibiotic which is routinely used to treat chlamydial disease in some wildlife hospitals, was not used by EVE for the following reasons:

1. A study by Griffith (2010) reported that after cessation of fluoroquinolone treatment in 29 koalas, shedding of chlamydiae increased again in 24 of the study animals indicating that microbial cure had not been achieved. Of the remaining koalas, three koalas were not monitored following treatment for recurrence and two koalas remained negative.

This indicates that whilst clinical infection may appear to resolve following treatment, recrudescence (recurrence) commonly occurs after cessation of treatment.

2. Pharmacokinetic studies have shown that enrofloxacin is not a suitable treatment option for this disease at dosages likely to be safe in koalas.

3. When chloramphenicol was periodically unavailable, AZWH used enrofloxacin as a last resort to treat koalas with chlamydiosis. The drug was administered using the same dose rates reported by other koala facilities, but it resulted in poor treatment success and some deaths.

### Discontinuation of Clearview® *Chlamydia* MF test

The Clearview® test kits were discontinued part-way through the *KTMP*. These provided a good "bed-side" test for chlamydial infection, often detecting infections without clinical signs, which were then treated. The discontinuation of these test kits resulted in a reliance on polymerase chain reaction (PCR) testing by university research groups on a non-commercial basis, usually with a lag time of days or weeks. A replacement "bed-side" test for chlamydial infection was not available at the time of writing.

### Individual responses to captive care

Although most koalas respond well to captive care and veterinary treatment, some individuals fail to thrive in care. There are two principal reasons for this:

1. A relatively small proportion of koalas are particularly stressed or unsettled while in captive care. Some of these koalas are "quiet stressers" who show few external signs of stress, but are generally inactive, have poor appetites and lose weight. These koalas must be very closely monitored and often are released prematurely, prior to the completion of the usual treatment course, because of the risk to their health and survival from prolonged periods in care.

2. Commonly, koalas with mild disease or a chlamydial infection with no obvious disease (e.g. strong Clearview positive result) are more difficult to treat as they feel well within themselves. These koalas need to be monitored closely for signs of decline and in some cases released prior to the end of treatment to reduce the risk of further deterioration. They may pace in their enclosures excessively, causing wear on their feet, and become chronically stressed. In addition, some koalas who are initially good patients when sick, become increasingly agitated in care when they feel better. Similarly, these patients must be carefully observed for deterioration and released early if necessary.

### Development of renal disease - oxalate nephrosis

Wild koalas are susceptible to the development of oxalate nephrosis, a potentially fatal condition of the kidneys which is irreversible in its advanced stage. When in captive care, it is important to monitor koalas closely during hospitalisation for signs suggestive of the onset of oxalate nephrosis (such as depressed behaviour, weight loss, inappetence, dehydration, decline in faecal pellet quantity and quality). Sonographically, the kidneys have a speckled white appearance due to the deposition of calcium oxalate crystals in the tissues which are very echogenic (**Plate 4.25**, overleaf). The definitive cause of oxalate nephrosis in Queensland koalas is unknown but it is likely to be multifactorial. Likely contributing factors are high levels of oxalate precursors in browse, the stress of captive care, and antibiotic treatment affecting oxalate-degrading bacteria in the gut. There appears to be a seasonal variation in the propensity of koalas to develop oxalate nephrosis, possibly due to seasonal and climatic variations in the concentration of oxalate precursors in the leaf.

We have observed that progression of this disease in koalas may be halted by the early release of affected koalas prior to the completion of treatment for their original condition, if necessary. Once the kidneys have become moderately to markedly hyperechoic from oxalate nephrosis, there is very little or nothing that can be done therapeutically to reverse this, and patients risk further decline if they remain in care. Following release, the kidneys sometimes show improvement over time (many months or years).

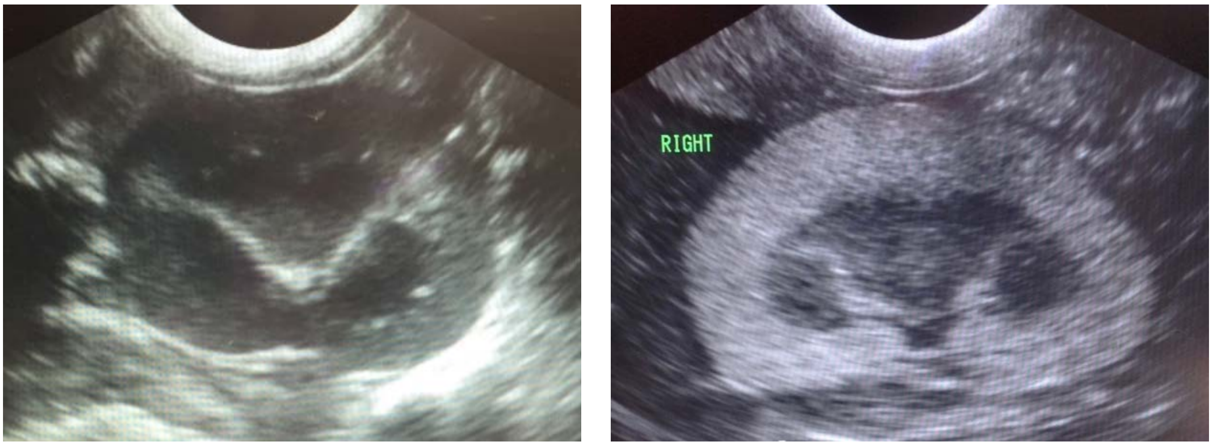



**Plate 4.25:** Sonograms showing a normal kidney (left image) and an abnormal kidney (right image). Normal kidney tissue is relatively echolucent, appearing quite dark or black sonographically, whereas the abnormal kidney appears to have bright white speckling - a result of massive numbers of microscopic calcium oxalate crystals in the kidney tissue bouncing the ultrasonic sound waves back (echogenic). The image on the right is from the koala *Satyam* who developed oxalate nephrosis while being treated for chlamydial cystitis (inflammation of the bladder) in January 2016. He was successfully treated and released, and was alive at the completion of the program.

**Plate 4.26**: Koala *Satyam* during treatment (February 2016)

## 4.4 Results

### 4.4.1 Chlamydial disease prevalence

The chlamydial disease prevalence of the MBR population decreased from around 28% to less than 1% by the end of the program (**Figure 4.1**). The reduction in disease prevalence was accomplished by the prompt and ongoing treatment of disease in the population (including euthanasia of individuals with severe disease unlikely to resolve by treatment). This was possibly also aided by the *Chlamydia* vaccine which was being trialled by the University of the Sunshine Coast in a subset of the MBR koalas. (See ***Chapter 5 - Field trial of a chlamydial vaccine for koalas*** for an overview of results to date).

It is important to note that the MBR population was not a closed population, allowing the immigration of *Chlamydia*-affected individuals who could infect or reinfect the tagged koalas. Peaks in the chlamydial disease prevalence were particularly evident in the latter months of each breeding season presumably because of increased transmission frequency and possibly also hormonal changes associated with breeding contributing to disease expression. PCR results indicate that a considerable subset of koalas have latent (asymptomatic) chlamydial infections that are not detected at veterinary examinations, which may also transition to clinical disease during the breeding season. It is unlikely that the rise in chlamydial disease prevalence that we observed each breeding season was due to recrudescence (or recurrence) of disease in previously treated koalas as only a small proportion of koalas were readmitted for chlamydiosis, and it never occurred in OHE patients (see also *Section 4.4.4*, below).

**Plate 4.27:** Rump of the koala *Fury* from Kippa-Ring (left image) showing the brown staining of the fur of the rump that is the classical clinical sign of cystitis in koalas. The staining is caused by persistent leakage of the very concentrated koala urine in koalas suffering from incontinence associated with severe and painful inflammation of the bladder. This koala also has severe ulceration and infection of the skin of the tail and around the common opening caused by urine scalding. Right image of koala *Fury* shows severe, chronic keratoconjunctivitis, causing blindness. She was also affected by bilateral reproductive disease. All three conditions are caused by chronic (long-term) chlamydial infection. She was euthanased while under anaesthesia on humane grounds, due to her poor prognosis, chronic pain and poor quality of life.

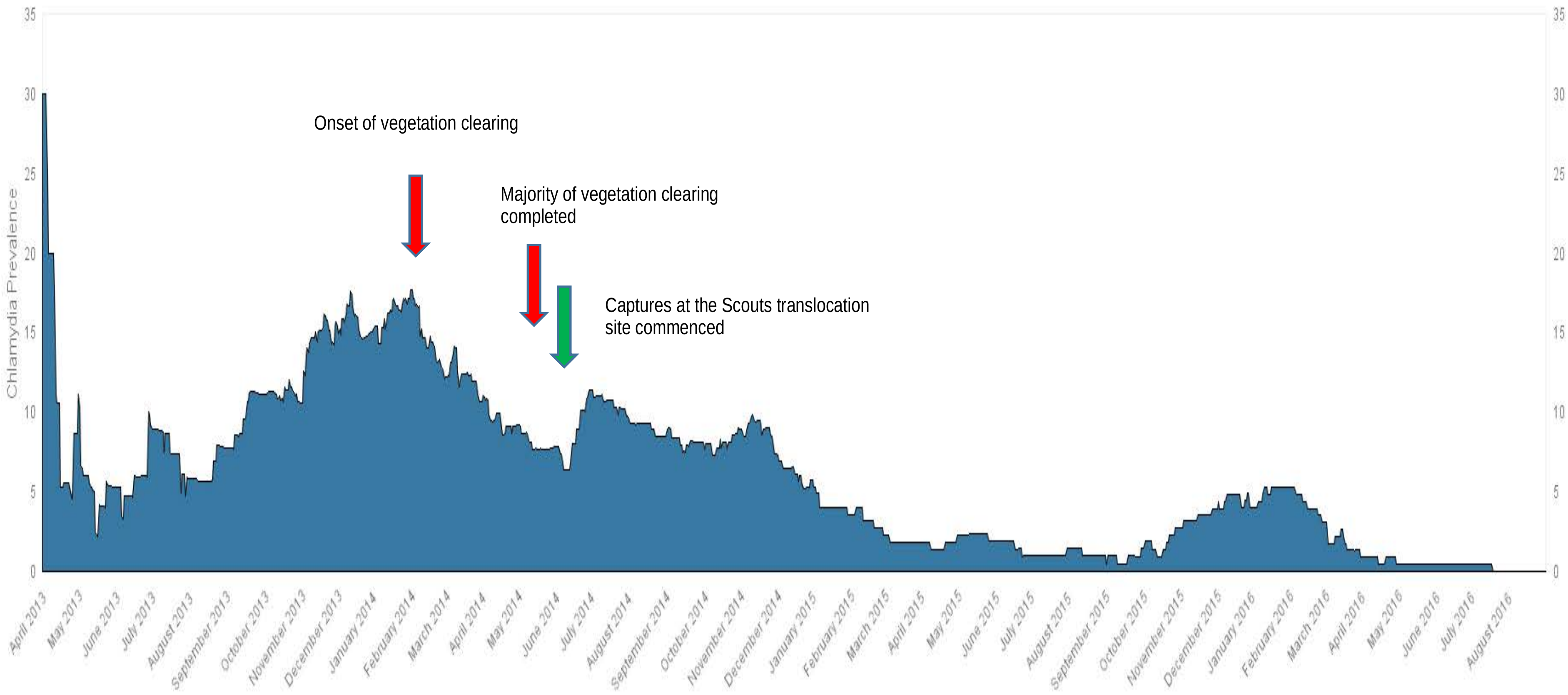



**Figure 4.1:** Graph showing the changes in prevalence of chlamydial disease over time from the commencement of the program. (The large "dip" in the graph in the first quarter is misleading due to the relatively low number of koalas in the program earlier on.) The onset of vegetation clearing and completion of majority of the clearing is indicated by the red arrows. The green arrow indicates where captures of resident koalas at the Scouts translocation site began - a sub-population in which the chlamydial disease prevalence was nearly 70%. As more and more of the population was captured, health-checked and treated, the prevalence of chlamydial disease diminished steadily. Peaks around the middle to end of the breeding seasons (November to February) are more noticeable as the background prevalence decreased over time. These coincide with times of high levels of sexual and territorial interaction among the koalas, higher levels of stress and higher rates of transmission and expression of disease. Towards the end of the program (2015 - present) the chlamydial disease prevalence significantly decreased; and only a handful of cases required treatment at the end of the 2016 breeding season.

### 4.4.2 Summary of koala health based on first veterinary examinations

The prevalence of chlamydial disease in all independent MBR koalas (i.e. not dependent joeys) at their first veterinary examination is presented in **Table 4.1** below. (Note: the figures below represent an inferred prevalence as all koalas were not captured at the same moment in time). For illustrative purposes related to this analysis, the MBR koala sub-populations have been defined by an artificial barrier (i.e. the Bruce Highway) rather than by the six koala search polygons (i.e. *Amcor*, *Bruce Hwy West* , *Mango Hill*, *Kinsellas Rd*, *Rothwell*, *Kippa-Ring*). The two translocation sites (Scouts and Griffin) are treated as their own sub-populations within the Moreton Bay region.

The MBR koala sub-populations for this analysis include individuals captured in the following areas:

1. West of the Bruce Highway (includes koalas from the *Amcor* and *Bruce Hwy West* polygons)
2. East of the Bruce Highway (includes koalas from the *Mango Hill, Kinsellas Rd, Rothwell* and *Kippa-Ring* polygons)
3. Scouts site
4. Griffin site

| Sub-population | Prevalence of chlamydial disease | Clearview *Chlamydia* test positive (2+ or greater), no disease lesions detected |
|---|---|---|
| West of the Bruce Highway | 32/181 (18%)<br>(11 male: 21 female) | 3/181 (2%)<br>(2 male: 1 female) |
| East of the Bruce Highway | 43/129 (33%)<br>(16 male: 27 female) | 5/129 (4%)<br>(1 male: 4 female) |
| Scouts site | 20/34 (59%)<br>(5 male: 15 female) | 0/34 (0%) |
| Griffin site | 2/12 (17%)<br>(2 male: 0 female) | 0/12 (0%) |
| TOTAL | 97/356 (27%)<br>(34 male: 63 female) | 8/356 (2%)<br>(3 male: 5 female) |

**Table 4.1:** Prevalence of chlamydial disease in the MBR koalas (based on first veterinary examinations of all independent koalas) (Note: the figures above represent an inferred prevalence as all koalas were unable to be captured at the same point in time). The figures demonstrate the quite dramatic differences in chlamydial disease prevalence across the landscape.

### 4.4.3 Euthanasia at first veterinary examination

Twenty-two (22) koalas were euthanased at the first veterinary examination due to the severity of disease. Of these, 20 koalas (3 male; 17 female) had chlamydial disease and two had disease that was not confirmed to be *Chlamydia*-related. These were *Timor*, a young male in poor body condition with non-regenerative anaemia, hypoproteinaemia, and chronic gastrointestinal disease; and *Lady*, an aged female in poor body condition with extensive lingual ulceration (of unknown aetiology), chronic gastrointestinal disease (plasmacytic enteritis) and lymphoid depletion.

The following tables summarise the findings in koalas euthanased at their first veterinary examination.

| Polygon of first capture | Male | Female | Total Koalas |
|---|---|---|---|
| Amcor | 1 | 2 | 3 |
| Bruce Hwy West | 1 | 2 | 3 |
| Mango Hill | 0 | 0 | 0 |
| Kinsellas Rd | 0 | 1 | 1 |
| Rothwell | 0 | 0 | 0 |
| Kippa-Ring | 0 | 6 | 6 |
| Griffin | 0 | 0 | 0 |
| Scouts | 1 | 6 | 7 |
| TOTAL | **3** | **17** | **20** |

**Table 4.2:** Number of koalas euthanased at their first veterinary examination for severe chlamydial disease

| Polygon of first capture | Cystitis only | Reproductive disease only | Cystitis and reproductive disease | Reproductive disease and conjunctivitis | Cystitis, reproductive disease and conjunctivitis |
|---|---|---|---|---|---|
| Amcor | 1 | 2 | 0 | 0 | 0 |
| Bruce Hwy West | 1 | 1 | 1 | 0 | 0 |
| Mango Hill | 0 | 0 | 0 | 0 | 0 |
| Kinsellas Rd | 0 | 0 | 1 | 0 | 0 |
| Rothwell | 0 | 0 | 0 | 0 | 0 |
| Kippa-Ring | 1 | 0 | 4 | 0 | 1 |
| Griffin | 0 | 0 | 0 | 0 | 0 |
| Scouts | 1 | 0 | 4 | 1 | 1 |
| TOTAL | **4** | **3** | **10** | **1** | **2** |

**Table 4.3:** Nature of chlamydial disease affecting koalas that were euthanased at their first veterinary examination.

### 4.4.4 Reproductive status of female koalas

The following section summarises some of the veterinary findings with respect to female koala health and reproduction. A more detailed analysis and summary of the reproductive characteristics of the MBR koala population is presented in ***Chapter 10 - Koala reproductive success***.

Between March 2013 and August 2016, 285 female koalas were captured as part of the koala management program. Of these females:

- 196 (69%) had no obvious reproductive lesions detected at any of their veterinary examinations and were considered fertile (Note: the ability for these females to reproduce was not confirmed in all cases, particularly when a follow-up examinations could not be conducted e.g. in cases of premature death or when a koala had dropped all of its telemetry tags and was lost to the program. These koalas were assumed to be reproductively healthy because there were no veterinary findings to suggest otherwise)
- 34 (12%) had bilateral reproductive disease detected at their first veterinary examination.
- 15 (5%) had unilateral reproductive disease or abnormal sonographic findings in their reproductive tract detected at their first veterinary examination. Bilateral disease was confirmed in 11 of these individuals at a subsequent veterinary examination whilst the remaining four died prematurely (e.g. from causes such as wild dog predation) prior to definitive determination of their reproductive status.
- 21 (7%) were sexually immature at the end of the program, when they slipped their tags (never to be located again) or when they died prematurely (e.g. from carpet python predation).
- 15 (5%) koalas had reproductive disease detected at a subsequent veterinary examination (i.e. reproductive disease was not present or detected at their first examination)
- 4 (1%) koalas were likely infertile or became infertile, as there was no evidence of the female ever having had a joey or the female stopped producing joeys, and they had subtle sonographic reproductive changes on ultrasound (although these changes could not be confirmed as definitive reproductive lesions).

See **Table 4.4** and **Figure 4.2** below for a summary of the reproductive health of the MBR female koalas.

| Reproductive status | Number of females |
|---|---|
| Healthy - no detectable reproductive disease as at 31 August 2016, time of death, or slipped tags | 196 |
| Sexually immature (as of 31 August, 2016, time of death or slipped tags) | 21 |
| Bilateral reproductive tract disease | 60 |
| Unilateral reproductive tract disease (including unable to definitively confirm status of alternate tract, and/or at death of koala) | 4 |
| Suspicion of reproductive tract disease, but not definitively confirmed by end of program | 4 |

**Table 4.4** Summary of the reproductive status of the MBR female koalas over the entire monitoring period (March 2013-August 2016)

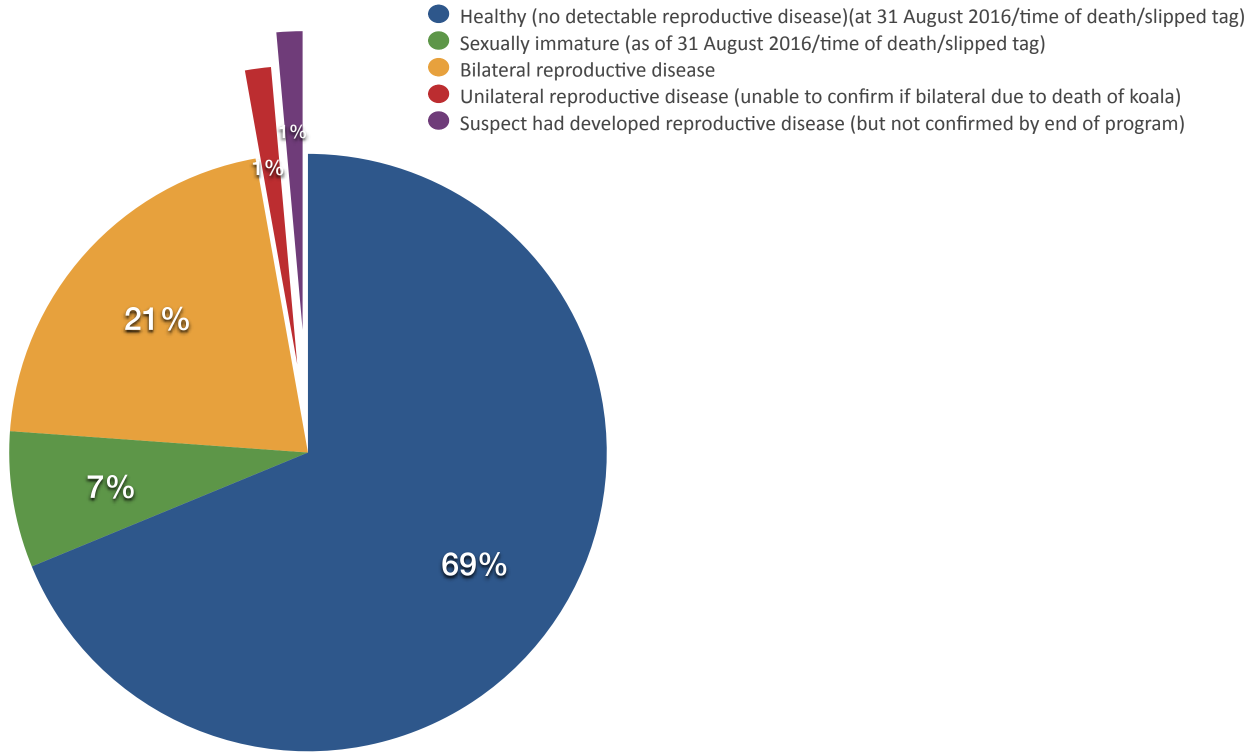



**Figure 4.2** Reproductive status of the female koalas over the *KTMP* monitoring period (March 2013- August 2016). The legend works from the 12 o'clock position in a clockwise direction.

| Reproductive Status | March 2013 - Feb 2014 | March 2014 - Feb 2015 | March 2015 - Feb 2016 |
|---|---|---|---|
| Total females alive at any time in this 12-month period under monitoring. | 179 | 198 | 148 |
| Total permanently Sterile | 31/179 (17%) | 42/198 (21%) | 24/148 (16%) |
| Total fecund | 135/179 (76%) | 136/198 (69%) | 111/148 (75%) |
| Sexually immature | 13/179 (7%) | 20/198 (10%) | 13/148 (9%) |

**Table 4.5:** Reproductive status of females throughout each year of the program. Although comparing the proportion and number of fecund females at the start and end of the program shows no improvement, a significant number of fecund females were killed in 2014-2015 by wild dogs, leaving the total number of fecund females quite diminished in 2015-2016. The marked reduction in wild dog deaths and significant improvement in koala health and fecundity towards the end of the program, would, over time, result in ongoing improvement in these figures. At the time of writing, all adult females still under monitoring were either fertile, or had been treated for chlamydial disease.

## 4.4.5 Sterile koalas having ovario-hysterectomy

Of the 60 female MBR koalas in which bilateral reproductive disease was detected, 29 were treated with antibiotics and ovario-hysterectomy (OHE), and were subsequently released. The remaining 31 koalas with reproductive disease were either euthanased at their first (or a subsequent) veterinary examination due to the severity of disease, or died from other causes (e.g. wild dog predation) before OHE could be performed. Of the females that had been ovario-hysterectomised, by the completion of the program:

- 20 were still alive (or were still alive at the time of their removal from the koala management program if this occurred prior to August 2016);
- 3 koalas had been killed by wild dogs;
- 1 koala was suspected to have been killed by a wild dog;
- 1 koala had been killed by a domestic dog;
- 4 koalas had been euthanased at a subsequent veterinary examination (due to disease e.g. cancer, AIDS-like condition, or complications post-treatment).

**Plate 4.28**: Koalas *Tanja* (left) and *Princess Shrek* (right) were surgically ovario-hysterectomised after antibiotic treatment for chlamydial reproductive tract disease. Both were returned to their home ranges after treatment and monitored until the completion of the respective monitoring programs (*AKHO-CM* and *KTMP*, respectively).

The monitoring of ovario-hysterectomised female koalas provided extremely valuable data with respect to the efficacy of treatment and the epidemiology of chlamydial infections in wild koala populations. None of the ovario-hysterectomised female koalas was readmitted for new chlamydial infections during the course of the program. This is an important finding because:

1. It provides supporting evidence that the treatment undertaken was effective at completely eliminating *Chlamydial* infection - rather than just suppressing it; and

2. It supports the hypothesis that in koalas that are apparently successfully treated, but have recurrences of disease, those recurrences are due to new infections acquired during sexual interactions with infected mates.

In contrast, some reproductively active koalas that had been treated for chlamydial infections contracted new infections leading to disease. Some of these cases are discussed below.

## 4.4.6 Veterinary treatment and outcomes

Over the course of the program, 136 koalas were admitted to EVE veterinary facilities and 69 koalas to the Australia Zoo Wildlife Hospital for medical treatment due to illness or trauma.

Of the 136 koalas admitted to EVE veterinary facilities:

- 94 were treated for chlamydial infection/disease (**Table 4.6**);
- 33 koalas were treated for conditions unrelated to *Chlamydia* (including neoplasia, fungal infections, hernia repair, mild injuries or irritation caused by anklets, lumpectomy, hypothermia/hypoglycaemia, ear infections);
- 9 were treated for traumatic injuries (e.g. injuries associated with vehicle strike and wild dog attack, miscellaneous injuries)

The figures given above do not include koalas that received one-off treatments at the time of veterinary examination and were immediately released (e.g. a single antibiotic injection given for minor conditions, lanced abscesses etc.), nor do they include koalas that were admitted for x-rays or observations where no treatment was given.

| Category | Female | Male | TOTAL |
|---|---|---|---|
| Total cases | 52 | 42 | 94 |
| Koalas admitted for chlamydial treatment | 46 | 40 | 86 (91.5%) |
| Koalas admitted for Clearview positive, no disease | 6 | 2 | 8 (8.5%) |
| Euthanased/died during or shortly after treatment | 7 | 5 | 12 (13%) |
| Released prior to completing treatment (e.g. stressed in care) | 1 | 0 | 1 (1%) |
| Released back to the wild following successful treatment | 44 | 37 | 81 (86%) |

**Table 4.6:** Summary of koalas admitted to EVE veterinary facilities for chlamydial treatment and their outcomes (March 2013 - August 2016).

**Plate 4.29**: *Bessie*, the nearly-independent joey of *Fu* at her release following her first veterinary check in October 2013. In February 2014, she became critically ill from chlamydial urogenital tract infection and was euthanased on humane grounds.

Of the 12 koalas that were euthanased or died during or shortly after chlamydial treatment at EVE:

- 2 koalas had concurrent disease that significantly contributed to death/euthanasia (myelodysplasia - a fatal disease of the bone marrow (one koala) and old-age/non-healing oral ulcer);
- 4 koalas had severe chlamydial disease refractive to treatment (two of these koalas were treated at a time when chloramphenicol was unavailable);
- 1 koala developed severe oxalate nephrosis;
- 2 koalas developed post-surgical complications;
- 3 koalas developed gastrointestinal dysbiosis (two of these koalas were being treated with florfenicol when chloramphenicol was unavailable).

Of the 69 koalas admitted to AZWH:

- 57 received treatment for chlamydial infection/disease (**Table 4.7**);
- 5 koalas were treated for conditions unrelated to *Chlamydia* (e.g. fungal infections, ear infections, tooth root abscess);
- 7 were treated for traumatic injuries (e.g. injuries associated with vehicle strike and wild dog attack).

| Category | Female | Male | TOTAL |
|---|---|---|---|
| Total cases | 42 | 15 | 57 |
| Koalas admitted for chlamydial treatment | 40 | 15 | 55 (96.5%) |
| Koalas admitted for Clearview positive, no disease | 2 | 0 | 2 (3.5%) |
| Euthanased/died during or shortly after treatment | 5 | 3 | 8 (14%) |
| Released prior to completing treatment (e.g. stressed in care) | 1 | 1 | 2 (4%) |
| Poor resolution of disease following treatment at AZWH* | 5 | 2 | 7 (12%) |
| Released back to the wild following successful treatment | 31 | 9 | 40 (70%) |

**Table 4.7:** Summary of koalas admitted to AZWH for chlamydial treatment and their outcomes (March 2013 - August 2016).

*These koalas had follow-up treatment at EVE because their condition had not resolved following treatment at AZWH. In some cases, this was due to a less efficacious compounded formulation of chloramphenicol used when the proprietary product was unavailable. Some koalas had received shorter courses of the residual stocks of the proprietary chloramphenicol at AZWH prior to its complete unavailability, but the antibiotic duration was not sufficient to completely resolve infection/disease in these individuals.

Of the 8 koalas that were euthanased or died during or shortly after chlamydial treatment at AZWH:

- 4 koalas developed oxalate nephrosis,
- 4 koalas developed gastrointestinal dysbiosis.

### Koala readmissions for treatment of chlamydial disease

Of the 94 koalas admitted to EVE veterinary facilities for treatment of chlamydial infection/disease with chloramphenicol, six (6%) were readmitted more than once for treatment. These koalas and their reasons for admission are summarised in **Table 4.8** below.

| Koala Name | Sex | Polygon | 1st Treatment | 2nd Treatment | 3rd Treatment |
|---|---|---|---|---|---|
| Kapok | Female | Kippa-Ring | **January 2014**- chronic, low-grade cystitis, Clearview positive (4+ UGT) | **February 2015**- reproductive disease | N/A |
| Copper | Male | Scouts site (resident) | **July 2014**- chronic, low-grade cystitis, Clearview positive (3+ urogenital tract) | **December 2014**- chronic, active cystitis, Clearview positive (UGT 2+ and urine sediment 4+) | N/A |
| Jeremy | Male | Scouts site (resident) | **October 2014**- subclinical, active cystitis | **November 2015**- chronic cystitis and Clearview positive (2+ urine sediment) | N/A |
| Athena | Female | Scouts site (resident) | **January 2015**- Clearview positive (3+ urogenital tract), no lesions detected | **May 2015**- mild, acute cystitis | N/A |
| Midori | Female | Scouts site (translocated from Amcor) | **April 2015**- acute to subacute cystitis | **September 2015**- acute to subacute, active cystitis, Clearview positive (4+ UGT and urine sediment) | **November 2015**- severe, chronic active cystitis, Clearview positive (3+ UGT and 2+ urine sediment) |
| Brodie | Male | Rothwell | **January 2016**- cystitis, unilateral kerato-conjunctivitis (right eye), Clearview positive (3+ urine sediment) | **July 2016**- severe, chronic, active, haemorrhagic cystitis | N/A |

**Table 4.8:** Summary of koala readmissions to EVE for chlamydial infection/disease

**Plate 4.30**: Koala *Midori* was admitted to EVE on three occasions in fairly close succession for severe chlamydial urogenital tract infection. She was in oestrus on each occasion, and it is likely that each was a new and separately acquired infection from an untreated male with whom she mated. By the final infection, the disease had taken a severe toll, and she was euthanased.

Of the 57 koalas admitted to AZWH for the treatment of chlamydial infection/disease, seven (12%) koalas were readmitted more than once for treatment and seven (12%) koalas had additional treatment at EVE immediately, or shortly after treatment at AZWH because of unresolved chlamydial infection. This was largely due to the chloramphenicol shortage and their subsequent use of a compounded formula of chloramphenicol which seemed to have lower efficacy. These koalas and their reasons for admission are summarised in **Table 4.9** below.

| Koala Name | Sex | Polygon | 1st Treatment (treated at AZWH) | 2nd Treatment (treated at EVE or AZWH) | Notes on treatment |
|---|---|---|---|---|---|
| Ozone | Female | Kippa-Ring | **Dec 2012-** chronic, low-grade kerato-conjunctivitis, chronic cystitis, reproductive disease | **Jan 2014-** chronic, haemorrhagic cystitis and mild, chronic, inactive kerato-conjunctivitis, (treated at AZWH- died in care) | Entered KTMP in March 2013 following treatment at AZWH. Died in care at AZWH in Feb 2014 (volvulus) |
| Molten | Male | Kippa-Ring | **March 2013-** subacute to chronic mild-moderate bilateral kerato-conjunctivitis, mild, subclinical cystitis | **Jan 2014-** unilateral kerato-conjunctivitis (right eye) (treated at AZWH- disease resolved) | |
| 2-D | Female | Mango Hill | **June 2013-** Clearview positive (4+ urogenital tract) | **Sept 2013-** cystitis (treated at AZWH- euthanasia) | Developed gastrointestinal dysbiosis during treatment at AZWH in Sept 2013 and was euthanased |
| Daisy* | Female | Kippa-Ring | **Nov 2013-** chronic, non-suppurative cystitis, Clearview positive (4+ urogenital tract and urine sediment), lower reproductive tract disease (suppurative) | **Jan 2014-** severe, chronic cystitis (treated at EVE- disease resolved) | Disease unresolved following 1st treatment at AZWH- shorter than normal antibiotic course given due to low supplies of chloramphenicol available. Disease detected in Jan 2014 was likely recrudescence (recurrence) of initial infection as had same joey in pouch and was unlikely to have been re-mated to obtain new infection. Disease resolved following second treatment at EVE. |
| Tuco* | Male | Mango Hill | **Nov 2013-** chronic, active cystitis, Clearview positive (4+ urogenital tract and urine sediment) | **Feb 2014-** chronic, haemorrhagic cystitis (treated at EVE- disease resolved) | Disease unresolved following 1st treatment at AZWH - shorter than normal chloramphenicol course given due to low supplies available. |
| Hera | Female | Amcor | **Nov 2013-** chronic cystitis, Clearview positive (4+ urine sediment) | **Oct 2014-** chronic cystitis, Clearview positive (2+ urogenital tract) (treated at EVE- euthanasia due to concurrent disease) | Disease in Oct 2014 treated at EVE (cystitis resolved but euthanased shortly after due to detection of myelodysplasia) |
| Jada | Female | Kippa-Ring | **Nov 2013-** chronic cystitis | **Oct 2014-** Clearview positive (3+ urogenital tract) (treated at AZWH) | |
| Susan* | Female | Kinsellas Rd | **Dec 2013-** chronic, haemorrhagic cystitis | *Transferred to EVE for additional treatment immediately following treatment at AZWH- disease resolved* | Disease unresolved following 1st treatment at AZWH – "ineffective" compounded formula of chloramphenicol used. Disease resolved following second treatment at EVE. |
| CJ* | Female | Kippa-Ring | **Dec 2013-** severe, chronic cystitis, Clearview positive (4+ urogenital tract) | *Transferred to EVE for additional treatment immediately following treatment at AZWH- disease resolved* | Had a complete course of "good" chloramphenicol but disease had not resolved. Disease resolved following treatment at EVE. |

**Table 4.9 :** Summary of koalas requiring additional chlamydial treatment following admission to AZWH (continued overleaf)
*Koalas that required additional treatment at EVE immediately or shortly after treatment at AZWH because of unresolved infection.

| Koala Name | Sex | Polygon | 1st Treatment (treated at AZWH) | 2nd Treatment (treated at EVE or AZWH) | Notes on treatment |
|---|---|---|---|---|---|
| Circe | Female | Kippa-Ring | **Dec 2013-** chronic, low-grade haemorrhagic cystitis | **March 2014-** reproductive disease - echogenic luminal material in both lower distal uteri, chronic, low-grade, haemorrhagic cystitis (inactive?) | Reproductive disease detected in March 2014 is possible sequelae from initial infection, but cannot rule out new infection |
| Venom | Female | Rothwell | **Dec 2013-** severe, chronic cystitis, unilateral reproductive disease - metritis right uterus | **Oct 2014-** chronic cystitis, reproductive tract disease (treated at EVE- disease resolved) | |
| Hawkeye* | Male | Amcor | **Jan 2014-** subclinical cystitis, Clearview positive (2+ urogenital tract) | *Transferred to EVE for additional treatment immediately following treatment at AZWH- disease resolved* | Disease unresolved following 1st treatment at AZWH – "ineffective" compounded formula of chloramphenicol used. Disease resolved following second treatment at EVE. |
| Denise* | Female | Griffin | **Dec 2014-** bilateral reproductive disease, cystitis, Clearview positive (2+ urogenital tract) | *Transferred to EVE for additional treatment immediately following treatment at AZWH- disease resolved* | Disease had not completely resolved following treatment at AZWH. Disease resolved following additional treatment at EVE. |
| Charlotte* | Female | Scouts | **Dec 2014-** cystitis, Clearview positive (4+ urogenital tract), reproductive disease | *Transferred to EVE for additional treatment immediately following treatment at AZWH- disease resolved* (**Plate 4.31**, below) | Had a complete course of "good" chloramphenicol but disease had not resolved. Disease resolved following additional treatment at EVE. |

**Table 4.9 (cont.):** Summary of koalas requiring additional chlamydial treatment following in-patient care at AZWH

*Koalas that had to have ongoing treatment at EVE immediately or shortly after treatment at AZWH due to having an unresolved chlamydial infection

**Plate 4.31:** Koala *Charlotte* in care at EVE. She was successfully treated for chlamydial infection, but was rendered sterile and required surgical removal of her diseased reproductive tract. She was a resident koala at the Scouts translocation recipient site, which had a high prevalence of chlamydial disease prior to treatment of affected koalas.

**Plate 4.32**: Koala *Susan* receiving Fungilin® for prevention of gastro-intestinal candidiasis (yeast infection), a common but easily treatable infection associated with antibiotic use and chronic stress. She had been admitted for treatment of a chlamydial infection of the urogenital tract - treatment was successful, and she was released back at the Griffin offset site in December 2016.

## 4.4.7 Disease (other)

The most common condition seen in the MBR koalas was chlamydiosis, with 33% (167/503) of the koalas having chlamydial disease or a strong positive Clearview® *Chlamydia* test detected at some stage of the program. Less common conditions encountered included malignant neoplasms (cancers), bone marrow disease, fungal dermatopathies, cryptococcosis (a systemic fungal disease), AIDS-like conditions, otitis media and externa (ear infections), and disease of the gastro-intestinal tract.

### Malignant neoplasia (cancers) and bone marrow disease

Neoplasia (cancer) (**Plate 4.33**) or myelodysplasia (bone marrow disease) was detected in 8 of the monitored koalas over the course of the program (**Table 4.10**). Most of these koalas appeared overtly healthy, but had dropped in body condition at the time that disease was detected. (Note: koala *Gecko* was euthanased at the first veterinary examination.) A non-monitored resident koala from the Scouts site was captured in November 2014 for welfare concerns because a possible injury to the left forearm was observed by EVE field personnel. At the veterinary examination, x-rays confirmed an osteosarcoma (malignant cancer of the bone) affecting the left radius/ulna, and the koala was euthanased (**Plate 4.34**). This koala was not included as part of the *KTrans* program as no further resident koalas at the Scouts site were being captured for monitoring purposes at that time. This case has therefore been excluded from the MBR statistics.

| Koala Name | Sex | Approx. Age at Time of Detection | Polygon of Capture | Condition |
|---|---|---|---|---|
| Deb | Female | 5yrs | Amcor | Lymphoma |
| Barnacles | Male | 7yrs | Amcor | Abdominal lymphoma (**Plate 4.33**, below) |
| Hera | Female | 3-4yrs | Amcor | Non-specified proliferative/ bone marrow condition |
| Jeremy | Male | 5-6yrs | Scouts | Osteochondroma and mesothelioma |
| Kas | Female | 7-8yrs | Scouts | Osteochondroma |
| One-tee | Male | 4yrs | Griffin (translocated from Kinsellas Rd) | Lymphoid leukaemia and lymphoma |
| Tyler | Male | 3yrs | Bruce Hwy West | Myelodysplasia |
| Gecko | Male | 2yrs | Amcor | Myelodysplasia |

**Table 4.10:** Summary of MBR koalas with malignant neoplasia or bone marrow disease

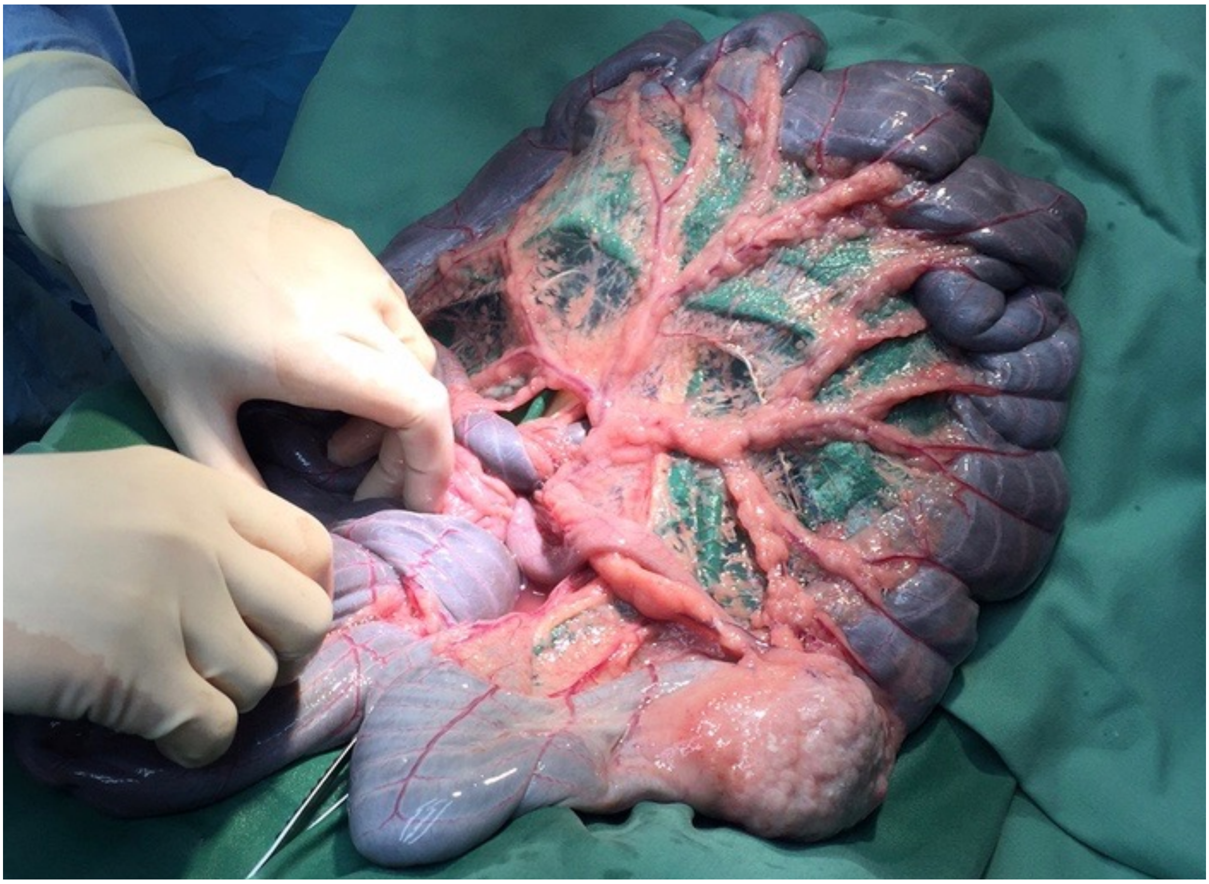


**Plate 4.33:** Koala *Barnacles* (abdominal lymphoma) during exploratory surgery, which found extensive neoplastic infiltration of the mesentery and caeco-colic lymphoid patch (the pale, fatty-looking tissue). *Barnacles* was euthanased intra-operatively for humane reasons because of the grave prognosis.

**Plate 4.34:** X-ray of an untagged resident female koala from the Scouts translocation recipient site (captured for welfare reasons) showing an osteosarcoma of the left forearm with extensive bone lysis (red arrows show the destruction and severe loss of bone of the radius and ulna) (November 2014). The koala was euthanased on humane grounds while under anaesthesia due to the grave prognosis.

## AIDS-like conditions

There are a range of pathological conditions in koalas potentially linked to infection with the koala retrovirus (KoRV), a virus which, to date, has been found in all Queensland and N.S.W. koalas and a proportion of southern koalas.

Although speculative at this stage, certain cancers and an AIDS-like condition are thought to be caused by KoRV infection, possibly with certain pathogenic strains of the virus. The AIDS-like syndrome is characterised by a constellation of clinical signs including some of the following conditions:

1. Chronic ill-thrift;
2. Severe or life-threatening fungal infection (e.g. candidiasis, cryptococcosis and fungal dermatopathies);
3. Unexplained poor body condition;
4. Severe periodontal disease;
5. Stomatitis, mouth or lip ulceration (**Plate 4.35**);
6. Severe chlamydiosis;
7. Gastrointestinal disease (e.g. typhlocolitis, caeco-colic dysbiosis, plasmacytic enteritis);
8. Plantar and palmar hyperkeratosis (thickening and horny growths on the foot pads);
9. Recurrent infections or conditions refractive to treatment;
10. Marginal or moderate non-regenerative or poorly regenerative anaemia, without criteria for diagnosis of myelodysplasia.

For our purposes, our criterion for making a diagnosis of AIDS-like syndrome (also called "?AIDS" in database entries) was that a koala was showing two or more of the conditions listed above, without an alternative reasonable explanation or aetiology. In all cases, the condition was ultimately fatal, although in some cases the clinical course was protracted, and in other cases another cause of death intervened prior to death from the AIDS-like condition *per se*.

**Plate 4.35:** Koala *Avah* (left image) with severe generalised perioral dermatitis with extensive ulceration of the lips, tongue and mouth. *Avah* was euthanased in October 2013 on humane grounds because of her poor prognosis. More recently, koala *Aida* (right image) was euthanased (in December 2016) with almost identical lesions. This poorly understood syndrome may be caused by infection with the koala retrovirus (KoRV) and/or other as yet undescribed viruses.

Over the course of the program, nine koalas fitted the above criteria for diagnosis of an AIDS-like condition (see **Table 4.11**). All were eventually euthanased on humane grounds, except for koalas *Red Queen* and *Copper*, who died naturally while in the wild.

| Koala name | Sex | Polygon | Clinical signs/necropsy findings |
|---|---|---|---|
| **Red Queen** | Female | Kippa-Ring | a) Severe, multifocal, scaly fungal dermatitis around digits and nose<br>b) Paronychia (chronic, fungal nail infection)<br>c) Sudden death - possible *Clostridium* toxicosis |
| **Benny B** | Male | Kippa-Ring | a) Multifocal, exudative, ulcerated fungal skin lesions<br>b) Moderate to marked cheilitis (inflammation of the lips) |
| **Mary Poppins** | Female | Amcor/Scouts | a) Severe periodontal disease<br>b) Otitis media<br>c) Previously treated for chlamydiosis |
| **Lady** | Female | Amcor | a) Extensive lingual ulceration (unknown aetiology)<br>b) Chronic gastrointestinal disease (plasmacytic enteritis) and lymphoid depletion<br>c) Poor body condition (body condition score 4) |
| **Avah** | Female | Amcor | a) Generalised fungal dermatopathy with severe, ulcerative dermatitis<br>b) Severe, ulcerative glossitis<br>c) Mild plasmacytic enteritis<br>d) Poor body condition (body condition score 3) |
| **Timor** | Male | Amcor | a) Chronic gastrointestinal disease<br>b) Poor body condition (body condition score 3)<br>c) Chronic ill-thrift |
| **Copper** | Male | Scouts | a) Candidiasis<br>b) Poor body condition (body condition score 3)<br>c) Periodontal disease<br>d) Has had recurrent chlamydiosis (although not detected at necropsy) |
| **Peanuts** | Male | Amcor | a) Cryptococcosis<br>b) Stomatitis |
| **Aida** | Female | Kippa-Ring | a) Muco-cutaneous dermatitis<br>b) Stomatitis<br>c) Poorly regenerative anaemia<br>d) Poor body condition |

**Table 4.11:** Summary of MBR koalas with an AIDS-like condition (March 2013 - December 2016)

## Fungal conditions

Fungal infections were detected in 14 koalas throughout the course of the program, ranging from mild conditions causing abnormal nail growth (*Frances* - **Plate 4.36**) to severe/fatal conditions such as cryptococcosis (*Peanuts*- **Plate 4.37***)*. Severe chronic, and/or life-threatening fungal infections are thought to be associated with immune-system suppression or deficiency.

**Plate 4.36:** Examples of fungal dermatitis with nail-bed involvement. Image on the left is from the koala *Frances* in May 2013 and then August 2013 (right image). On each occasion the foot was cleaned with antiseptic and anti-fungal cream applied. This koala was an easily stressed koala and not suitable for prolonged in-patient care. She was killed some months later by a wild dog at the Amcor site. Fungal skin and nail infections often take months of treatment to heal. (See **Plate 4.38** - *Poppy*, overleaf.)

**Plate 4.37:** X-ray of koala *Peanuts* (left image) showing lysis of the mandibular bone caused by osteomyelitis (bone infection) with secondary complete fracture of the mandible (red arrow) (caused by the yeast fungus *Cryptococcus neoformans)*. *Peanuts* was euthanased for humane reasons due to the severity of disease. Right image taken during necropsy examination shows the severe, chronic, granulomatous inflammation associated with the pathological bone fracture of the lower jaw. Chronic, severe, fungal infections are probably often associated with immunosuppression or immunodeficiency syndromes.

| Koala name | Sex | Polygon | Pathological condition |
|---|---|---|---|
| Frances | Female | Amcor | Chronic, localised fungal dermatitis and paronychia |
| Red Queen | Female | Kippa-Ring | Severe, multifocal, scaly fungal dermatitis around digits and nose, and paronychia |
| Benny B | Male | Kippa-Ring | Multifocal, exudative, ulcerative fungal skin lesions |
| Poppy | Female | Amcor | Paronychia (chronic, fungal nail infection) |
| Sara | Female | Amcor | Paronychia (chronic, fungal nail infection) |
| Justin | Male | Kippa-Ring | Scaly, facial fungal dermatitis |
| Avah | Female | Amcor | Generalised fungal dermatopathy with severe, ulcerative dermatitis |
| Zed | Male | Amcor | Fungal dermatitis on hind feet |
| The Dursk | Male | Amcor | Fungal dermatitis on forepaw |
| Rocket | Female | Amcor | Dermatophytosis on left forepaw and right ear margin. |
| Peanuts | Male | Amcor | Cryptococcosis |
| Coco | Female | Amcor | Fungal nail infection - forelimbs |
| Leia | Female | Kippa-Ring | Mild focal dermatitis lesion - right forepaw |
| Friar Tuck | Male | Kippa-Ring | Mild, superficial, multifocal fungal dermatopathy |

**Table 4.12:** Summary of MBR koalas with fungal conditions (March 2013 - December 2016)

**Plate 4.38**: Koala *Poppy* relaxing at the EVE clinic in May 2014 during a prolonged (months-long) treatment for fungal infection of the claws. The treatment was successful and she was released at the Scouts translocation recipient site in December 2014. Some koalas are excellent in-patients and thrive during periods of captive care.

### Other conditions

Some miscellaneous conditions detected at the veterinary examinations included:

- Old corneal injury with adhesion of conjunctival membrane to cornea (koala *Bev* - **Plate 4.39**);
- Inguinal hernia (koala *Naomi)*- surgically repaired at EVE facilities in September, 2014;
- Scoliosis (koalas *Gollum, Emma* and *Pistachio*);
- Hydronephrosis (left kidney) (koala *Grundy* - **Plates 4.40** and **4.41**)- *Grundy* had a dilated ureter/ renal pelvis (left kidney) detected sonographically at his first veterinary examination. Surgical nephrectomy was performed to prevent complications and chronic discomfort/pain.

**Plate 4.39:** Koala *Bev* with an old corneal injury causing adhesion of conjunctival membrane to the cornea, which resulted in unilateral (one-sided) blindness. The eye was surgically repaired in April 2013, restoring sight in that eye (image below).

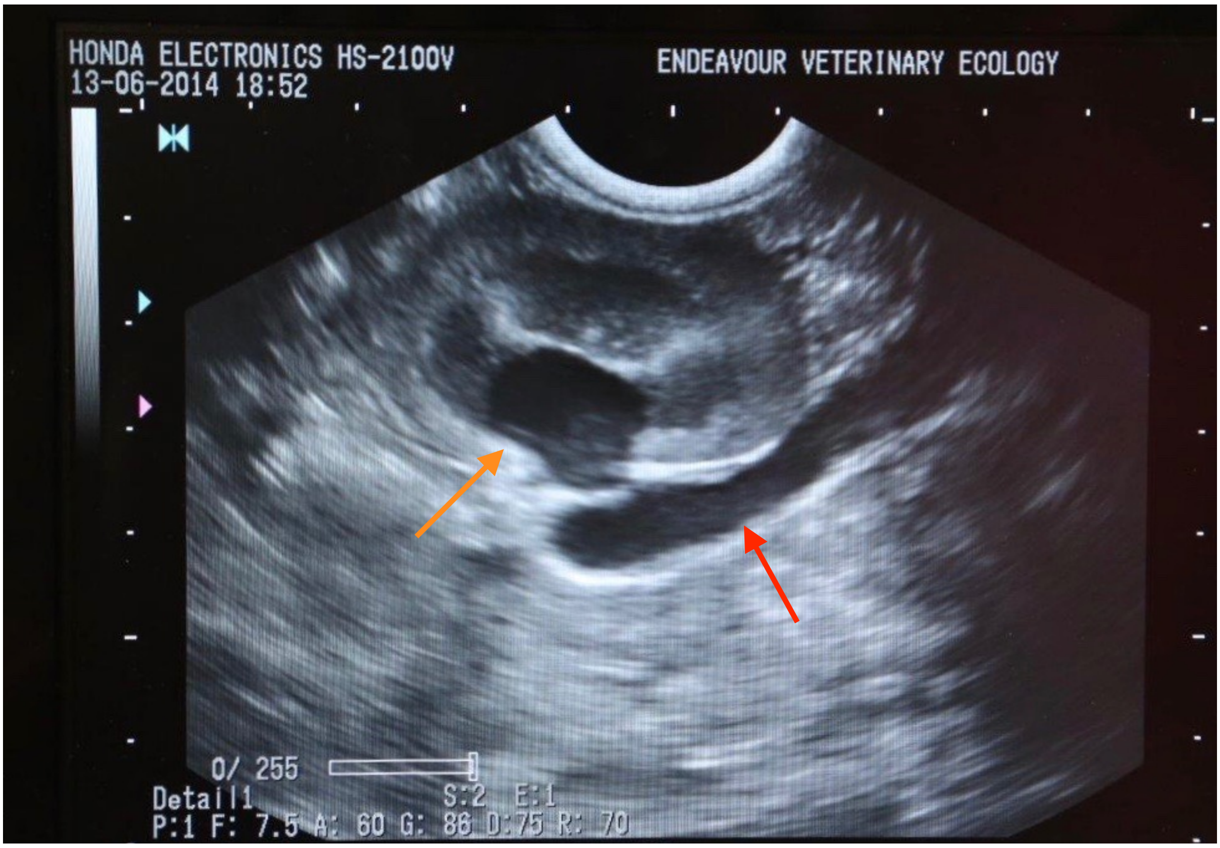



**Plate 4.40**: Koala Grundy- sonographic image of the left kidney and ureter showing massive dilatation of the renal pelvis (orange arrow) and ureter (red arrow)  It was removed surgically after biopsy demonstrated end-stage kidney disease. See image below, showing removed kidney sectioned longitudinally with massive dilatation of the renal pelvis and ureter. Grundy was monitored in the wild until the cessation of monitoring at the Scouts translocation site in February 2016.

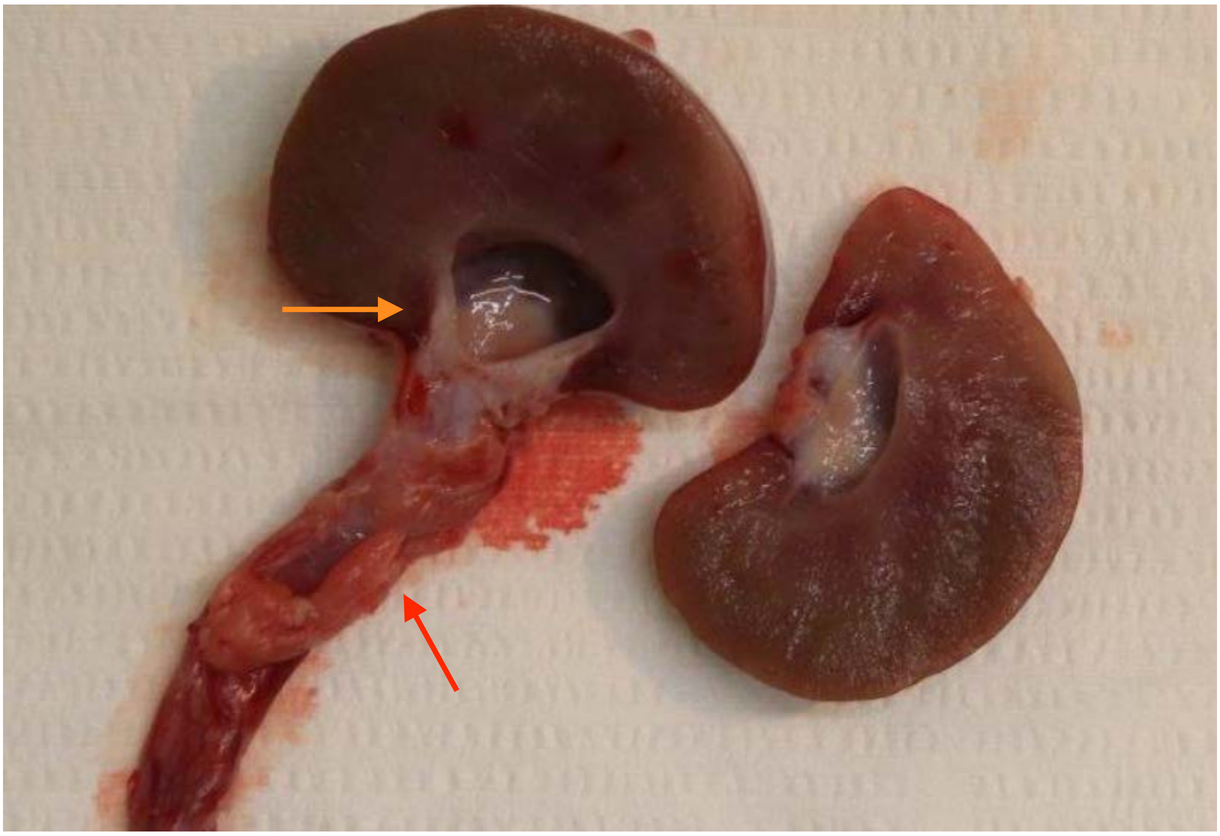


**Plate 4.41**: Photograph of the surgically removed left kidney of koala *Grundy*, which has been longitudinally sectioned and shows massive dilatation of the renal pelvis and ureter (arrows).

## 4.4.8 Trauma

### Vehicle strike

Eight koalas were hit by cars and killed (or died from their injuries or treatment complications) while under monitoring for the koala management program: *Buffy, Mark, Noey, Layla, Diana, Sage, Kay9* and *Igor.* In addition, two koalas were reported killed by cars after removal from the program - *Nuelli* and *Rambo.* Koala *Kylie* was suspected to have been killed by a car strike on Anzac Avenue at the Bruce Highway crossing, based on circumstantial evidence, but her body and tags were never recovered.

Five MBR koalas (*Greg, Spry, Lynx, Jerilly* and *Rosie)* were hit by a cars between March 2013 and December, 2016 and survived their injuries. All had varying degrees of soft tissue trauma (e.g. tongue lacerations, wounds that required suturing) and were treated at AZWH or EVE facilities. Only one of the five sustained a fracture: koala *Greg* - fractured proximal left fibula (see **Plate 4.42**, below). In addition, one koala, *Saba,* that had been removed from the *KTMP* having moved well away from the rail corridor, was reported by a koala rescue group to have also been hit by a car. She was successfully treated at AZWH and eventually released. Two male koalas, (*Kirk* and *Kenny*), were found with injuries consistent with vehicle strike, but their cause could not be confirmed. They sustained a fractured femur and fractured tibia/fibula, respectively. See **Table 4.13** below for a summary of MBR koalas hit by cars.

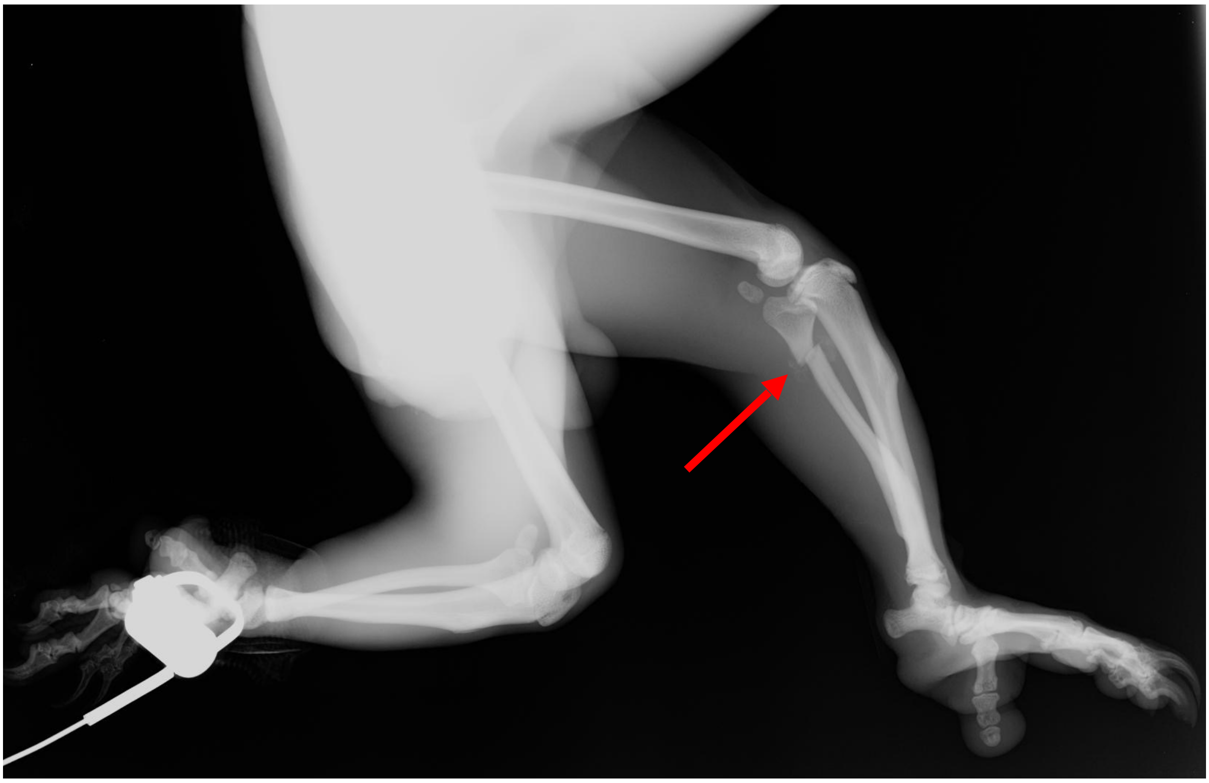


**Plate 4.42:** Koala *Greg* (hit by car)- fracture of left proximal fibula sustained in a vehicle strike on 3 September 2014. The fracture healed uneventfully without surgical intervention, and *Greg* was released at the Scouts translocation recipient site on 13 October 2014. The radio-opaque object on the left of the image is the VHF anklet.

Koala *Kirk* had a mid-shaft left femoral fracture detected at his veterinary examination conducted in June 2014. He resided near a busy road, so it was likely that he sustained his injury after being struck by a vehicle, however other forms of trauma (e.g. tree fall) cannot be ruled out. *Kirk* was admitted to AZWH for x-rays (**Plate 4.43**) and then referred to Dr Phil Moses, a small animal surgeon at the Veterinary Specialist Services, for orthopaedic repair of his fractured femur. *Kirk* was translocated in November 2014 to the Scouts site where he remained until he was de-collared in March 2016.

| Category | Number |
|---|---|
| Hit by car (died/euthanased) | 8 |
| Hit by car (injured but survived) | 5 |
| Suspect hit by car (survived) | 2* |
| Suspect hit by car (killed) | 1** |
| **Following removal from *KTMP****** | |
| Hit by car (died/euthanased) | 2* |
| Hit by car (injured but survived) | 1 |
| Total | 19 |

**Table 4.13:** Outcomes of MBR koalas hit by a car between March, 2013 - December, 2016.

* Koala had sustained injuries consistent with vehicle strike (e.g. fractured femur), however other forms of trauma (e.g. tree fall) cannot be ruled out (koalas *Kirk* and *Kenny*);

** Possibly hit by a car (body not found)- based on circumstantial evidence (e.g. koala was residing by a busy road, reports of a koala being hit in the area on the night the koala went missing, part of collar found damaged on footpath) (koala *Kylie*);

*** Outcomes of koalas that had been removed from the *KTMP* were notified to EVE by koala rescue groups or wildlife care facilities.

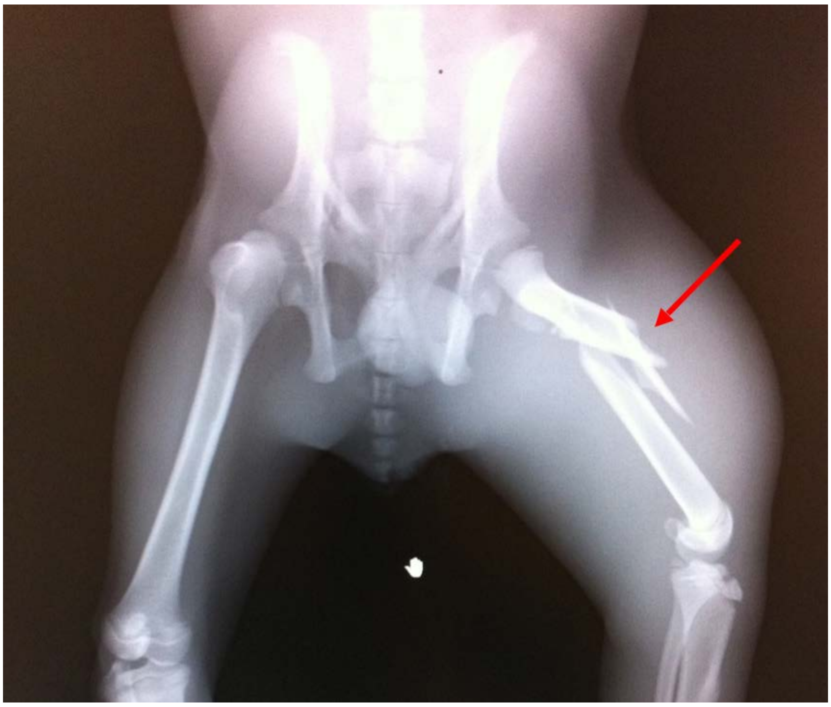


**Plate 4.43:** Koala *Kirk*- mid-shaft left femoral fracture (red arrow). The fracture was surgically repaired by specialist surgeon, Dr Phil Moses, and the koala was released back into the wild at the Scouts translocation recipient site following recovery.

### Trauma from wild and domestic dog attack

Aside from the killing of koalas by wild dogs documented in other chapters, three koalas were attacked by a wild dog, but not killed outright, and were rescued alive. These were koalas *Fern* (found alive 4 Feb, 2014), *Demeter* (found alive 2 April, 2014) and *Mungo Jerry* (found alive 13 July 2015). In all cases, the koala died or was euthanased, and all had injuries consistent with the usual injuries inflicted by the "Amcor Dog". All were living in habitat in or near the Amcor site during the periods of activity of this wild dog.

Of the seven MBR koalas attacked by a domestic dog (a summary of domestic dog-caused koala deaths is provided in ***Chapter 8 - Causes of death of koalas***), only one koala (*Disco*) was found alive (Note: two of these deaths were equivocal and may have been caused by wild dogs rather than domestic dogs). *Disco*, a recently dispersing sub-adult male, was attacked by a German Shepherd cross in the backyard of a house on Anzac Ave, Petrie. He was rescued by the Pine Rivers Koala Care Association who transported him to an after-hours veterinary hospital for emergency treatment. He was later transferred to EVE where he was euthanased for humane reasons, having sustained critical head and brain injuries (**Plate 4.44**, below).

**Plate 4.44**: Serious head injuries caused by a domestic dog attack of koala *Disco*. Left image shows deep punctures to the chin and throat; top right image shows fractures to the skull causing significant brain injury; and lower right image shows a fracture to the mandibular symphysis. The koala was euthanased on humane grounds during anaesthesia for veterinary assessment at the EVE veterinary facilities.

### Trauma from inter-male fighting

Injuries caused by bites and scratches during inter-male fighting events were commonly observed in most adult male koalas, and were, predictably, most commonly observed during the breeding season (July - December). While in most cases the injuries were relatively superficial and required no treatment, in a number of cases the injuries were sufficiently severe to benefit from veterinary treatment, and in a small number of cases koalas died following inter-male fighting events. (See ***Chapter 8 - Causes of death of koalas***.)

The following koalas required some treatment for inter-male fight injuries: *Pudding* (**Plate 4.45**, below), *Walt* (**Plate 4.46**, overleaf), *Belvedere, Marcus, Neptune, Justin* and *Peter.*

**Plate 4.45**: Koala *Pudding* sustained a serious koala bite wound over the lateral aspect of his right upper forearm (top images) and an opposing wound to the right axilla resulting in an abscess (lower images). The abscess was lanced and cleaned and he was released back into the wild.

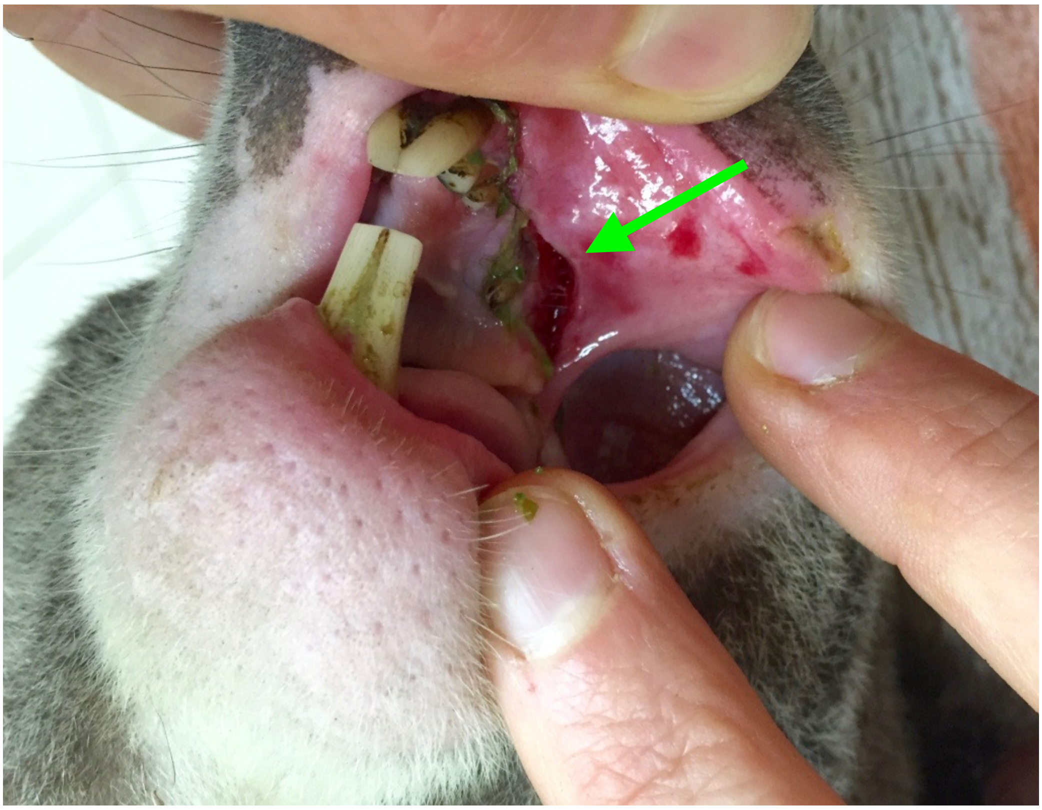


**Plate 4.46**: Koala *Walt* had multiple fight wounds detected at his veterinary examination in October 2015. A bite wound from another male koala resulted in a laceration to his oral mucosa (green arrow). This wound is similar to that found at koala *Belvedere's* necropsy examination (*Belvedere* died from shock and dehydration associated with inter-male fighting. See ***Chapter 8 - Causes of death of koalas***).

### Treatment of 'trauma- other'

Occasionally koalas were treated for less common injuries, including those associated with a suspected raptor attack (*Jim),* a possible tree fall (*Emma)* and an attempted predation by a carpet python (*Tonia*).

- *Jim,* a recently independent joey, was found low to the ground during routine tracking. He was hypothermic, moribund and in poor body condition. His injuries were consistent with an attempted predation (likely from a raptor). He responded to treatment well and was released following a period in care.

- *Emma, a* subadult female koala, was found on the ground and lame. She had a fractured left distal femur of unknown cause, possibly caused by a fall from a tree during a mating event, as she did not reside near a road and is unlikely to have been hit by a car. *Emma* was admitted to AZWH for treatment and the fracture was repaired, but she developed caeco-colic dysbiosis/typhlo-colitis syndrome and was euthanased for humane reasons.

- *Tonia*, a sub-adult female koala was being tracked for a scheduled capture when she was observed falling from a tree while being constricted by a carpet python. The carpet python was considered to be too small to ingest her, and the koala was rescued. On presentation for veterinary assessment she had minor injuries associated with two primary bites - one to her right forelimb, containing two python teeth, and one to her right hindlimb. She recovered uneventfully, and was released some days later.

**Plate 4.47**: Carpet python bite injuries in koala *Tonia*. Left image shows one of two bite sites, showing the typical U-shaped bite wounds inflicted by a python bite, and the right image shows one of two carpet python teeth extracted from the bite site on the right forelimb.

### Iatrogenic injuries related to the capture and tagging of koalas

Foreign devices, such as telemetry collars, have the potential to cause harm and discomfort to the animals wearing them. Many of the telemetry collars currently on the market are unsuitable for koalas for a variety of reasons: too bulky, sharp edges, collar material holds moisture, etc.; and pose a significant risk to the welfare of the koalas. The injuries that can be caused by collars are often difficult to treat and can sometimes be fatal. Hang-ups, when a collar becomes ensnared in vegetation are almost invariably fatal. Anecdotal evidence suggests that collar-related injuries are common, but rarely reported in the scientific literature. Furthermore, tag-related deaths are likely to be under-detected, as most studies do not monitor their tagged animals frequently enough to determine a cause of death (i.e. the carcass is found in an advanced state of decomposition preventing a diagnostic *post-mortem* examination). These were not acceptable outcomes for the MBR koala management program, and hence koala safety and welfare with respect to tagging and monitoring was paramount.

Koalas monitored as part of the *KTMP* were fitted with two telemetry devices (if their weight was greater than 3kg). The second device (usually a VHF anklet) was a back-up in the event of primary tag drop-off or failure. This redundancy reduced the risk of loss of a koala during the particularly risky period of vegetation clearing. Hence, most koalas were fitted with the following tags:

- a GPS collar with a built-in VHF transmitter; and
- a VHF anklet- a lightweight tracking device (originally designed for the New Zealand kiwi bird) fitted to the ankles of koalas by a Velcro® attachment.

In our experience, VHF anklets are far less likely to be associated with complications than the ‘off-the-shelf” tracking collars commonly used in koalas. Nevertheless, while anklets are generally fairly low impact, strict protocols must be in place regarding tracking of koalas wearing these devices to avoid or detect issues that occasionally arise. The Velcro® attachment has no “give” so sudden growth spurts or injuries that result in inflammation (such as fractures following vehicle strike) can result in constrictive injuries.

In recognition of the potential risks of tagging koalas, EVE designed a safer, more streamlined collar specifically for use in koalas, which was used to attach the LX *K-Tracker* telemetry tags. The design of the LX *K-Tracker* collar included:

- a “breakpoint” so the collar would drop off if the koala became entangled, preventing hang-ups;
- collar material that did not retain moisture or trap it against the skin (which is often the cause of dermatitis lesions); and,
- hinged components that allowed the upper (GPS electronics) and lower (VHF transmitter) devices to “flip up” rather than get snagged as koala push through vines and vegetation.

Of the hundreds of koalas that had LX *K-Tracker* collars deployed for the koala monitoring program, only two koalas (*Ali* and *CJ*) suffered mild rub injuries associated with the collars. Only *Ali* required minor treatment. (See summary outlining tag lesions below).

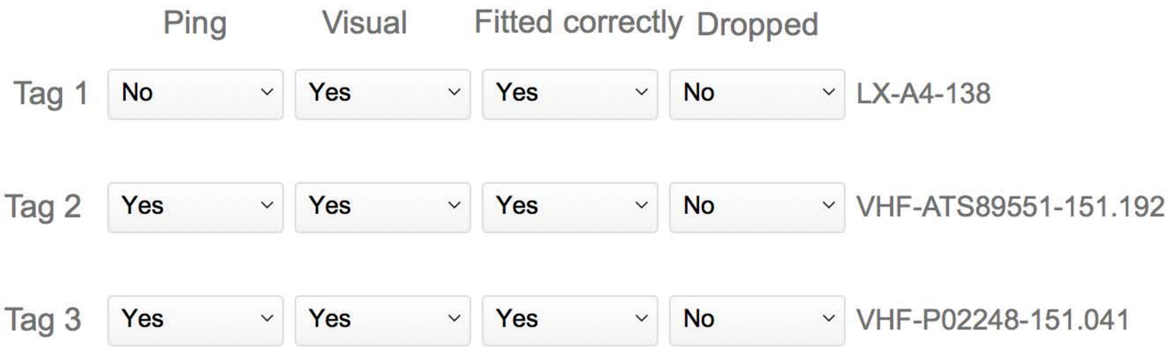
Of more than 200,000 koala collar tracking days, only the following tag-related injuries occurred:

- 4 koalas (*Matt*, *Burbridge*, *Kirk* and *Courtney*) had the Velcro® attachment of their VHF anklet slip half-way over their foot (i.e. the koala was unable to get the anklet all the way off) resulting in an abrasion or exudative lesion (sometimes with associated inflammation). These lesions all healed quickly but prompt detection by field staff of a partially slipped anklet was important for treatment success.

**Plate 4.48**: Most koalas can slip their anklets all the way off their foot (e.g. if it becomes snagged on vegetation). Occasionally the anklet can become partially stuck over the foot. Astute field observations are necessary to detect incidents like this early to avoid serious injury.

- 2 koalas had mild skin lesions caused by the LX *K-Tracker* collars. One koala (*CJ*) had a mildly exudative lesion on her neck (that was caused by the edge of the heat shrink on her collar. Treatment for this lesion was not required. (Note: the collar design was modified over time and heat shrink, which is generally quite benign, was replaced by smooth brass fittings). The second koala (*Ali*) had a superficial, mildly exudative rub lesion over his right collar bone (he had put on a significant amount of weight which potentially changed the fit of the tag). He had a one-off antibiotic injection and was released the same day.
- 2 koalas had a constrictive injury caused by the Velcro® attachment of their VHF anklet. One koala (*Kenny*) had undergone a traumatic event of unknown origin, possibly vehicle strike, and had fractured his right tibia and fibula, the same leg his anklet had been attached. Following the injury, his leg became inflamed. Since the Velcro® attachment of the anklet has no "give", when the leg became inflamed, it caused a constrictive injury to his leg. The second koala (*Circe*) had a similar tag-related injury. Whilst there were no palpable fractures detected, it is likely that her ankle injury occurred after there was soft tissue swelling from a sprain and the Velcro® was unable to expand. The lesions on both of these koalas healed well.
- 2 koalas had anklet rub with alopecia and exudate (*Bessie* and *Justin*). Anklet rub is often caused due to sudden growth spurts tightening the fit of the anklet. Anklets must be regularly refitted in growing koalas. Sometimes it occurred for unknown reasons.
- 1 koala had collar rub dermatitis (from a non-LX collar)(*Raylee*). The inclement weather and tick bites around the neck had contributed to the infection. This koala was successfully treated and released.
- One koala (*Wolf*) had a mild infection associated with the placement of a WID ear-tag. This resolved rapidly after removal of the tag.

EVE implemented strict monitoring protocols, including observations of the tag fit at each tracking event using binoculars, or a high-magnification spotting scope if there was concern, to minimise the risk of a serious tag-related injury. These protocols facilitated prompt detection of tag-related injuries or issues, enabling capture of the koala in a timely fashion (**Figure 4.3**, overleaf).



| | Ping | Visual | Fitted correctly | Dropped | |
|---|---|---|---|---|---|
| Tag 1 | No | Yes | Yes | No | LX-A4-138 |
| Tag 2 | Yes | Yes | Yes | No | VHF-ATS89551-151.192 |
| Tag 3 | Yes | Yes | Yes | No | VHF-P02248-151.041 |

**Figure 4.3**: Screen-grab from the FileMaker® koala database used by field staff during field tracking of koalas. At each field monitoring event, the koala's telemetry tags were visually checked with binoculars (or a spotting scope if there was a concern) to assess the fit of the tags, and the findings recorded in the koala monitoring database.

### Trauma associated with koala capture

Koala capture is not without risks, and each koala responds differently to being flagged down from the tree. Some koalas respond well to the flagging pole and descend the tree readily, while other koalas jump about erratically. Of more than 3000 koala captures, there was one significant capture-related injury. This occurred during the capture of a near-independent female joey (*Lou*) who grabbed onto the flagging pole during the capture, then fell and landed on the ground feet first. She was lame upon capture, and subsequently x-rays revealed a fracture of the left femur. An orthopaedic repair was conducted by specialist surgeons at *Veterinary Specialist Services* in Underwood. Post-operative rehabilitation occurred at the EVE facilities, and *Lou* was eventually released back to the wild.

Koala *Gerber* suffered mild temporary lameness after falling during a capture. He was treated with a single anti-inflammatory injection, recovered uneventfully, and was released some days later.

No koalas died as a result of capture and tagging.

**Note:** Notification of the *Animal Ethics Committee* occurred in all instances of injury caused to koalas by program methods or devices.

**Plate 4.49**: Koala *Lou*, the only koala to sustain a serious injury in over 3000 koala capture events. She sustained a fractured femur, which was successfully surgically repaired, and she was released back into the wild.

## 4.5 Discussion and recommendations

### 4.5.1 General comments

The provision of high-quality veterinary care to koalas was a critical factor in stakeholder acceptance of the program and compliance with relevant legislation, particularly the *Animal Care and Protection Act, 2001.* Given the well-recognised impact of *Chlamydia* infections in wild koala populations, the veterinary component of the program facilitated the delivery of a novel, but valuable "offset" which formed part of the package of holistic compensatory and offset measures proposed during project planning. In that respect, the program delivered excellent outcomes, in that chlamydial disease prevalence and incidence were reduced to a few percent. New cases presented mainly during and after the breeding season; and the *Chlamydia* vaccine trial was successfully implemented and reported. EVE's veterinary management far exceeded the program's objective to have no significant increase (>5%) in disease or mortality of resident or translocated koalas at the translocation sites. In fact, disease prevalence decreased significantly at all sites due to treatment of sick and infected koalas.

Veterinary expertise was also essential to the determination of causes of death in program koalas: this information informed and guided the adaptive management approach that was central to the holistic offsets program. In addition, the accurate determination of causes of death of nearly all program koalas mitigated risk associated with adverse and spurious criticism that might have sought to blame the project for koala deaths, and thereby cause reputational harm to the project, the project owner and contractors. A detailed analysis of causes of death in program koalas is presented in ***Chapter 8 - Causes of death of koalas****.*

In summary, the implementation of a high-standard veterinary management program demonstrated the commitment of the MBR project to compassionate management of the koalas as well as facilitating key project objectives and meeting legislative obligations.

**Plate 4.50**: Koala *Ali* relaxes on the scales after being sedated for a scheduled veterinary examination. Comprehensive veterinary examinations were performed on all koalas every 6 months to monitor health and reproductive success.

### 4.5.2 Chlamydial disease treatment and management

Chlamydiosis was the most common and significant disease affecting the MBR koala population during the program's duration. Chlamydial disease not only has considerable impacts on individual animal welfare but it also reduces population viability through mortality and because of reduced fecundity caused by reproductive disease. Chlamydial immuno-pathogenesis is complex and poorly understood in koalas. The expression of chlamydial disease is often blamed on stress associated with habitat loss and urbanisation. However, there is no robust scientific evidence that supports the contention that these stressors are a primary factor in chlamydial pathogenesis or high population prevalences of disease. Our data do not support this contention either: highest chlamydial disease prevalence was observed in the most undisturbed site (Scouts translocation site) and lowest prevalence was in the highly disturbed Amcor site.

One of the aims of the koala management program was to reduce the impact of chlamydial disease as a compensatory measure for the unavoidable impacts of the rail project on the local koala population. Disease management involved three primary components: veterinary assessment and monitoring of all program koalas; treatment of disease; and implementation of the *Chlamydia* vaccine field trial. In addition, appropriate treatment of sick program koalas was an expectation of community stakeholders and an obligation under the *Animal Care and Protection Act, 2001*. Chlamydial disease is often chronic (long-term) before koalas are noticed to be sick and presented for treatment. By this time, ongoing inflammation and fibrosis may have caused irreversible damage to organs and tissues. Early detection and treatment of chlamydial disease results in better outcomes, and lower risk of chronic sequelae associated with irreversible organ and tissue damage.

Over the duration of the program, chlamydial disease prevalence was reduced from around 28% at the commencement of the *KTMP* to less than 1% at the time of writing. The disease was not entirely eradicated from the population because many koalas carry the infection asymptomatically, and the population was not closed to immigration and emigration. The incidence of new infections was similarly reduced, such that only a handful of new cases were occurring each year (towards the end of the breeding season) in the monitored population. The *Chlamydia* vaccine showed promising results in vaccinated animals, and data were analysed and reported by collaborators at USC (see ***Chapter 5 - Field trial of a chlamydial vaccine for koalas***).

MBR koalas affected by chlamydial disease were treated at the AZWH in the early phase of the *KTMP*, but from mid-2014 were treated in purpose-built rehabilitation facilities at the EVE clinic at Toorbul, where a higher level of patient monitoring and care was achieved. Overall, 81 out of 94 koalas (86%) were successfully treated for chlamydial infections at EVE veterinary facilities, whereas only 40 of 57 (70%) were successfully treated at referral facilities (early in the program).

There is some inconsistency between koala treatment facilities regarding the most suitable treatment regimen for chlamydiosis in koalas. As demonstrated by the results of the program, chloramphenicol injection achieves excellent results, and longitudinal monitoring of treated koalas has shown that in most cases the treatment is curative. This is the only treatment regimen currently supported by scientific evidence based on PCR analysis and telemetric monitoring. Of the 6 koalas treated for chlamydiosis at EVE that had a recurrence of chlamydial disease (of the 94 treated), it is likely that all were either reinfected (new infections) or the subsequently detected lesions were sequelae from the original infection. Whether these koalas had new infections, recrudescence (recurrence) of the initial infection due to inadequate treatment, or pathological sequelae from the original infection is difficult to definitively determine.

The absence of recurrence of disease observed in the 29 desexed females over the duration of their post-treatment monitoring is evidence that properly administered chloramphenicol is effective in the treatment of chlamydial infection/disease. Note, however, that if recrudescence of a previously treated infection is triggered by hormonal changes associated with reproductive cycling, then this could be another explanation for why recurrences of disease in desexed females were not observed. In other words, desexed females provide compelling evidence, but not proof, of the efficacy of treatment in providing a microbiological cure for infection rather than suppression of infection. Additional evidence may be available after more detailed PCR analyses of post-treatment biological samples, however at the time of writing, these analyses had not been performed. The longitudinal monitoring of the MBR koalas over a number of years has proven the success of chloramphenicol treatment for chlamydial disease, and this remains the only treatment regimen subjected to such rigorous evaluation of efficacy.

The MBR koala management program has shown that population-scale disease treatment and management can have substantial population health and animal welfare benefits. The significant reduction in disease prevalence and incidence over time is labour-intensive and costly, but readily achievable in manageably-sized populations living in discrete habitat blocks. It is not impossible to achieve in open populations, but immigration of infected individuals will result in constant presence of infection in the population. This highlights the value of vaccination in providing longer-term suppression of chlamydial disease in affected and at-risk koala populations.

**Plate 4.51**: Newborn koala joey attached to the right-hand teat inside the koala *Little's* pouch. The head of the joey is to the right, with the mouth attached to the teat. The very well developed fore-limbs are clearly visible, and allow the joey to climb - unaided by the mother - from birth canal to the pouch - a distance of some centimetres. The hind-limbs are poorly developed at birth and barely discernible. Data on reproductive success is essential to population viability analysis. If death rates are persistently higher than birth rates, then populations will decline to extinction.

## 4.5.3 Management of injury and non-chlamydial disease

As expected, the monitored koalas were subject to a variety of natural and anthropogenic threats, which resulted in a spectrum of injuries and conditions from the very minor, to severe/life-threatening or fatal. Potentially the most important infection in koalas, aside from *Chlamydia*, is the koala retrovirus, KoRV. We observed a variety of disease conditions thought to be either directly or indirectly caused by KoRV infection, including a variety of malignant cancers and AIDS-like conditions. None of these is treatable, and the affected koalas were humanely euthanased.

The early detection and treatment of a variety of injuries and illnesses was facilitated by the intensive telemetric monitoring of koalas, and a significant number of koalas were saved because of this. This highlights the value of intensive monitoring not just for the acquisition of valuable scientific data, but as a critical tool in the management of animal welfare. It also satisfies community expectations about the compassionate management of wild animals and meets legislative obligations with respect to both wildlife protection and animal welfare. The LX *K-Tracker* telemetry system was an innovative technology that was central to the thorough monitoring of program koalas.

### 4.5.4 Achievement of objectives

**Table 4.14** (below) outlines some of the key objectives defined during project planning relating to koala health and veterinary management, and the outcomes following implementation of the program. All key objectives were achieved as was compliance with the intent and provisions of the relevant animal welfare and wildlife protection legislation.

| Objective | Outcome | Comment |
|---|---|---|
| Investigate the prevalence, incidence and nature of disease affecting the koala population living in, or near, the MBR corridor. | Achieved. | The *KTMP* has provided an unprecedented and immensely valuable body of qualitative and quantitative data on disease in a free-living koala population. |
| Reduce morbidity and mortality associated with disease by:<br>a. Treatment of sick koalas;<br>b. Reducing the spread of infectious diseases;<br>c. Improving fertility and fecundity (reproductive rates). | Achieved. | Chlamydial disease management has been very successful and has resulted in a substantial decline in disease prevalence and incidence, and an improvement in fecundity. The duration of this benefit beyond the termination of the program is unknown, but some projections of future trends are presented in ***Chapter 11 - Population viability analysis*** |
| Provide high-quality veterinary care and treatment to koalas in the program affected by illness and injury, including foster care of orphans. | Achieved. | Best-practice veterinary care was provided to program koalas, including the use of specialist surgeons for treatment of fractures. Purpose-built facilities were provided for in-patient care. |
| Conduct a scientific field trial to assess the efficacy of a chlamydial vaccine in reducing the impacts of chlamydial infection. | Achieved. | The koala management program was essential in the field trial of a variety of forms of the *Chlamydia* vaccine. The analysis of data was published in a number of papers and additional papers were in preparation at the time of writing. Early analysis of data showed good immune responses and protection induced by some versions of the vaccine. |
| Determine causes of mortality and the relative importance of each threatening process to allow for adaptive management. | Achieved. | In only a few cases of death of program koalas was a cause of death not determined. This represents the most significant study of natural koala mortality ever conducted, and provided valuable information guiding adaptive management of koalas by the MBR project, as well as data of immense value to the general body of scientific knowledge on koala ecology and threats to conservation of the species. |

**Table 4.14**: Summary of outcomes with respect to *KTMP* objectives relating to veterinary management of koalas.

### 4.5.5 Recommendations

The early commitment by the MBR project to conduct a comprehensive koala management program ultimately resulted in the substantial benefits to koala welfare and conservation achieved by the program. While the program solidly achieved the objectives defined during the planning phase, the value of the broader benefits that have flowed from the program with respect to our scientific understanding of koala ecology and conservation cannot be overstated.

From each individual koala's perspective, the thing of most value to it is its own welfare - which the program respected and provided for, to a standard never before applied in a major development project. This is also one of the few projects that has scientific proof of its compliance with the intent of State and Federal legislation relating to koala protection during development. This outcome relied upon three critical components:

1. Application of population-wide management and intensive monitoring by telemetry;
2. Provision of high-standard veterinary expertise and resources;
3. Provision of appropriate funding to support the program.

We recommend the following, from the perspective of koala/wildlife management:

1. That the MBR koala management program be held up as an example of best-practice wildlife management, and that the model be applied on future transport infrastructure projects;

2. That future infrastructure projects that are likely to significantly impact on wildlife health and welfare implement appropriate wildlife management programs that provide suitable veterinary expertise and resourcing to ensure good population health and animal welfare outcomes, as well as meeting legislative obligations;

3. That the broad benefits that arise from well-conducted wildlife management programs, in terms of both scientific/academic benefits and community/stakeholder satisfaction, are acknowledged and considered during resource/budget allocation planning.

4. That the likely wildlife impacts and impact management approaches are very carefully considered, through consultation with experts, *very early on in project planning*, so that appropriate pre-construction investigations can be conducted prior to commencement of major construction works.

5. That an intensive veterinary program to manage disease in a koala population, including the desexing of sterile female koalas, will address one of the leading causes of population decline (associated with mortality and reduced fecundity), as a component of offset packages for infrastructure development projects.

Early consultation with experts including EVE occurred some years prior to the commencement of construction activities for the MBR project. This allowed sufficient time for key project personnel to become informed of, and properly understand the nature of the likely impact of the project on koalas; and also the complex responses required to manage and mitigate those impacts in a meaningful way. It also facilitated the early development of the vision for a compassionate and holistic approach to koala protection. This was crucial during early engagement with key community stakeholders and the development of trust and respect in that group.

# CHAPTER 5: FIELD TRIAL OF A CHLAMYDIAL VACCINE FOR KOALAS


## Key points

- Chlamydial vaccine field trial was a valuable and relevant research collaboration with USC
- Vaccination is a key strategy to reduce the impact of chlamydial disease in koalas - major threat to population survival
- Vaccine trials commenced in early 2013 and continued throughout, with over 12,000 samples and even more data supporting the research, derived from the *KTMP*
- Trial could not have been achieved without *KTMP*/MBR support - important component of alternative offsets strategy
- Promising results to date, with good immune responses in most vaccinated koalas
- Ongoing research and evaluation required - recommendation for support through future transport infrastructure projects

# Chapter 5: Field trial of a chlamydial vaccine for koalas

**Prof. Peter Timms, University of the Sunshine Coast**

## 5.1 Background

There are many threats to the long-term future of the koala, several of which have been identified in the Moreton Bay Rail population program. One that is potentially amenable to addressing is disease caused by infection with the bacterium, *Chlamydia*. The availability of the well-studied and analysed koala population in this case has meant that a prototype vaccine for *Chlamydia* could be trialled and tested – a world first.

Despite our efforts, wild koala populations in geographically diverse regions throughout the country continue to decline. This decline has been attributed to several variables such as (a) habitat loss, resulting in fragmentation of koala habitat and populations; (b) disease; (c) motor vehicle trauma; and (d) dog attacks.

A recent study suggested that addressing disease, amongst the many variables affecting koala survival, would have the greatest potential impact on stabilising population decline. Disease caused by infection with the intracellular bacterial pathogen, *Chlamydia pecorum*, is a major threat to the ongoing survival of many koala populations. *C. pecorum* infections in koalas have been associated with a spectrum of diseases ranging from kerato-conjunctivitis (ocular disease) leading to blindness, rhinitis and pneumonia, as well as urinary and genital tract disease, resulting in inflammation and fibrosis of the bladder and the upper female genital tract. An effective vaccine to prevent the complications of chlamydial infections in koalas would provide a valuable management tool to stop the decline in wild populations by (a) reducing the infectious load in infected animals, and (b) preventing the development of disease in both healthy and infected but asymptomatic koalas.

Several previous *Chlamydia* vaccine trials have been conducted by our group, however these have all been done with captive, healthy koalas, or have not involved a natural wild koala population. It is essential to test the vaccine in wild koalas, in their natural situation, to determine the efficacy of the vaccine. The Moreton Bay Rail project's koala management program provided a unique and valuable opportunity to test the vaccine. Such a trial is not only a world first for a koala *Chlamydia* vaccine but is also very novel for any chlamydial vaccine.

**Plate 5.1**: Koala *Swepson* at his final release at Kippa-Ring. *Swepson* was vaccinated with the VIDO-MOMP *Chlamydia* vaccine. He remained free of chlamydiosis for the duration of the program.

## 5.2 Overview of the vaccine trials

Over the past 2-3 years, we have conducted two *Chlamydia* vaccine trials in the Moreton Bay Rail population. The first trial involved 60 koalas: it has been completed and is fully analysed. This is the trial that will be expanded on below.  The second trial involved 80 koalas. At the time of writing the sampling had only recently been completed and data analysis had not been completed.

### Trial A: Analysis of the beneficial effect of vaccination of koalas with a chlamydial vaccine

Koalas included in the study (n = 60) were part of the larger population-wide study by the Queensland Government Department of Transport and Main Roads (as part of the Moreton Bay Rail project), conducted between 2013 and 2017 in the Moreton Bay Region, Queensland, Australia. Criteria for inclusion into the study were animals of breeding age (>1 year) of either sex, with no clinical signs of chlamydial disease, as assessed by EVE. Animals were randomly assigned to either the vaccinated or control (non-vaccinated) group at initial capture. The vaccinated group (n = 30) received a three-dose regimen of the vaccine via the subcutaneous route, given at one-month intervals, consisting of the three MOMP proteins as the antigens (50μg each of MOMP-G, MOMP-A, and MOMP-F) and an immuno-stimulating complex adjuvant (50μg, ISC, Zoetis Australia). Animals were re-captured at 1 month, 2 months, 6 months, and 12 months for the purposes of (i) additional vaccinations for the vaccine cohort animals only (1 month and 2 months) or (ii) detailed health checks and sampling (2, 6 and 12 months). While 30 animals were originally recruited into each group, unfortunately, only 23 vaccinated and 27 control koalas could be resampled at the six-month time point due to animal losses associated with, for example, misadventure, predation, trauma, and disease. At 12 months, again, further losses had occurred and numbers were considerably reduced in each cohort to 15 vaccinated and 14 control koalas.

All procedures were approved by the University of the Sunshine Coast (USC) Animal Ethics Committee (Animal ethics number AN/A/13/80) and by the Queensland Government (Scientific Purposes Permit, WISP11532912). The trial was performed under the *Australian Pesticides and Veterinary Medicines Authorit*y Permit PER 7250.

# 5.3 Results

## 5.3.1 Vaccine safety data

All vaccinated animals were monitored for up to 24 hours post-vaccination and given a thorough veterinary health check at 2 months and thereafter at their regular 6-monthly capture and sampling events. There were no short or longer-term adverse events reported due to administration of the vaccine in any of the animals.

## 5.3.2 Immune response to vaccination and level of protection required

All vaccinated koalas produced a strong immune response to the vaccine, as indicated by high titres of specific plasma antibodies, demonstrating that the vaccine produced a good immune response in all vaccinated koalas.

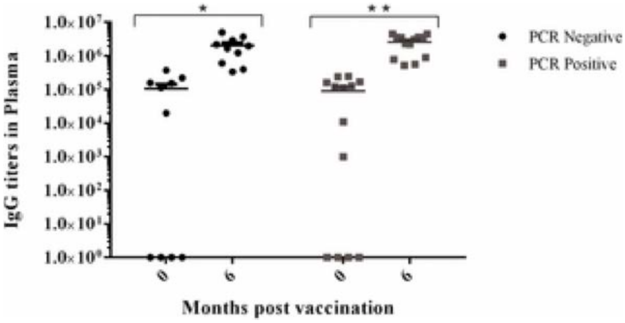



**Figure 5.1**: Immune responses of koalas following vaccination of PCR negative (left) vs PCR positive (right) groups

**Plate 5.3**: Ultrasound examination is an essential diagnostic tool in the assessment of reproductive health in koalas. Here, EVE veterinarian Dr Amy Robbins performs ultrasound assessment of koala *Tanja* during her treatment as an in-patient for chlamydial infection in December 2016. She was successfully treated and released.

### 5.3.3 Changes in chlamydial load following vaccination

For animals that were infected at the time of recruitment, we measured their *Chlamydia* load by quantitative-PCR (qPCR) at 0, 6, and 12 months to evaluate the effect the vaccine had on the level of chlamydial shedding. At 6-months post-vaccination, animals in the vaccine group were significantly more likely to decrease or stabilise their chlamydial load, whereas animals in the control group were significantly more likely to increase their load. This effect was observed as a near significant trend ($p > 0.01$) using the conservative (raw) data and a significant effect based on the more sensitive (%) data. For example, at the ocular site 90% (9/10) of vaccinated animals decreased or stabilised their load, compared to the control group where only 33% (2/6) had decreasing or stabilising loads. Similarly, at the UGT site, 100% (8/8) of animals in the vaccinated group had decreasing or stabilising loads compared to 69% (9/13) in the control group.

At 12 months, the positive vaccine effect was maintained at the UGT site with 100% (5/5) of vaccinated animals showing a decrease in chlamydial load compared to 83% (5/6) in the control group. We are cautious about drawing conclusions on the statistical significance of this owing to the difference of only a single individual. However importantly, throughout the entire study, not one animal in the vaccine group showed an increase at the UGT site. At the ocular site at 12 months, 100% (7/7) of vaccinated animals also decreased or stabilised their chlamydial load, although a similar trend (100% [4/4] decrease) was seen in the control group.

### 5.3.4 Progression to chlamydial disease

To investigate the impact that vaccination had on the progression of chlamydial disease, we compared the presence and absence of disease in vaccinated and control animals. Over the 12 months of the study, only 1 of 23 (4% of koalas) vaccinated animals developed clinical signs of chlamydial disease, whereas 4 of 27 (14.8%) control animals developed clinical disease over the same time period. Based on percentage differences, the control and vaccinated groups were significantly dissimilar ($X^2 = 7.037$, $p = 0.013$), but the same result could not be observed in the raw data ($X^2 = 1.512$, $p = 0.363$) owing to the sample size. The one vaccinated animal developed mild, sub-acute, chronic cystitis, was treated in care with the standard chloramphenicol regimen and released as healthy. Three of the four animals that developed disease in the control group developed cystitis and were treated; the final animal developed severe and extensive reproductive disease as well as severe chronic cystitis, and was euthanased.

| | **Eye (0 vs. 6 months)** | | | **Eye (0 vs. 12 months)** | | | **UGT (0 vs. 6 months)** | | | **UGT (0 vs. 12 months)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Decrease** | **Stable** | **Increase** | **Decrease** | **Stable** | **Increase** | **Decrease** | **Stable** | **Increase** | **Decrease** | **Stable** | **Increase** |
| Control | 33% (2) | 0% (0) | 67% (4) | 100% (4) | 0% (0) | 0% (0) | 69% (9) | 0% (0) | 31% (4) | 83% (5) | 0% (0) | 17% (1) |
| Vacc | 50% (5) | 40% (4) | 10% (1) | 71% (5) | 29% (2) | 0% (0) | 88% (7) | 12% (1) | 0% (0) | 100% (5) | 0% (0) | 0% (0) |
| $X^2$ | 85.677 | | | 31.619 [a] | | | 45.299 | | | 16.458 [a] | | |
| $P$ | **< 0.001 (0.052 *)** | | | **< 0.001 (0.496)** | | | **< 0.001 (0.099*)** | | | **< 0.001 (0.999)** | | |

[a] analysis based on 2 x 2 contingency table Chi-square owing to no individuals with decreasing loads for both control and vaccinated koala

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**Table 5.1:** Change in *Chlamydia* PCR load following vaccination: Percentage (and raw number calculations) of koalas that were *C. pecorum* positive at 0 months (i.e. at initial vaccination time), and then exhibited changes in their *C. pecorum* load between either 0 and 6 months, or between 0 and 12 months, post-vaccination.

## 5.4 Discussion

We have, for the first time, examined the effect of a MOMP-based anti-chlamydial vaccine on chlamydial infection risk and outcome in free-ranging koalas. The vaccine induced a significant immune response in wild-caught koalas. The incidence of new *C. pecorum* infections was lower at both anatomical sites in vaccinated animals, despite not being statistically significant. Importantly, we also found that vaccinated koalas were more likely to have stable or decreasing *C. pecorum* PCR loads, and were also less likely to increase their chlamydial burdens at 6 months post-vaccination at both anatomical sites. At 12 months, this positive effect could still be observed in the vaccinated cohort, with no animals increasing their chlamydial loads at either anatomical site. Lastly, we showed a positive effect for protecting against progression to disease in vaccinated animals.

These results are extremely promising for the future development of a chlamydial vaccine for koalas. This is the world's first field trial of this prototype koala chlamydial vaccine. Our results suggest that vaccinated *Chlamydia*-infected koalas have an improved infection outcome—an outcome that highlights the potential for the development of a *therapeutic* vaccination schedule for this species (in addition to *prophylactic* use of the vaccine). This is especially promising given the small sample sizes, and the natural variability of an outbred population. In the koala, the main goal for population management from an ecological standpoint is maintaining health and young animal recruitment. Therefore, if a vaccine is able to lower or prevent increases of infection load, as well as to decrease the progression to disease, then this will have positive effects on population health and fecundity and will be an important tool in the management and conservation of declining koala populations.

### 5.4.1 Recommendations (by EVE)

With respect to the *Chlamydia* vaccine for koalas, we make the following recommendations:

1. That support of the further development and refinement of the single-dose *Chlamydia* vaccine be considered as a component of offsets packages for future infrastructure projects impacting on koalas.

2. That the use of an efficacious vaccine for *Chlamydia* infection in koalas may significantly extend the duration of benefit arising from veterinary management programs that are implemented to offset and manage project impacts, thereby improving the ultimate outcomes of offset and compensatory packages. Therefore, vaccination should be a component of holistic impact management programs for koalas.

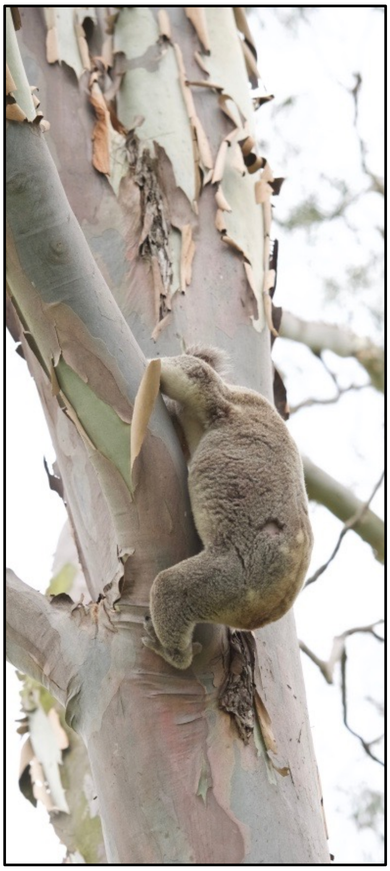
## 5.5 Acknowledgments

The development of a chlamydial vaccine for koalas is a major undertaking, and it has only been possible to obtain the very promising results so far achieved with the assistance of many partners. In addition to the major support provided by the Moreton Bay Rail project and the Department of Transport and Main Roads, the project has also been supported by our other collaborators including Queensland Department of Environment and Heritage Protection, Moreton Bay Regional Council, Redlands City, City of Gold Coast, Endeavour Veterinary Ecology Pty Ltd, Australia Zoo Wildlife Hospital, Friends of the Koala, Lone Pine Koala Sanctuary and VIDO, Canada for their continued support. This project has also received financial support from the Australian Research Council Grant Scheme.

The first vaccine trial has been published in the journal, PLoS One.

**Plate 5.4**: Koala *Whitey* and her 8-month joey *Captain Slow* during a scheduled vet check in July 2014. *Whitey* received the VIDO-MOMP *Chlamydia* vaccine in January 2015 and remained healthy for the remainder of the program.

# CHAPTER 6: RANGING BEHAVIOUR AND HABITAT USE BY KOALAS




## Key points

- Home ranges determined by *KTMP* well before vegetation clearing
- Most koalas did not need translocation - shifted home ranges sideways
- *KTMP* guided appropriate management response - telemetry allowed protection of koalas and guided assessment criteria for koala translocation
- Urban habitat remnants and corridors are critical for regional koala population survival
- Appropriate mitigation, fencing, culverts etc can allow koalas to persist safely in heavily modified human environments.
- Innovative technology - LX *K-Tracker* telemetry system was central technology in *KTMP* and won a National Engineering Excellence Award in 2015

# Chapter 6: Ranging behaviour and habitat use by koalas

## 6.1 Background

The Moreton Bay Rail Link (MBRL) corridor had been set aside for many decades prior to its final development. Construction of the project was fast-tracked by local, State and Federal governments in 2010 to provide a rail link for the rapidly growing population in the coastal Moreton Bay region. The addition of the Lawnton to Petrie rail upgrade to the MBRL project in early 2013 resulted in a change of name to the Moreton Bay Rail (MBR) project, which is the designation we use from here on.

As a consequence of the ongoing urbanisation in the region, the undeveloped rail corridor preserved some increasingly valuable remnants of koala habitat, with urban development encroaching up to the boundary of the rail corridor in many areas. The rail corridor appeared to be important for the local koala population, with surveys indicating higher densities in the rail corridor and adjacent bushland than in the highly urbanised surrounds. Koala habitat along the corridor varied from relatively undisturbed forest to highly disturbed and fragmented patches of vegetation (see ***Chapter 2 - General methods***).

Koalas use habitat of varying degrees of intactness for daily and seasonal requirements. Bushland and urban habitats provide feeding, resting, breeding and ranging opportunities. Urban habitats such as parks, reserves, road reserves and backyards generally result in higher exposure of koalas to anthropogenic threats, associated with the urban/suburban environment and transport infrastructure. These areas are likely to have densities of koalas below that which the amount of available habitat could theoretically support, due to a higher level of premature mortality. However, many urban areas with fragmented habitat continue to support koalas and provide important resources and linkages to other habitat.

Development-caused habitat loss can have severe impacts on koalas. Immediate and short-term consequences include injury or death of individuals from vegetation clearing operations and increased exposure to threats, as koalas are displaced and attempt to navigate the high-risk urban matrix. Longer-term impacts include the isolation of groups of animals or populations in habitat “islands” and localised extinctions of populations (extirpation). In short, development projects can cause impacts through a variety of mechanisms, including loss or reduction of habitat for koalas, increased mortality and exposure to risks, and the loss of habitat connectivity, leading to habitat fragmentation and isolation. The development of the MBR project has significantly reduced the amount and connectivity of koala habitat along the rail corridor.

To mitigate these impacts, a series of fauna crossing structures (culverts) were installed beneath the rail line and new koala habitat was established to offset habitat loss through vegetation clearing. A program of work, known as the *Alternative Koala Habitat Offsets (AKHO)* program, assessed the effectiveness of strategies to offset habitat loss and improve permeability, thereby mitigating the barrier effect of the rail corridor to koalas (see ***Chapter 12 - AKHO-CM and GOSM Programs***).

This chapter provides analyses and discussion regarding the ranging behaviour and use of habitat by koalas prior to, during and after construction. The information provided herein is not exhaustive, but rather provided to illustrate key findings and concepts. A considerable body of data was collected with respect to koalas’ use of habitat and movement through their changing landscape, over the course of the koala management program. This is worthy of detailed analysis and would no doubt provide insights into social interactions, epidemiology and behavioural ecology; but those analyses are beyond the scope of this report.

The management of some koalas by translocation and the responses of resident and translocated koalas in the recipient sites are discussed in the following chapter, ***Chapter 7 - Koala translocation.***

## 6.2 Methods

### 6.2.1 Koala capture

An intensive koala search and capture program was conducted between March 2013 and July, 2013 and again between September 2013 and January 2014. Opportunistic captures occurred throughout the program up until the end of June 2015 (when monitoring continued, but few new koalas were recruited). The program aimed to recruit as many koalas as possible in relevant areas (described in ***Chapter 2 - General methods***) prior to the commencement of vegetation clearing. The primary reason for aiming to catch *all* koalas in the target areas was to protect them from risk associated with vegetation clearing and construction works. This was achieved by locating each at-risk koala on the day of clearing using their telemetry devices. Koalas were captured for scheduled health assessments and tag checks throughout the program and telemetry monitoring of koalas continued until June 2016. Thereafter, a subset of koalas (around one half (110)) were monitored until December 2016 under the ***AKHO-Connectivity Monitoring (AKHO-CM)*** program of works.

### 6.2.2 Koala movements and dispersal

Koalas were monitored prior to, during and after construction of the MBR project based on standard monitoring schedules (described in ***Chapter 2 - General methods***). The LX *K-Tracker* telemetry system provided near-real-time data on the movements of koalas on-site and dispersal off-site while in range of a base station. A geofencing feature to provide more frequent locations of koalas, when within certain distances of the rail corridor, was later programmed into the *K-Tracker* tags. Instead of the regular 12-hourly uploads, when the tag recorded its last location within 50 m of the rail corridor, the tag was programmed to give more frequent uploads, from every hour to as frequently as every minute (**Table 6.1**, below). Koalas were field-tracked using conventional VHF radio-telemetry during dispersal events, to detect their movement out of range of the *K-Tracker* base stations, making animals easier to monitor and locate at subsequent tracking events, or prompting the installation of additional *K-Tracker* base stations.

| Distance from rail corridor | GPS fix frequency |
|---|---|
| 1-10m | Every minute |
| 11-20m | Every 5 minutes |
| 21-50m | Every hour |
| >50m | 12-hourly (10am and 10pm) |

**Table 6.1**: Frequency of GPS uploads for LX *K-Tracker* tags in relation to distance from the rail corridor

Home ranges were determined for koalas that had greater than 20 GPS positions. Home ranges were examined prior to vegetation clearing, during clearing and post-clearing, and recorded prior to and after the establishment of permanent fauna fencing along the completed rail corridor. On occasions when koalas dispersed from one area and settled in another, home ranges were split to better represent the size of the ranging area of those animals. The *adehabitatHR* program in *R* (a statistical analysis software package) was used to calculate the 95% *Kernel Density Estimates* (KDE) for each koala. This home range estimation was used in preference to the *Minimum Convex Polygon* (MCP) method to better reflect the area in which a koala spent the majority (95%) of its time. The MCP method calculates the total area that an animal might use, drawing a polygon to incorporate all points recorded for an animal, some of which may be brief exploratory movements and not part of their usual home range.

### 6.2.3 Koala management during vegetation clearing

Vegetation clearing of the MBR corridor commenced at the Amcor site on 29 January, 2014 and was largely completed by 29 May, 2014 when the last small patch of vegetation was removed at the Amcor site. Three vegetation clearing fronts operated along the corridor during these months. Koalas with home ranges in imminent clearing areas were tracked early each morning on a daily schedule to determine their locations. The trees in which they were resting were clearly identified with flagging tape and the on-duty wildlife spotter/catchers notified of koalas in or near the work zones. Small trees were temporarily retained at the clearing front to provide temporary habitat links across the corridor for koalas (**Plate 6.2**).

**Plate 6.2**: Vegetation clearing was one of the critical risks to koalas mitigated by the *KTMP*. Vegetation clearing and grubbing commenced at the end of January 2014 by which time essentially all koalas in at-risk areas had been captured and tagged. Tagged koalas in the vicinity of clearing operations were monitored daily to determine their locations. Small trees were temporarily retained to provide some habitat linkage across the corridor.

### 6.2.4 Permeability of the corridor to movement of koalas

As the vegetation clearing and construction of the MBR project progressed through the various stages, the short-term and longer-term permeability of the rail corridor to koalas was altered as follows:

- Vegetation clearing for the corridor created a habitat-void or non-physical barrier to koala movement. That is, there were no impediments to the movement of koalas across the cleared corridor if the koala was willing to traverse open ground;

- Temporary fencing, consisting of para-webbing and sediment fence material, was used to delineate the vegetation clearing boundaries and to control sediment. This fencing, at 1.2m in height was easily climbable by a koala, but provided an impediment to koala movement across the corridor;

- Temporary fencing was used to restrict access to construction zones and consisted of 1.8-high chain-mesh fencing resting in blocks. It was possible for koalas to pass under or climb over the fencing in some areas, but it presented a slight impediment to movement;

- Permanent safety and fauna fencing was installed in stages at the completion of construction of the rail line itself. This fencing consisted of 1.8m chain-mesh flush with a ground-level concrete plinth and a 600 mm wide sheet metal strip (Colorbond®-type shear sheeting) fixed to the top of the wire to render it unclimbable by koalas. This provided a generally effective physical barrier to koala movement into the constructed rail corridor.

The longer-term permeability of the operational rail corridor was addressed with the inclusion of koala and fauna-specific solutions:

1. Fauna culverts: five dedicated fauna crossing structures consisting of 1.2m - 1.8m-high box culverts were installed beneath the rail corridor. All but one (F6) included 'fauna furniture' consisting of a post-and-rail structure running the length of the culvert to provide elevated safe passage through the culvert for koalas and other fauna (**Plate 6.3**, below). Storm-water drainage culverts and pipes and vehicular access culverts also provided potential fauna crossings routes.

**Plate 6.3**. Five dedicated fauna culverts were installed beneath the rail corridor to provide corridor permeability and retention of some ecological connectivity between koala habitat. Post-and-rail fauna furniture provided opportunities for safe passage / travel off the ground for koalas, although they were more commonly used by possums.

2. Bridges: rail bridges over creeks provided avenues for koala movement along riparian habitat corridors transected by the rail line; these crossed Yebri Creek, Black Duck Creek, Freshwater Creek and Saltwater Creek (from west to east) (**Plate 6.4**, overleaf). One road bridge over Freshwater Creek at Cecily Street was constructed during MBR-associated works. All four rail bridges, the Cecily Street bridge and the existing Bruce Highway bridge over Freshwater Creek were monitored for koala movements using trail cameras installed by EVE as part of the ***AKHO-CM*** program of work.

3. Fauna fencing: koala proof features of the corridor safety fencing aimed to keep koalas out of the rail corridor and to funnel koalas to dedicated crossing structures (**Plate 6.5**, overleaf). While the fencing reduced the overall permeability of the site, it was installed to avoid koala mortality from train strike. Koala escape or egress poles were incorporated into the fencing design to provide a means of escape from the rail corridor to the surrounding bushland in the event that a koala gained access to the rail corridor.

**Plate 6.4**: Bridges such as the new Yebri Creek Rail bridge on the Amcor site provides suitable safe passage under the rail line for koalas and other fauna where dry areas exist. Elevated passage using post-and-rail structures is available on both sides of the creek. These were commonly used by brushtail possums.

**Plate 6.5**: Koala proof fencing consists of chain wire fencing with a 600mm wide sheet of non-climbable sheet-metal attached to the top of the fence. The fencing serves the dual purpose of funnelling koalas to dedicated safe fauna crossing structures beneath the rail corridor and mitigating the risk of koala mortality from train strike. This photo also shows an escape pole designed to facilitate the exit of a koala from the rail corridor.

### 6.2.5 Design and trial of one-way koala egress valves

While escape or egress poles provide an opportunity for koalas to exit infrastructure corridors, the likelihood of their use by koalas has not been sufficiently investigated to support their installation as sole egress devices. To assist the rapid exit of koalas from fauna-fenced linear infrastructure, we designed a fauna egress valve at ground level and subjected a number of prototypes to trials using MBR koalas spending time at the EVE veterinary clinic for scheduled veterinary checks or treatment. (See also ***Chapter 2 - General methods.***)

The aim of the work was to develop and test a device that could be incorporated into TMR road design documents as a standard mitigation measure for use with koala proof fencing along fenced transport corridors. Structures had to be of simple design and manufactured with readily sourced materials (**Plate 4.6**), a 20-year life-span and with minimal maintenance required. Prototypes designs considered the behaviour and psychology of koalas moving across the ground. In short, koalas moving across the ground are used to having to push through or under ground-cover vegetation, and may not have the cognitive ability to immediately recognise an escape pole as a means to traverse a fauna fence. Rather, they tend to fence walk and attempt to push through or under fences, particularly those that are constructed of see-through materials, like chain-mesh. In reality, even though they can readily climb chain-mesh fencing, they often do not, and spend significant time fence-walking and searching for a push-under spot or breach in the fence. In the context of linear transport infrastructure, the longer that fauna takes to exit a fenced transport corridor, the higher the risk to it, and to motorists.

A number of designs were trialled including:

1. Netting: netting draped from the valve in the fence allows a koala to easily push underneath the netting in one direction, but excess netting on the ground makes it nearly impossible for koalas to manoeuvre under it in the reverse direction. (See left image, below.)

2. Levered /swinging door: a delicately-weighted Perspex® door swings from a 45 degree angle resting on the ground, upwards as the koala pushes through the frame in the fence, and swings back to the ground after the koala clears the door. The door is horizontally hinged. (See right image, below.)

**Plate 6.6**: Two early prototypes of the koala egress valve. The left image shows a netting valve; the right image shows a horizontally-hinged Perspex® door. Both were used by trial koalas, but not consistently.

3. Box with hinged double doors (**Plate 6.7**, below): vertically-hinged, lightly-sprung Perspex® doors allow a koala to easily push through them in one direction, closing behind the koala, making it difficult to open the door and return through the valve. This was the most successful design, and construction plans are presented in *Appendix 10 - Construction plans and installation instructions for the EVE fauna egress valve prototype*.

**Plate 6.7**: Prototype of the most successful koala egress valve, with two vertically-hinged, lightly-sprung Perspex® doors.

Prototype valves were positioned in outdoor koala enclosures made of chain-mesh and Corflute® and koalas were placed in the trial enclosure and left to move around the enclosure at their leisure. Prototype devices were redesigned after initial trialling to enhance their ease of use by koalas. Results of the trials are presented in the section below. Use of koalas in the trial was authorised by the DAF community-access AEC under the approval CA 2014/06/777.

EVE has provided the design and installation instructions for the koala egress valves to TMR, with permission for use throughout Queensland.

### Monitoring rail corridor permeability to koala movement

The permeability of the completed rail corridor to koalas was assessed by monitoring many of the culverts and bridges using trail cameras, as part of the *AKHO-CM* program of works. A summary of this work and the monitoring of tree growth in, and koala use of, the revegetation areas at the Griffin offset site is contained in ***Chapter 12 - AKHO-CM and GOSM Programs.*** This program commenced in June 2016 as the *KTMP* was nearing completion, and was ongoing at the time of writing. Chapter 12 provides a summary of the approach and findings to date, but a detailed report on that program was to be provided separately.

### 6.2.6 Koala visibility score

At each koala field tracking event, the field personnel applied a *koala visibility score* (*KVS*), based on the following criteria (**Table 6.2**):

| Score | Meaning |
|---|---|
| 0 | Koala unable to be found. |
| 1 | Koala very difficult to spot. Only part of koala showing, visible primarily with binoculars, and from only very limited angles. |
| 2 | Koala difficult to see, whole/most of koala visible only from limited angles. |
| 3 | Koala moderately difficult to see, but easily seen from certain angles. |
| 4 | Koala easily seen from most angles. May be missed from limited angles, but otherwise easy to see. |
| 5 | Koala obvious. Easily seen from all angles. |

**Table 6.2**: Criteria used to apply a *koala visibility score* during each koala field-tracking event using radio-telemetry.

To be clear: Each tagged koala was tracked by field personnel using VHF radio-telemetry so that its location could be determined with a high degree of accuracy (generally to within a 15-20m radius). Once the general vicinity of the koala had been determined, the time taken for field personnel to locate the koala was recorded.

Upon observation of the koala, a *koala visibility score* was determined and recorded with each field tracking event. In the event that a tracked koala could not be spotted, despite at least 20 minutes of searching, a *koala visibility score* of zero was applied. **Table 6.3**, below, summarises the meaning, metrics and implications for non-telemetry guided koala surveys, in terms of probability of sighting a koala with respect to its *koala visibility score*.

| KVS | Meaning | Approximate time to find during radio tracking (guideline only) | Estimated likelihood of detection during survey | Sighting likelihood during survey |
|---|---|---|---|---|
| 0 | Koala unable to be found | 20+ minutes searching | <5% | Very unlikely |
| 1 | Koala very difficult to spot. Only part of koala showing, visible primarily with binoculars. | 15-20 minutes searching required to find | 5-10% | Unlikely |
| 2 | Koala difficult to see, koala visible only from limited angles. | 10-15 minutes searching | 20-40% | Possible |
| 3 | Koala moderately difficult to see, but easily seen from certain angles. | 5-10 minutes searching | 50% | Even chance |
| 4 | Koala easily seen from most angles. | up to 5 minutes searching | 60-90% | Likely |
| 5 | Koala obvious. Easily seen from all angles. | Seen immediately | >90% | Very likely |

**Table 6.3**: Koala visibility score meaning, time-to-find guideline and estimated likelihood of detection during a normal koala survey (without radio-telemetry).

The results of the analysis of *koala visibility scores* overall, and by polygon are presented in the results section below. Refer also to ***Chapter 11 - Population viability analysis***.

## 6.3 Results

### 6.3.1 General statistics

There was a total of 471 koalas monitored in the field along the MBR corridor and translocation recipient sites between March 2013 (*KTMP* commencement) and August 2016 (*KTMP* ramp-down), resulting in more than 50,000 in-field tracking records (**Figure 6.1**). Intensive koala search and capture efforts occurred between March and July, 2013, and also in the months prior to the commencement of vegetation clearing (September 2013 - January 2014). During this second period there was a 57% increase in the numbers of koalas recruited to the program (**Figure 6.2**), due partly to the capture of joeys nearing the age of independence from their mothers. It was critical that this age group was tagged as they are typically more difficult to detect in trees because of their small size. It was estimated that around 95% of independent koalas residing in the koala search polygons just prior to clearing were captured and tagged.

Four koalas were recruited into the program when they were detected by the wildlife spotter/ catchers (WS/C) engaged by the principal contractor during vegetation removal. Opportunistic capture of untagged koalas observed by field personnel occurred throughout the program, up until mid-2015 for all sites except the Griffin offset site, where capture of cleanskins was discontinued in January 2016. Capture and tagging of near-independent joeys continued until June 2016 for the ***AKHO-CM*** program of work. **Table 6.4** (below) and **Figure 6.3** (overleaf), below, summarise *KTMP* recruitment.

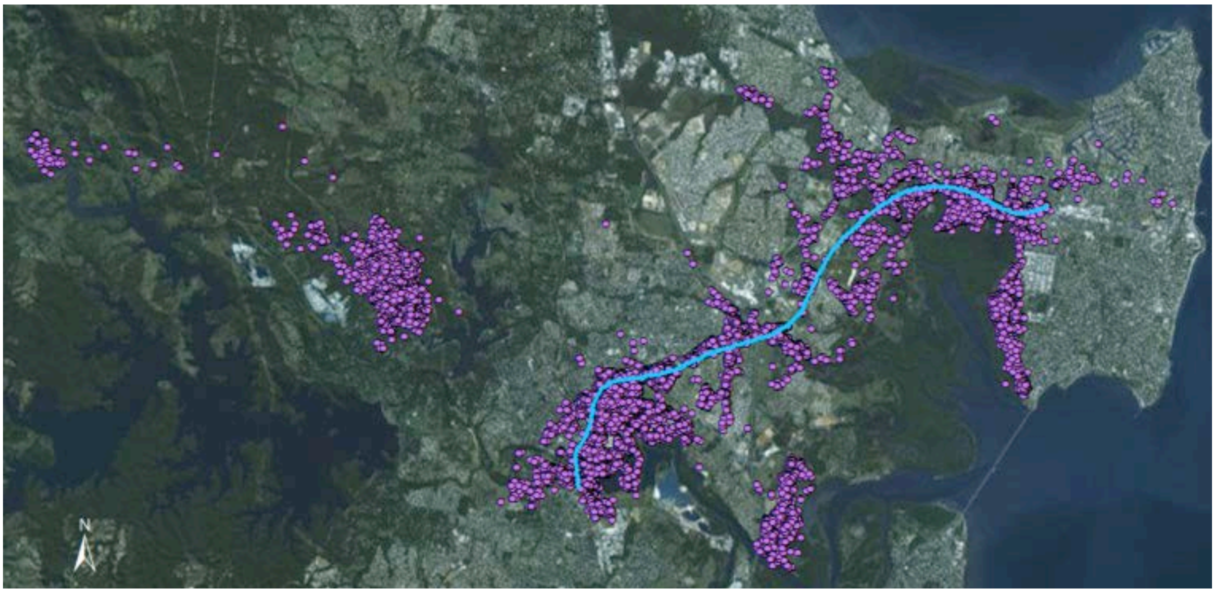


**Figure 6.1**: All koala field tracking events showing the locations of monitored koalas in the KTMP from 2013 to 2016 along the rail corridor and two translocation receive sites.

| Category of recruitment into KTMP | Number of koalas |
|---|---|
| Intensive search and capture (EVE) | 185 |
| Dependent young of tagged mother | 147 |
| Opportunistic sighting and capture (EVE) | 145 |
| Entry to *KTMP* via wildlife rescue group, MOP or wildlife hospital | 22 |
| Wildlife spotter/catcher (WS/C) sighting, EVE capture | 4 |

**Table 6.4**: Number of koalas entered into the KTMP by *category of entry*. (See Figure 6.3, overleaf.)

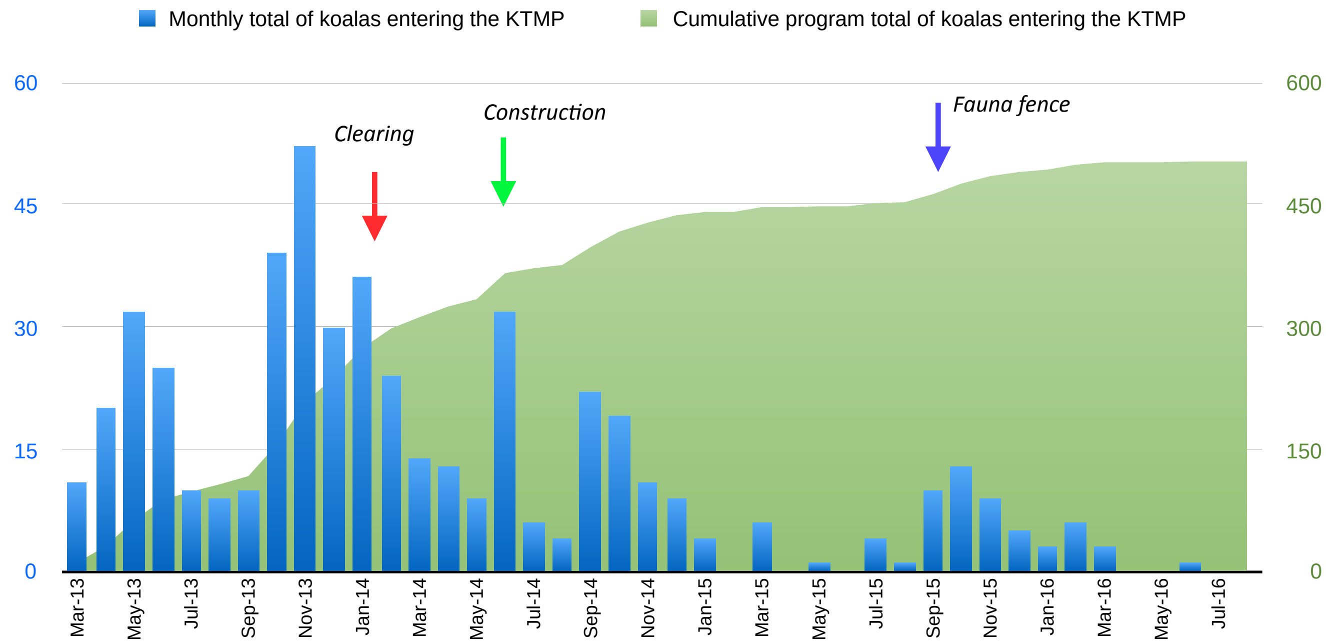



**Figure 6.2**: Koala recruitment to the *KTMP* per month. Intensive search and capture in the months leading up to vegetation clearing more than doubled the number of koalas in the project by the end of January 2014. Koalas continued to be captured and monitored during clearing, construction and post-construction stages. Peaks in the blue bars between March 2013 and July 2013, and October 2013 - January 2014 correspond with times of intensive search and capture. Later peaks are associated with capture of resident koalas at the translocation recipient sites and seasonal peaks in recruitment of near-independent koala joeys. Red arrow indicates the commencement of vegetation clearing, green arrow indicates the commencement of construction works and the blue arrow indicates establishment of the safety/fauna fence, marking the establishment of the permanent barrier to koala movement across the rail corridor.

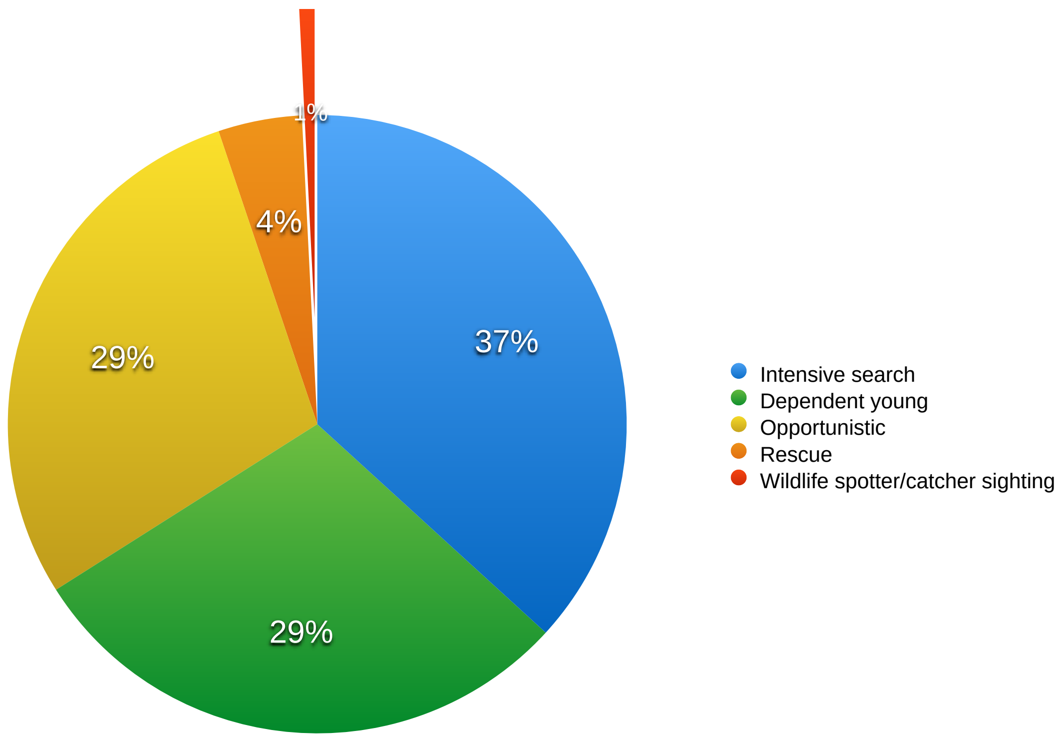



**Figure 6.3**: Pie chart showing proportions of *categories of recruitment* of koalas into the KTMP. Most were through observation and capture by EVE personnel in the koala search polygons site, 22 (4%) were via koala hospitals and rescue groups, and 4 koalas (1%) were spotted by wildlife spotter/catchers during vegetation clearing activities for the MBR project.

## 6.3.2 Habitat use during construction stages

All habitat within and adjacent to the rail corridor was highly permeable to koalas before construction. Prior to construction works, the significant barriers to safe koala movement were the heavily developed urban and suburban areas, Gympie Road (Petrie) and the Bruce Highway as it transected the significant east-west habitat corridor along Freshwater Creek. Intensive urban development prior to and after commencement of MBR construction essentially obliterated koala habitat remnants and corridors between Mango Hill and Rothwell (in the *Kinsellas Rd* polygon).

Koalas freely moved around the rail corridor and were found using most of the vegetation in the polygons. This included remnant vegetation with koala food tree species, regrowth vegetation with koala food tree species, non-endemic vegetation with eucalypts from other regions (particularly at the Amcor site), native vegetation with no koala food tree species (such as riparian species and mangroves) and non-native/exotic vegetation in parks and backyards. The Amcor polygon habitat had high levels of disturbance and high noise and dust levels around the mill area, yet koalas were captured throughout the site (**Figure 6.4**,(left image) below). The monitoring of these koalas showed that they occupied and ranged in every available habitat on the site and used a range of native and exotic trees (**Figure 6.4**, right image).

**Figure 6.4**: Locations of first capture/recruitment of Amcor koalas into the *KTMP* program (left image); and tracking locations of koalas monitored on the Amcor site (right image), showing widespread use of most areas of the site, including heavily disturbed and degraded habitat.

### Koala use of habitat in the rail corridor

118 koalas monitored during the early stages of the *KTMP* (March 2013 to the end of January 2014) had home ranges that included habitat in the rail corridor prior to commencement of vegetation clearing (**Table 6.5**, overleaf). Of these, 71 koalas were still active in the rail corridor at the start of the clearing – the remainder moved away from the corridor, dispersed off site, or had died prior to clearing. During the four months of clearing operations, 88 koalas (17 of which were new recruits to the program during that time) were monitored ranging in the rail corridor habitat, or, once it was cleared, using the corridor to access habitat on either side. By the end of the *KTMP*, only 16 of the tagged koalas were using habitat on either side of the rail corridor. In simple terms, although the corridor was permeable to koalas, relatively few animals used habitat on both sides. The permeability of the corridor was significantly less in the large habitat areas of Amcor, which had two potential crossing structures, compared with Kippa-Ring, which had 10 potential crossing structures.

| Metric | Before clearing | During clearing | After clearing (no koala fence) | Koala fence established |
|---|---|---|---|---|
| Time | 10 months | 4 months | 19 months | 8 months |
| Koala habitat removed | 0 ha | 81 ha (up to June 2014) | 86 ha (up to Sept. 2014) | 93 ha* |
| Total koalas monitored during this period | 240 | 221 | 279 | 154 |
| Total field tracking records | 9,064 | 7,019 | 24,799 | 8,060 |
| Koalas using the rail corridor | 118 | 88 | 54 | 16 |

**Table 6.5**: Monitoring statistics prior to, during and after clearing operations for the construction of the rail line. * Note that habitat removed included some areas of degraded habitat with open fields, and also included associated works, such as upgrades of Kinsellas Road and Cecily Street. The final area measurement was based on aerial photography.

### Impact of habitat removal on koalas

Only one koala had the habitat in its home range completely removed due to the development of the MBR: the female koala *Regina* ranged almost exclusively in Kenna Park at the eastern extent of the rail corridor at Kippa-Ring, which is now occupied by Kippa-Ring Station and its carpark. She was also located on three occasions in habitat adjacent to Kenna Park that is occupied by the rail line (**Figure 6.5**). Four other koalas used Kenna Park, but also used adjacent habitat, so their home ranges were not as severely impacted as that of *Regina's*. *Regina* persisted in Kenna Park in a small patch of habitat until eventually moving late in the vegetation clearing phase, using small strips of vegetation that had been temporarily retained as a link to surrounding habitat (**Figure 6.6**). *Regina* ranged over a significantly greater area (75 ha compared to 12.5 ha) after clearing was finalised, using bushland north and south of the corridor and a park surrounded by residential development to the north of the MBR corridor. She was first located in Sunstate Park, to the south of the corridor on 16 February 2015 after residing in Fleet Dr Park (to the north of the corridor) for over two months. *Regina* had a well-established home range in Sunstate Park by the time the koala-proof fencing was finalised. She remained healthy and produced two joeys after re-establishing a home range in the area.

**Plate 6.8**: Approximately 10-11-month juvenile *Cora* (joey of *Regina),* at the time of her first collaring in July, 2014. *Regina* produced four joeys over the course of the *KTMP*, three of which survived to the age of independence. *Cora* survived to the completion of the koala management program and was de-collared in December, 2016. During that time she produced two joeys herself - *MacNish* and *Booth*.

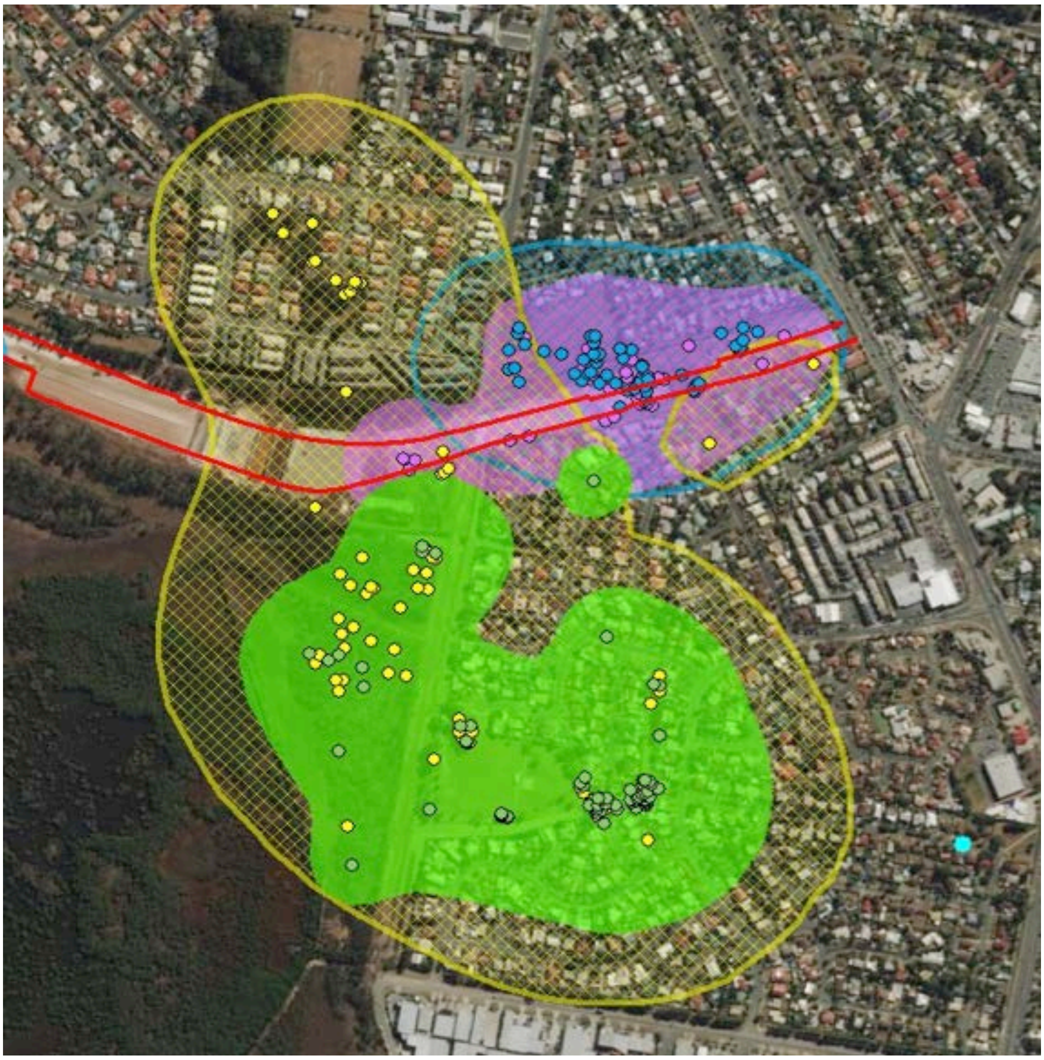


**Figure 6.5**. Koala *Regina* lost 100% of her home range from the development of the MBR. She ranged almost exclusively in Kenna Park prior to clearing (solid purple area and purple dots); remained in the park as tree clearing commenced until almost all of the trees were cleared (blue hashed area and blue dots); ranged considerably after clearing, exploring bushland and parks to the north and south of the corridor (yellow hashed area and yellow dots; established a stable home range prior to the installation of the koala proof fence (solid green area and green dots). Shaded solid and cross hatched polygons represent 95% Kernel Density Estimate and dots are in-field tracking locations.


**Figure 6.6**. Koala *Regina* remained in Kenna Park until most of the habitat was cleared, eventually moving into surrounding habitat via the temporary strip of vegetation that had been retained to facilitate her movement out of the park (red arrow). Right image shows completed section of the MBR project in the area of *Regina's* original home range.

Koala *Sara* caused minor delays to the vegetation clearing schedule by resolutely remaining in two large blue gum (*E. tereticornis*) trees with interconnecting canopies in the rail corridor near Petrie Station (**Figure 6.7a** and **b**, below). She remained in these trees for approximately two months; her already small home range of 3.4ha considerably reduced during the clearing period. Her ranging area post-clearing included part of her original home range with small extensions to the north and south. She was suspected to have been killed by a wild dog in December 2014, so longer-term ranging data are not available.

**Figure 6.7a:** The Amcor corridor was cleared by March 2013, except for a small patch of trees (red arrow) that continued to be occupied by koala *Sara* (left image). The trees were removed two months later at the end of May 2014 (right image), completing the clearing of the rail corridor. (Yellow line shows the western boundary of the Amcor koala search area polygon.) **Figure 6.7b**, below, shows the change in ranging behaviour after vegetation clearing.

**Figure 6.7b**: Graphical representation of the changing ranging behaviour of *Sara* pre-clearing (tan KDE area), during clearing (barely visible red dots within tan KDE area) and post-vegetation clearing (blue KDE area). Left image shows the extent of pre-clearing habitat, image on the right shows extent of completed rail development. She was presumed killed by a wild dog in December 2014, some 7 months after the effective completion of vegetation clearing works.

The majority of koalas maintained most or part of their original home range after the completion of clearing, with adjustments that expanded their new home range into adjacent habitat that they previously had not utilised (**Figure 6.8**, overleaf). Koalas that lost a substantial portion of their home range habitat in the vegetation clearing corridor almost always re-established a home range to the side where the largest remnant of their original home range remained, and most koalas did not attempt to cross the corridor once clearing had occurred. Some koalas already living in limited habitat remnants, particularly those in the *Bruce Hwy West* polygon, suffered significant home range loss and fragmentation, and consequently some of those koalas were translocated to alternative habitat. (See ***Chapter 7 - Koala translocation***).

**Plate 6.9**: Large male koala *Mango* living in habitat at the Kippa-Ring bushland was one of the early recruits to the *KTMP*. This photograph was taken in June 2013. His home range overlapped the rail corridor, but prior to the commencement of vegetation clearing he fell victim to wild dog predation.

**Figure 6.8**: Pre-clearing (top) and post-clearing (bottom) home ranges of a group of koalas at the Amcor site. Most koalas whose home ranges incorporated part of the rail corridor habitat prior to vegetation clearing were able to make slight alterations to their ranging areas and continue to persist in the vicinity of the rail corridor. The significant shift in home range for sub-adult male koala *Satyam* (light tan) could be attributed to dispersal movements typical of that demographic. The red lines delineate the vegetation clearing footprint for the MBR project. (See also **Figure 6.8a**, overleaf.)

**Figure 6.8a**: Home ranges of all koalas captured and monitored before clearing commenced in the Amcor polygon. The two stippled polygons show the large ranging behaviour of two dispersing koalas: *Rosie* (green-lined polygon) and *Lucas* (orange stippled polygon). The polygons show the complexity of koala ranging and use of habitat; hence, selection of a subset of koala home ranges to display on aerial images is more informative and less cluttered.

| Koala name | Sex | Construction stage | | |
|---|---|---|---|---|
| | | Pre-clearing HR (ha) | Clearing HR (ha) | Post-clearing HR (ha) |
| Barnacles | Male | 34.7 | 41.6 | 99.5 |
| Cowboy | Male | 30.4 | 28.7 | 16 |
| James | Male | 28.5 | 48.9 | 30 |
| Jim | Male | 41.3 | 27.1 | 55.6 |
| Jules | Female | 23 | 20.6 | 3.1 |
| Louise M | Female | 4.9 | 14.4 | 9.2 |
| Old Bean | Female | 4.4 | 4.6 | 6.4 |
| Patricia | Female | 17.7 | 9 | 23.8 |
| Pumba | Female | 11.9 | 6.8 | 6.7 |
| Robyn | Female | 18.6 | 10.1 | 15.1 |
| Sara | Female | 3.4 | 1.1 | 14.2 |
| Satyam | Male | 11.9 | 137 | 23.1 |
| Savannah | Female | 11.2 | 11.7 | 65.3 |
| Steve | Male | 11.3 | 9.2 | 12.7 |
| **Averages** | Male (M), Female (F) | 26.4 (M), 11.9 (F) | 48.8 (M), 9.8 (F) | 39.5 (M), 18.0 (F) |

**Table 6.6**: Summary of changes in home range sizes at different phases of the MBR project for koalas at the Amcor site. A variety of factors was likely to have influenced these changes other than the vegetation clearing, such as significant wild dog predation (reducing koala density), seasonal ranging behaviours, and age-related variation in dispersal/ranging behaviour.

## 6.3.3 Dispersal and seasonal movements

Numerous sub-adult and adult animals dispersed or made significant movements from their point of origin to other habitat around the rail corridor. Koalas moved in all directions in the landscape, not necessarily using bushland during their travels. Koalas crossed main roads, suburban streets, cleared and disturbed areas, backyards and parks to reach new habitat. Dispersal success was variable: for example koala *Disco* was fatally injured by a domestic dog (**Figure 6.9**, below); however koalas were also assisted out of harm's way when clearly in danger, influencing dispersal outcomes.

The majority of dispersing animals were sub-adult and young adult koalas who were yet to breed. No female koalas dispersed while they had young, however some young adult females dispersed to establish new home ranges after losing or weaning a young. Two mature female koalas, *Venom* and *Anna*, ranged widely in the breeding season during which time they dispersed away from their usual home range for at least a month and a half before returning to it later (**Figures 6.10** and **6.11**, overleaf). One female koala showed extreme seasonal movements – koala *Saba* ranged extensively in the suburbs of Kippa-Ring and Redcliffe during dispersal events and sustained vehicle-related trauma on at least one occasion crossing a multi-lane major road. A number of dispersing-age koalas at Kippa-Ring dispersed southwards, using a narrow habitat corridor linking larger habitat remnants at Clontarf with the large Kippa-Ring bushland habitat. This linkage is critical for the local koala population, and should be a high priority for protection.


**Figure 6.9**: Screen-grab from the LX *K-Tracker* website showing GPS positions of koala *Disco* up until his demise from a dog attack in which he sustained serious injuries requiring euthanasia in September, 2016. (See also page 129.) Yellow dots and lines are the most recent positions and movements, purple the older. His route of transit across the rail corridor was not determined, but appears to have been in the vicinity of the drainage culvert designated M12.

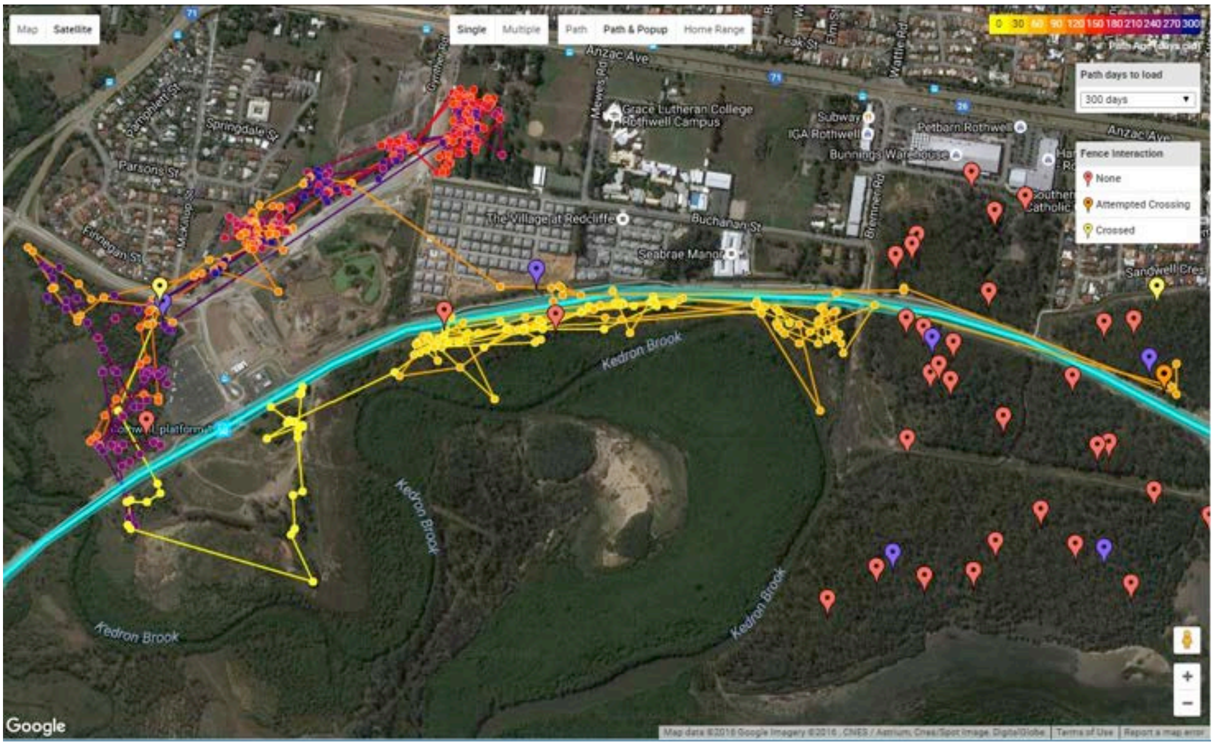



**Figure 6.10**: Habitat use by koala *Venom* shows ranging behaviour during the 2016 breeding season (July - December), using habitat on both sides of the rail corridor, and presumably transiting via the Saltwater Creek rail bridge or vehicle culvert V1 just to the west of the new Rothwell Station. Interestingly, she had been ovario-hysterectomised for reproductive disease, which should have obviated sex hormone influences on ranging behaviour. She returned to her usual home range three months later.


**Figure 6.11**: Habitat use by koala *Anna* shows seasonal exploratory movements under the the Bruce Highway at Griffin and back again one and a half months later.  The trip back east seemingly involved an incursion into the very busy 8-lane dual carriage-way of the Bruce Highway. She was recaptured in a small tree in the road reserve in October, 2016, then released back into the Griffin offset site adjacent to her capture location, on the safe side of the koala fence. Aside from the ranging data, the LX *K-Tracker* telemetry system was very valuable for keeping koalas safe.

### 6.3.4 Habitat fragmentation and permeability of the rail corridor

The construction of the MBR created a significant barrier to koala movement. Nearly 50% of the tagged koalas regularly or seasonally traversed the habitat within and/or adjacent to the rail corridor prior to clearing. (See **Figure 6.12**, below.) During clearing, the removal of vegetation and associated temporary (but not koala-proof) fencing created a partial barrier or impediment to movement, with 40% of koalas that once used habitat on both sides of the corridor (and within the corridor) subsequently residing only on one side - usually the side with the largest remnant of their original home range habitat.

The erection of permanent koala-proof fencing created a more complete barrier to koala movement, with as few as 10% of monitored koalas using habitat on both sides of the rail corridor. Trail cameras mounted at the entrances to bridges, dedicated fauna and drainage culverts and pipes beneath the rail line captured a number of crossing events by different koalas, and these data supplemented that derived from field tracking and the LX *K-Tracker* telemetry system. Some of these koalas were dispersing sub-adults and four were adult koalas whose home ranges included the rail corridor prior to construction (**Plate 6.10**, overleaf). Further discussion of the movements of koalas across the rail corridor after completion of construction is presented in ***Chapter 12 - AKHO-CM and GOSM Programs***.

The most significant fragmentation effects were created at either end of the rail corridor: at Kippa-Ring in the east, and at the Amcor site in the west. The Kippa-Ring bushland was bisected through its northern third by the east-west-aligned corridor; and at the Amcor site through its north-eastern third as a large section of the rail corridor arcs to the north and east from Petrie Station. The Kippa-Ring section retains good permeability to koalas via 10 culverts, of which four are dedicated fauna culverts, five are drainage culverts and one is a vehicular access culvert. In contrast, the Amcor section of the rail corridor has comparatively poor permeability, with only one permanently wet drainage culvert at the north-eastern extent of the arc of the rail corridor (M12), and the highly permeable Yebri Creek corridor to the south. The distance between the two is approximately 1km.

The potential barrier effect of the rail corridor (and associated infrastructure) as it transects important koala habitat corridors at three locations on the Freshwater Creek system and Saltwater Creek is sufficiently mitigated by bridges over riparian corridors, which facilitate easy and safe transit across the rail corridor by koalas.

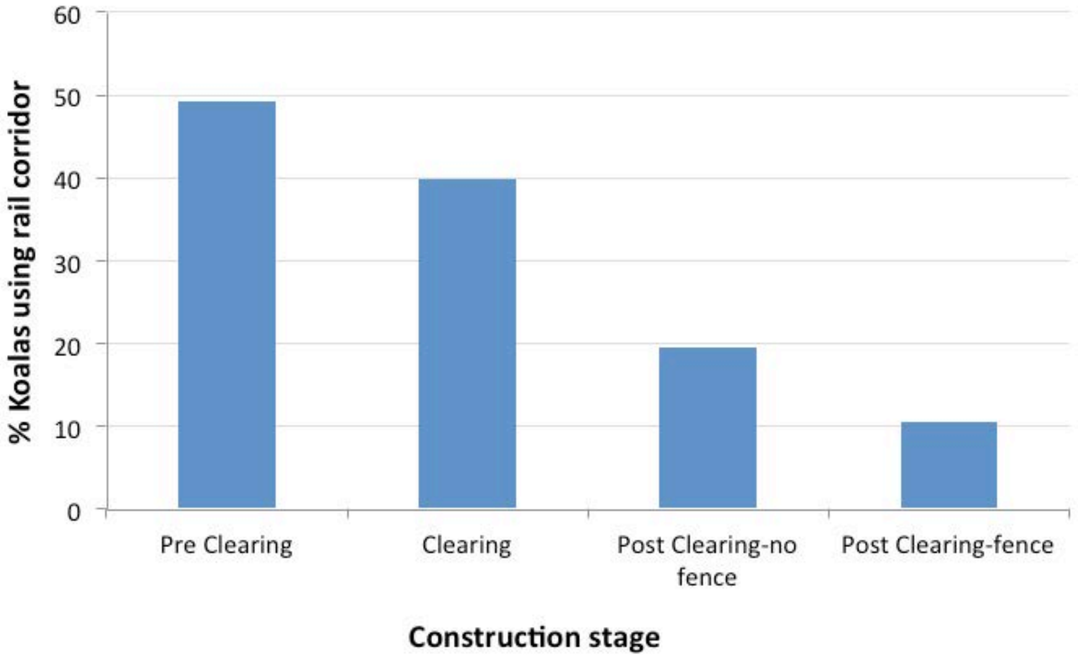



**Figure 6.12**: Graphical representation of the changes in use and/or crossing of the rail corridor, as the barrier effect of the MBR project intensified. Almost half of the koalas monitored before vegetation clearing commenced made use of habitat within the rail corridor. Once the koala-proof fencing was completed, only 10% of koalas that were monitored were using habitat on either side of the rail corridor.


**Plate 6.10**: Koala *Igor* is captured on trail cameras using a drainage culvert (designated M29) at Kippa-Ring to transit the completed rail corridor from south to north, demonstrating continued, albeit reduced, permeability of the rail corridor. Koalas' use of dedicated fauna culverts, bridges and drainage structures was monitored as part of the ***AKHO-CM*** program of works, some of which is reported in ***Chapter 12 - AKHO-CM and GOSM Programs***.

### Geofencing firmware upgrade to the LX *K-Tracker* telemetry system

At EVE's request a geofencing firmware upgrade to the LX *K-Tracker* system was developed by LX Solutions to allow finer-detail GPS data to be collected when tagged koalas were in close proximity to the rail corridor. The geofencing functionality increased the frequency of GPS fixes in tagged koalas as a scaled increase based on proximity to the rail corridor fence. The objective was to provide information on how koalas interacted with the rail fence and potential crossing structures, such as culverts and bridges - information which was not achievable with the standard 12-hourly GPS fix-rate pre-programmed into the *K-Tracker* tags.

An example of the geofencing functionality is shown in **Figure 6.13**, below, demonstrating the movements of the koala *Alistair* during a rail corridor transit event.


**Figure 6.13**: Koala *Alistair's* LX *K-Tracker* tag was in geofencing mode when he crossed underneath the rail line, providing a convincing crossing route from the southern to the northern side of the rail corridor. The shaded aqua-blue overlay shows the geofence trigger area, programmed into the *K-Tracker* tags to trigger a scaled increase in GPS fix rate with increasing proximity to the rail corridor. (Image is a screenshot taken in October, 2016.)

The geofencing feature was particularly useful and informative when the koala *MacGyver* entered the rail corridor and was unable to escape. GPS data clearly show him tracking along the northern and southern fence-lines inside the rail corridor as he searched for an exit route. The one-minute GPS fixes and uploads provided detailed movement data in near-real-time, and he was subsequently rescued in a timely manner.  In addition, the data provided compelling evidence of his repeated failure to use escape poles installed along the northern fence-line to exit the fenced rail corridor (**Figures 6.14** and **6.15**, below).

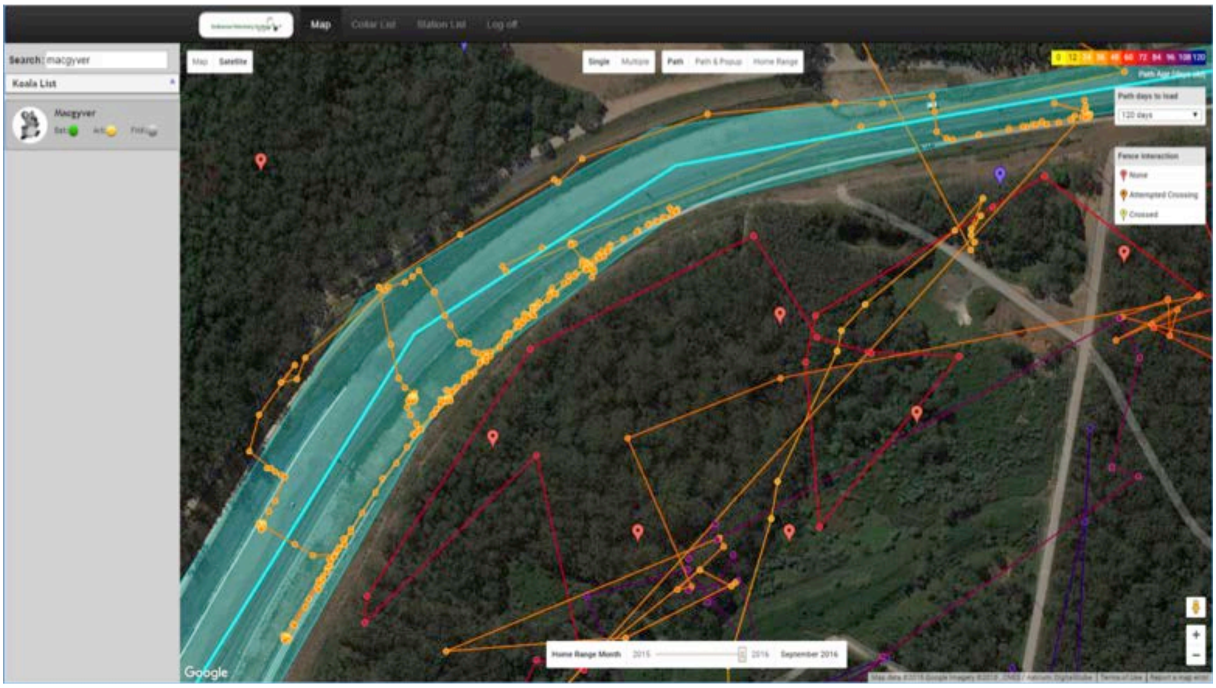



**Figure 6.14**: Geofencing functionality on koala *MacGyver's* tag clearly shows his entrapment in the rail corridor and fence-walking, during which time he passed, but failed to use, a number of escape poles along the northern fence.  He was subsequently rescued from the corridor and released back into habitat south of the rail corridor.  **Figure 6.15** below shows his dispersal away from the rail corridor following the entrapment event.


**Figure 6.15**: Extract from the *K-Tracker* website showing koala *MacGyver's* dispersal to the east in the weeks following his entrapment in the rail corridor.  Both the entrapment event and his subsequent dispersal in an easterly direction are consistent with, and typical of dispersal behaviour in sub-adult koalas.   The dispersal east is not necessarily a response to his entrapment, but rather the ranging behaviour typical of that demographic group.

## 6.3.5 Results of the trial of the koala egress valve

Trials of a variety of egress valve designs demonstrated that koalas will readily use suitably designed structures to move through fencing. Some structures were more successful than others, as assessed by the frequency and ease of use by the koalas. The most readily-used design consisted of two Perspex® 'one-way' gates that swing open to each side when lightly pushed, but will not swing open when pushed from the other side (**Plate 6.11**, below; see also design specifications in *Appendix 10 - Construction plans and installation instructions for the EVE fauna egress valve prototype*). The egress valve structure is placed at an approximately 45 degree angle to the fence-line and includes a short section of "wing-wall" fencing to assist in funnelling a fence-walking koala into the valve.

The one-way valve design appeared to be effective, based on the trialling of koalas in the fencing structure overnight. During such trials, motion-activated infra-red cameras recorded numerous unsuccessful attempts by koalas to navigate back (pass retrograde) through the valve. During one monitoring night, a koala attempted to pass retrograde through the valve on 77 occasions, unsuccessfully. Design specifications were drawn up at the completion of the trial to allow the device to be replicated and used in conjunction with wildlife fencing to mitigate koala and other wildlife road mortality. Koalas caught within road or rail corridors are often killed when unsuccessfully trying to find egress points into habitat areas. The final design is simple and uses materials that can be readily sourced, providing a practical, durable and cost effective device to facilitate the safe egress of koala and other fauna entrapped in fenced transport infrastructure.

**Plate 6.11**: One-way valve design with Perspex® gates that swing in one direction proved an effective solution to provide koalas with a rapid egress route from fenced transport infrastructure to safe habitat. The left image shows the koala *Ian* passing normograde through the valve (left). He was subsequently unable to pass retrograde through the device, despite many attempts during the trial (right image).

The use of ground-based egress devices is preferable to the provision of escape poles because koalas and other fauna will much more commonly attempt to push through, or under fencing during fence-walking, rather than seek routes of exit involving climbing. The efficacy of such devices will be improved by treatments such as wing-walls or other funnelling devices that encourage or direct fauna into the device. Devices with moving parts, such as the egress valve described above must be placed on a substrate and/or maintained such that weeds and other debris do not obstruct or interfere with movement of the valve doors.

### 6.3.6 Koala visibility scores

At each koala field tracking event including capture events, a *koala visibility score* (KVS) was applied based on the ease of sighting the koala, time taken to find the koala after locating its general area using telemetry, and how obscured it was by vegetation. The scoring criteria are outlined in section **6.2.6**, earlier in this chapter. The KVS provided a repeatable index of koala visibility applied across a massive dataset, and provided a metric against which the likelihood of detection during a normal koala survey could be estimated.

The average visibility score for koalas across the entire project and for the duration of the koala monitoring program, comprising scores from 48,329 field tracking events was 2.56, on a scale of 0 - 5. A summary of *koala visibility scores* by polygon is shown in **Table 6.7** and **Figure 6.16** below.

| Polygon | Average KVS | No. of records | % of scores of 0 |
|---|---|---|---|
| Amcor | 2.45 | 17792 | 6.2 |
| Bruce Hwy West | 2.55 | 3894 | 4.0 |
| Mango Hill | 2.35 | 1103 | 7.5 |
| Kinsellas Rd | 2.72 | 839 | 5.5 |
| Rothwell | 2.75 | 1221 | 4.4 |
| Kippa-Ring | 2.7 | 16278 | 1.8 |
| Scouts (translocation site) | 2.54 | 4341 | 1.8 |
| Griffin (translocation site) | 2.41 | 2861 | 2.6 |
| **All polygons** | 2.56 | 48329 | 3.9 |

**Table 6.7**: Average *koala visibility score* by polygon, with number of records and percentage of records in that polygon with a koala visibility score of zero.

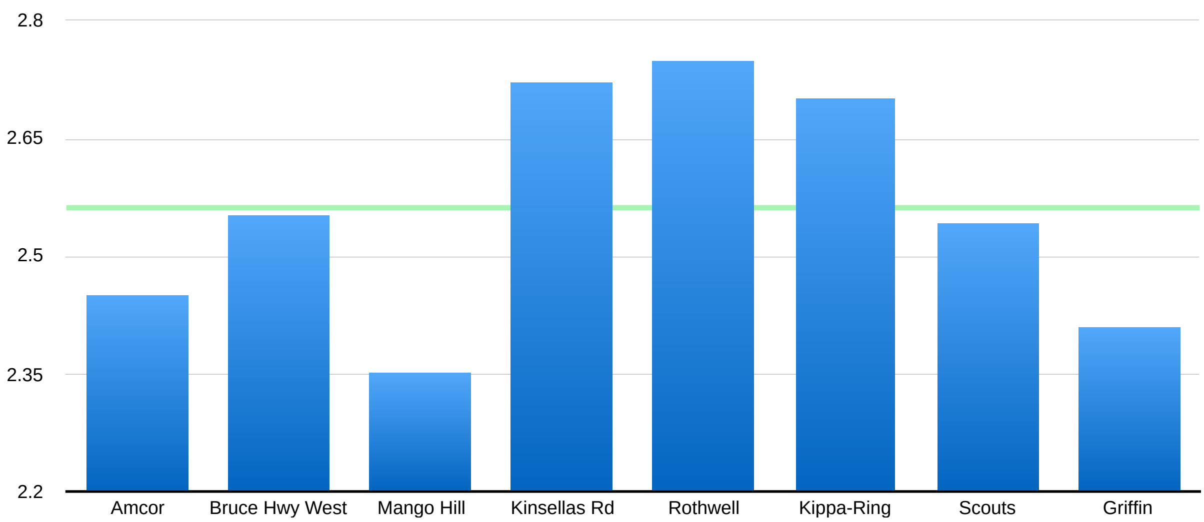



**Figure 6.16**: Histogram showing average koala visibility score by polygon. The higher scores (higher visibility, on average) are consistent with the more open vegetation in those polygons, with lower scores in polygons with areas of dense vegetation and thick understory. The average visibility score across all polygons is indicated by the pale green line.

The average visibility scores of all polygons was between 2 and 3. A score of 2 is given when a koala is difficult to see and only clearly visible from limited angles; when tracking it may take field personnel 10-15 minutes of searching once in the general location of the koala. Generally, the koala is largely obscured by vegetation or understory, but the whole or parts can clearly be seen from limited angles. By comparison, a score of 3 is given when a koala is moderately difficult to see in general, but easy to see from some angles, translating into up to 10 minutes of searching once in the general area of the koala.

The *Mango Hill* and *Amcor* polygons had the highest percentages of “0” scores (7.5% and 6.2% respectively). These are tracking events in which the koala was not able to be sighted. At the Amcor site this is because of the very dense understory vegetation in some parts obscuring the canopy layer, and dense riparian vegetation. At Mango Hill, much of the koala habitat is riparian zone along Freshwater Creek, and contains dense vegetation, which is often partially submerged, limiting access to koalas.

**Plate 6.12**: Near-independent juvenile koala *Bessie* with her mother *Fu* in October 2013 at Kippa-Ring. The koala visibility score average at Kippa-Ring was higher than the overall average due to the relatively open forest vegetation compared with other polygons. A summary of a koala detection rate survey in Kippa-Ring is provided in the following section.

## Koala detection rate survey

Prior to the de-collaring of koalas at the Kippa-Ring and Griffin sites, EVE conducted a koala survey using four *experienced koala ecologists* to determine koala detection rates during transect searching of two polygons containing tagged koalas. The purpose of this survey was to quantify the proportion of koalas likely to be missed during transect searches at sites with differing vegetation types and density.

The survey was conducted in ideal conditions (clear skies) and resulted in 74% (23/31) of tagged koalas being spotted in the survey area at Kippa-Ring, and a 50% (6/12) spotting rate at the Griffin offset site. The variation in these results was significantly influenced by the vegetation density and site characteristics. Specifically, the Kippa-Ring site has relatively open vegetation consisting primarily of large koala habitat trees, with a relatively sparse understory, allowing good visibility of the canopy in most areas. In contrast, the northern sections of the Griffin site were characterised by dense mid-level and understory vegetation, and significant areas of swamp/inundated habitat (see **Plate 6.13**, below).

In dense or swampy areas at the Griffin site only 1 of 6 koalas (17%) was spotted. In comparison, the relatively open and easy terrain in the Kippa-Ring site and southern portion of the Griffin site resulted in detection rates of 74% (23/31) and 83% (5/6) respectively. Collectively, the spotting rate in "easy" habitat was 76% (See **Figures 6.17** and **6.18**, overleaf.)

In comparison, the spotting rate of koalas by a group of four *wildlife spotter/catchers* at the same site at Kippa-Ring, conducting surveys for habitat features and fauna (including koalas) was 23%, with only 7 of 30 tagged koalas spotted during the survey. This survey was also conducted in ideal conditions approximately two weeks after the initial survey. The implications of these findings for koala management are discussed in the following section. The findings are the subject of a scientific paper (in preparation at the time of writing).

**Plate 6.13**: Koala *Jones* (arrow), the only koala spotted of 5 tagged koalas present in dense vegetation at the Griffin site during a *koala detection rate* survey conducted by EVE in November, 2016. This area was particularly challenging due to the dense middle and understory vegetation and the inundated conditions of the ground, but this replicates real-life conditions.

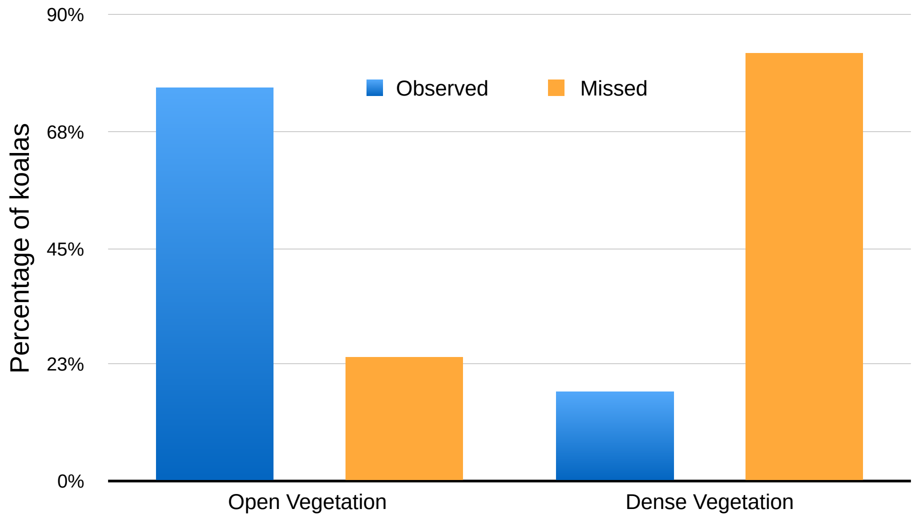



**Figure 6.17**: Comparison of the koala detection rates in vegetation at Kippa-Ring and the Griffin offset site based on density of vegetation and adverse site characteristics (inundation). The blue columns indicate percentage of koalas spotted, vs the orange columns representing percentage of koalas missed. The detection rate is considerably lower in the dense vegetation, with only 17% of koalas spotted. These results were obtained using experienced koala ecologists as the survey team.

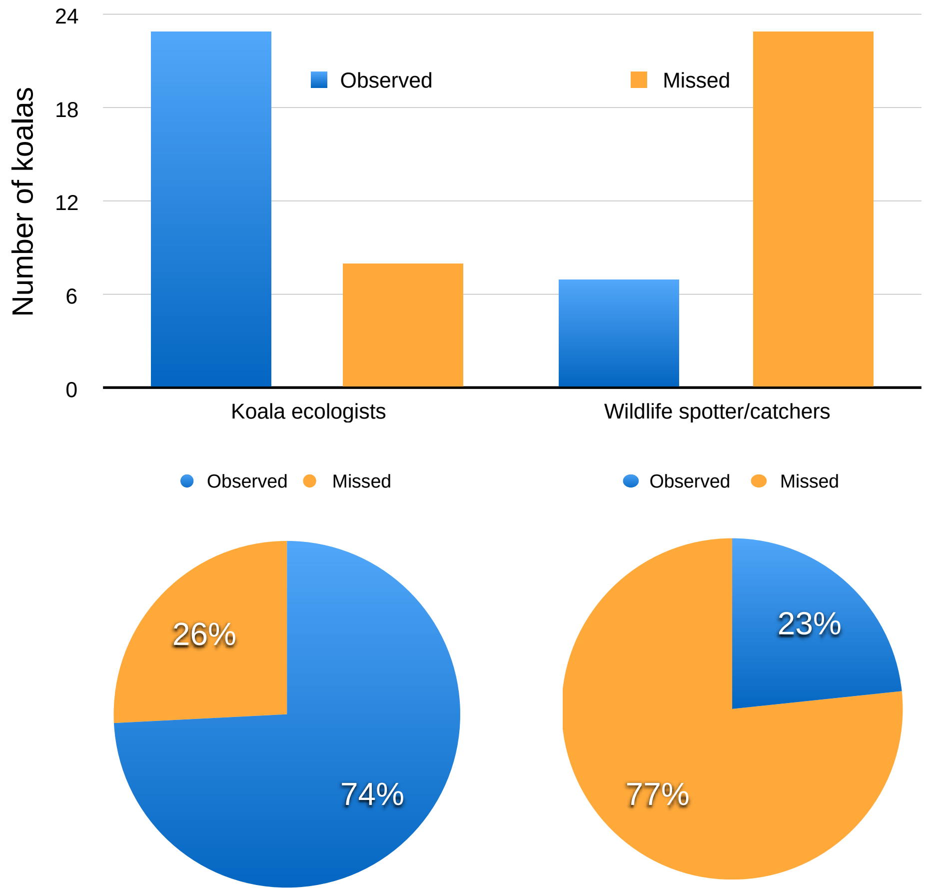



**Figure 6.18**: Bar chart (above) and pie charts (below) showing relative numbers of koalas observed (blue) and missed (orange) by *experienced koala ecologists* (left side) and *wildlife spotter/catchers* (right side) during a transect survey of the Kippa-Ring site. The surveys were conducted on two different days to avoid interference between the groups. The koala ecologists were focussed entirely on spotting koalas, the wildlife spotter/catchers were surveying for habitat features such as nests and tree hollows, as well as koalas, to replicate real-life circumstances. The difference is dramatic - wildlife spotter/catchers spotted less than one quarter of koalas in ideal conditions and open vegetation. This has serious implications for risk to koalas during vegetation clearing if capture and telemetry methods are not used, and it validates the approach taken to protect koalas during construction of the MBR project.

## 6.4 Discussion and recommendations

### 6.4.1 Koala dispersal and responses to clearing and construction

Koalas continued to use habitat around the rail corridor during and after construction of the rail project. Many koalas were only 'partially' displaced by the loss of habitat and were able to continue to occupy some or most of the habitat in their pre-clearing home ranges. The *KTMP* ensured that the risk of harm to, or death of koalas during vegetation clearing was minimised, as the locations of nearly 100% of koalas using the site were known or could be determined at any moment in time. Permeability of the rail corridor significantly decreased during construction of the project, with loss and fragmentation of habitat from rail construction and associated infrastructure such as fencing, access roads and stations. However, koalas were able to utilise purpose-designed fauna and other potential crossing structures beneath the rail corridor to facilitate seasonal movements, ranging and dispersal. Some koalas were considered to be at high risk, or had very limited opportunities to contribute to the viability of the local koala population, due to fragmentation, isolation and/or loss of their home range habitat, and were translocated. These cases are discussed in the following chapter.

Tagged koalas dispersed to new habitat areas in the breeding seasons prior to, during and after construction of the rail line. Dispersal of sub-adult koalas from their natal home range is a common behaviour and is an essential component of regional koala population dynamics, enabling regional genetic exchange and avoiding overcrowding. Social pressures and interactions such as fighting or attempted mating, particularly from larger dominant animals, may trigger dispersal events of sub-adult koalas. The tagging and monitoring of juvenile animals to independence and into adulthood provided valuable insight into the ranging behaviour of koalas as they matured. The monitoring program identified critical habitat linkages, such as the pinch-point at Clontarf that was used by at least 11 dispersing koalas. The information and data derived from the *KTMP* should be used to inform regional koala management strategies and planning to ensure that tenuous but critical linkages are protected and, if possible, strengthened.

Animals that dispersed using continuous tracts of habitat were more successful than those that attempted to cross roads or traverse residential areas. The location of the rail corridor within the regional development footprint limited safe dispersal opportunities for young koalas to the large habitat remnants south of the rail corridor at Kippa-Ring and Petrie. Dispersal of sub-adults coincides with the start of the koala breeding season, which is at the end of June/beginning of July each year. Koalas naively venture into unfamiliar areas and are highly susceptible to vehicle and domestic dog injuries in urban areas. Likewise, dispersing animals are also more at risk of wild dog attack, as they can range many kilometres in one night, necessarily spending long periods on the ground as they traverse the landscape.

It is difficult to determine if some of the dispersal movements observed in the koalas were a direct or indirect consequence of being 'displaced' as a result of vegetation clearing. Clearing was finalised at the end of May 2014, hence most of the corridor had been cleared at least a few months before the start of the koala breeding season. This was fortuitous and may have given koalas the chance to establish new home ranges before breeding season social pressures were in force. More dramatic koala ranging behaviour may have been observed had the clearing occurred in the breeding season. The opportunity to identify and track dispersing animals was greatly increased with the tagging of juvenile animals each year. Some koalas moved short distances, for example, to another part of the same polygon, yet others dispersed many kilometres, and one animal ranged widely without establishing a stable home range for the duration of her monitoring (*Saba*).

Where koala densities are high, there is more likelihood of sub-adult koalas dispersing away from a site. High mortality rates of koalas, particularly from wild dog predation at the Amcor site, kept koala densities at less than the carrying capacity of the habitat, and may have facilitated a greater retention of sub-adults close to their natal/maternal home ranges.

Koalas used a variety of habitat types along the rail corridor and were able to successfully adapt to the loss of part of their home range habitat by vegetation clearing. The routes taken during home range shifts or dispersal events may be determined by habitat and landscape preferences such as habitat quality, tree species composition, ground cover and understory, as well as interactions with other koalas. Dispersal ranging may be as much related to chance as to defined factors, such as those listed above. Some examples follow: Koala *Regina* tended to favour urban park environments, as demonstrated by her choice of home range when there was arguably more 'suitable' intact bushland habitat in her vicinity. Koala *Sara* spent months in two large blue gum trees (*E. tereticornis)* that provided 100% of the food and shelter that she required, despite being surrounded by the recently largely cleared rail corridor, and being adjacent to the noise of Petrie Station.

The Amcor site was the most disturbed habitat along the corridor, with buildings, dams, fill sites, areas of heavy weed infestation and vehicle tracks throughout. However, the infrastructure and operations of the paper mill did not appear to significantly affect the ranging and habitat usage of the resident koalas, who successfully ranged throughout the site and used single trees in noisy and dusty surrounds. The complex vegetation structure with upper, mid and understory were well utilised by koalas. Dense understory vegetation, such as the camphor laurel trees, were often used by koalas during hot weather, presumably providing a cool refuge because of their dense foliage. The Amcor site supports a very healthy population of koalas, which could be a valuable natural asset to future development of the area if it is well considered and protected.

**Plate 6.14**: Koala *Nyx* was a resident of habitat in the *Bruce Hwy West* polygon. She has unusual pigmentation of the eyes seen occasionally in koalas either unilaterally (one-sided) or bilaterally, as in her case. She was a vaccine control animal and was monitored in the *KTMP* for 3 years.

## 6.4.2 Permeability of the completed rail corridor

Permeability of the rail corridor to koala movement significantly declined during the development of the MBR with a drop from 50% to 10% of the koala population using habitat on either side of the rail corridor. During construction, the removal of vegetation and associated temporary (but not koala-proof) fencing created a partial barrier that impeded the movement of most koalas. Very few koalas that regularly traversed the rail corridor continued to do so after removal of the vegetation. Most koalas remained on the same side of the corridor that they were using while clearing occurred.

The permeability of the completed rail corridor to koalas was facilitated by the construction of rail bridges over creek habitat corridors, and installation of drainage culverts and pipes, and fauna culverts. Koala-proof fencing was installed along the length of the rail corridor, with the exception of train stations (for human safety and access reasons), to keep koalas from entering the rail corridor. The potential permeability of the rail corridor varied along its length, with limited opportunities at the Amcor site, but numerous potential crossing structures at the Kippa-Ring end. Some stretches of the rail corridor resulted in the isolation of habitat fragments, prompting the translocation of some koalas. For example, development of the rail project in the Kallangur Station area left three koalas isolated from the remaining small group residing in that area. Future urban planning intent was clearly inconsistent with retention of sufficient habitat for the koalas, so two were translocated, and the third, a female (*Mali*), was left *in situ* because of her age, sterility and persistently stable home range.

Early results of the ***AKHO-CM*** program of works demonstrated the relatively frequent crossing of the rail corridor by koalas, detected using a combination of GPS and camera trap data. Camera data show widespread use of structures beneath the rail corridor as crossing points for a range of wildlife, including koalas, kangaroos, reptiles, echidnas and other mammals. While the permeability of the rail corridor has been permanently reduced by its development, nearly all of the 18 monitored structures were being used to varying degrees by wildlife to cross the rail corridor. Results of the ***AKHO-CM*** and Griffin offset site monitoring programs (*GOSMP*) are presented and discussed in ***Chapter 12 - AKHO-CM and GOSM Programs***.

Safe passage of koalas between habitat along either side of the rail corridor is essential to maintain genetic exchange between sub-populations, and, in turn, maintain the genetic diversity and health of the population. Population viability analysis (PVA) of the MBR koala population clearly demonstrated that the koala population reversed its decline and began a growth trajectory as a result of significant reductions in disease and wild dog mortality rates, and an improvement in fecundity (see ***Chapter 11 - Population viability analysis***). The reduction in permeability of the corridor appears not to significantly affect the results of the PVA, because sufficient movement of koalas is occurring to facilitate genetic exchange between the sub-populations living north and south of the rail corridor

If the benefits of the successful management of the MBR koala population are to be durable, a regional framework for koala management, including local threat mitigation, must be developed by the Department of Environment and Heritage Protection, and implemented by relevant stakeholders, particularly local government. The increase in recruitment resulting from improved fecundity in the MBR-managed population will eventually lead to increased local abundance, and a need for safe routes for dispersal of young koalas. Many urban landscapes with fragmented habitat continue to support koalas, and, with appropriate management these can continue to support thriving and viable koala populations. In addition, urban and peri-urban habitat remnants, particularly riparian vegetation, can be important refugia for koalas from threats such as bushfire and heatwave conditions. Urban koala populations can also be source populations after mass koala die-offs when bushfires affect large habitat remnants. The need for enhancement of urban habitat corridors for koalas provides opportunities for offsets from other projects to be meaningful: For example, by strategic fencing, retrofitting safe crossing structures, and improvement of habitat connectivity and density by planting. Alternative offsetting, as has been well demonstrated on the MBR project, can provide more immediate and tangible benefits for koalas than the usual offsets.

### 6.4.3 Escape poles and development of a fauna egress valve

The geofencing feature in the LX *K-Tracker* tags provided valuable insights into the behaviour of koalas interacting with the rail corridor and potential crossing structures. It was also instrumental in the timely rescue of the koalas *MacGyver* and *Anna*. Both koalas breached the koala fences of transport infrastructure (the MBR corridor and Bruce Highway, respectively), and remote monitoring of *K-Tracker* tag data prompted their timely rescues.

In the case of *MacGyver, K-Tracker* data showed that he passed at least two escape poles while fence-walking during his entrapment in the rail corridor, but did not use them to exit the rail corridor. While koalas have the ability to climb such devices, we suggest that ground-level egress devices may be far more effective. A koala egress valve was designed and tested at the EVE facilities at Toorbul, and showed good effectiveness under trial conditions. The valve was also very effective at preventing retrograde movement of koalas The key features are a lightly-sprung, vertically-hinged Perspex® gates, inside a box tunnel, coupled with a "wing-wall" or funnel section of fencing.

Egress valves were not installed in the MBR corridor fence due to safety concerns with respect to human access to the rail corridor. Further evaluation of the efficacy of the devices is warranted, and probably best achieved by retrofitting devices in areas of known high wildlife presence, or on new projects, with motion-activated cameras installed to monitor use.

### 6.4.4 Koala visibility

Understanding how many koalas are missed when a site is surveyed using typical koala survey methods is important for both koala management and research. In the context of development, detecting koalas is important for environmental impact assessments, as it is during vegetation clearing activities, when undetected koalas are at risk of suffering injury or death.

Data collected during field tracking of tagged koalas included a score based on the visibility of the koala when it was found - the *koala visibility score* (KVS). The score ranged from 5 (koala very obvious) to 0 (koala unable to be seen). The average score for koalas across the project length and duration (derived from over 48,000 records) was 2.56. There were 1885 (3.9%) tracking events in which a tracked koala could not be seen, even though its location was definitively known by radio-telemetry tracking, resulting in a KVS of 0.

While the KVS has not been statistically evaluated with respect to its correlation with likelihood of detection during a transect koala survey (without the aid of telemetry) it nevertheless provides a subjective indication of the relative difficulty of spotting a koala. Based on the average KVS throughout the *KTMP* of 2.56, koalas are generally difficult to see (see criteria and meaning of scores in section **6.2.6**) , and therefore as likely (or more than likely) to be missed as not, in a standard koala survey. This supports the decision by the MBR project to protect koalas using telemetry devices and daily tracking, rather than relying solely on wildlife spotter/catchers working at the vegetation clearing front.

The results of the koala detection rate survey clearly demonstrate the risk associated with relying on wildlife spotter/catchers as the primary method of protecting koalas during vegetation clearing. At the site with one of the highest average *koala visibility scores* (Kippa-Ring), the spotting rate of koalas by wildlife spotter/catchers, working in ideal conditions was only 23%. In contrast, at the same site, experienced koala ecologists spotted 74% of koalas. Irrespective of the competence of the koala spotters, the risk of mortality or serious injury of the undetected koalas during vegetation clearing, should strongly compel the use of more effective measures to protect koalas. In the case of the MBR project, the implementation of the *KTMP* was the crucial measure that ensured zero koala mortality attributable to vegetation clearing, and that result is a sound validation of the methodological approach. Further analysis of koala detection probability, based on the KVS, is contained in ***Chapter 11 - Population viability analysis.***

**Plate 6.15**: Koala *Graham* at the Amcor site in June 2013. This site had very dense vegetation with low koala detection probability in some areas. The *KTMP* was a critical component of koala protection measures during construction, allowing tagged koalas to be located at any time, and it also guided adaptive management responses to key threats.

### 6.4.5 Summary

Although the MBR project was successful in achieving all of its key objectives with regard to koala protection and regulatory compliance, it is important to acknowledge the landscape and legislative context in which the project occurred. Surrounding areas are heavily urbanised and key threats to koala population viability are generally poorly managed. From a legislative context, the MBR project met its obligations admirably, as well as satisfying community expectations, but did so in a void of effective broader strategic planning with respect to regional koala conservation. Hence the benefits to the local koala population, although profound and meaningful in the short-term, may not be durable unless State regulatory authorities urgently develop and implement a meaningful regional strategy for koala protection and conservation.

Strategic planning to identify current and future koala habitat linkages needs to occur in a timely manner, particularly with large scale/regional projects that can have widespread and long lasting consequences for increasingly vulnerable koala populations. Offsets and other measures to compensate for habitat loss delivered at a local scale should be prioritised over offsets somewhere else within the region, unless guided by a strong regional koala conservation strategy. Compensatory measures implemented by the MBR project in the form of the ***AKHO-CM*** program provided tangible benefits to the local koala population directly or indirectly affected by construction of the rail line. Many offsets of koala habitat are provided where larger areas of land can be purchased at a relatively cheaper price than land around a project area. These areas are commonly poorer quality koala habitat sustaining low-density koala populations, and the benefits for long-term koala conservation are questionable. Hence, the current offsetting framework should be reviewed with a focus on providing real, tangible and measurable benefits for affected species, rather than the existing crude and generally inadequate requirements for replacing trees.

**Plate 6.15**: *Rhonda* and her unnamed joey at Kippa-Ring, shortly after their release following her first veterinary examination, in December 2013. Her next joey was *Aerona.*

## 6.4.6 Recommendations

With respect to the management of koalas around transport infrastructure development, we make the following recommendations:

1. That currently, the definitive method for protection of koalas is through capture and radio or remote telemetry of all at-risk animals. This facilitates protection during vegetation clearing as well as a range of other objectives relating to regulatory compliance, community expectations and adaptive management.

2. That urban habitat remnants are recognised as of very high value to local and regional koala conservation, particularly where they connect otherwise fragmented habitats, and through alternative offsets are appropriately preserved, enhanced and installed with appropriate mitigation devices to protect koalas from proximate threats.

3. That the generally low visibility of koalas in habitats typical of SEQ is recognised with regard to the risk of relying solely on wildlife spotter/catchers as the method of detection and protection. This approach is likely to lead to an unacceptable level of mortality and injury to koalas that are not detected, which may exceed 80%.

4. That further development of mitigation devices, such as fauna egress valves, be implemented on applicable future transport infrastructure projects and/or as a retrofit program to reduce fauna mortality on fenced transport infrastructure. EVE has given permission for free use of the EVE koala egress valve by TMR throughout Queensland.

5. That the importance of creating and maintaining permeability of transport infrastructure to koalas and other fauna using safe crossing structures and fencing is recognised as critical to population health and genetic resilience; importantly, too, that such structures can be as simple (and as inexpensive) as drainage culverts.

# CHAPTER 7: KOALA TRANSLOCATION


## Key points

- Translocation is an important and valuable tool for management of at-risk and displaced koalas: *KTrans* program
- Needs careful consideration and assessment of individual and habitat factors
- Comprehensive and scientifically robust assessment criteria developed and applied
- Translocated koala survived, thrived and reproduced well - no impact of translocation
- Resident koalas showed no adverse response
- Significant benefit to Griffin offset site from translocation program
- Recommend changes to regulatory framework and policy on koala translocation based on large body of data and information derived from *KTrans*

# Chapter 7: Koala translocation

## 7.1 Background

The translocation of koalas as a management tool has been used with varying degrees of success. Typically the southern states of Victoria and South Australia translocate koalas to address over-abundance issues, while in Queensland, koalas have been translocated as a strategy to manage the impacts of development-related habitat loss and fragmentation. Multiple studies conducted over the last two decades on translocated koalas in Queensland (using telemetric monitoring) have shown that koalas can survive, thrive and breed after translocation when release sites are chosen carefully. Regardless, translocation should be viewed as a management option of last resort. It should be considered when the present threat to koalas living in their native habitat is severe or extreme, and their likelihood of surviving, and/or contributing meaningfully to the sustainability of the wider koala population is low.

Queensland State legislation defines translocation as the release of a koala outside prescribed natural habitat, or more than five kilometres from its point of origin. The translocation of koalas is only permitted when conducted under a scientific purposes permit (SPP) or authorised by EHP. In contrast, a koala released away from its point of origin but within five kilometres, is considered a *relocation*. Permits authorising the translocation of individual koalas, usually after rehabilitation for illness or injury, may be granted due to the lack of suitable habitat at the point of rescue. At present, there is no policy or framework permitting the translocation of at-risk koalas displaced by development.

When a translocation program involves a larger numbers of koalas, the program must consider both short and long-term implications for the viability of donor (where koalas will be removed from) and recipient site (where koalas will be translocated to) koala populations, as well as individual animal welfare. Also, some insight into how threat profiles and population security might change over time (for example, as land use changes) is important when longer-term population viability is considered. As such, the translocation recipient site must offer better prospects for survival and reproductive contribution than the donor site. Therefore, an appropriate level of investigation of both sites (translocation recipient and donor sites) must be conducted to achieve a sufficient level of knowledge to make this judgment. If the translocation recipient site is chosen well it will provide suitable habitat, sufficient carrying capacity, and a reduced threat profile to enhance the survival of translocated koalas, and have a minimal effect on the receiving site's resident population. Very few, if any, koala translocation projects have monitored the resident population of koalas at the recipient site prior to translocation.

**Plate 7.2**: Koala *Susan* was translocated to the Griffin offset site in 2014. She reproduced and thrived at the site, and was de-collared in December, 2016. Her original home range, and most habitat in the area was completely cleared for urban development, with very limited opportunities for safe movement to remnant habitat. Her circumstances strongly validated the need for translocation of some MBR animals, even though the impact of the rail project was minimal in the context of surrounding development pressures.

A relatively high density koala population along the MBR corridor was apparent during the early stages of the project; much larger than first anticipated. Habitat quality along the rail corridor varied from relatively intact bushland to highly fragmented and degraded vegetation. It was clear that some koalas would be more severely impacted by habitat loss and fragmentation than others, and that some sites might be close to the sustainable ecological carrying capacity considering the high densities of koalas. Proposed transport-orientated residential development adjacent to the rail line, a planned road bypass and other development in the region would further compound the loss and fragmentation of habitat in the short to medium term. To be able to effectively manage the welfare of koalas for MBR project, and to manage the viability of the population in the medium term, an option to translocate koalas was necessary. This allowed for the planned translocation of individuals from areas assessed as low survival potential for koalas in the medium term, or the reactive translocation of individuals that were in immediate danger. The large number of koalas monitored in the project would enable a scientific comparison of *in situ* and *ex situ* management options for wild koalas impacted by habitat loss on the MBR project.

The aim of the translocation program, referred to as the *KTranslocation* or *KTrans* program was to collect and analyse data on the movements, survival, health, fecundity and behaviour of koalas in four different groups:

- Koalas left *in situ* in remnant habitat along the rail corridor in high impact areas;
- Koalas left *in situ* in remnant habitat near the rail corridor, but away from direct rail impacts;
- Koalas translocated to new habitat and monitored *ex situ*;
- Koalas already living in the recipient habitat, a first for koala translocation projects.

**Plate 7.3**: Release of the first translocated koalas to the 65ha TMR-owned and revegetated koala habitat offset site at Griffin in September 2014 attracted political and media attention and resulted in positive publicity for the project.

## 7.2 Methods

### 7.2.1 Legislative requirements and definitions

This work was conducted under the Department of Agriculture and Fisheries Animal Ethics Committee permit CA2013/09/719 and the Department of Environment and Heritage Protection Scientific Purposes Permits (SPP) WISP 13661313 and WITK 14173714. According to the *Nature Conservation Act, 1992* and associated regulatory framework, the translocation of koalas is defined as the release of animals outside of their natural prescribed habitat, or greater than 5 km from their point of origin. Some of the translocated koalas did not meet this criterion, having been translocated within 5km of their point of origin. Regardless, they were considered translocated koalas for the purposes of the program if they were moved to one or other of the translocation recipient sites.

### 7.2.2 Translocation site selection

A desktop analysis of koala habitat in the Moreton Bay region shortlisted nine sites that had characteristics that were considered suitable as potential receive sites for the translocation of koalas impacted by the MBR project. Field assessments were conducted at seven of these sites between December 2013 and February 2014 and included:

1. Estimation of koala density using line transect surveys by an experienced koala field team;
2. Estimation of disease prevalence using the 3-5X rule developed by Loader, 2010;
3. Assessment of koala demographic makeup without the capture of koalas;
4. Assessment to confirm vegetation types and habitat suitability;
5. Assessment of any logistical constraints at the site, such as accessibility for intensive field work and mobile phone coverage, to enable use of the LX *K-Tracker* telemetry system.

Sites at the Murrenbong Scouts campsite 'Scouts', Kurwongbah and the TMR offset site 'Griffin' (**Figure 7.1**, overleaf), at Griffin were chosen after assessing the sites according to the criteria outlined in **Table 7.1**, below.

| Criterion | Consideration |
|---|---|
| **Known koala presence** | Essential for scientific purpose to enable interactions between resident and translocated koalas to be observed. Desirable to demonstrate suitability of habitat. |
| **Distance threshold** | More than a few kilometres from the subject koala's original home range to reduce home-range fidelity response in translocated koalas. |
| **Habitat quality** | Similar habitat and vegetation/Regional Ecosystem (RE) mapping desirable to improve likelihood of successful adaptation |
| **Land tenure** | Protected land in a non-urban/low threat area, ideally in public ownership, conservation tenure or other secure tenure |
| **Land management** | Actively managed to minimise threats to koala survival and population viability, such as fire, wild dog control |
| **Habitat occupancy** | Koala abundance is below the habitat carrying capacity therefore able to receive additional animals - essential, but subjective assessment by experts |
| **Genetics/disease** | Long-distance translocation undesirable due to inappropriate genetic mixing and disease/pathogen exposure in translocated or resident koalas. Long-distance criterion considered to be beyond reasonable natural boundaries or barriers to movement, such as significant mountain ranges/other geological feature, major rivers. |

**Table 7.1**: Assessment criteria for potential translocation recipient sites.

The key characteristics of these two sites that made them suitable for the receiving of koalas are described in *Appendix 11 - Key characteristics of translocation sites*. In summary, the Scouts site is located within a large tract of contiguous bushland in Kurwongbah, and is approximately 4.5 km from its south-eastern site boundary to the closest part of the MBR corridor at Petrie. The site was managed to protect the natural values of the area with a conservation focus. There were few impediments to the movement of koalas within the site and to adjoining vegetated properties. One local road, with minimal night-time traffic bordered the site and no development was proposed in the vicinity in the short and medium term. Vegetation communities comprised R.E. 12.11.18/12.11.19 with *Eucalyptus moluccana* open-forest and 12.11.18a with *Eucalyptus moluccana*, *Eucalyptus tereticornis* and *Lophostemon confertus* open-forest. There was good floristic diversity on the site, which included 21 koala food tree species.

The Griffin site is an approximately 65ha site that was replanted with 24,800 trees in partial fulfilment of offset obligations for the MBR project. The site is bordered by the Pine River to the south and the Bruce Highway to the west, with koala proof fencing on its western boundary adjacent to the Bruce Highway. It is approximately 3.5 km from its northern site boundary to the closest point of the MBR corridor at Mango Hill. The site supported substantial stands of remnant vegetation including *E. tereticornis* on alluvial plains in association with *Melaleuca quinquenervia*, *E. siderophloia* and *Corymbia intermedia*, comprising regional ecosystems 12.3.6, 12.3.11 and 12.3.5. The revegetated areas included a good mix of koala habitat tree species that were locally common, occurring naturally on the site and/or within the region.

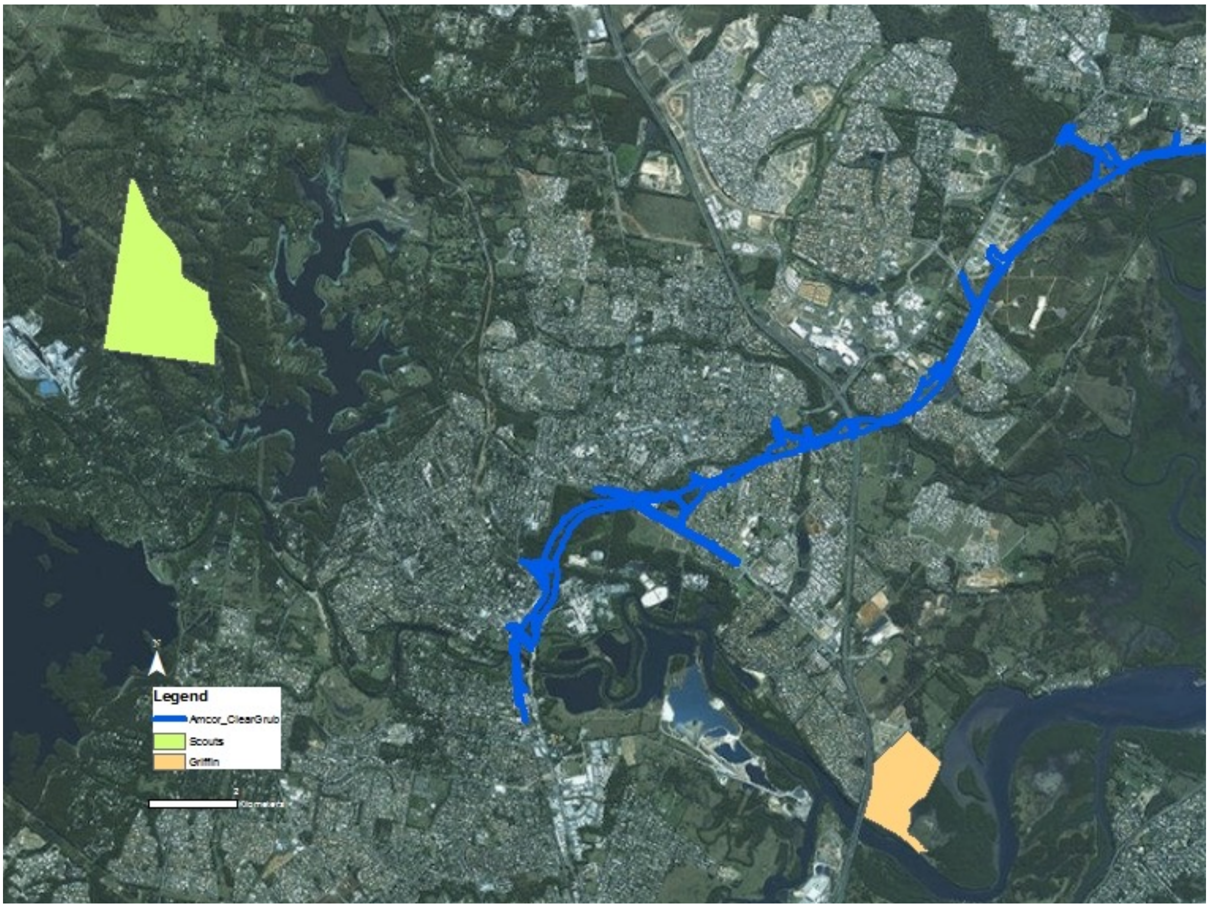



**Figure 7.1** The location of the two translocation receive sites in relation to the MBR corridor. The Griffin site (orange polygon) was within 3.5 km at its closest point to the rail corridor, and the Scouts site (lime green polygon) was within 4.5 km at its closest point to the rail corridor at Petrie.

### 7.2.3 Koala candidates for translocation

Prior to vegetation clearing commencement, each koala was assessed against comprehensive criteria to determine its suitability for translocation (*Appendix 7 - Assessment process and recommendations for translocation of koalas from the Moreton Bay Rail project's Koala Tagging and Monitoring Program sites.*). These criteria took into account habitat connectivity, patch size, individual health status and demographic group, presence and management of threats (wild dogs, roads etc) and the short to medium-term planning intent for the koala's home range habitat.

In accordance with the SPP, a koala was selected as a candidate for translocation when:

1. Its current home range habitat was likely to be significantly destroyed during operational works for the MBR project, or other approved or imminent developments, and it was likely to be displaced into areas of high risk or unsustainable habitat areas (see **Figure 7.2**, overleaf, for an example - koala *Greg*);

2. Its current home range habitat fragment was likely to be effectively isolated by an impassable barrier, or a barrier that presented a very significant risk to life (such as a major arterial road), and the habitat fragment was less than 10ha in total area (see **Figure 7.3**, overleaf, for an example - koala *Rhubarb*);

3. The koala was a dispersing-age juvenile or subadult koala (12 mths - 3 years age), its habitat fragment was either:

    a. considered to be at or to have exceeded its sustainable carrying capacity for koalas; and/or

    b. was a small remnant (<10ha of bushland habitat) from which safe pathways of emigration were very limited and clearing for the MBR project would have had some impact. (For example: koalas living in remnant habitat between Kinsellas Rd East, Anzac Avenue and Halpine Drive);

4. The prospects for the koala being reasonably able to survive and contribute to the local or regional koala population for the foreseeable future was poor, (due to present threats, isolation, and/or future development intent) and/or;

5. The remnant koala habitat adjacent to the impact area was larger than 10ha, and/or had reasonable connectivity with other habitat remnants, but was considered to be at, near, or have exceeded its sustainable koala carrying capacity, nominally at 0.5 koalas/ha.

A detailed assessment process (consistent with the five points above) was also applied prior to final recommendations of koalas for translocation. A detailed description of this process and the results are contained in *Appendix 7 - Assessment process and recommendations for translocation of koalas from the Moreton Bay Rail project's Koala Tagging and Monitoring Program sites.*


**Figure 7.2**: Koala *Greg* was displaced by the clearing of his home range for a large residential development at Lawnton. He was using a small strip of vegetation to the east of Gympie Road, and occasionally crossed the road to use isolated groups of trees to the west. *Greg* was hit by a car (orange pin on Gympie Rd), sustaining soft tissue trauma and a fractured fibula. He was translocated to the Scouts site after treatment. Blue lines show the last 10 days of *K-Tracker* data.


**Figure 7.3**: Koala *Rhubarb* was left isolated in a small patch of habitat once the rail corridor was cleared. Planning for the area south of the rail corridor indicated that this area was intended for high density transport-orientated development. Hence, *Rhubarb* satisfied translocation assessment criteria and was translocated to the Griffin site. Blue lines show the last 10 days of movements based on her LX *K-tracker* data and the orange pin was her location on 28 July, 2014.

### 7.2.4 Translocation methods

Resident koalas at the Scouts and Griffin sites were monitored for a minimum of 3 months before koalas were translocated to the two recipient sites. This provided an opportunity to assess the health and threats to koala survival at the recipient sites and mitigate threats if necessary before the translocation of koalas.

Resident koalas were caught at the Griffin site in late March and early April 2014. The Griffin site koalas were relatively young, with the high population turnover likely due to wild dog predation, which was detected at a concerning level during monitoring of resident koalas during the pre-translocation period. The MBR wild dog control program was expanded to include this site to reduce or eliminate the wild dog threat prior to the release of translocated koalas. Koala translocations commenced at the Griffin site at the end of September 2014 and continued until the end of June 2015.

Capture of resident koalas at the Scouts site occurred from mid to late June 2014. The Scouts site supported an older population of koalas, and many of these animals were diseased. A significant proportion of the resident koala population required veterinary treatment before koalas were translocated or relocated to the site. Koala translocations to the Scouts site commenced on 5 September, 2014 and were completed on 19 February, 2015.

Prior to translocation, each koala was subjected to a standardised and comprehensive veterinary examination performed under general anaesthesia to determine its suitability for translocation. Any koala that showed signs of significant clinical illness was treated prior to translocation. Koalas were monitored for a minimum of 12 months from the date of the last translocation to the site, hence most koalas were monitored for more than 12 months post-translocation. At each monitoring event, data were collected as described previously. A koala's monitoring schedule was dependent on the tracking devices it was wearing and its circumstances – new recruits to the program, recently translocated koalas and juveniles were monitored more frequently. At a minimum, a translocated koala was tracked the day after release, every third or fourth day for the next two weeks, and fortnightly thereafter (**Table 7.2**, below). Regardless of the type of tag fitted, a koala was tracked as often as twice daily if there were health or welfare concerns.

| Koala status | Monitoring device | Tracking schedule | | | |
|---|---|---|---|---|---|
| | | 1st week | 2nd week | 3rd week | 4th week> |
| New to program resident - adult | VHF collar | Daily | Every second day | Twice per week* | Twice per week |
| New to program resident - dependent joey | VHF collar | Twice per week (first tracking event to be day after release) | Twice per week | Twice per week | Twice per week |
| New to program resident - adult | Biotelemetry collar | Twice per week | - | - | Fortnightly |
| Translocated | VHF collar | Daily | Every second day | Twice per week | Twice per week |
| Translocated | Biotelemetry collar | Twice per week (first tracking event to be day after release) | Twice per week | Twice per week | Fortnightly |

**Table 7.2**: Monitoring schedules for resident koalas entering the *KTrans* program and those translocated to recipient sites. Schedules are based on the circumstances of the koala and the tags that the animal was wearing. Schedules were altered as necessary to ensure that health or welfare concerns were addressed, always resulting in more frequent monitoring. *Note: *twice per week* required koalas to be tracked no later than 4 days after the previous tracking event; for example, on Mondays and Thursdays, where the interval between tracking events is either 3 days or 4 days.

Koalas were given 6-monthly health checks, and more frequent tag checks in growing animals. At the completion of the monitoring period, each koala was recaptured, the monitoring devices removed, and a comprehensive veterinary examination conducted. The koala was then released at its point of capture at which time it was removed from the program. Koalas that were detected with signs of illness or injury during monitoring were recaptured and treated as appropriate. Koalas that died during the program were subjected to a necropsy examination to determine the cause of death.

### Home range estimates

The *adehabitatHR* package in *R* was used to calculate the 95% Kernel Density Estimates (KDE) for each koala. This home range estimation was used in preference to the Minimum Convex Polygon (MCP) method to better reflect the area in which a koala spent the majority (95%) of its time. The MCP method calculates the total area that an animal might use, drawing a polygon to incorporate all GPS fixes derived for that individual, some of which may be brief exploratory movements and not part of their normal home range.

**Plate 7.4**: Koala *Hot Lips* and her joey *Honey Boo Boo. Hot Lips* was hand-reared after her mother *Cate* was killed by a wild dog at the Amcor site in October 2013. She was successfully hand-reared and released at the Scouts translocation site in June 2014.

## 7.3 Results

Twenty-eight koalas were translocated from habitat around the MBR corridor to the Scouts (n = 12) or Griffin (n = 16) recipient sites. The majority of koalas quickly established home ranges, and most remained on site and reproduced (females). At the time of de-collaring, the two sites supported equal or greater numbers of koalas than at the start of the program. The populations were assumed to be more viable with a reduced threat profile as a consequence of the management of wild dogs and disease, although a PVA was not conducted for those sites individually.

### 7.3.1 Site koala density

The koala density estimate at the Scouts site at completion of the program was equal to that at the start of the program with approximately 0.16 koalas per hectare (**Table 7.3**, below). Twelve koalas were added to the site, replacing the 7 koalas that were euthanased at their first veterinary examination due to severity of disease. Twenty-four Scouts koalas were tagged and monitored; however, there were frequent sightings of untagged animals at the site. As such, the density of 0.2 koalas per hectare is a conservative estimate and the number of tagged koalas on site is likely to represent around 75% of the resident population. The density of 0.17 koalas/ha at the Griffin site was highly accurate as every resident koala was tagged and monitored. It was 15 months from the start of the monitoring before an untagged koala was sighted at Griffin.

| Population parameters | Griffin (65 ha site) | | Scouts (157 ha site) | |
|---|---|---|---|---|
| | Project start | Project finish | Project start | Project finish |
| **Site density (koalas / ha)** | 0.17 k/ha (residents) | 0.21 (residents and translocated) | 0.16 k/ha (residents) | 0.16 k/ha (residents and translocated) |
| **No. of koalas** | 11 | 20 (5 off site) | 25 | 29 (3 off site) |
| Resident | 10 | 9 | 24 (+7 euthanased) | 21 |
| Trans/Relocated | 1 (relocated) | 11 | 1 (relocated) | 8 |
| **Healthy** | 82% (9/11) | 95% (19/20) | 48% (12/25) | 93% (27/29) |
| Resident | 8 | 8 | 11 | 20 |
| Trans/Relocated | 1 | 11 | 1 | 7 |
| **Annual mortality of monitored koalas** | 45% (5/11) | 26% (7/27) | 25% (8/32) | 25% (10/40) |
| Resident | 4 | 3 | 1 | 6 |
| Trans/Relocated | 1 | 4 | 0 | 4 |
| **Breeding** | 75% (6/8) | 55% (5/9 breeding age) 71% (5/7 of breeding capacity (not inc. OHE)) | 31% (5/16) | 44% (8/18 breeding age) 73% (8/11 breeding capacity (not inc. OHE)) |
| Resident | 6 | 1 | 5 | 4 |
| Trans/Relocated | N/A | 4 | N/A (not of breeding age) | 4 |
| **Average age (years)** | 3 (range 2 to 5) | 4.2 | 5.1 (range 2 to 13) | 4.2 |

**Table 7.3:** Summary of the status of the koala population at the start of the monitoring and at program completion with residents and translocated koalas. Scouts koala status was assessed when all koalas were de-collared in March 2016, Griffin koala status was at the end of August 2016, as these koalas continued to be monitored for the *GOSM* program. Mortality and breeding at "Project start" were calculated for the initial monitoring period for residents before koalas were translocated to the site, and for "Project finish" for the 12 months prior to program completion.

### 7.3.2 Population age structure

The age structures of the Scouts and Griffin populations contrasted noticeably (**Figure 7.4**, below). The Griffin koalas represented a very young population with an average age of 3 years (range 2 to 5 years) prior to the commencement of translocations. At project completion, the average age of the Griffin population was 4.2 years. In contrast, the Scouts site supported an older population of koalas prior to translocation, with an average age of 5.1 years (range of 2 to 13 years). At the completion of the project, the average age of koalas at Scouts was on par with the Griffin koalas at 4.2 years of age. More than half (54%) of the Griffin koalas were 3 years old, and while Griffin had no koalas older than 5 years, nearly 50% of the Scouts koala population was 6 years old or older. In comparison, the average age of the MBR koala population in August 2016 was 5 years, with a range of 2 to 13 years. The average age of koalas translocated to Scouts was 2.4 years (range 1 to 5 years), and the average age of koalas translocated to Griffin was 2.9 years (range 1 to 7 years). Many (58%) of the translocated koalas were approximately 1.5 year-old sub-adults, the majority of which had been in care.

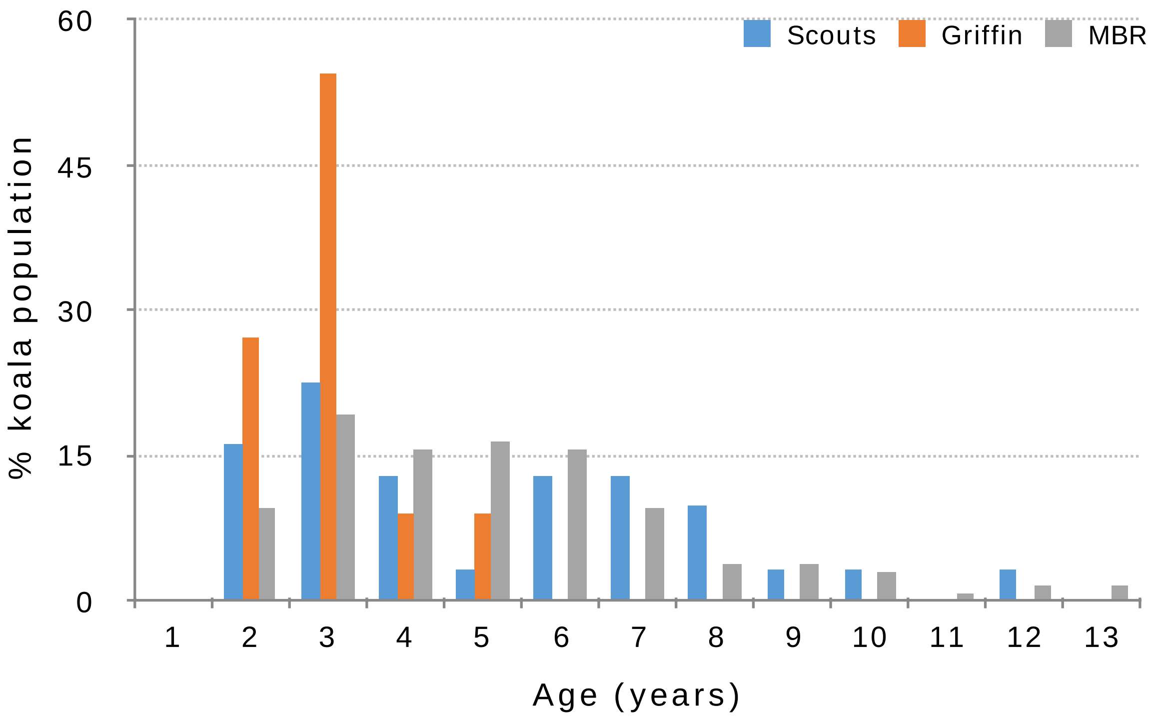



**Figure 7.4:** Age structure of the Griffin and Scouts resident koala populations in comparison to the MBR koalas. The average age of the resident Griffin koalas was 3 years, with over half of the koalas of this age. In comparison, the average age of resident Scouts koalas was 5 years, and while Griffin had no koalas older than 5 years, nearly 50% of the Scouts koala population was 6 years old or greater.

## 7.3.3 Survival and mortality

### Griffin site

Half (5) of the resident koalas monitored at the Griffin site died before koalas were translocated to the site in late September 2014. One of these animals was a rehabilitated and recently released 'relocated' koala. All deaths were the result of wild dog predation. Two wild dogs were removed from the site, and one was still observed using the site at the time of the translocation of the first three koalas. One of the translocated koalas was killed by a wild dog two weeks after release and during this time another two of the residents were also predated. After that, there was no further wild dog predation of koalas at the site until two translocated koalas were killed in March 2016, 9 months after being translocated to the site; both lived in the same part of the site. Additionally, one translocated koala at the Griffin site was euthanased because of a diagnosis of leukaemia five months after translocation (*One-Tee*), and one resident was euthanased after poor recovery from treatment of reproductive tract disease (koala *Kelly*).

### Scouts site

Seven resident Scouts koalas were euthanased at their first veterinary examination due to the severity of *Chlamydia*-related disease. Wild dogs were known to use the site, however there was no predation recorded until one resident (koala *Viv*) and one translocated koala (koala *Poppy*), both ranging in the same area of the site were killed within 8 days of each other in December 2014. Disease was the primary cause of mortality, accounting for nearly two-thirds (64%) of deaths (7 of 11; 2 translocated, 5 resident). One resident koala was euthanased for traumatic injuries in combination with advanced age. The first koala to be translocated to the site was found dead in a creek 15 months after being translocated, but a definitive cause of death could not be determined.

### Mortality compared with the MBR population

Resident koalas experienced a higher mortality rate than translocated koalas during the monitoring period, although the difference was not significant. Disease and wild dogs were the predominant causes of death. Overall, wild dog predation and suspected predation accounted for half (55%) of the deaths, primarily at Griffin. Chlamydiosis and other disease-related deaths accounted for 38% of the deaths, primarily at Scouts, with one death each (4%) due to trauma and unknown cause. When compared with deaths in the MBR koala population over the same monitoring period, the Griffin and Scouts koala populations had lower annualised mortality rates (**Table 7.4**, overleaf). The MBR population lost an *additional* 2.4% annually when compared with the mortality rate at Scouts, and a further 3.4% each year compared with the Griffin koala population.

**Plate 7.5**: Amcor koala *Gav* at the Amcor site in May 2013 after his first vet check. He dropped his tags and was never found again, possibly the victim of wild dog predation - a factor contributing to the excessive and unsustainable mortality rate of the MBR koalas in the first two years of the *KTMP*.

| Site / polygon | Annualised mortality rate (%) | |
|---|---|---|
| Scouts | | 35.3 |
| Griffin | | 29.0 |
| MBR *KTMP* | Scouts monitoring period | 37.7 |
| | Griffin monitoring period | 32.4 |

**Table 7.4**: Comparison of annualised mortality rate at the Scouts and Griffin sites (top two rows), and the annualised mortality rate of the main MBR *KTMP* koala population during the Scouts monitoring period (third row) and the Griffin monitoring period (fourth row). The annualised mortality rate was the highest at the MBR site during the Scouts monitoring period (37.7%), because this occurred during the main periods of activity of the "Amcor Dog". The Scouts mortality was high, due to high levels of euthanasia of severely *Chlamydia*-affected koalas in the resident population. All sites showed substantial improvement in annualised mortality rates as chlamydial disease and wild dogs were controlled. Mortality rates at the translocation sites were lower than the MBR population during the applicable periods of monitoring, although the differences are probably not statistically significant.

The proportionate causes of death of koalas at the translocation sites (including both resident and translocated koalas) are shown in **Figure 7.5**, below.

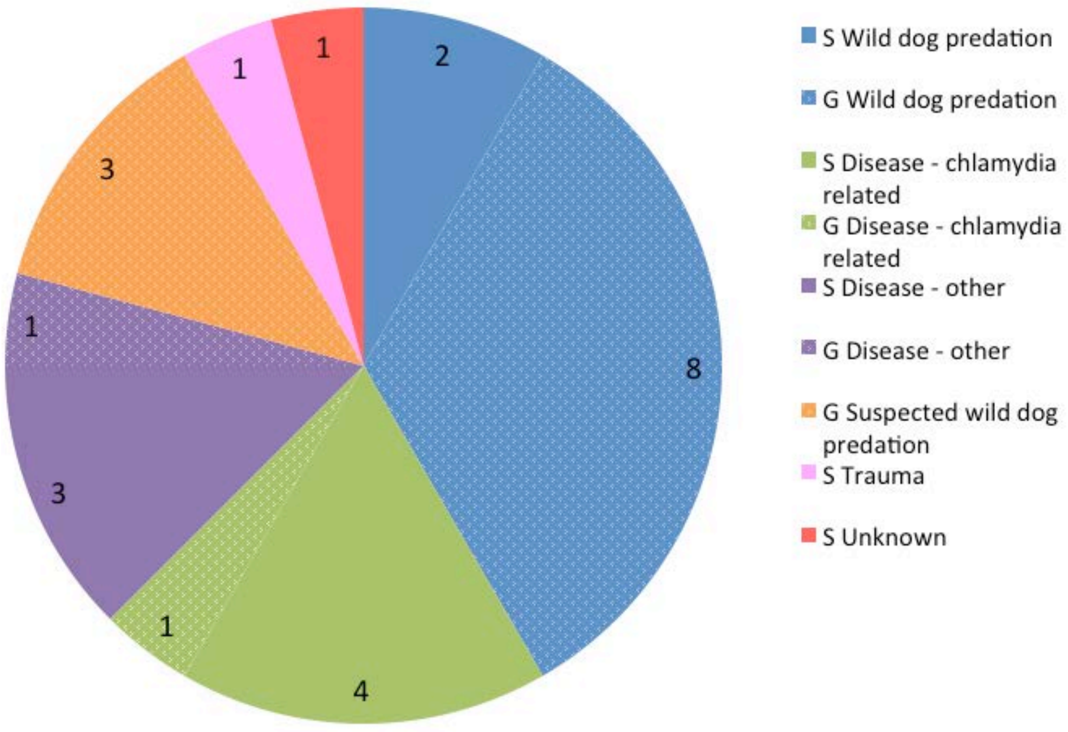



**Figure 7.5:** Causes of mortality of koalas monitored at the Scouts (S) (plain colours) and Griffin (G) (stippled colours) translocation sites. Wild dog predation and suspected wild dog predation accounted for 13 deaths - the majority at the Griffin site. Chlamydiosis and other disease-related mortality was highest at Scouts (n=7).

### 7.3.4 Ranging behaviour of translocated koalas

Translocated koalas showed no behavioural site fidelity; that is, they did not attempt to return to their former home ranges after translocation or relocation. Most koalas settled quickly at the recipient sites or in adjacent habitat and established home ranges within three months. Translocated koalas at Griffin ranged closer to their point of release, with the core of their home range, on average, 182m (range 57m to 752m) from their point of release, and most (81%) home ranges included their release area (**Figure 7.6**, below). Translocated koalas at the Scouts site established home ranges, on average, 1207m (range 10m to 7700m) from their release point. The home ranges of only three of the Scouts koalas included the area where they were released. The large average distance from point of release to core home range for Scout koalas is skewed by one koala (*Midori*) that dispersed 7700m from her release point.

At the end of three months, over half of the koalas (57%) had established a home range within 200m of their translocation or relocation release point, the majority (75%) were ranging within 500m of their release point, and all but two translocated koalas were still ranging within 1300m of their release locations (**Figure 7.6**, below).

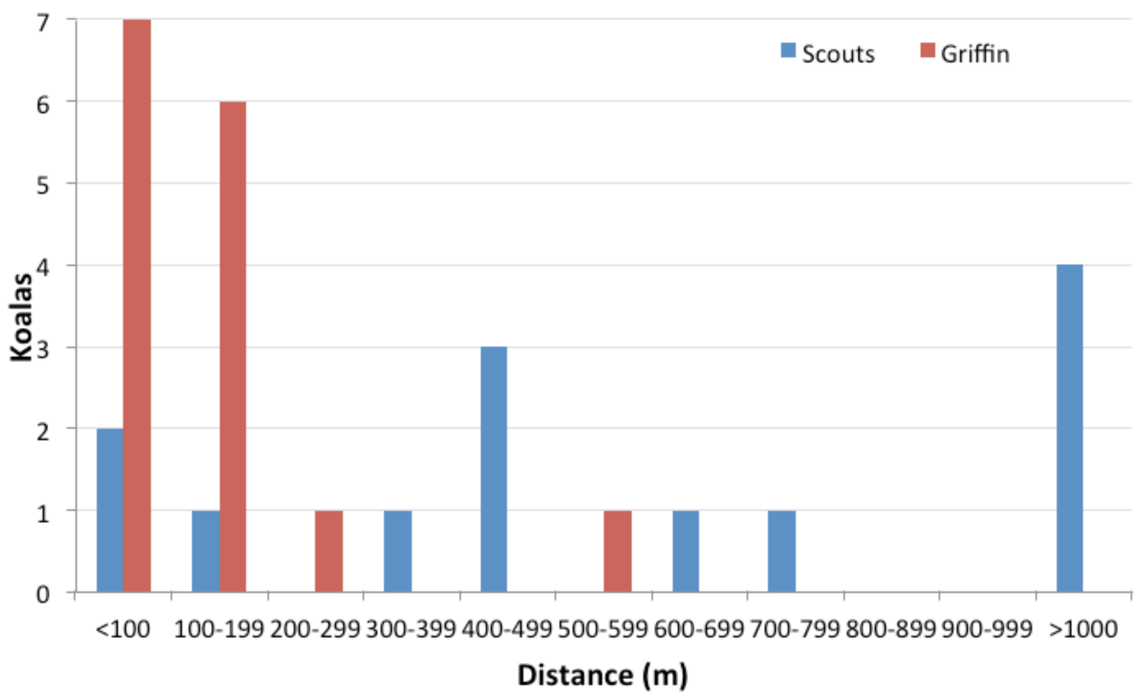



**Figure 7.6:** Over half of the translocated and relocated koalas (57%) established home ranges within 200m of their point of release, with the majority (75%) ranging within 500m of their release location. Griffin koalas tended to establish home ranges encompassing their release location, while Scouts koalas ranged further from their point of release, with one koala (*Midori*) dispersing 7700m (linear distance between release point and final home range). She had recently weaned her joey *Kahlua.*

## Dispersal behaviour of translocated koalas - case studies

### Mary Poppins

Koala *Mary Poppins* travelled south immediately after release (**Figure 7.7**, below). She had settled in an area approximately 1.7 km south of her release location within 2 weeks, ranging over a small area in acreage properties for a further 3 weeks before becoming ill and being admitted to a wildlife hospital where she was eventually euthanased.

**Figure 7.7:** Koala *Mary Poppins* immediately dispersed south off the Scouts site after release at the location shown by the red dot. She had settled in habitat on acreage properties approximately 1.7km from her release location after two weeks, and spent a further three weeks establishing a home range before succumbing to illness and being admitted to a wildlife hospital, where she was ultimately euthanised due to a severe middle-ear infection.

### Midori

Koala *Midori* and back-riding joey *Kahlua* were translocated to the Scouts site after repeated monitoring events showed her crossing Gympie Road at Lawnton which bisected her 14.7ha home range (**Figure 7.8**, below). This area was a known black spot for koala deaths. She fulfilled the criteria for translocation and was released in the central part of the Scouts site. **Figure 7.9**, below, shows her movements as she dispersed to the west, eventually settling approximately 7.7km away at Rush Creek.

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**Figure 7.8:** *Midori's* original home range included a section of Gympie Road that is a known black spot for koala injury and death from vehicle trauma (left); *Midori's* final home range included 65.2ha of partly cleared grazing land and bushland nature refuge (right).

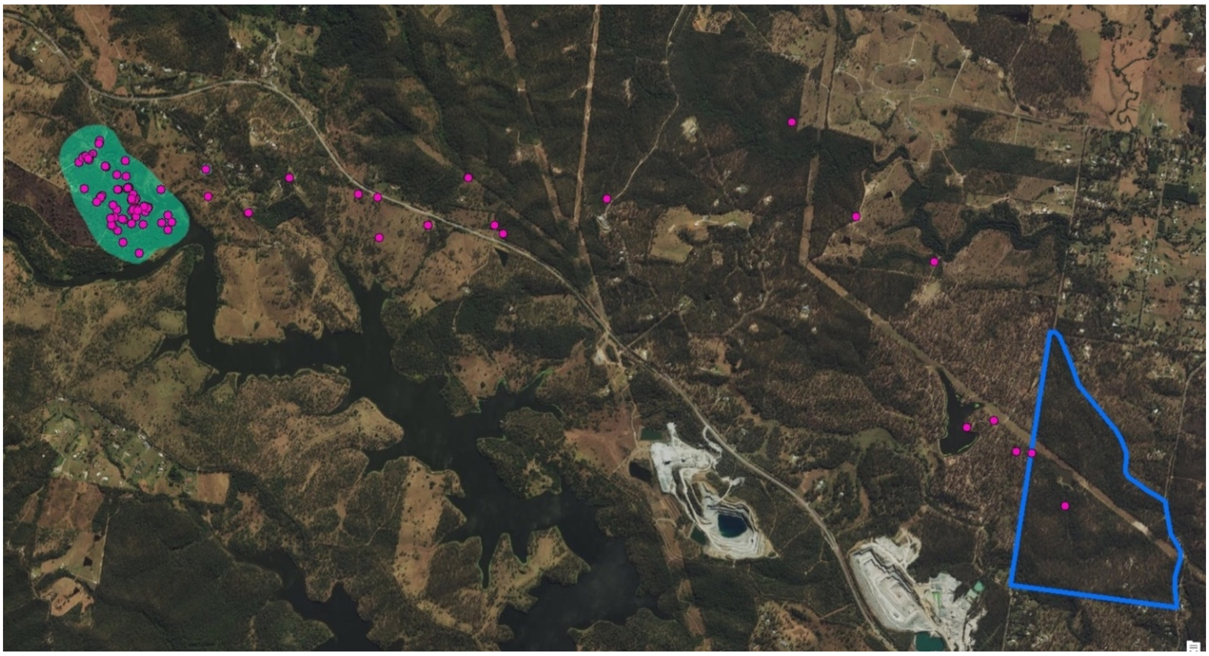


**Figure 7.9:** *Midori's* dispersal path from the Scouts translocation site (blue outline) to her final home range at Rush Creek (green polygon).

## 7.3.5 Impacts on resident koalas

The release of translocated koalas did not result in any apparent significant ranging changes or displacement of the resident koalas at either the Scouts and Griffin sites. Translocated koalas were released in the centre of the Scouts site within the area that was prioritised for the search and capture of resident koalas (**Figure 7.10**). The release locations overlapped many of the resident koalas' home ranges, yet there were no detectable significant home range shifts of these koalas attributable to the translocated koalas. Koala release locations were more dispersed over the Griffin site, but still occurred within the existing ranges of the resident koalas.

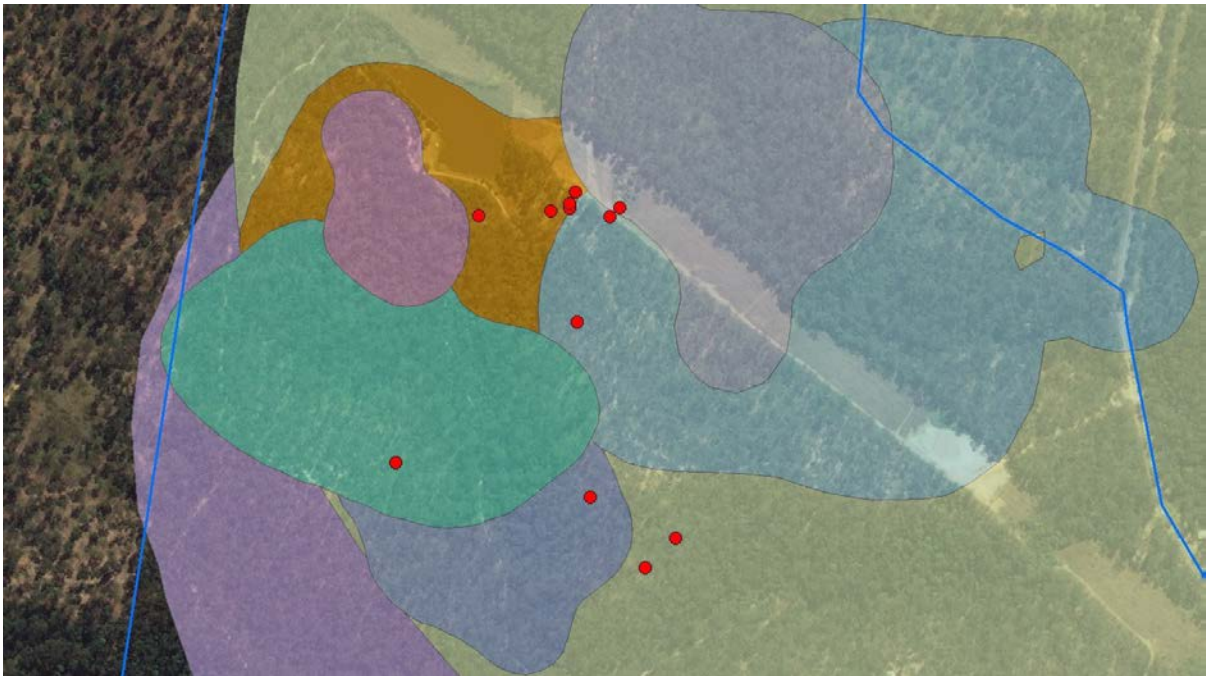


**Figure 7.10:** Release locations of koalas translocated to the Scouts site (red dots) and home ranges of resident koalas (95% KDE; shaded polygons).

**Plate 7.6**: Koala *Mali* at her final release in bushland near Kallangur Station. She was assessed against the translocation criteria, but did not meet the criteria for suitability. She was an aged female koala who was sterile from chlamydial disease, and maintained a stable home range.

## 7.3.6 Health

There was a significant difference in the health of the resident koalas at the two receive sites. Eighty-two percent of the Griffin koalas were in good health, compared with less than half (41%) of the Scouts koalas. Seven Scouts koalas captured for possible tagging were euthanased on humane grounds at their initial veterinary examination due to the severity of disease. Disease management throughout the program resulted in a marked improvement in the overall health of the Scouts koalas by project completion – 93% of koalas were in good health at the time of de-collaring. Only one Griffin koala was detected with disease as of August 2016, with 95% of koalas in good health.

In general, disease prevalence at first veterinary examinations increased with age of koalas (**Figure 7.11**, below). Koalas younger than 2 years of age had less than 10% disease prevalence at their first veterinary examination. Nearly half of eight-year-old koalas caught for the MBR project were affected by disease (45%). On average, over the duration of the *KTMP*, 20% of all koalas showed signs of disease *at their first health check*, which was still well below the 59% of Scouts resident koalas that were detected with disease at their first capture.

These data are consistent with a model of disease prevalence resulting from increasing exposure to a risk factor over time. In this case, the risk of exposure to chlamydial infection increases with sexual maturity and over time - as more mating events occur - a primary route of infection. Hence, the risk of development of *Chlamydia*-related disease also increases over time/with age. As chlamydial disease leads to chronic disease changes, the prevalence of disease increases with age, and the data reflect this trend.

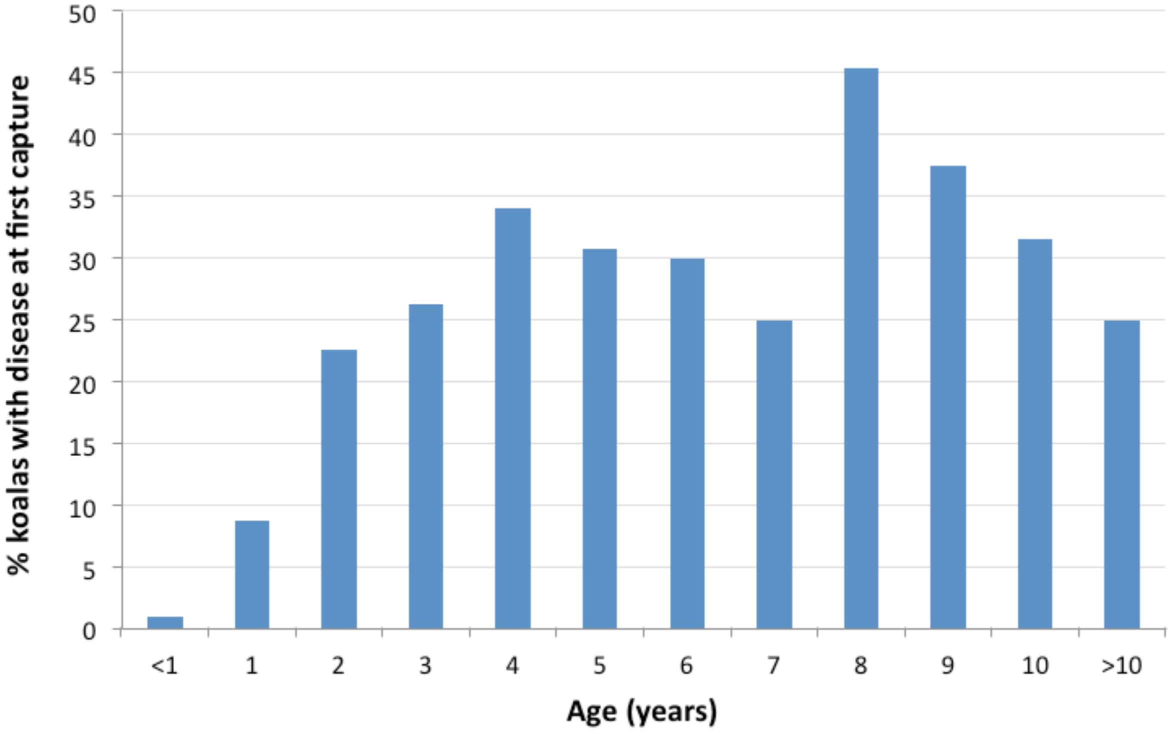



**Figure 7.11**: The percentage of MBR corridor koalas detected with disease at first capture increased with age. Less than 10% of koalas of one year of age or younger showed clinical signs of disease at first capture. Around one third of koalas eight years or older were affected by chlamydial disease. The trend is consistent with the model of increasing exposure to risk of infection (and therefore disease development) with age in sexually active animals.

## 7.3.7 Fecundity

Sixteen resident females of breeding age were initially captured at Scouts, however only 5, or 31% showed evidence of breeding (**Figure 7.12**, below). Nine females had reproductive disease and two others were observed with pouch young at a later date. At project completion, there were five independent young on site, two from translocated females and three from resident females. Eighteen resident and translocated females were alive at the end of the project, plus two independent juvenile females that were not of breeding age. Eight of these koalas, or 44% of breeding females had dependent juveniles present at their final exam. Seven of the 18 females were sterile, having been treated for reproductive tract disease (with ovario-hysterectomy (OHE)), so ultimately 73% of females of breeding capacity (non-OHE) were breeding at the end of the program. The remaining 3 females (two residents and one translocated) were not pregnant or with joeys at time of de-collaring, but two of these females had produced young in the previous season.

Resident Griffin koalas were highly fecund, with 6/8 females (75%) with pouch young at first capture. Four of these six breeding females were killed by wild dogs within 6 months of the commencement of monitoring, significantly reducing the breeding capacity at the site. At project completion, 55% of females (5 of 9) had young present, comprising one resident and four translocated koalas. Two of the nine koalas were resident females that were sterile, having been treated for reproductive tract disease with OHE, so ultimately 71% or 5 of 7 females of breeding capacity (non-OHE) were breeding. The remaining two resident females both produced joeys during the program that did not survive to independence, but were equivocally affected by reproductive tract disease as of 31 August 2016. (See **Figure 7.12**, below.)

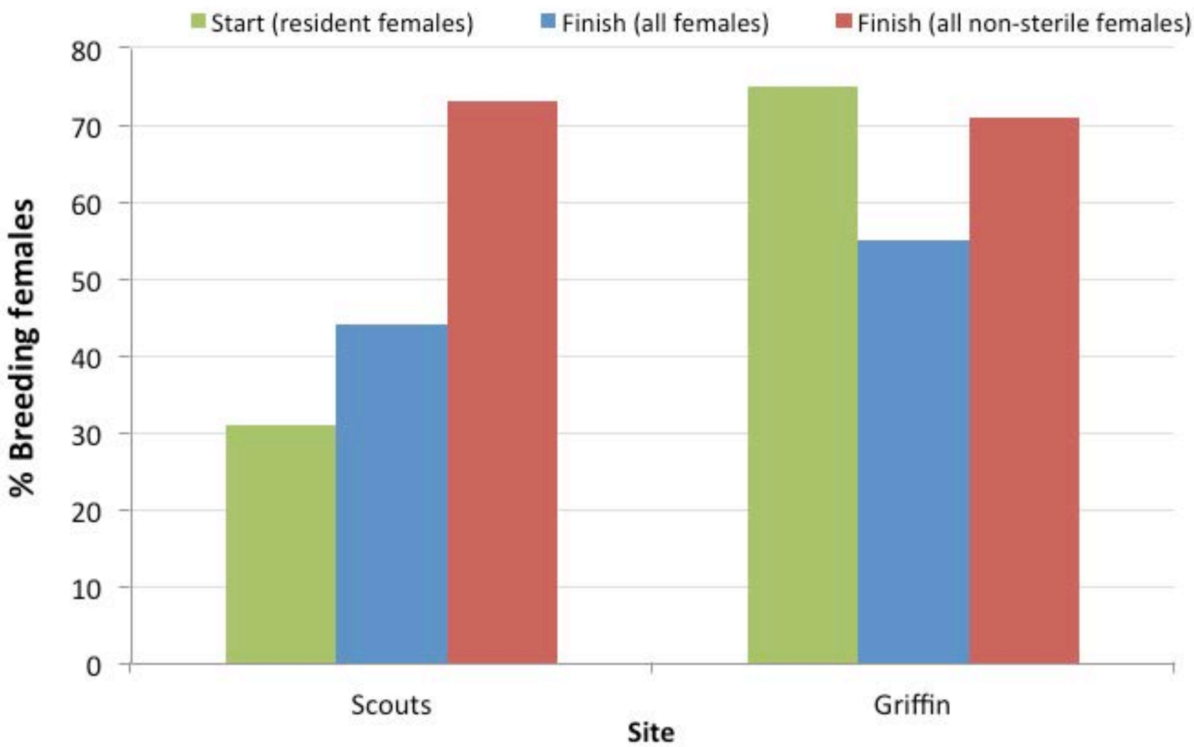



**Figure 7.12**: The percentage of females of breeding age that were breeding at the start and completion of the translocation program. The data show a marked improvement in the fecundity of the Scouts site, which originally had been severely affected by loss of fecundity associated with chlamydial disease. The net change in fecundity at the Griffin site is insignificant and attributable to its high relative fecundity at the project commencement, which was reduced by the loss of breeding females to wild dog predation, and addition of OHE females. In other words, fecundity at the Griffin site was high, and is still high.

## 7.4 Discussion

### 7.4.1 Success of the *KTrans* program

The translocation/relocation of a small number of MBR koalas to the two recipient sites was a success, based on comparisons of the resident koalas at the recipient sites and with the koalas that remained *in situ* along the MBR corridor. Success was assessed with respect to the survival and fecundity of translocated koalas, their establishment of home ranges, and their integration into the recipient population after their translocation events. It was also evaluated with respect to impacts and benefits for the resident population, with respect to disease prevalence, mortality and disturbance to ranging behaviour. The data confirm that, when conducted properly, translocation can be a successful management tool for displaced koalas; also, that old paradigms of translocation causing death of koalas are invalid. The findings support the decision by the MBR project to manage a subset of koalas subject to high-risk environments, or uncertain futures, by translocation, and that the decision was morally and scientifically sound.

Previous koala translocation projects have produced mixed results, with varying degrees of success. This has led to divided opinion about the appropriateness of translocation or relocation as a management tool for koalas displaced by habitat loss. Outcomes of koala translocations are influenced by a large range of factors, such as habitat suitability, threat profiles, weather conditions and koala health. However, with careful planning and management, many of these variables can be controlled to improve the success of such programs.

The results of the *KTrans* program demonstrate that the methods used were effective in terms of:

1. Assessing the suitability of sites as recipient habitat for koalas;
2. Selection of candidates for translocation, based on rigorous assessment criteria;
3. Monitoring of resident and translocated koalas, with respect to home range establishment, fecundity and mortality;
4. Supplementing the local koala populations to counteract high mortality rates - with respect to the Griffin site particularly;
5. Management of disease to improve the health and fecundity of koalas, and improve population viability;
6. Monitoring of the dispersal of translocated koalas and their progeny from recipient sites, thereby providing valuable information on the role of translocation in supplementing koala populations in decline, or extirpated from particular areas;
7. Implementation and evaluation of a model of best practice management of displaced and at-risk koalas.

Appropriate site selection is a critical factor in the success, or otherwise, of any translocation or relocation endeavours. As tempting as it may be to release koalas in 'vacant' habitat where there was a historical koala presence, the reasons for the present lack of koalas in an area needs to be determined. Such factors could include that:

1. The habitat quality may have lessened over time, resulting in a significantly reduced koala population;
2. Habitat quantity may have reduced as a consequence of land practices, poor fire regimes or weed control;
3. Unknown or unquantified threats on site, such as bushfire, wild dogs or a high prevalence of disease may have led to the loss of koalas.

With no, or few, resident koalas at such a site, there is no opportunity to determine existing population dynamics in the local area, and what environmental or anthropogenic factors (such as habitat fragmentation or reduced connectivity) may have led to the decline.

Until koalas were captured at Scouts, the high prevalence of chlamydial disease was not known. The Griffin site had a very significant wild dog problem, but determination of that required capture and monitoring of the resident koalas. Both the Scouts and Griffin sites had different threat profiles that prompted different adaptive management responses prior to the translocation of koalas. In the case of the Scouts resident koala population, significant numbers of animals required treatment of chlamydial disease; at the Griffin site intensive wild dog monitoring and management was required in response to high-level predation of resident koalas. The adaptive management responses were guided principally by information derived from the capture and monitoring of the resident koala population in the months prior to the commencement of translocation.

The lead in time to 'prepare' a site and a koala population to receive translocated animals can be lengthy. Often, decisions to relocate or translocate animals are made with relatively short notice, leading to little or no investigation and comparison of threat profiles at donor and recipient sites. This can lead to adverse and even catastrophic outcomes. The approach taken with the *KTrans* program avoided the risk of such failure by appropriate preliminary investigation and adaptive management of key threats as scientific data came to hand.

### 7.4.2 Translocation considerations

A major concern regarding translocation of wildlife relates to adverse effects on the health of the receiving population. Thorough veterinary assessment and disease management of resident and translocated koalas significantly mitigated the risk of adverse outcomes related to disease during the *KTrans* program. However, it is important to note that the Scouts site koala habitat was broadly contiguous with extensive tracts of koala habitat throughout the region. Hence, disease management by EVE was localised, and likely to have a shorter duration of benefit that that which occurred at other sites with lower connectivity.

There is much speculation, but very little scientific data, regarding the impacts of translocation on resident koalas in the recipient habitat. This project was the first to intensively monitor resident koala movements and home ranges prior to release of koalas at receive sites to robustly assess the responses of resident koalas to the incursion of new koalas. We found no evidence of displacement of resident koalas or dramatic changes in ranging behaviour attributable to the arrival of translocated koalas. Neither did translocated koalas show evidence of maladaptation or excessive ranging in the months following their translocation to the recipient site, and their mortality rate was not significantly different from that of the resident animals. (In fact, it was slightly less, but the difference was not statistically significant.) While the koala *Midori* dispersed a significant distance from her release point in the Scouts site, she nevertheless eventually settled into suitable habitat and established a stable home range.

### 7.4.3 The Griffin offset site

The Griffin site had a number of characteristics that made it particularly suitable as a translocation recipient site for koalas:

1. Koala predation by wild dogs had significantly reduced the population density at the site prior to the commencement of translocations into the site;
2. Chlamydial disease prevalence was low;
3. It had been extensively replanted with koala habitat trees over approximately 50% of its area.

Hence, in respect of factors 1 and 3, above, the site provided ample carrying capacity for additional koalas, and that capacity will increase over time with the maturation of revegetation areas.

Tree growth in revegetation areas and koala use of those areas were monitored up until January 2017 as part of the ***Alternative Koala Habitat Offsets*** program. Results of that monitoring are reported in ***Chapter 12: AKHO-CM and GOSM Programs***.

## 7.4.4 Translocation to enhance local populations

The *KTrans* program and associated adaptive management responses has, arguably, resulted in more viable koala populations at the Scouts and Griffin sites. The abnormal skewing of the population age structure at Scouts towards older animals was a consequence of poor fecundity leading to low recruitment of young animals and a higher average age. In contrast, the skewing of the age structure towards young animals at the Griffin site was an indication of high risk of premature death, attributable at that site to heavy predation by wild dogs. At the completion of the koala management programs (*KTMP* and *KTrans*), the age distribution of the Scouts and Griffin populations more closely matched that of the MBR koala population.

The MBR corridor koala population provided an exceptionally large and detailed data set, and sampled koalas inhibiting a variety of regional ecosystem types. As such, comparisons of the translocation site koala populations parameters with those of the MBR koalas is justified, and it provides the only detailed dataset for comparison, in any case. (see ***Chapter 11 - Population viability analysis***). The average age of the Griffin koalas increased, and the average age of the Scouts koalas has decreased, even though the koalas would have aged by the approximate 33 month duration of the monitoring. Both of these trends tended to "normalise" the age distribution of the population. At Griffin the increasing average age was due to reduction in premature mortality, and at Scouts the decreasing average age was due to improved fecundity, and recruitment (partly through translocation) of young animals. Hence, both sites benefitted from the program, although only some of the benefit is directly attributable to the recruitment of translocated koalas.

## 7.4.5 Number of koalas translocated

Fewer koalas required translocating than was first anticipated. One of the key reasons for this was the reduction in koala density along the rail corridor, and particularly the Amcor site, due to high levels of mortality by wild dog predation. Chlamydial disease also contributed significantly to mortality in the first half of the koala management program, but this was entirely expected. Hence, one of the potential reasons for requiring higher numbers of animals to be translocated - loss of habitat causing localised overabundance, did not eventuate. Also, the scientific evidence gathered with respect to ranging behaviour and causes of mortality in the MBR koala population did not support a higher level of translocation. The dramatic decline in koala mortality rate in the latter half of the koala management program (after the implementation of the *KTrans* program) validates the decision not to translocate a larger number of koalas.

Another factor that contributed to the low numbers of koalas requiring translocation, was the establishment of permanent permeability of the rail corridor to the movement of koalas, with culverts and bridges. This prevented the ecological isolation of a number of habitat fragments that might have resulted in translocation criteria being met.

## 7.4.6 Stakeholder support

The implementation of a translocation program for displaced koalas and dispersing sub-adults was advocated for and strongly supported by koala stakeholders. Most expected a much higher number of koalas to be translocated, but were satisfied with the final level of translocation because it was based on comprehensive assessment criteria, and the resulting decisions regarding the selected translocation group were robust and defensible. In addition, the scientific data derived from the monitoring of koalas during the *KTrans* and *KTMP* programs of work validated the decisions.

Criticism of the translocation program in the media was scientifically invalid and the key contentions were erroneous. These were: that some large number of koalas was translocated (figures ranged between 200 and 300); and all or most died because of their translocation. In reality, 28 koalas were translocated, and their mortality rates were slightly better (lower) than the larger population. Like all living things, koalas eventually die, but often such media stories imply that they should live forever. Nevertheless, that adverse media exposure received significant "air-time", partly because of the emotive and controversial topic, and that, in turn, damaged the reputation of the project.

In retrospect, it would have been beneficial to take every opportunity to publicise the beneficial outcomes of the koala management program, so that a broad public perception of the program as being of benefit to koalas could be established. In turn, that would have mitigated the risk of poorly informed potentially adverse media which would then be inconsistent with the general perception. This communications strategy is of particular importance regarding contentious issues, such as the management of koalas.

### 7.4.7 *KTrans* findings and koala translocation policy change

The *KTrans* program achieved two key objectives:

1. It provided a mechanism for the protection of a number of koalas that otherwise would have been exposed to significant risk of injury or death; and therefore it contributed to the fulfilment of the MBR project's statutory obligations to protect koalas; and
2. It provided robust and comprehensive scientific data and analysis of the responses of koalas to translocation - both resident koalas and the translocated koalas. Information on responses of resident koalas had not previously been available.

The information derived from the *KTrans* program provides a sufficient body of evidence to support a change to the regulatory framework and policy regarding translocation of koalas. The program has clearly established that translocation is an appropriate tool in the management of koalas displaced by loss of habitat, particularly in urbanised landscapes. When properly conducted, translocations can augment populations that are in decline, and ensure that koalas in high-risk situations are not lost unnecessarily due to insufficient management in the development context. It also allows developers to plan for a cost-effective, reliable method of achieving their legislative obligations while minimising the potential impact to individual koalas.

However, the key features the *KTrans* program, which were crucial to its success, should form the basis of new policy regarding the translocation of koalas. These are:

1. The careful assessment and selection of potential recipient sites using robust criteria;
2. The careful assessment and selection of individuals for translocation;
3. The scientific investigation and adaptive management of threat profiles at donor and recipient sites to validate the appropriateness of the proposed translocation;
4. Suitable veterinary management of individual and population health;
5. Suitable management of additional threats to individuals and population health, such as wild dog control;
6. Appropriate monitoring of resident and translocated koalas for evaluation of short-term and, whenever possible, long-term success of programs.

Any change to koala conservation policy and regulation, including that regarding management of displaced and at risk koalas and koala populations (i.e. with respect to translocation), should be guided by an overarching regional koala conservation strategy. This does not exist presently, but its development should be a high priority for the regulator (EHP). Strategic alliances between TMR and other government bodies could allow a number of permanent recipient sites to be maintained and monitored in future, so that translocation of koalas can take place from a wide number of development projects, with little lead-in time required.

### 7.4.8 Recommendations

Regarding the *KTrans* program and management of at-risk koalas generally, we make the following recommendations:

1. That the need for koala translocation be considered and appropriately assessed in future transport infrastructure projects likely to cause adverse impacts on koalas or koala populations. It is a valuable tool in the management of isolated and at-risk koalas and populations, and can be used with great success to achieve beneficial outcomes.
2. That koala management planning be conducted as early as possible in project lifespans to ensure that management responses are appropriately informed and guided by scientific investigations, which often require significant lead-in time before producing meaningful results.
3. That key components of koala management during translocation are embedded in scope and specifications documents, such as appropriate veterinary management, telemetry monitoring, site and individual assessment criteria, etc.
4. That monitoring programs be extended for as long as possible, or revisited at medium-long-term time points to properly evaluate success. Failure of long-term monitoring and evaluation is a common (and valid) criticism of many wildlife management programs.
5. That koala/wildlife stakeholder engagement and consultation be conducted as early as possible in project lifespans.
6. That the numerous positive media opportunities that arise from koala work are used to the greatest possible advantage to build a strongly positive public perception of koala management programs. This considerably mitigates the risk of poorly informed, potentially adverse media, which can gain significant traction and momentum if a void in public perception exists.

**Plate 7.8**: *Mary Poppins* and koala capture team member Kye McDonald

Note regarding "stress" and chlamydial disease:

There is a common misconception that the high levels of chlamydial disease observed in some koala populations are primarily driven by stress associated with the clearing of habitat. This is not supported by data, and the Scouts site illustrates the reality of the situation quite well: despite being entirely unaffected by urban development, almost completely vegetated and with relatively high-quality and intact koala habitat, it nevertheless had the highest prevalence of chlamydial disease of any site (59%). In contrast, the Amcor site, which was surrounded by urban development and affected by a variety of impacts related to its industrial use, had the lowest prevalence of chlamydial disease (11%). Chlamydial disease causes variable impacts to koala populations throughout their range, and affects population viability accordingly.

# CHAPTER 8: CAUSES OF DEATH OF KOALAS


## Key points

- Important information to guide adaptive management approach to key threats
- Only achievable with high-intensity monitoring, innovative technology and veterinary expertise
- Important data input to population viability analysis
- Mortality rate reduced by the end of the program to one fifth of the rate at commencement
- First evidence for significant mortality of koalas by carpet python predation
- Crucial in establishing the presence and *modus operandi* of the Amcor Dog
- High-priority for scientific investigation of wildlife populations to guide management and mitigation measures - recommendation for future infrastructure projects/standard guidelines

# Chapter 8: Causes of death of koalas

**Plate 8.1**: One of the first orphans of the numerous female koalas killed by the “Amcor Dog” during his nearly two-year koala killing spree in habitat in the Amcor and western half of the *Bruce Hwy West* koala search polygons. This is *Pistachio,* joey of *Caz,* one of dozens of koalas killed, but not eaten by the dog. He was successfully hand-raised by EVE koala ecologist Dr Deidre de Villiers, and released back into the wild. Careful and astute necropsy examination was an important tool in building the evidence for a single “Amcor Dog”. (See also ***Chapter 9 - Wild dogs***).

## 8.1 Introduction

The determination of causes of death in wildlife populations that are under threat is critical to informing conservation strategies. In simple terms, wildlife populations will decline if the mortality rate exceeds the birth rate, and if that ratio continues then the population will become extinct. The rate of progression towards extinction will be influenced by factors that affect both mortality and fecundity (reproduction). With respect to mortality, of greatest importance are factors that cause the premature death of animals, because their opportunity to contribute to the population reproductively is reduced (as opposed to old-age-related illness). This is particularly important in the case of females when male availability is not a significant limiting factor - as is the case with koalas. Hence, conservation strategies that are targeted and appropriately proportional to the relative importance of the various causes of death, are likely to be far more effective (and cost-effective).

If the causes of premature death are not determined, then conservation strategies must make assumptions about them and implement measures to reduce the *assumed* causes of premature death. In the case of koala populations living in and around urban areas, it is often assumed that vehicle strike, domestic dog attack and other human-related factors will have the most significant impacts with respect to premature death. (The data show that this was not the case in respect of the MBR koala population over the duration of the program.)

However, the risk of not definitively determining important causes of premature death is that conservation measures are not appropriately targeted and resources are wasted; and in the worst scenarios, entirely ineffective at addressing population decline. As will become clear in the following sections of the chapter, had MBR project's koala offset strategies targeted road deaths and domestic dog attacks alone (based on the aforementioned assumptions), they would have been largely ineffective at reversing the population's decline.

The definitive determination of causes of death is therefore of central importance in planning and applying effective conservation and mitigation measures. This requires a number of things to happen:

1. The death of animals in the target population must be detected sufficiently soon after death to permit a diagnostic necropsy (*post-mortem*) examination to occur;

2. The body must be recovered promptly and stored appropriately to slow decomposition prior to necropsy examination;

3. The necropsy examination must be performed by a veterinarian or veterinary pathologist with the skills and experience to accurately determine cause of death in the species;

4. At a population level, the animals subjected to necropsy examination must be representative of the population, as much as possible.

Point 4, above, relates to avoiding bias in the sample of animals on which necropsy is conducted. For example, if the primary mechanism for detection of death and recovery of bodies is relying on the general public to present deceased animals, then the sample will be biased in favour of causes of death close to human habitation - particularly on roads, for example. The results will then disproportionately represent motor vehicle strike and other human-related causes of death, and may not accurately reflect the important causes of death at the wider population level. This is why admissions data from wildlife hospitals are a very biased dataset, and will not accurately represent proportionate causes of death of the wider koala population, or properly inform mitigation and conservation strategies. This assertion is validated by the results in the following section.

The definitive method of determining causes of death in wildlife populations is to monitor a representative group of individuals sufficiently frequently that death is detected rapidly. In practical terms for koalas, this necessitates the use of telemetry methods, with tracking or monitoring frequency of at least 2-3 times per week. Even with this frequency, in hot weather animal carcasses can deteriorate rapidly, leading to advanced decomposition within days and a significantly reduced likelihood of achieving a diagnosis of cause of death.

This section details the methods and results of investigations of causes of mortality in the koala population under management for the Moreton Bay Rail project, as well as those inhabiting the translocation recipient sites. We have not discussed every single cause of death, but rather those of most importance and some of particular interest. Note that for statistical analysis, we have limited the data to those relating to deaths between the commencement of the koala management program on 18 March, 2013 and the significant commencement of de-collaring of koalas in the program around 31 August, 2016. However, for the sake of interest and completeness, a number of koala deaths occurring after this period are included for descriptive/qualitative reasons because ongoing monitoring of some koalas continued until the end of January 2017.

## 8.2 Justification

Aside from the ecological justifications outlined above, the monitoring and determination of causes of death of koalas during the Moreton Bay Rail project was critical for a number of important reasons:

1. To inform the development and implementation of mitigation and conservation measures;
2. To ensure that the project itself (including koala management activities) were not contributing to premature death of koalas;
3. To protect the reputations of the project, client and contractors involved in koala management;
4. To inform koala/wildlife stakeholders and maintain their confidence in the appropriateness of the koala management methods and protection measures.

One of the most significant risks to the reputation of the MBR project was the presumption by stakeholders and the general community that the project was causing or contributing to significant koala mortality and/or hastening the decline of the koala population. The management of this risk was part of the motivation (although not the primary factor) for conducting the *Koala Tagging and Monitoring Program*, and required that the program properly and thoroughly investigate the deaths of program koalas. This was clearly also necessary for the adaptive management approach outlined as a key component of koala management activities in the early project plans.

**Plate 8.2**: Koala *Copper* as he was found in July 2015 - cause of death is not apparent. He was a resident animal at the Scouts translocation recipient site. He had a long history of poor health, and ultimately succumbed to an AIDS-like condition, the diagnosis of which was only possibly by astute and detailed necropsy examination.

## 8.3 Methods

Essentially, all koalas living in habitat within the koala search area polygons were captured, subjected to veterinary examination and released back into the wild (when appropriate) fitted with radio and bio-telemetry devices. In the early phase of the project most koalas were monitored using standard VHF radio-telemetry, but this was eventually superseded by the rollout of the bio-telemetry devices (LX *K-Tracker* telemetry system) (see ***Chapter 2 - General methods*** for a detailed outline of specific methods and technology).

### 8.3.1 The *post-mortem* interval (PMI)

All koalas were subjected to thorough and systematic veterinary examinations on initial capture, at six-monthly intervals, when illness or injury was detected, and at the completion of veterinary treatments when treatment was warranted. Some koalas were euthanased at the time of their first veterinary examination due to the severity of illness and/or poor prognosis. Others developed illness during their monitoring period in the field and were readmitted for treatment. (Clinical management and findings are reported in ***Chapter 4 - Veterinary management of koalas***.) When koalas were euthanased on humane grounds, or were recovered promptly after death, the *post-mortem interval* (PMI) was relatively short, and carcass decomposition was minimal, allowing a more productive necropsy examination to occur. As the PMI lengthens, the carcass deteriorates through a process of *autolysis* (early degradation of the tissues due to membrane break-down and the action of endogenous enzymes) and then microbial decomposition and putrefaction. Liquefaction of soft tissues and skeletonisation of the carcass occur due to the processes of microbial decomposition and invertebrate activity, such as by carrion beetles and flies. The rate of decomposition is significantly influenced by a number of factors, including the following:

1. Ambient temperature: high temperatures speed up decomposition;
2. Humidity and moisture: rain and high humidity speed up decomposition;
3. Ecological environment: moist forests tend to harbour more carcass-degrading invertebrates;
4. Infections: some infectious causes of death (such as septicaemia and *Clostridium spp.* infections and toxicoses) lead to rapid decomposition.

The processes of *post-mortem* decomposition can be significantly slowed by chilling of the carcass by refrigeration or packing it with ice. This was done as a routine measure when koala carcasses were recovered from the field.

The carcasses of koalas that died *in the field* (as opposed to during hospitalisation), were generally recovered within a few days of death and immediately placed on ice, allowing diagnostic necropsy examination. However, in the following circumstances, necropsy examination was not possible, and/or resulted in limited data:

1. When predation had occurred with ingestion of the entire or nearly all of the carcass;
2. When the telemetry tags were undetectable (that is, a body or body parts could not be found);
3. When hot weather, and/or delayed recovery of the carcass resulted in advanced *post-mortem* degradation of the carcass.

(A tabulated summary of these is contained in the Results section, below.)

### 8.3.2 Necropsy examination

Necropsy examinations were conducted on the recovered carcasses of koalas as soon as possible after death was detected. These were performed by an experienced koala veterinarian (usually Dr. Jon Hanger). Photographs were taken during the necropsy examination, and clinical and pathology details were recorded in the FileMaker® koala database. In most cases a cause of death was determined. In cases where cause of death was not definitively determined, a range of possible diagnoses was provided, with discussion of the evidence in support of the most likely scenario. Additional testing, such as bacterial culture and examination of tissues by microscopy (histopathology) was frequently conducted (but not always) to confirm a cause-of-death diagnosis determined by gross necropsy examination, or to assist in determining or refining cause-of-death diagnosis when it was not definitively determined during gross necropsy examination.

### 8.3.3 Histology and culture

Preparation of sections of necropsy tissues for histological examination was conducted by Queensland Medical Laboratories (QML) Vetnostics division. They also performed culture and other diagnostic testing as required.

### 8.3.4 Diagnosis of cause of death

Diagnosis of cause-of-death, and/or the factors contributing to death, was made by the veterinarian by considering necropsy findings, circumstances surrounding the death, and individual animal and environmental factors around the time of death. In most cases, a definitive cause-of-death diagnosis was made with a high degree of certainty. In a handful of cases, the cause-of-death diagnosis was based on circumstantial but nevertheless compelling evidence, and in a small number of cases, definitive diagnosis was not achieved with a high degree of certainty.

### 8.3.5 Analysis of data

This chapter includes analyses of mortality data with respect to the proportional impacts of a variety causes of death and the changes in those impacts over time. While the overall mortality rate and collated causes of death over the whole project period provide some useful information, the most informative analysis is the changes in the relative contribution of the various causes of death over time. This analysis clearly indicates the beneficial effect of disease management and wild dog control in terms of mortality rate. Some of the graphs shown herein are derived from the FileMaker® koala database developed for the MBR koala management programs. For graphs displaying annualised rates, such as mortality rates, the graph uses a 90-day window with a 2-day frame-shift to create each of the points used to create the graph.

**Plate 8.3**: In some cases an entire carcass was not available for full necropsy examination. Nevertheless, careful recording of data and photos is essential to proper mortality investigation. This is the exhumed hindlimb of koala *Dennis* found because of the anklet - a victim of wild dog predation at the Amcor site in July 2013 - prior to the arrival of the “Amcor Dog”.

## 8.4 Results

### 8.4.1 General Statistics

In total, 503 koalas (217 males, 285 females and 1 intersex) were captured and processed for the *KTMP* and *KTrans* programs of work. Between the commencement of the program on 18 March, 2013 and 31 August, 2016, 247 koalas perished (either died or were euthanased), and an additional 37 were presumed dead based on the circumstances, but their remains were never found. In total, suspected and confirmed deaths over that period was 284. This figure does not include dependent joeys of mothers who died, or untagged recently independent juveniles that disappeared or perished.

The average age of koalas at death was 4.6 years; for comparison, a koala dying of "old-age" is likely to be around 12-15 years. There was a small improvement in this average in the last year of the project, probably as a result of the significant reduction in wild dog predation - a major cause of premature death early in the program. In addition, near-independent juveniles were not being tagged from early 2016 onwards as the program ramped down, and hence the absence of their mortality data may also have improved the 2016 average. The graph below shows the variation in age at death over the years of the program.

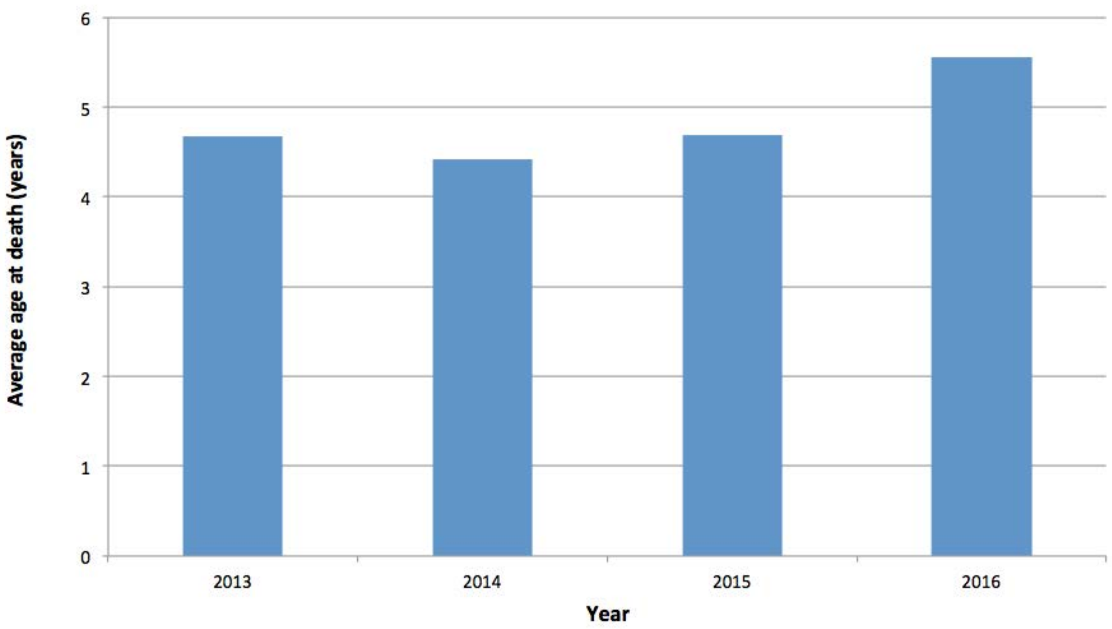



**Figure 8.1**: Graph showing changes in **average age at death** of koalas by year over the duration of the program. Wild dog predation deaths were most numerous in 2014, which helps to explain the relatively low average age at death in that year.

The table (**Table 8.1**) overleaf shows the breakdown of koala deaths with respect to necropsy examination and whether a definitive diagnosis was achieved.

| Category | Number /Total Deaths | Percentage | Reason/Comment |
|---|---|---|---|
| Diagnostic necropsy | 175 | 62% | Diagnosis of primary cause of death and/or significant contributing factors achieved with reasonable degree of certainty. |
| Necropsy without definitive diagnosis achieved | 9 | 3.2% | *Audrey, Bianca, Big Bill, Burbridge, Button, Chloe, James, Linky, and Red Queen*. Most failures of diagnosis are attributable to decomposition masking diagnostic changes, or acute illness resulting in few pathological changes, such as possible *Clostridium spp.* toxicoses. |
| Only parts of carcass recovered (no necropsy performed) | 60 | 21% | All of these are cases of wild dog predation in which body parts were located with, or in the vicinity of telemetry tags and/or ear tags. No necropsy or limited necropsy examination of remains was conducted. |
| Death presumed (but not confirmed) | 37 | 13% | Nearly all presumed deaths (36) were suspected to be wild dog predation, based on circumstantial* evidence. One koala (*Kylie*) was a presumed motor vehicle hit, based on circumstantial evidence, but her body was never recovered or never apparently presented to a koala care facility. |
| Death of koala after exit from the *KTMP* program (advised by other entities) | 3 | 1.1% | *Rambo*, *Nuelli*, *Brodie*. These koalas were reported to EVE as deceased by koala hospitals or koala rescue organisations (*Rambo* and *Nuelli*), or treated and euthanased by EVE after removal from the *KTMP* (*Brodie*). Date of death of these koalas was after removal of telemetry tags and removal from the program. |
| Totals | **284** | **100%** | |

**Table 8.1:** Summary of MBR koala deaths from March 2013 - August 2016 and whether a diagnosis was achieved. *Note: despite the common misconception, *circumstantial evidence* can be very compelling, and contributes considerably to the achievement of a diagnosis of cause of death in many cases. It is not evidence of a lesser quality, but evidence relating to the circumstances around a death, rather than the direct physical evidence derived from necropsy examination.

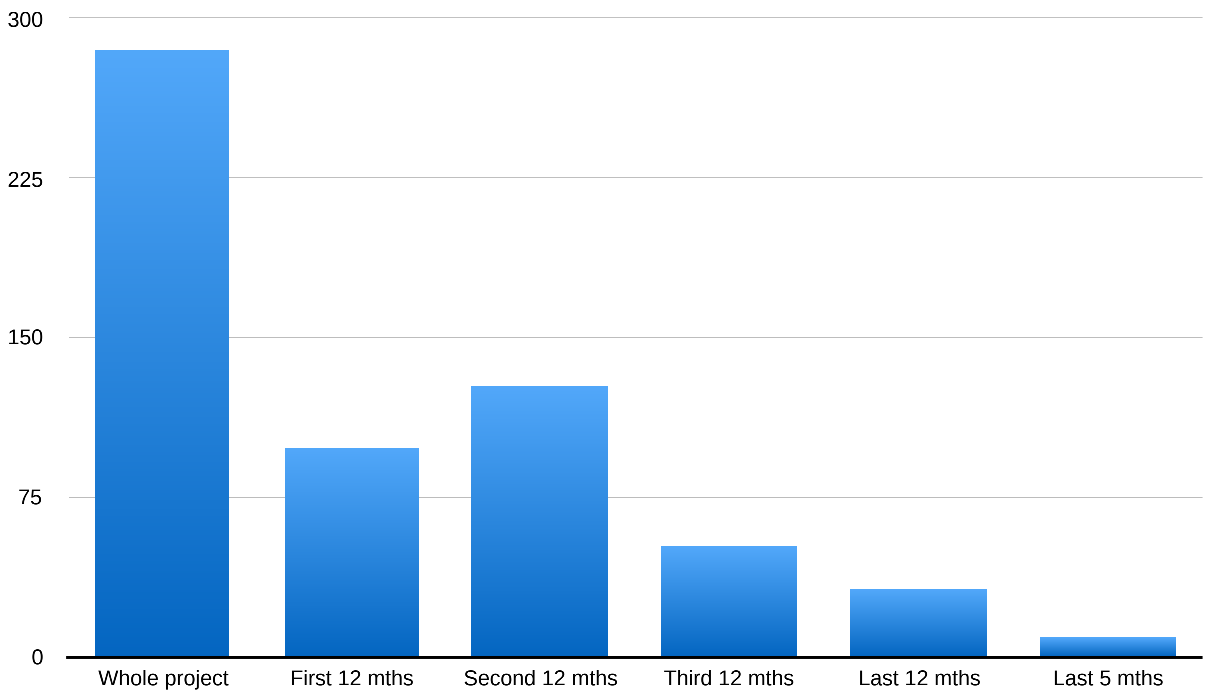



**Figure 8.2**: Graph showing trends in total koala mortalities by year. During all periods the approximate number of koalas under monitoring was 200 +/- 10%. The graph spans the period 18 March 2013 to 31 August 2016.

## 8.4.2 Natural death vs euthanasia

From an animal welfare perspective, it is better to predict imminent death in a sick animal and perform euthanasia on humane grounds than to allow an animal to die naturally. This is particularly so when the dying process may be prolonged, uncomfortable and/or distressing, or associated with significant pain. Euthanasia of an animal that is dying or has a poor prognosis should not be seen as a failure of veterinary care, but a compassionate course of action to prevent further suffering.

**Table 8.2** (below) shows the break-down of categories of death for all deaths over the duration of the program (18/03/2013 - 31/08/2016). Suspected deaths are included as **Not recovered/ suspected dead**, and the three deaths of koalas that occurred after their removal from the program are included.

| Category | Number of koalas |
| --- | --- |
| Died in field | 169 |
| Died in transit | 2 |
| Died in care | 4 |
| Euthanasia in care | 72 |
| Not recovered/suspected dead | 37 |
| TOTAL | **284** |

**Table 8.2**: Number of koala deaths by category.

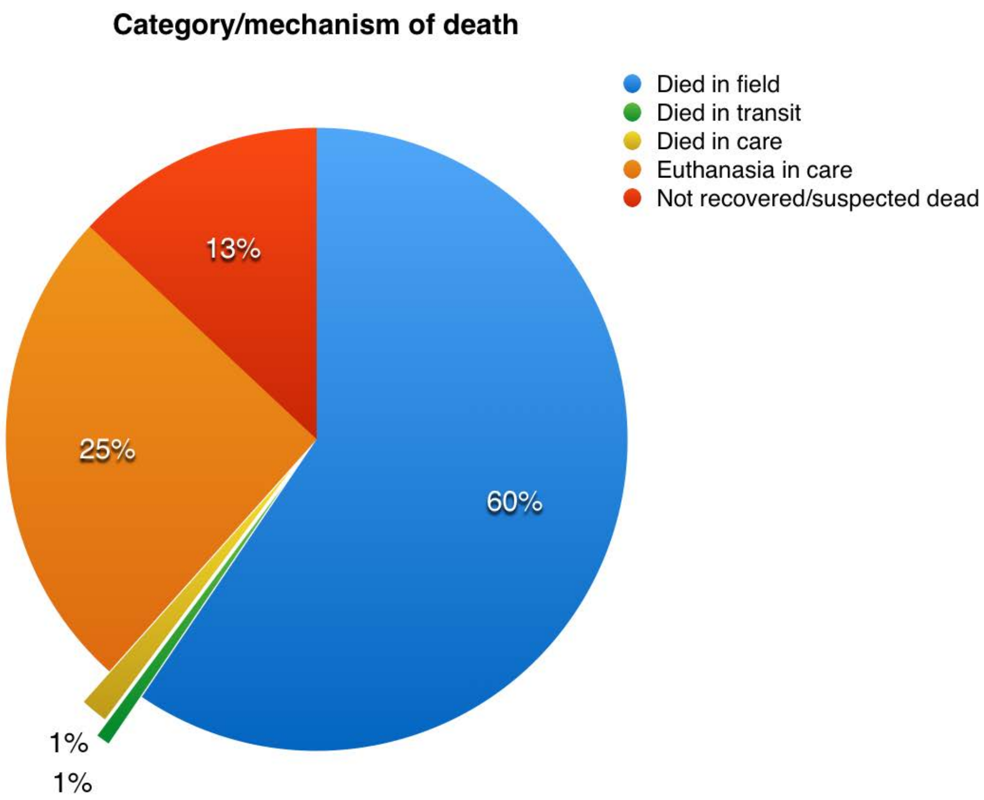



**Figure 8.3:** Categories of death of koalas. The proportion dying unassisted while in care is low (1% of deaths) - an important metric of good animal welfare standards. (Deaths in transit were koalas that were found critically ill or injured in the field that died in transit to emergency veterinary facilities.)

### 8.4.3 Causes of death - general findings

Over the duration of the *KTMP* and *KTrans* programs of work (18 March 2013 - 30 June 2016) plus the months of July and August 2016, there were 503 koalas processed, and 284 deaths (including 37 presumed deaths in which the carcass or remains were not found but circumstantial evidence strongly suggested the death of the koala). This represents a mortality of approximately 56% over the duration of those programs. Disease (mainly chlamydial disease) and predation of koalas by wild dogs were the predominant causes of death in the first two years of the program.

Brief summaries of necropsy findings from all koalas that received necropsy examinations are contained in *Appendix 6 - Summary of necropsy findings.*

| Cause of death | Whole project (18/3/13-31/8/16) | First 12 months | Second 12 months | Third 12 months | Last 12 months (1/9/15-31/8/16) | Last 5 months (18/3/16 - 31/8/16) |
|---|---|---|---|---|---|---|
| Wild dog | **154** | 47 | 88 | 19 | 2 | 0 |
| Disease - *Chlamydia* | **51** | 26 | 19 | 5 | 4 | 1 |
| Disease - other | **33** | 7 | 6 | 14 | 14 | 6 |
| Carpet python | **20** | 8 | 5 | 6 | 5 | 0 |
| Trauma - car | **10** | 3 | 3 | 3 | 2 | 1 |
| Trauma - other | **5** | 3 | 2 | 1 | 1 | 0 |
| Domestic dog | **5** | 3 | 2 | 0 | 0 | 0 |
| Unknown | **3** | 1 | 0 | 2 | 2 | 0 |
| Old-age-related | **2** | 0 | 1 | 0 | 1 | 1 |
| Misadventure | **1** | 0 | 0 | 1 | 1 | 0 |
| TOTALS | **284** | **98** | **126** | **51** | 32 | **9** |

**Table 8.3:** Causes of deaths (and presumed deaths) by general category from program commencement in March 2013 to the commencement of significant de-collaring of koalas in August 2016. Note that the "Last 12 months" data overlaps with the "Third 12 months" and "Last 5 months" data. It is included to demonstrate the significant proportional changes of the various causes over time. The data are illustrated graphically in the charts below. Note: this table includes suspected deaths as well as confirmed deaths.

## 8.4.4 Changes in mortality rate and causes over time

The mortality rate in the monitored koala population declined very significantly over the course of the program primarily due to two factors:

1. Wild dog predation reduced markedly in the third year due to wild dog control measures implemented by the MBR project, and the apparent disappearance of the “Amcor Dog”; and

2. The control of chlamydial disease by treatment, and possibly some beneficial effect of administration of the *Chlamydia* vaccine to some animals.

The decline in mortality rate is demonstrated in the graph below, showing annualised mortality rate (from all causes) calculated from 90-day windows, with each point on the graph representing a 2-day frame-shift. At the time of writing, annual mortality rate had declined to around 10%, which is very satisfactory for a wild koala population, and consistent with a growth trajectory when coupled with the observed reproductive output for the population.

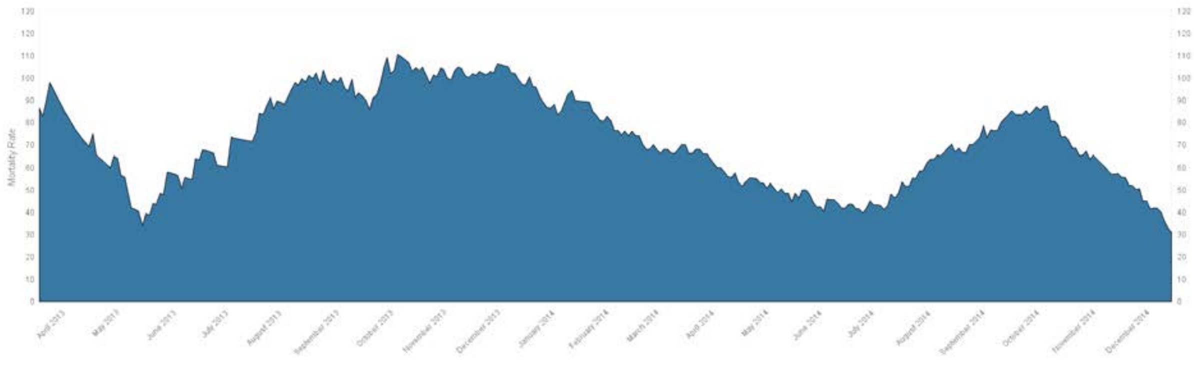
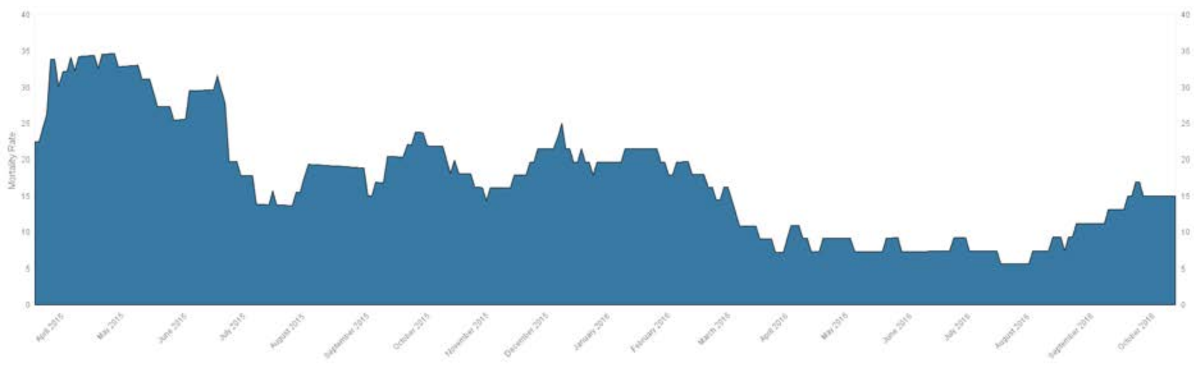


**Figure 8.4:** Changes in ***annualised mortality rate*** over the first 2 years of the program (18 March, 2013 - 17 March, 2015). The graphs are created by the FileMaker® koala database using a 90-day window, 2-day frameshift. (Each “point” on the graph is the average mortality rate in a 90-day window, annualised. Each point is shifted 2 days from its neighbouring points.) Note that when the annualised mortality rate exceeds 100%, as it does between August 2013 and January 2014, this indicates a rate sufficient to extinguish the population within a year *if that rate persisted.* Therefore an annualised mortality rate of 110%, for example, in October 2013, is a *hypothetical* rate, based on very high mortality over a number of months, which, if sustained, would cause extinction of the population. The graph below shows trends in the ***annualised mortality rate*** in the final two years of the program (18 March, 2015 - 13 January, 2017). Note that the graph gets “chunky” and the trends a bit rubbery due to the significantly lower total number of koalas under monitoring in the last 6 months to date (only 31 in the wild monitored on 13 January 2017) . Nevertheless the annualised mortality rate has reduced very significantly from high points of over 100%, to an average of between 10-15% in the final 12 months.



**Note:** The lower graph above has a different vertical scale to the one above it. Overleaf is a graph allowing a better appreciation of the scale of the reduction in annualised mortality rate over the duration of the program.

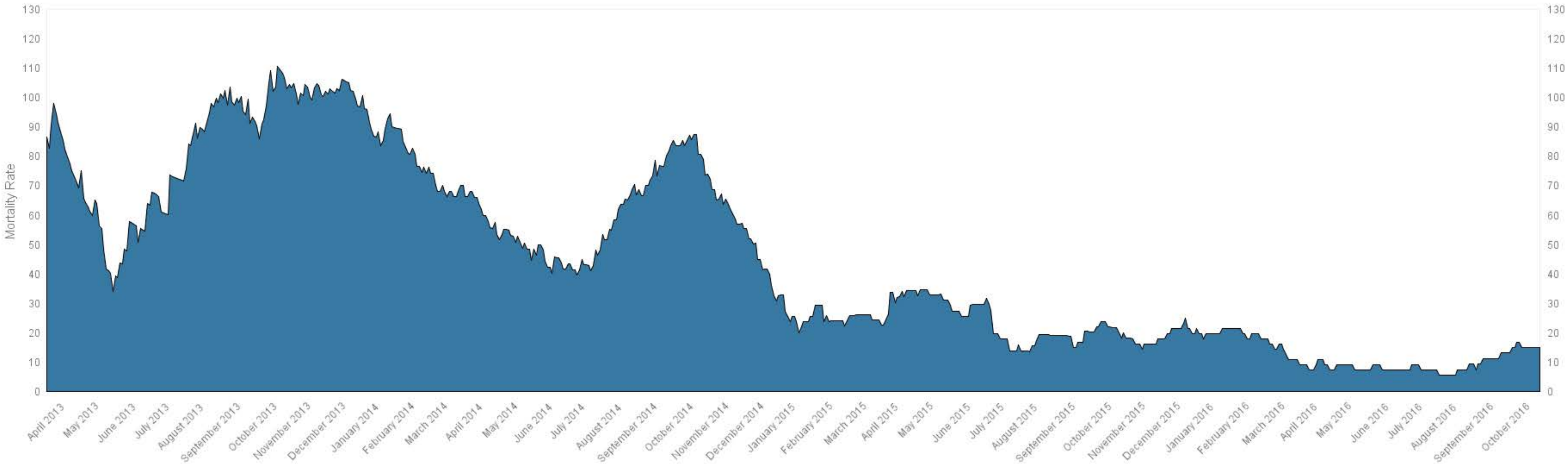



**Figure 8.5**: Graph showing trends in the annualised mortality rate over the duration of the koala management program from commencement on 18 March, 2013 to virtual completion in January 2017. Note the significant decrease in annualised mortality rate over the life of the program, particularly in the last two years. The "Amcor Dog" contributed significantly to the significant peaks in the first two years, during which annualised mortality rate over short periods exceeded 100% .Sections of the graph in the first few months and very last few months are a bit "rubbery" due to low total numbers of koalas under monitoring as the project ramped up, and ramped down, respectively.

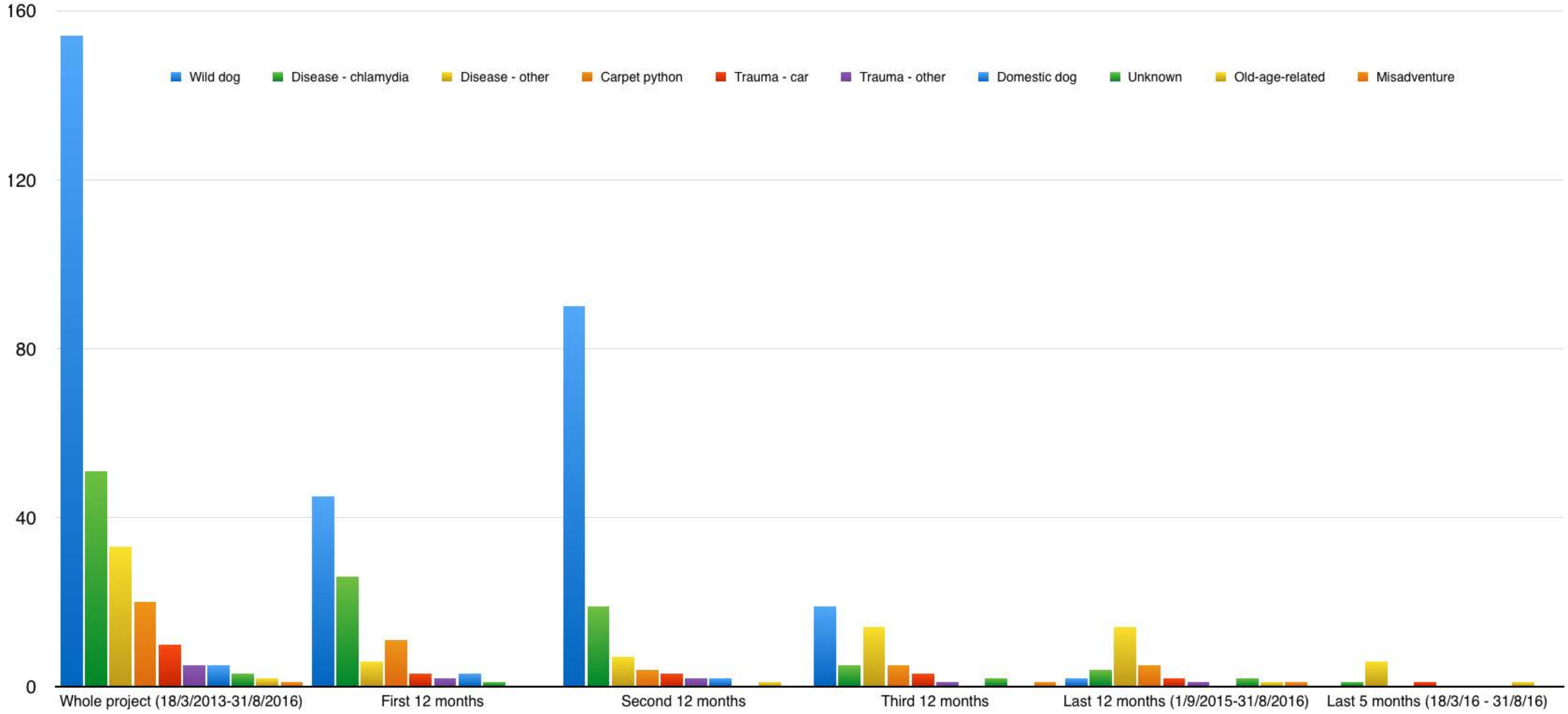
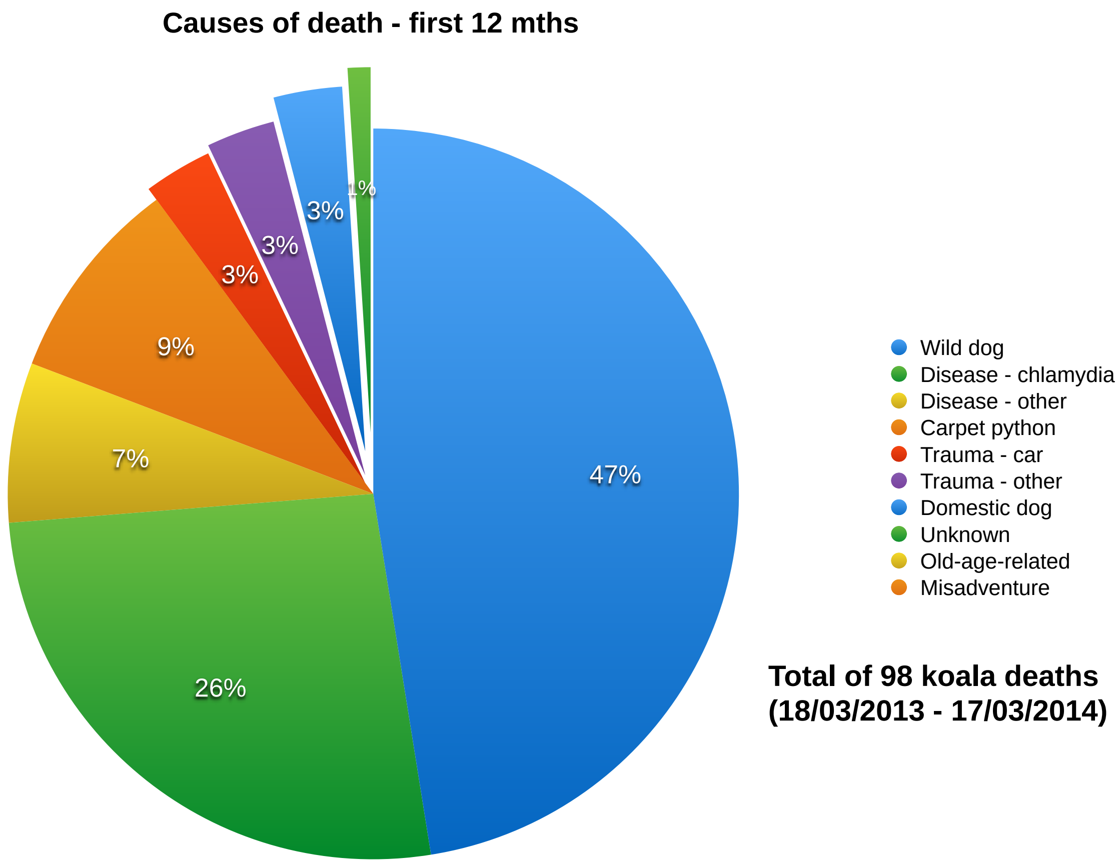



**Figure 8.6**: Bar chart showing breakdown of koala deaths by year and cause, plus the last 5 months, showing significant declines in deaths attributed to wild dogs and chlamydiosis in the last 12 months of the koala program. Y-axis indicates number of koalas

The pie charts below, show the proportionate causes of death in the first 12 months, and final 12 months to demonstrate the dramatic shift in causes of mortality between those years.  The second pie chart is shown proportionately smaller to reflect the considerably lower number of koala deaths in the final 12 months.



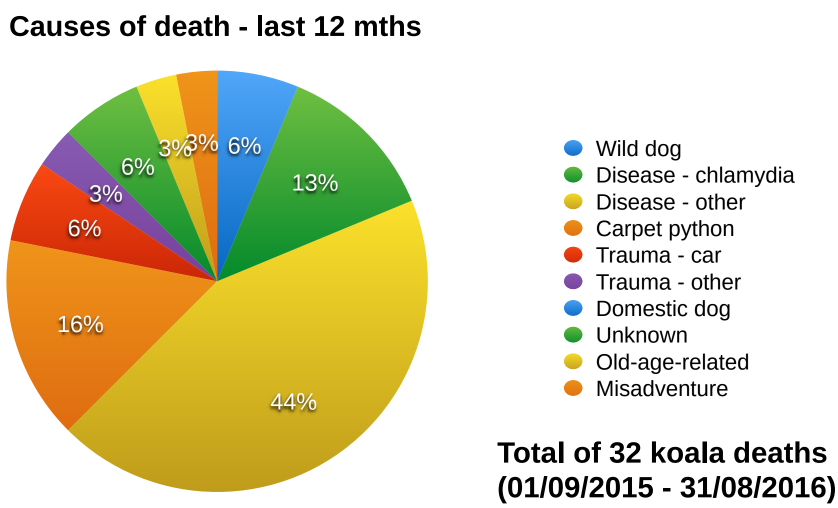




**Figure 8.7:** Proportionate causes of mortality in the first and final 12 months of the program. Note that in both pie charts, the causes of death legend to the right of the pie chart lists causes commencing at the 12 o'clock position and progressing in a clockwise direction.  In some cases, a cause was not diagnosed in that year - for example in the first 12 months there were no old-age-related deaths diagnosed or misadventure diagnoses.  The lower chart is shown proportionately smaller to demonstrate the significantly fewer deaths in final 12 months.

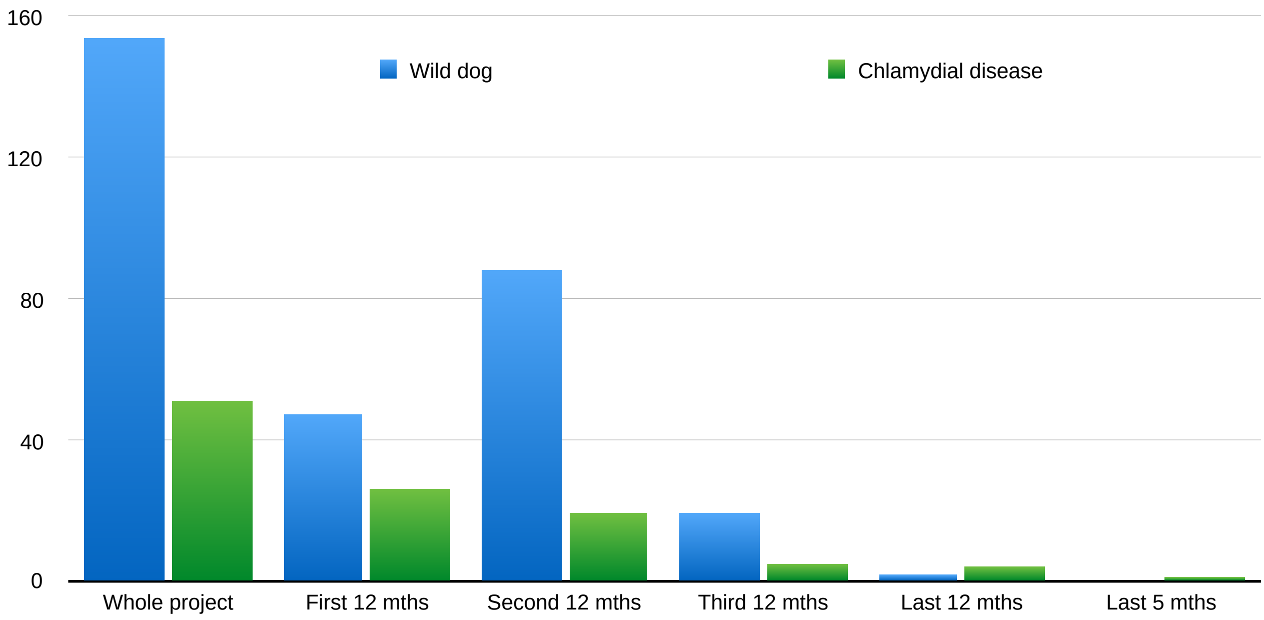
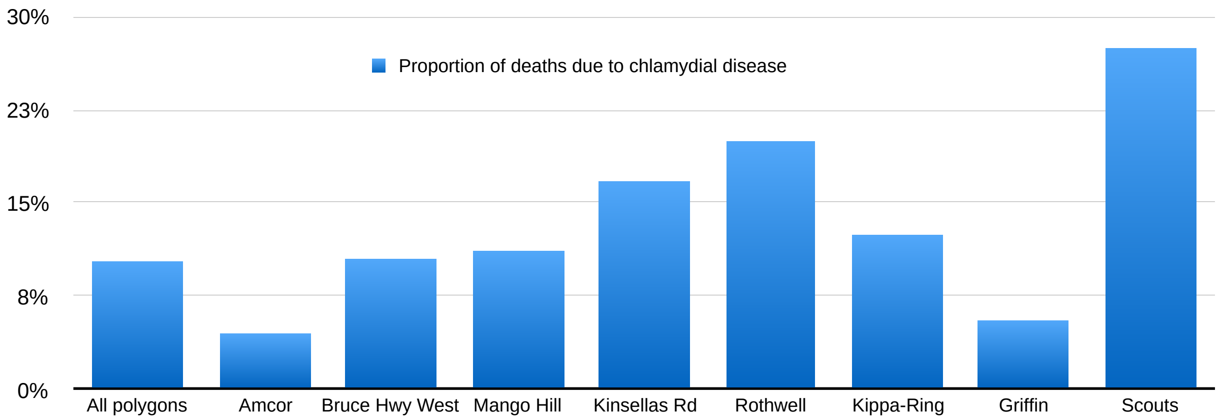



**Figure 8.8:** Changes in wild dog and *Chlamydia*-related death by years demonstrating reduction over time.



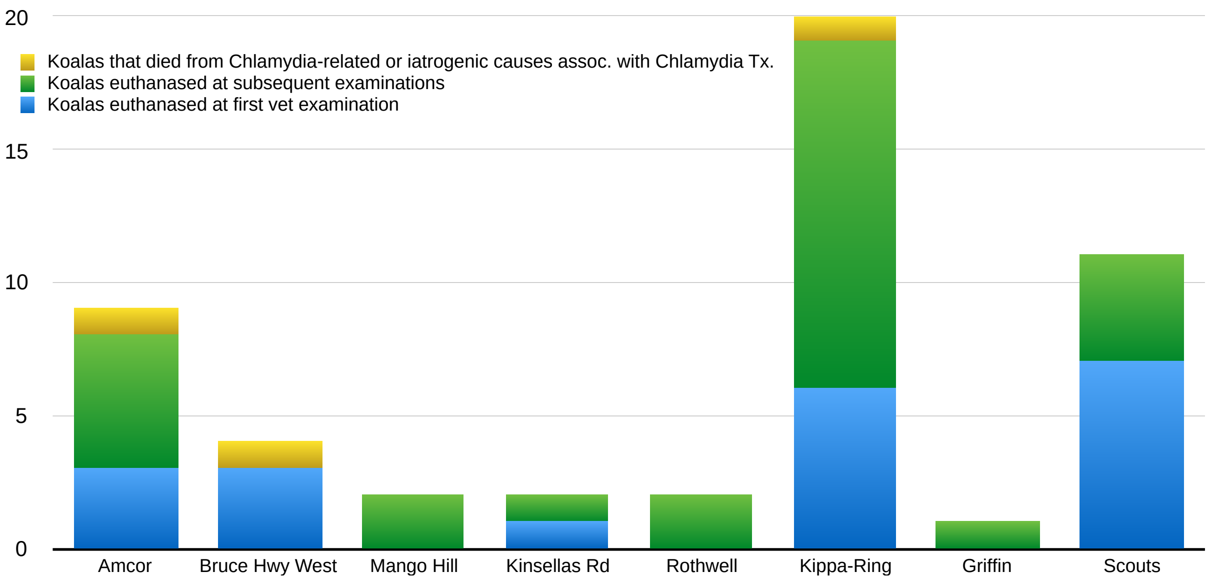




**Figure 8.9**: Total numbers (top graph) and proportion of koalas processed (bottom graph) of koala deaths attributable to chlamydial disease or chlamydial disease treatment (iatrogenic contribution), by polygon. Note that although Kippa-Ring has the highest total number of *Chlamydia*-related deaths, the Scouts polygon had the highest proportion of koalas lost to *Chlamydia*-related illness. Amcor was the lowest proportionately. These figures reflect the overall prevalence of chlamydial disease at those sites.

### 8.4.5 Wild dog predation

In the first two years of the koala management programs, wild dog predation was the predominant cause of koala mortality. From commencement of the program through to 31 August 2016, there were 116 *definitive* cases of wild dog predation and 38 *suspected* predation deaths (based on circumstantial evidence). In the latter group, in 4 cases some remains were found, but either the identity of the remains (koalas *Mitch* and *Solo*), or the cause of death (koalas *Jodie* and *Tom*), could not be achieved with a high degree of certainty. For comparison, there were two koalas definitively killed by domestic dogs (*Penny* and *Adrianna*), and three cases which were suspected to be caused by domestic dogs (based on necropsy and circumstantial evidence), but for which the degree of certainty was less regarding whether wild or domestic dog; two such cases were equivocal (koalas *Setchy* and *Friar Tuck*) and the third (*Moon Unit*) was subject to necropsy at the Moggill Koala Hospital and findings were not sufficiently detailed to permit a definitive diagnosis.

For the purposes of definition of deaths as definitely attributable to *wild dog predation* versus *suspect wild dog predation*, the criteria are contained in ***Chapter 9 - Wild dogs***. In short, if there was evidence of wild dog predation sufficient to remove all reasonable doubt, then a diagnosis of *wild dog predation* was made. If the circumstances or evidence were less compelling, but still suggestive of wild dog predation, i.e. on the balance of probability, then a classification of *suspect wild dog predation* was made. In cases where less evidence, or no evidence of wild dog predation was found, but a koala "disappeared" - that is, signals were suddenly lost on both telemetry tags and the koala was never found again, a possibility still remains that the koala was killed by wild dogs, but that diagnosis is speculative.

It is important to note that in cases of *wild dog predation* the carcass was not always consumed by the predator. In a considerable proportion of cases the carcass was not consumed at all, or only partly consumed. In some of the cases, body parts were buried or cached (for example, the upper and lower body of koala *Silver* in two separate brush turkey mounds), and in one case the entire body of the koala was buried (koala *Marty*- **Plate 8.4**).

**Plate 8.4**: Exhumed body of the near-independent juvenile koala *Marty,* which was cached by burial. *Marty* was the joey of *Jahnie,* who was killed at the same time - victims of the "Amcor Dog". She was eviscerated and cached in thick lantana, not buried. See following chapter for additional photographs taken at the cache site during exhuming of the body.

In many cases in which the carcass was intact, it was left on the ground. In three cases of wild dog trauma/predation, the koala was found alive, but died or was euthanased shortly after admission to koala care facilities (the koalas *Mungo Jerry, Fern* and *Demeter*). Fortuitously, in a handful of cases, the joeys of deceased mothers were recovered alive and hand-reared to independence (*Pistachio* (**Plate 8.5**)*, Iskeli, Cashew, Dibsy, Hot Lips* and *Linky*). In all of these cases (with the exception of the equivocal cases of *Setchy, Friar Tuck* and *Moon Unit*) the leaving of an intact carcass and/or a fatally injured koala was a feature typical of the "Amcor Dog".

**Plate 8.5:** Body of "Amcor Dog" victim *Caz* with her joey *Pistachio*, who was successfully hand-reared (May 2014).

**Plate 8.6**: Koalas are very susceptible to wild and domestic dog attack, and attack by large domestic livestock (cattle and horses) when travelling across open ground. Koala *Fozzie* after final release at the Griffin offset site in December 2016.

The "Amcor Dog"

In all of the cases in which the carcass was left intact, and the three cases aforementioned that were discovered alive (koalas *Fern, Demeter* and *Mungo Jerry*), the offending dog is believed to be the "Amcor Dog". This is a large male dog of dingo appearance who ranged in koala habitat in the *Amcor* and *Bruce Hwy West* koala search polygons and was the only dog captured on trail cameras in those areas for the period between December 2013 and July 2015. Further discussion of wild dogs and wild dog control and the evidence for the "Amcor Dog" are presented in the following chapter ***Chapter 9 - Wild dogs***.

A summary of the field findings in cases of wild dog predation is presented in the table below:

| Koala search polygon | Total wild dog predations | Koala alive | Carcass entire | Carcass partial* | Limited remains* | Amcor Dog |
|---|---|---|---|---|---|---|
| Amcor | 69 | 2 | 24 | 34 | 9 | 55 |
| Bruce Hwy West | 8 | 1 | 2 | 3 | 2 | 8 |
| Mango Hill | 2 | 0 | 0 | 0 | 2 | 0 |
| Kinsellas Rd | 2 | 0 | 0 | 0 | 2 | 0 |
| Rothwell | 2 | 0 | 0 | 0 | 2 | 0 |
| Kippa-Ring | 23 | 0 | 0 | 12 | 11 | 0 |
| Griffin | 8 | 0 | 0 | 5 | 3 | 0 |
| Scouts | 2 | 0 | 0 | 1 | 1 | 0 |
| Totals | **116** | **3 (2.6%)** | **26 (22%)** | **55 (47%)** | **32 (28%)** | **63 (54%)** |

*Carcass partial: recognisable portions of a carcass, such as limbs, torso, but a least some disembowelling or dismemberment of the carcass has occurred.
*Limited remains: fur, gastrointestinal tract, fragments of bone etc., but not limbs or sections of torso.

**Table 8.4:** Field findings of wild dog predation remains by polygon and "Amcor Dog". Note that all of the cases definitively diagnosed as *wild dog predation* in which an entire carcass or live koala was found are attributable to the "Amcor Dog" and were found in either the *Amcor* polygon or the adjacent areas of the *Bruce Hwy West* polygon.

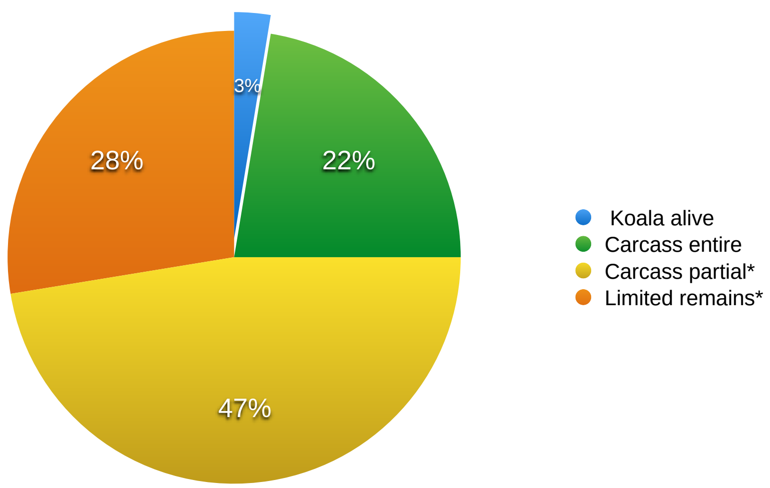



**Figure 8.9:** Koala remains following wild dog attack/predation. Legend lists categories from the 12 o'clock p osition in a clockwise direction. **Carcass partial*, refers to remains that are easily recognisable as a koala, but have had parts removed or are eviscerated; *Limited remains* refers to small and/or not-easily recognisable parts of koalas, such as fur, bone fragments, abdominal contents etc.

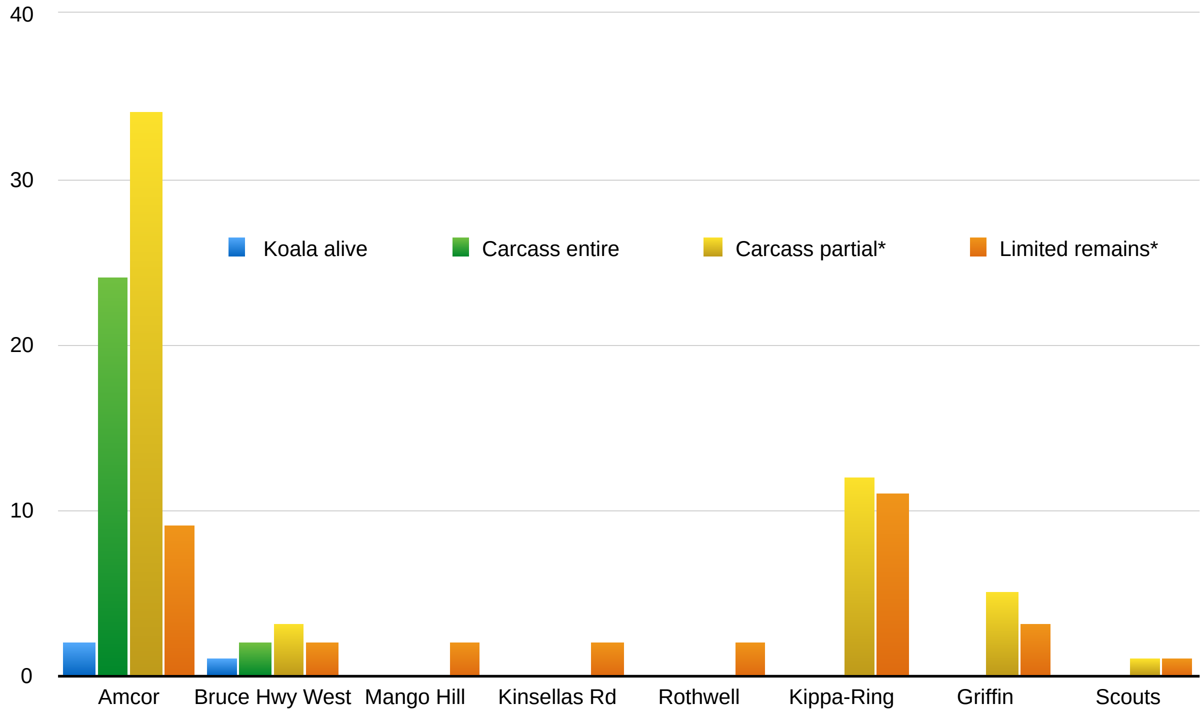



**Figure 8.10:** Wild dog deaths by polygon (includes translocated koala deaths) and remains. Note that live victims and entire remains were *only* found at the sites at which the "Amcor Dog" was known to be active - *Amcor* and *Bruce Hwy West.* During his period of highest activity, he appeared to have a very "casual" approach to his victims, leaving some alive - three were found barely alive, and many others were found dead but had *post mortem* evidence of having been left alive (but fatally injured).

The following table summarises the wild dog deaths by polygon and various categories, including resident koalas vs translocated koalas. The data are presented graphically on the following pages.

| Polygon | Resident koala deaths | Transloc. koala deaths | Suspect wild dog deaths (none translocated koalas) | Total koalas processed at each polygon | Number of koalas killed/ suspect killed by wild dogs | % of population killed by wild dogs (excl. translocated koalas) definite | % of population suspect killed by wild dogs (excl. translocated koalas) |
|---|---|---|---|---|---|---|---|
| Amcor | 69 | 0 | 11 | 206 | 80 | 33 | 5 |
| Bruce Hwy West | 8 | 0 | 2 | 38 | 10 | 21 | 5 |
| Mango Hill | 2 | 0 | 0 | 18 | 2 | 11 | 0 |
| Kinsellas Rd | 2 | 0 | 1 | 12 | 3 | 17 | 8 |
| Rothwell | 2 | 0 | 1 | 10 | 3 | 20 | 10 |
| Kippa-Ring | 23 | 0 | 20 | 161 | 43 | 14 | 12 |
| Griffin | 4 | 4 | 3 | 18 | 7 | 22 | 17 |
| Scouts | 1 | 1 | 0 | 40 | 1 | 3 | 0 |
| Totals | **111** | **5** | **38** | **503** | **149** | | |

**Table 8.5**: Koala deaths by polygon and category: resident vs translocated; definitive vs suspect; total number vs proportion of koalas processed - by polygon.

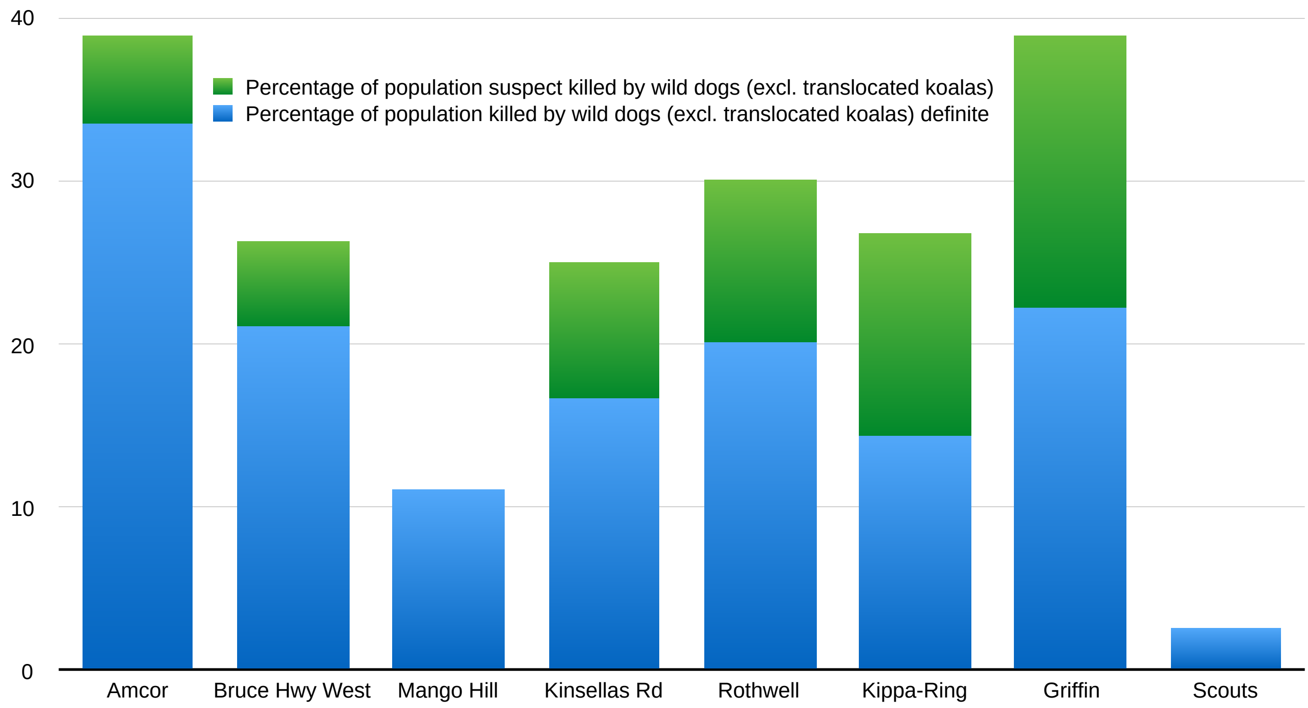



**Figure 8.11** Wild dog deaths by polygon as a percentage of koalas processed at each polygon.

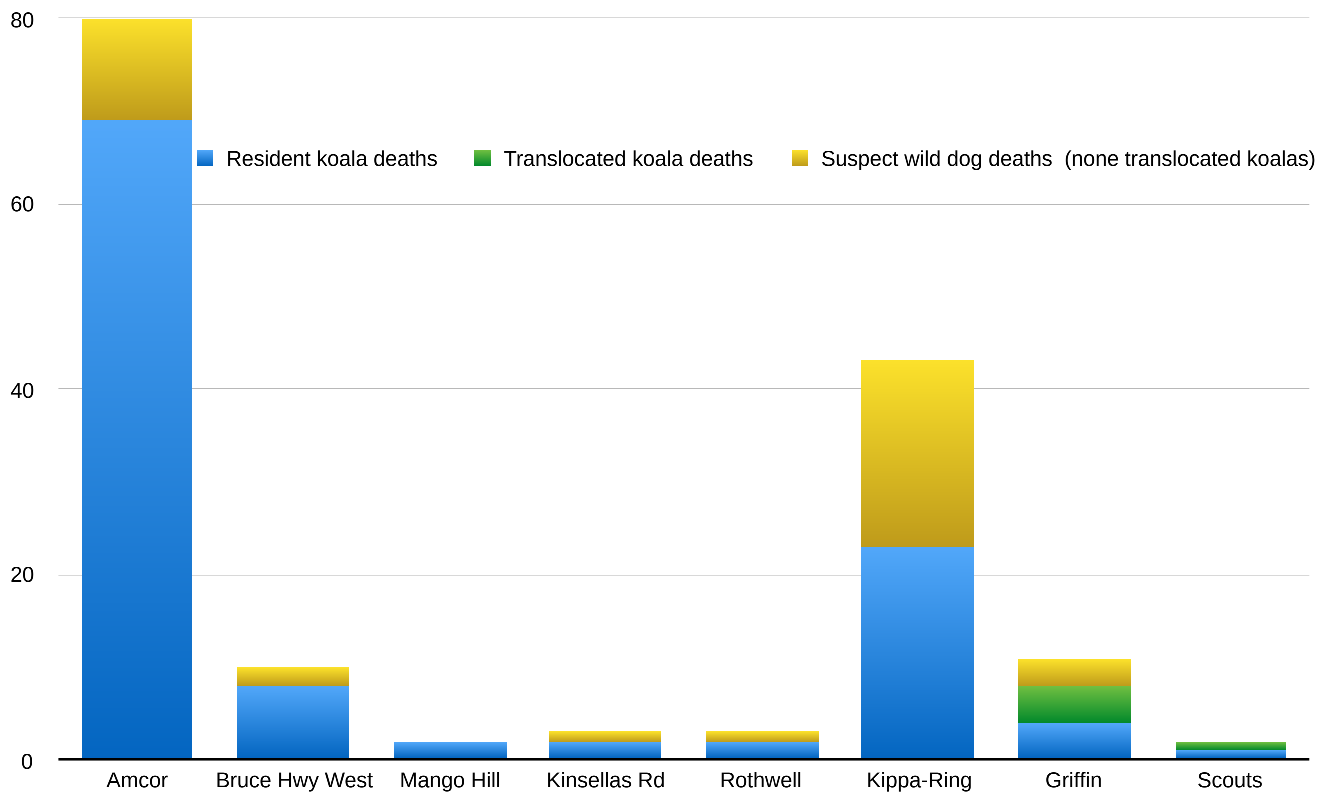



**Figure 8.12**: Wild dog deaths by polygon shown as total numbers in each category of “resident koalas” (blue bar section), “translocated koalas” (green bar section) and “suspected” wild dog predation cases (yellow bar section), of which none was a translocated koala.

Further discussion of wild dogs is presented in the following chapter.

**Plate 8.7**: The koala *Mungo Jerry* shortly after being found in the field during tracking for scheduled health check capture on 13 July, 2015 (left image), and koala *Demeter* as she was found during routine tracking in April 2014 (right image). Both had suffered massive trauma to the neck as a result of a single dog bite. The accurate bite to the neck was typical of the "Amcor Dog", as was the leaving of the victim fatally wounded, without any attempt to consume or cache the carcass.

**Plate 8.8**: Koala *Mungo Jerry* undergoing treatment following his attack by the "Amcor Dog". He was treated for 7 days, but was eventually euthanased due to systemic inflammatory response syndrome (SIRS) as a consequence of the massive tissue damage in the neck. The image shows the almost surgically precise bite to the neck typical of the *modus operandi* of the "Amcor Dog".

### 8.4.6 Carpet python predation

Carpet python predation was a significant cause of death of wild koalas during the koala management program. This was somewhat unexpected, although there are occasional anecdotal reports of carpet pythons attacking koalas. During the nearly four years of the koala management programs for the MBR project, 21 koalas were killed by carpet pythons (definitively diagnosed). Carpet python predation accounted for 7% of all confirmed and suspected deaths of koalas and was the second-most important predation cause-of-death (after wild dogs), accounting for 11% of predation deaths (including *suspect wild dog predations*). (Data from 18/03/2013 - 31/08/2016 only, used for population mortality statistics.) These figures do not include loss of untagged dependent joeys that went missing (some of which may have been predated by carpet pythons), and young joeys of mothers killed by pythons.

**Plate 8.9:** Carpet python with ingested koala *Silk* (red arrow pointing to pronounced "koala bulge" in the snake)

**Plate 8.10**. Classical signs of a non-ingested carpet python predation - slicking of the fur with saliva (left image) and a clearly-defined primary bite site (right image) showing the typical U-shaped pattern of fine punctures. Koala *Madso,* January 2014.

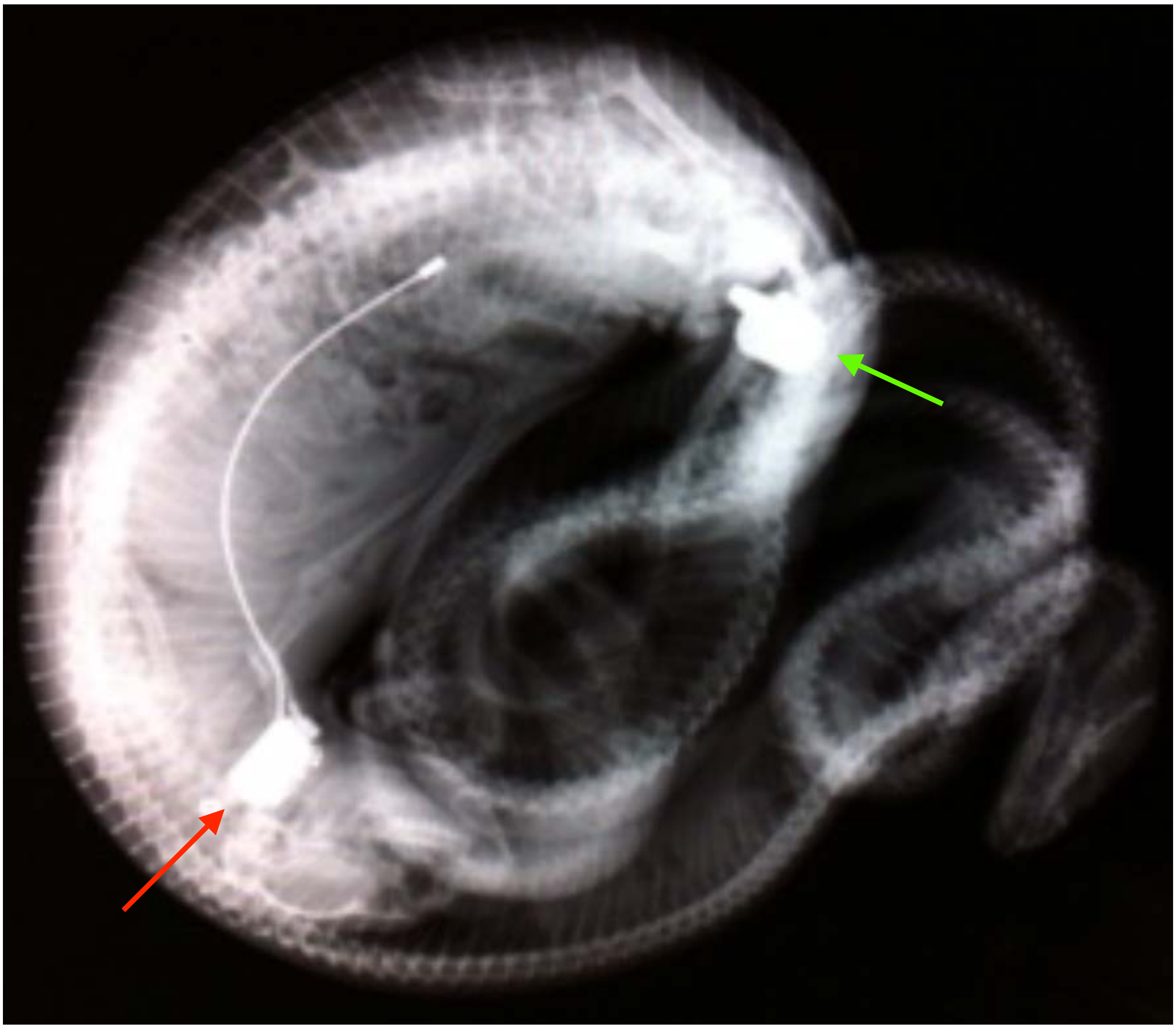


**Plate 8.11:** Radiograph of carpet python with ingested koala *Ned* (red arrow pointing to VHF collar, green arrow pointing to VHF anklet). The head of the python is on the far right, lower quarter of the image.

## Seasonal variation in carpet python predation/deaths

Marked seasonal variation in carpet python predation/deaths of koalas was noted. This is referable to the poikilothermic (environmental temperature-dependent) physiology of reptiles, and consequently their greater activity during warmer weather. The graph below clearly shows the seasonal variation in carpet python predation/deaths over the duration of the project, with mortalities clustering in warmer weather.

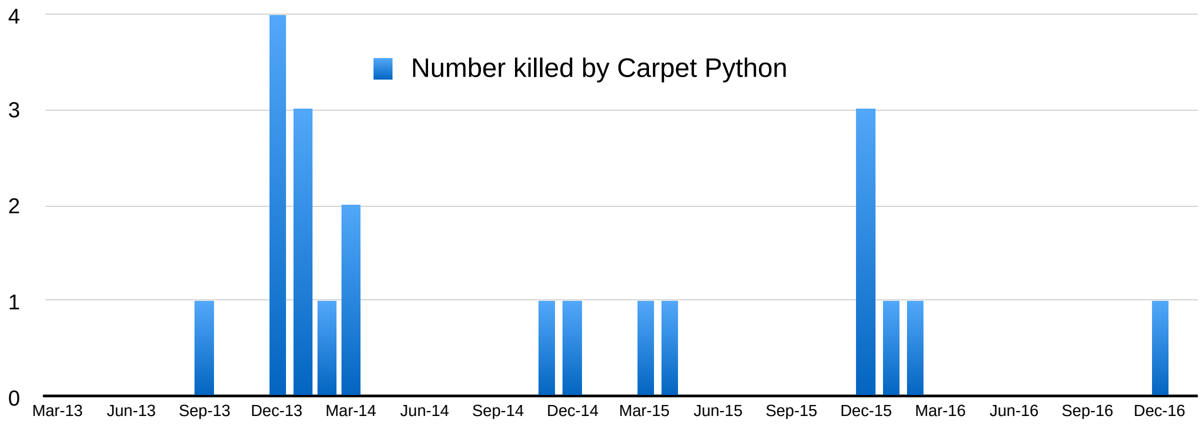



**Figure 8.13:** Seasonal variation in carpet python predation of koalas. Deaths are clustered around the warmer months when snakes are more active and more likely to feed.

In only 8 of the 21 cases (38%) was the koala ingested. There was no significant sex difference (3 of 9 males ingested, 5 of 12 females ingested). The age-range of ingested koalas was 11.5 months - 14 months; weight at death was not determined, but based on age and previous weight records for those individuals, is likely to have been in the range of 1.2 - 3.5kg. Thirteen (6 male, 7 female) (62%) koalas were killed by carpet pythons but not consumed. The age-range of non-ingested koalas was 10.5 months - 7 years; and weight range was 1.3 - 7.2kg. These details are summarised in the table below.

| Koala name (#) | Sex | Age (Years) | Weight in kg (approx.) | Ingested/not ingested |
|---|---|---|---|---|
| Jenny B (32) | Female | 4.38 | 5.49 | Not ingested |
| Red Baron (58) | Female | 2.59 | 4.8 | Not ingested |
| Ned (190) | Male | 0.98 | 2.04 | Ingested |
| Miles (170) | Male | 1.06 | 2.62 | Not ingested |
| Kate G (82) | Female | 5.51 | 5.35 | Not ingested |
| Inara (131) | Female | 1.01 | 1.52 (1mth prior) | Ingested |
| Hugo (137) | Male | 1.06 | 2.23 (7 days prior) | Ingested |
| Madso (247) | Male | 1.04 | 2.46 | Not ingested |
| Silk (231) | Female | 1.14 | 2.52 (1.5-2mths prior) | Ingested |
| Varney (230) | Male | 2.29 | 5.12 | Not ingested |
| Peaches (135) | Female | 1.3 | 3.65 | Not ingested |
| Mattaeus (388) | Female | 0.96 | 1.82 (6 days prior) | Ingested |
| Faith (401) | Female | 0.98 | 1.89 (1 month prior) | Ingested |
| Spartan (300) | Male | 7.02 | 7.19 | Not ingested |
| Felicia (438) | Female | 1.15 | 2.54 (1.5 mths prior) | Ingested |
| K-ski (478) | Male | 0.96 | 1.16 (1 mth prior) | Ingested |
| Mud (455) | Female | 1.07 | 2.97 | Not ingested |
| Lisa (482) | Female | 0.88 | 1.59 | Not ingested |
| Tait (383) | Male | 3.39 | 6.07 (2 mths prior) | Not ingested |
| Slick (498) | Male | 0.97 | 1.27 | Not ingested |
| Geisha (264) | Female | 12.9 | 5.17 | Not ingested |

**Table 8.6:** Koalas killed by a carpet python between program commencement in March, 2013 and end in January 2017.

**Plate 8.12**: Collateral damage: the 1-month-old joey of *Red Baron* (who was killed by a python, but not ingested). Predation of female koalas usually led to loss of their dependent joeys as well, except in a small number of cases.

## Pathological findings

Carpet pythons cause death by constricting their prey, resulting in asphyxiation due to compression of the chest and inhibition of respiratory movements. The sequence of events during the predation event is as follows:

1. The carpet python strikes and grabs at the prey with its mouth, rapidly throwing loops of its body around the prey;
2. The coils are gradually constricted around the prey as it struggles, eventually compressing the chest and inhibiting respiratory movements until asphyxiation occurs. The python may maintain these coils for some minutes after the prey has ceased struggling and breathing;
3. The primary bite is released and the snake uncoils from its prey;
4. The python searches for a suitable starting point for ingestion of the prey whole; this is generally the head;
5. The prey is either successfully ingested, or is regurgitated if it cannot be entirely ingested. A python may not make any attempt to consume a killed prey if it is disturbed or for other reasons.

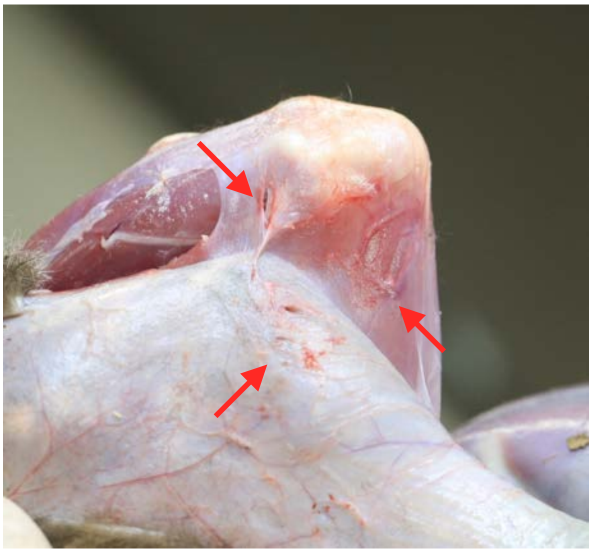
There are three cardinal pathological signs of carpet python-caused constriction death:

1. Finding of the primary bite site;
2. Generalised, even, diffuse congestion of the lungs;
3. Slicked fur caused by the saliva of the python if an attempt at ingestion has occurred.

The pathological findings in cases of carpet python constriction death (without ingestion) can be subtle and difficult to detect at necropsy. The examining veterinarian must carefully and systematically examine the carcass, both externally and internally, and frequently extensive clipping of the fur is required to find the primary bite site. These signs will be easily overlooked at necropsy, are rapidly obscured by exposure and *post-mortem* decomposition, and are often the only pathological findings in an otherwise very unremarkable necropsy examination.

The images below show these lesions in the koala *Red Baron* - one of the cases with subtle lesions:

**Plate 8.13:** U-shaped, fine puncture marks on the forearm of koala *Red Baron* (left image) and subtle slicking of the fur around the muzzle (right image). These subtle lesions require very careful and thorough examination of the carcass, including extensive clipping of the fur to search for the fine punctures of the primary bite site. *Post-mortem* decomposition rapidly masks the more subtle signs, such as the very limited slicking of the fur of the muzzle in this case.



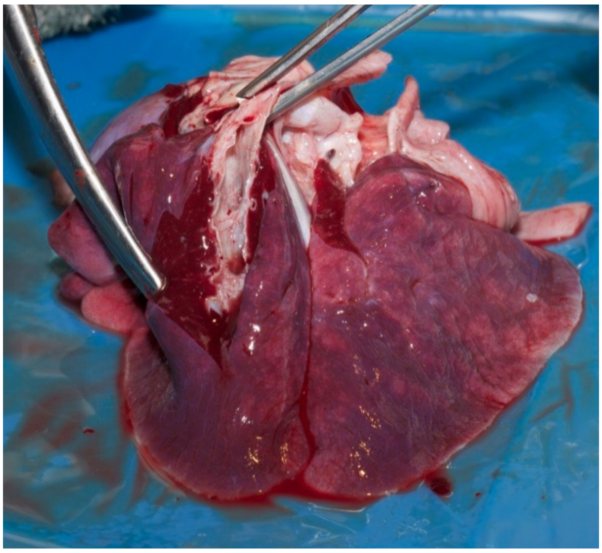


**Plate 8.14**: The three cardinal necropsy signs of carpet python predation, from top: slicking of the fur, usually of the head, caused by partial ingestion then regurgitation of the carcass; primary bite site with fine punctures (red arrows) (lower left image) and generalised congestion of the lungs (lower right image). Note that lung congestion is a non-specific finding, but in other cases not primarily associated with pulmonary disease, it tends to be patchy congestion. This is generalised congestion, which is unusual unless pulmonary disease is present. In carpet python-related deaths, this generalised congestion is caused by the fatal constriction of the prey, massive adrenaline release, and exaggerated efforts to breath during the process of asphyxiation. The primary bite site can be very difficult to find, and in some cases slicking of the fur may not be present if the python did not attempt to consume the prey. Photos above are from the necropsy of *Varney* (top and lower left) and *Red Baron* (lower right).

In the first two years of the program *carpet python predation* was the third most common cause of death after *wild dog predation* and *disease.* In the last year of the program, carpet python predation was the second most common cause of death, although the total number did not change significantly. This change in proportion was due to the significant decrease in *wild dog predation* cases.

This report is the first documentation of the significant contribution that carpet python predations make to premature mortality of koalas. Carpet pythons should be considered a significant and "normal" predator of koalas, as they are of other native mammals and birds. For the record, carpet pythons (*Morelia spilota*) are a native Australian reptile. It is notable that in less than half of the cases (38%) was the carcass consumed, suggesting that pythons will often attack and constrict prey that exceeds the maximum size that they can consume. In some cases, it is possible that the prey was regurgitated or otherwise not consumed because the snake was disturbed during the feeding phase.

### 8.4.7 Predation of koala joeys

It is likely that carpet pythons are a significant predator of late back-rider and near-independent koala joeys, and may explain the disappearance of a significant number of this group of joeys (see ***Chapters 10 - Koala reproductive success*** and ***11 - Population viability analysis***), whose survival to independence was just under 80%. Lace monitors (*Varanus varius*), white-bellied sea eagles (*Haliaeetus leucogaster*), wedge-tailed eagles (*Aquila audax*) and possibly other native predators, are likely to prey upon late back-rider and near independent joeys as they spend time separated from the mother and are vulnerable to opportunistic predation. Although we made no direct observations ourselves, a lace monitor was observed (on another project) attempting to take a back-rider joey (J. Callaghan, *pers*. *comm*.).

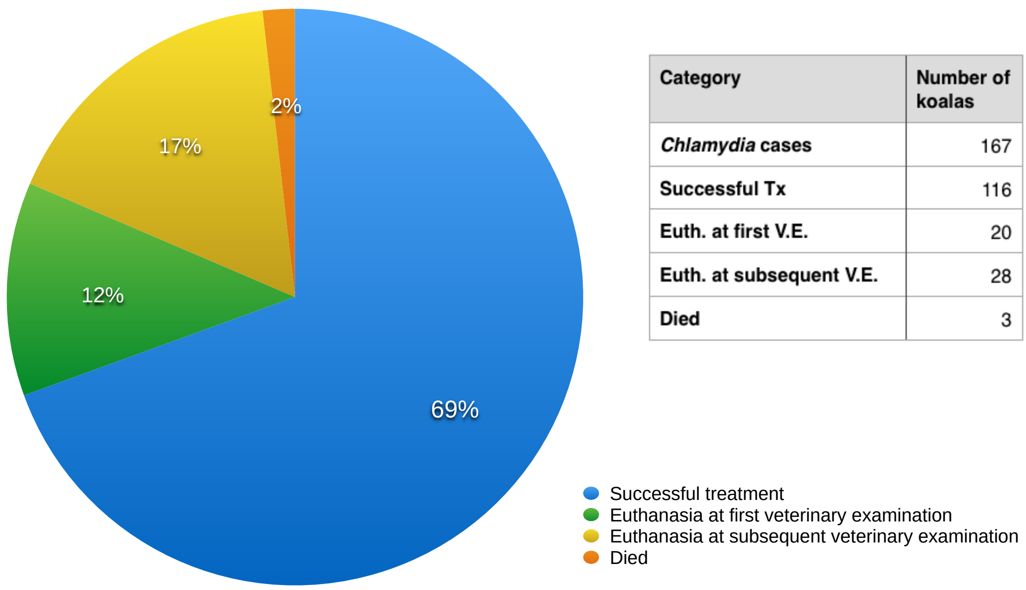
## 8.4.8 Chlamydial disease

The classical presentations of chlamydial disease include kerato-conjunctivitis (pink-eye) and urogenital tract disease. The latter manifests as infertility/sterility in female koalas (and to a lesser extent in males) and cystitis (inflammation of the bladder/urinary tract) in both sexes. Chlamydial disease tends to be a chronic disease (that is, long-term), and is associated with development of scar tissue and loss of function in affected organs and tissues. Ultimately, the disease can lead to blindness, chronic pain, renal failure and death. Sterility is a common sequela to urogenital infection in female koalas, leading to significant reproductive loss at a population level. Gastrointestinal and respiratory tract infections may also occur, but the pathogenesis and pathology of these conditions is less well understood.

Chlamydial disease can be associated with significant pain and discomfort, and koalas with cystitis (bladder inflammation) often vocalise in pain as they attempt to urinate. In koalas with a relatively poor prognosis for treatment (advanced and severe disease) or aged koalas with short life-expectancy, the most humane veterinary management option is euthanasia. A more detailed discussion of treatment for chlamydial disease and clinical outcomes is presented in ***Chapter 4 - Veterinary management of koalas***.

A high prevalence of chlamydial disease was expected in the MBR koala population because of previous research by EVE. In other studies, prevalence rates were in the order of 40-50%. Hence, a key objective of the koala program was to document and manage chlamydial disease as part of the holistic offsets and compensatory package. Of the 503 koalas processed over the course of the program (18 March 2013 - 31 August 2016 for this analysis) 167 (33%) either had, at the first examination, or subsequently developed, chlamydial disease (or strong Clearview *Chlamydia* positivity), of which 20 (12%) were euthanased at their first veterinary examination because of the severity of lesions and/or concurrent old-age, and a further 31 (19%) were subsequently euthanased (28) or died (3) due to their illness and/or from complications arising from treatment and/or captive care (iatrogenic conditions).

The table and pie chart below summarise the outcomes for chlamydiosis-affected koalas over the period March 2013 - 31 August 2016. (Additional koalas were treated for disease after this period (during program ramp-down), but were not included at the time this analysis was performed.)




| Category | Number of koalas |
|---|---|
| ***Chlamydia* cases** | 167 |
| **Successful Tx** | 116 |
| **Euth. at first V.E.** | 20 |
| **Euth. at subsequent V.E.** | 28 |
| **Died** | 3 |

**Figure 8.14:** Chlamydial disease outcomes for MBR koalas between 18 March 2013 and 31 August 2016.

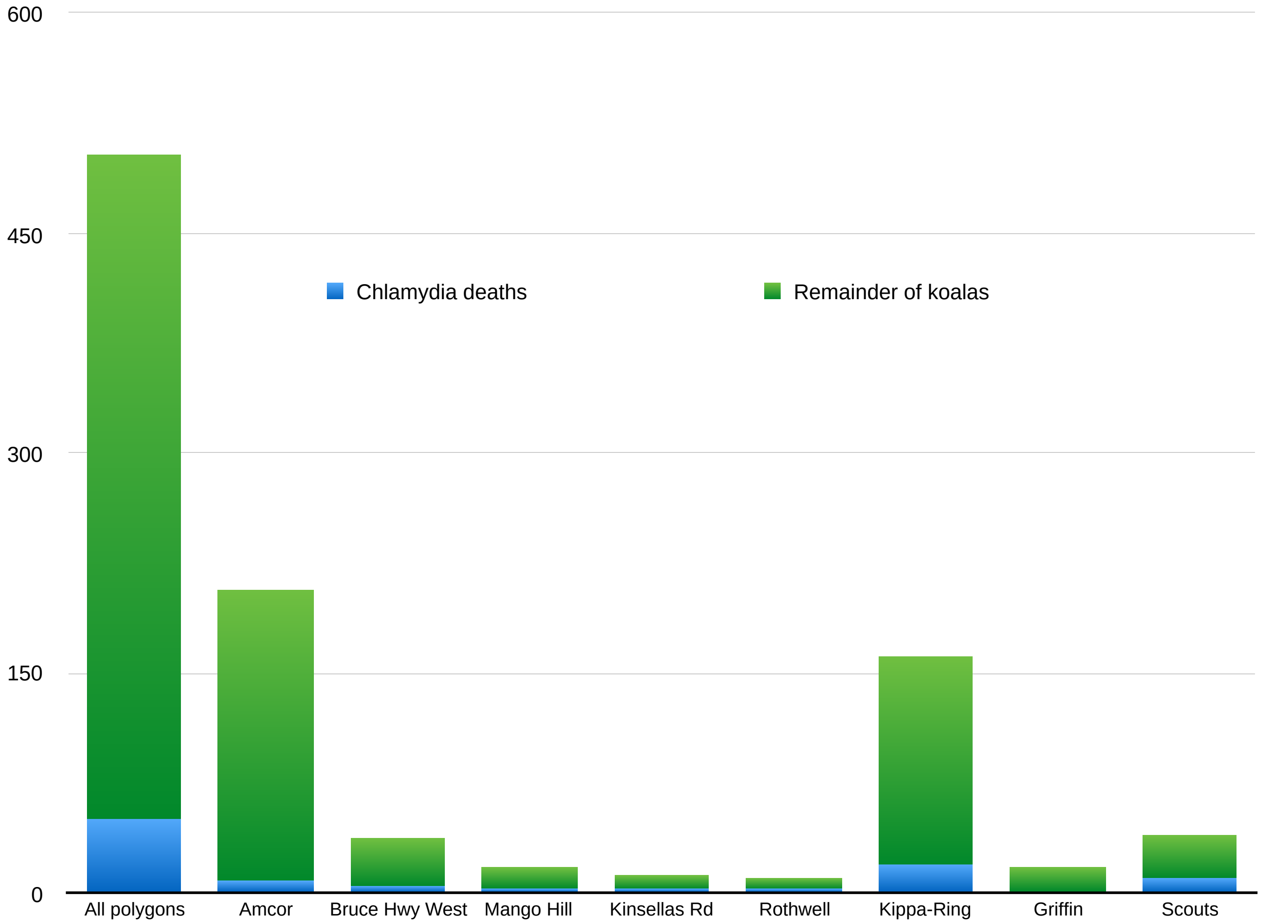



**Figure 8.15**: *Chlamydia*-related deaths (blue), as a proportion of total koalas processed (blue + green), by polygon. Note that Amcor had the lowest prevalence of chlamydial disease and therefore the lowest proportional loss of koalas due to chlamydial disease. (Data derived from 18 March 2013 - 31 August 2016.)

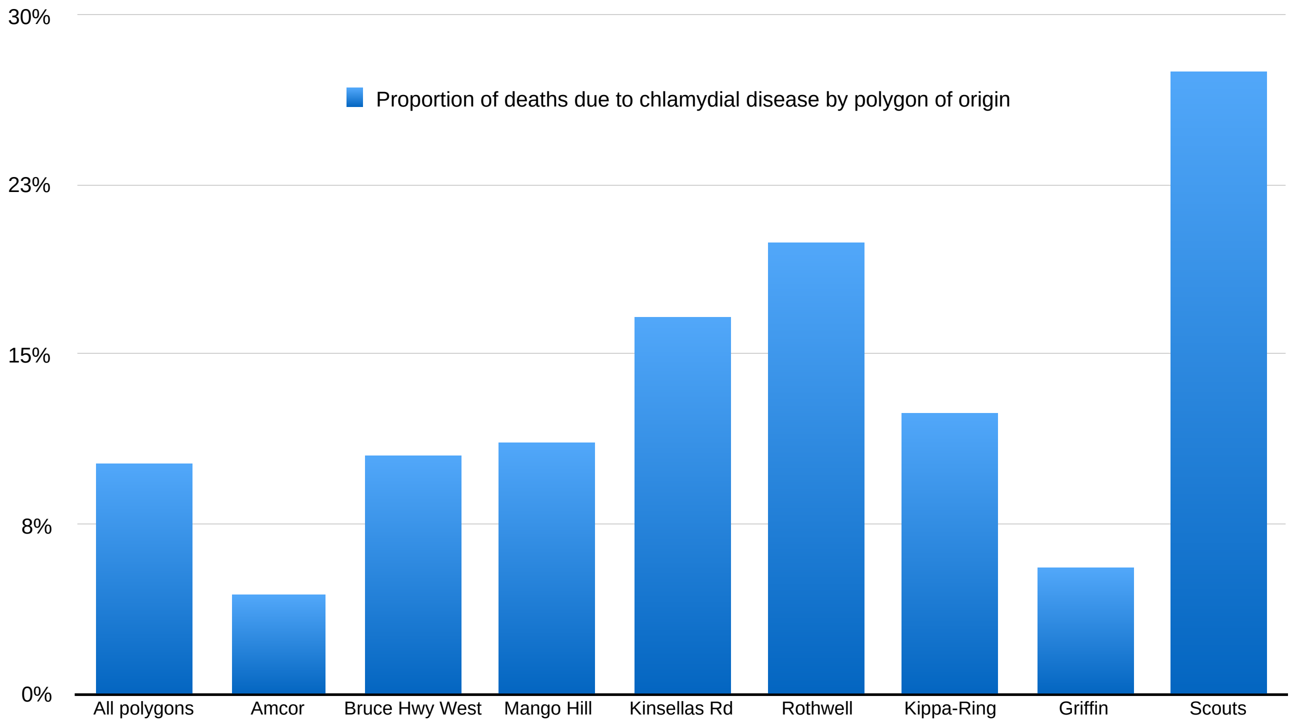



**Figure 8.16**: Bar chart showing percentages of total koalas processed by polygon that died or were euthanased due to *Chlamydia*-related disease. Note that Amcor has the lowest proportion, and Scouts the highest.

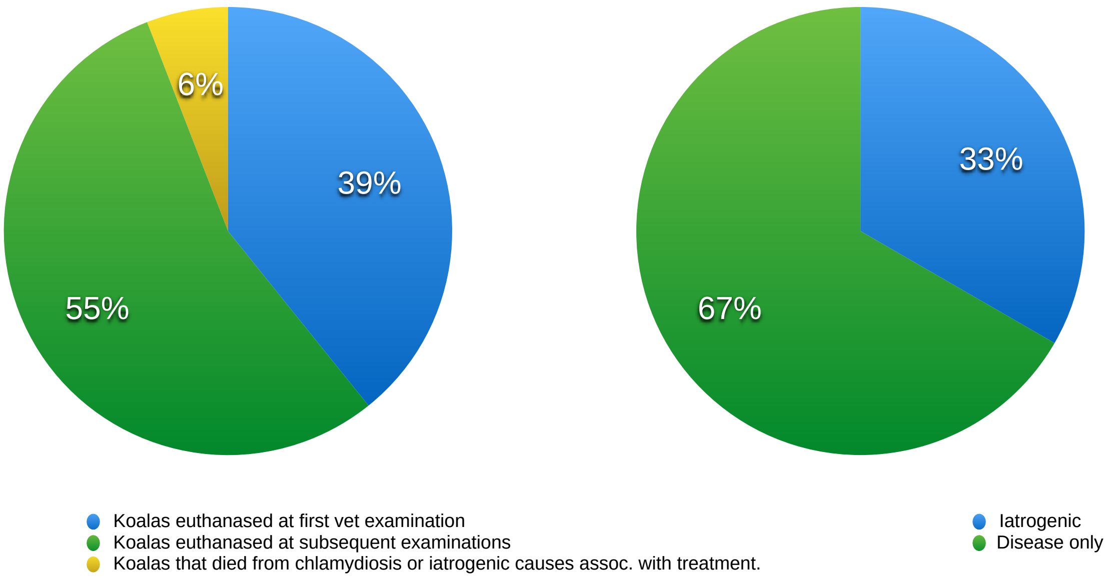



**Figure 8.17:** Proportions of the 51 koalas with *Chlamydia*-related deaths. Pie chart on the left shows proportions with respect to euthanasia or natural death and whether euthanasia was at the initial/first examination or later in treatment. The pie chart on the right shows total *Chlamydia*-related deaths with respect to proportion in which iatrogenic factors contributed to death or euthanasia, irrespective of whether they were euthanased or died naturally.

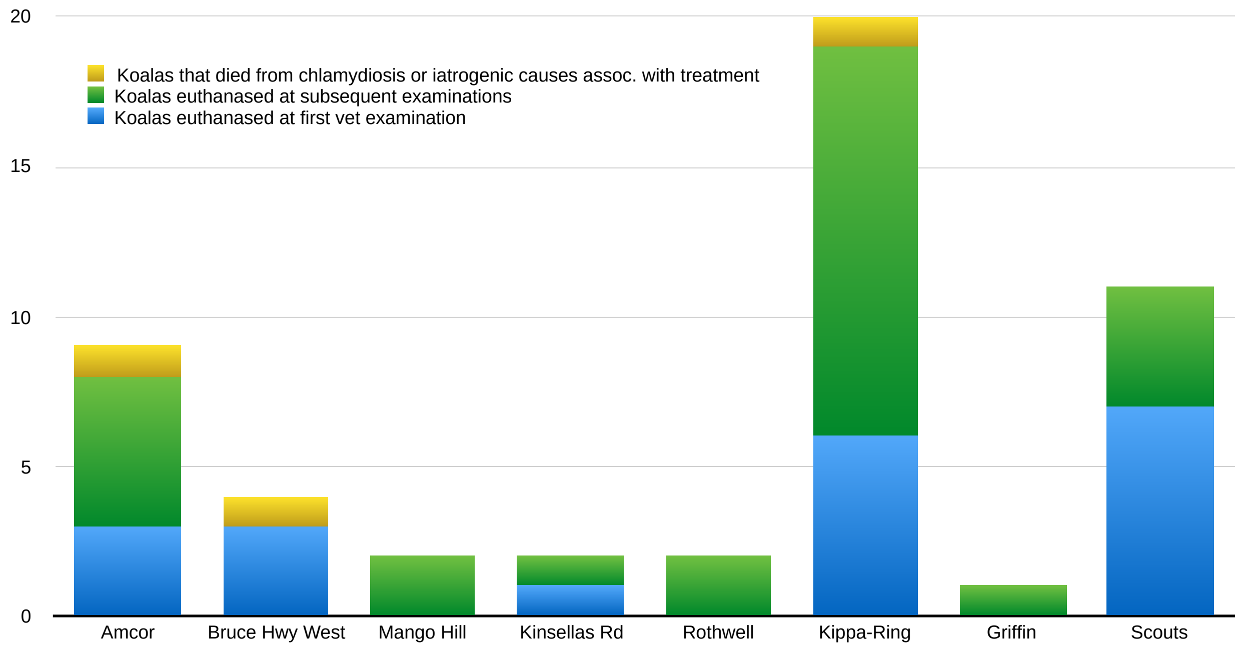



**Figure 8.18:** *Chlamydia*-related deaths by polygon. Note that this is total deaths, not proportions. See **Figure 8.16** (previous page), for deaths due to chlamydial disease as a proportion of the total koalas processed at each of the polygons.

### Note regarding iatrogenic conditions:

Iatrogenic conditions are those which have been caused by the clinician or clinical care, such as during diagnostic procedures or treatment, patient care, drug side-effects, nosocomial (hospital-acquired) infections, and the like. They are conditions that are not directly caused by, or related to, the primary condition for which the patient is treated. Although sometimes a result of clinician error or neglect, they may also occur as a result of factors which cannot be controlled, such as in the development oxalate nephrosis in koalas.

An additional section on deaths in which there was an iatrogenic contribution follows.

For our purposes, we have also included all cases in which some aspect of treatment or care contributed significantly to the death of the animal, or the decision to euthanase the animal.

The natural mortality rate from chlamydial disease in wild koalas is unknown. In most monitoring programs there is either some attempt to have disease cases treated, or alternatively, monitoring frequency is not sufficient to detect mortality early enough to allow diagnostic necropsy examination. Despite this, estimates of likely time of death of chlamydial disease-affected koalas in this program were made for the purposes of the population viability analysis (***Chapter 11 - Population viability analysis***), so that predictions could be made about population trends had there been no disease management. In our program, the treatment and management of chlamydial disease was a key objective, so the following statistics reflect the rate of euthanasia of severe cases, rather than what might naturally occur in the wild.

| Category | All sites | Amcor | Bruce Hwy West | Mango Hill | Kinsellas Rd | Rothwell | Kippa-Ring | Griffin | Scouts |
|---|---|---|---|---|---|---|---|---|---|
| Koalas euthanased at first vet exam | 20 | 3 | 3 | 0 | 1 | 0 | 6 | 0 | 7 |
| Koalas euthanased at subsequent exams | 28 | 5 | 0 | 2 | 1 | 2 | 13 | 1 | 4 |
| Koalas that died from *Chlamydia*-related or iatrogenic causes assoc. with chlamydial Tx. | 3 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| **TOTALS** | **51** | **9** | **4** | **2** | **2** | **2** | **20** | **1** | **11** |
| Iatrogenic | 17 | 2 | 1 | 2 | 1 | 0 | 9 | 1 | 1 |
| Disease only | 34 | 7 | 3 | 0 | 1 | 2 | 11 | 0 | 10 |

**Table 8.7:** *Chlamydia*-related deaths - summary by polygon. Note that the second-last row "Iatrogenic" relates to koalas with chlamydial disease whose death or euthanasia was partly as a result of iatrogenic causes.

## 8.4.9 Iatrogenic conditions

As described above, iatrogenic conditions are those in which an adverse effect has occurred as a result of medical management or captive care. For our purposes, this section deals with only those cases that have died, and in which an iatrogenic condition or factor significantly contributed to the death of the koala or the decision to perform euthanasia. In the total of 21 cases, 17 were being treated, or had been treated, for chlamydial disease, 2 were hand-reared orphans, and 2 were trauma cases.

The main iatrogenic conditions and numbers affected are listed in the table below, and graphically displayed in the pie chart below (**Figure 8.19**). A description of each of the main conditions is provided on the following pages.

| Iatrogenic Category | Number |
|---|---|
| Oxalate nephrosis | 5 |
| Dysbiosis - standard Tx | 7 |
| Dysbiosis - Nuflor | 4 |
| Surgical complications | 2 |
| Other | 1 |
| Orphan | 2 |
| **TOTAL** | **21** |

**Table 8.8:** Iatrogenic deaths by cause category

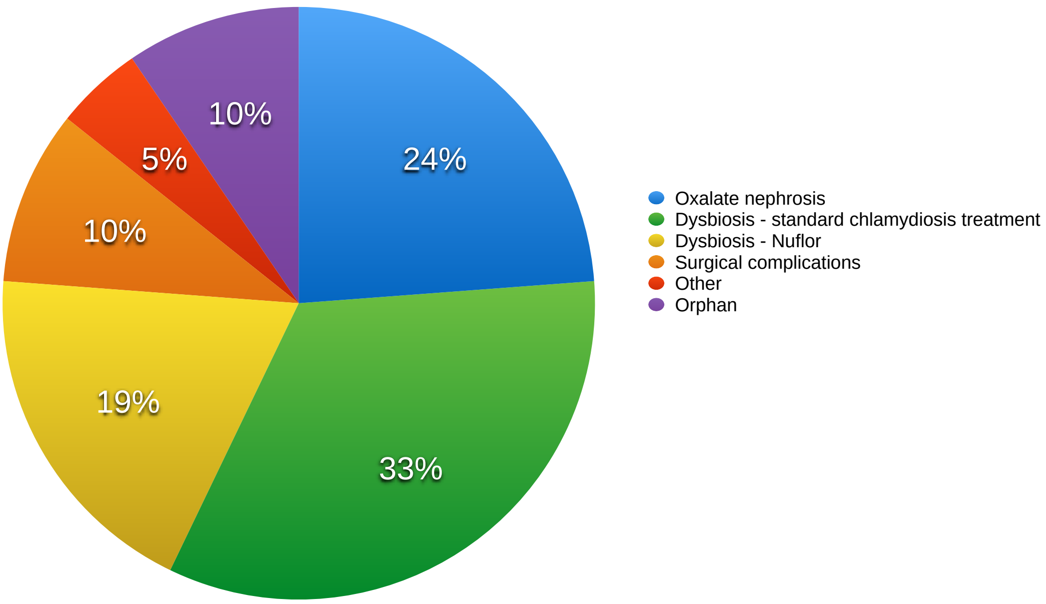



**Figure 8.19:** Iatrogenic deaths by cause category

## Oxalate nephrosis

Oxalate nephrosis is a degenerative condition of the kidneys in which insoluble crystals of calcium oxalate form in the tissues of the kidneys causing physical damage to, and obstruction of, the renal tubules, inflammation and deposition of scar tissue. In severe cases the condition leads to death from renal failure. The causes of oxalate nephrosis have not been definitively determined, but contributing factors probably include high levels of oxalate or oxalate precursor molecules in the browse (which may vary due to seasonal and weather changes), use of antibiotics (which may affect oxalate degrading bacteria in the gastro-intestinal tract) and the stress of captivity and treatment. A variety of treatment and prevention methods have been tried with limited success. Oxalate nephrosis occurs in the wild and is a leading cause of death reported in koalas from South Australia.

Development of oxalate nephrosis is monitored by renal sonography while koalas are in care for prolonged periods. If increasing renal echogenicity is detected, koalas may be placed on oral calcium supplementation (in an attempt to bind oxalate and prevent absorption), but if it progresses, affected koalas are often released prematurely. Offering brush box (*Lophostemon confertus*) and swamp box (*Lophostemon suaveolens*) as browse may provide some "natural" therapy for oxalate nephrosis, and these species are often preferred by koalas affected by advanced oxalate nephrosis. Further information on oxalate nephrosis is presented in ***Chapter 4 - Veterinary management of koalas***.

## Dysbiosis

The most common iatrogenic condition was caeco-colic dysbiosis caused, at least partly, by use of antibiotics. Koalas have very specialised intestinal bacteria which are critical for digestion, detoxification and absorption of components of the diet, as well as providing a protective lining for the caecum and proximal colon. Significant loss of these bacteria leads to inanition and death, usually within weeks. In some cases, the use of antibiotics which are commonly used in koalas, usually without significant side effects, can, in some individuals, cause dysbiosis. If uncomplicated dysbiosis is detected early, it can be successfully treated with transfaunation therapy (giving "pap" - caeco-colic content from a healthy, recently-dead koala). Complicated dysbiosis, with inflammation, ulceration and or other contributing factors has a poor prognosis. This condition is called caeco-colic dysbiosis/typhlo-colitis syndrome.

Over the course of the program 11 koalas succumbed or were euthanased due to caeco-colic dysbiosis/typhlo-colitis syndrome. Of these, 7 had received "standard" treatments or antibiotics used commonly in koalas, usually without incident, and 4 had received the antibiotic florfenicol (Nuflor®) during the period that Chloramphenicol 150 Injection was unavailable for treatment of chlamydial disease. This represents a mortality rate of approximately 17% of the 23 koalas that received Nuflor treatments for chlamydiosis. Data on Nuflor-treated cases were included in a scientific report on the use of the drug in koalas. The drug appeared to have little or no clinical efficacy, and it is not used at all by EVE when Chloramphenicol 150 injection is available.

## Surgical complications and other causes

Surgical complications contributed to the deaths of two koalas (koalas *Ivy* and *Kelly*) following ovario-hysterectomy procedures for treatment of chronic reproductive disease. In one koala (*Ozone*), who died at the Australia Zoo Wildlife Hospital during treatment for chlamydial disease, the iatrogenic cause was not clearly defined. In two cases of very young orphaned joeys that were being hand-reared (koalas *Chilli* and *Melody*), gastrointestinal conditions were the causes of death - in one (*Chilli*) it was caeco-colic dysbiosis/typhlo-colitis syndrome; in the other (*Melody*) a severe volvulus (twisted bowel) without defined predisposing cause, resulted in death.

The pie charts overleaf show the proportions of iatrogenic deaths, by the condition for which the koala was being treated primarily (top chart) and as a proportion of total deaths (lower chart).

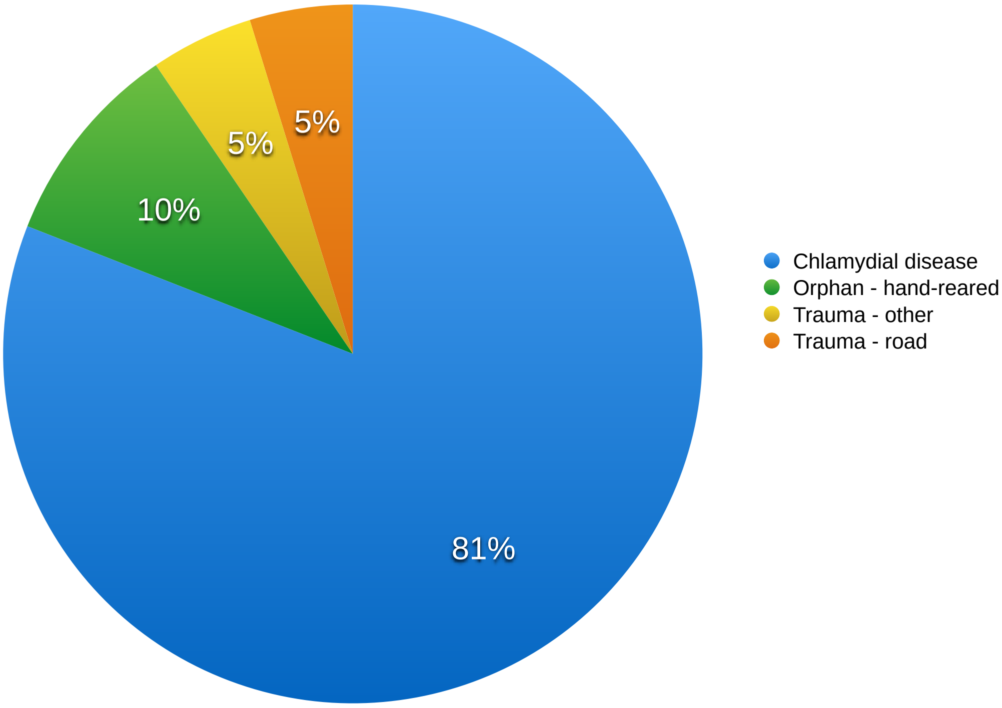



**Figure 8.20**: Proportions of iatrogenic deaths by presenting clinical condition category. (That is, the primary condition for which the koala was undergoing treatment.)

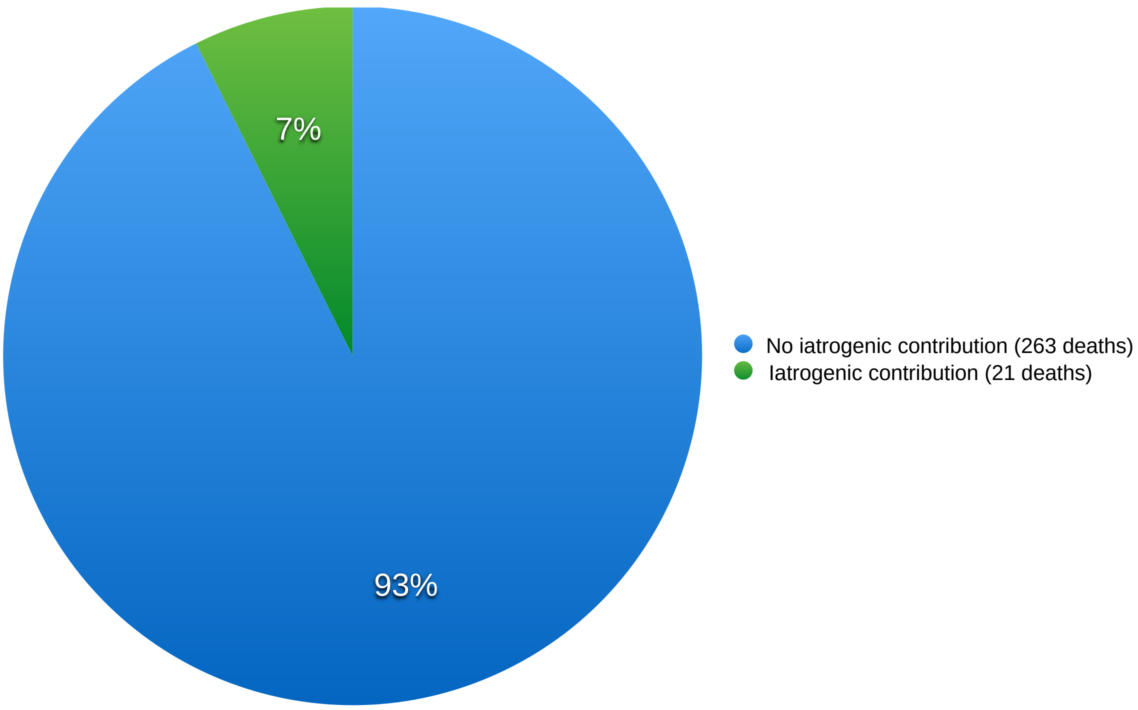



**Figure 8.21**: Iatrogenic deaths as a proportion of total koala deaths between 18 March 2013 and 31 August 2016.

**Plate 8.15:** Koala joey *Melody* receiving oral glucose shortly after rescue (found alive in her dead mother *Mariah's* pouch after she had been killed by a wild dog) (March 2016). *Melody* died after a period in foster care due to a volvulus of the distal colon (twisted bowel).

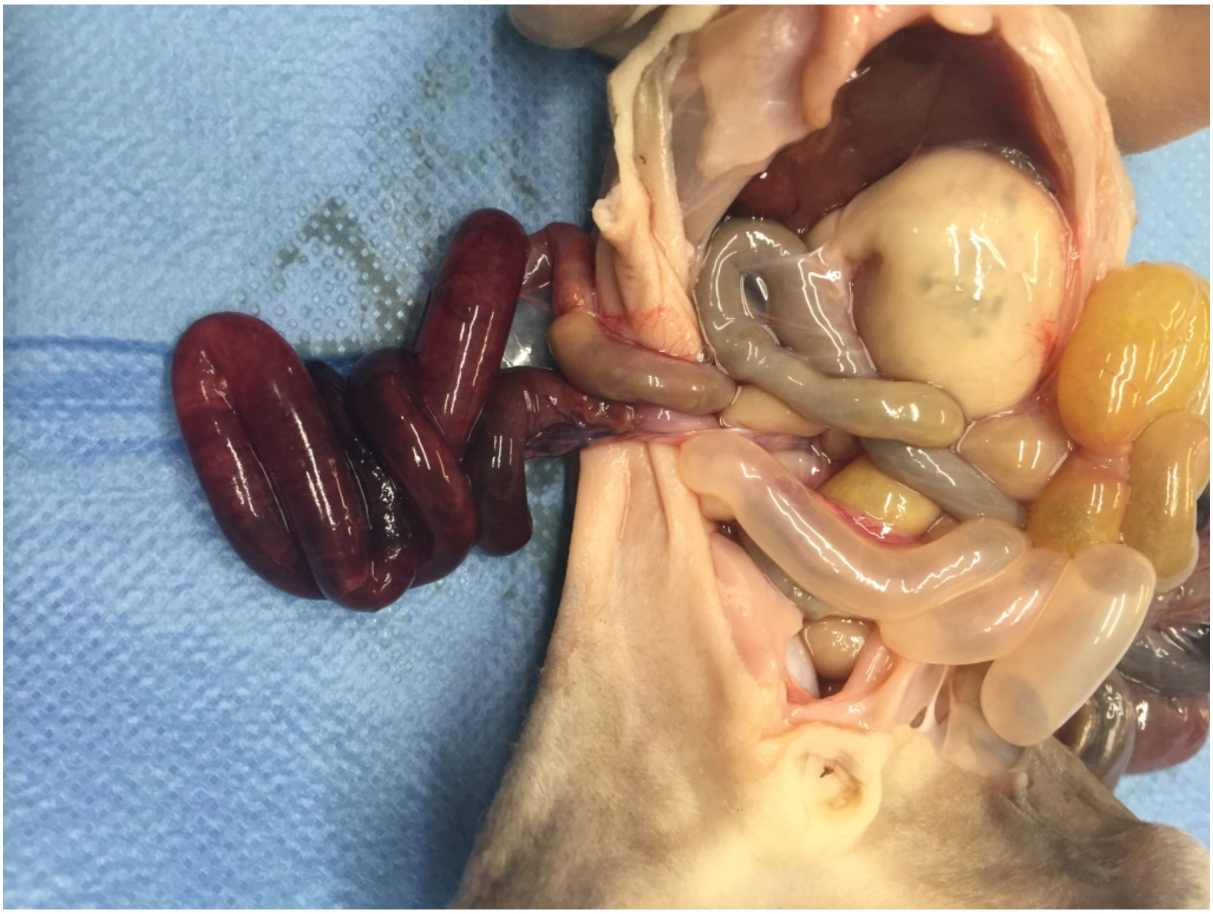


**Plate 8.16**: Necropsy examination of *Melody* showing distended and severely compromised bowel due to volvulus (twist) of unknown cause. The twist has caused avascular necrosis of the affected section of bowel (dark purple section). The stomach and bowel proximal to the volvulus are also distended. The inciting cause was not determined.

## 8.4.10 Vehicle strike

Trauma associated with vehicle strike was far less common than anticipated prior to commencement of the *KTMP*. Between March 2013 and December 2016, eight *KTMP* koalas (4 male: 4 female) were hit and killed by cars (HBC) or died as a result of their injuries and/or treatment for those injuries. Two additional male koalas (*Nuelli* and *Rambo*) were reported by koala rescue groups to have been hit and killed by cars following their removal from the *KTMP*. (Note: these koalas had been de-collared because their home ranges were away from the rail corridor.) One female koala, *Kylie,* was presumed to have been killed by a car strike due to field evidence (the finding of fragments of the telemetry tag enclosure on the road), but her body and telemetry tags were never found.

One koala, *The Captain*, was hit by a train, taken to an external veterinary facility and euthanased.

Excluding the koala *Igor* (killed in late 2016) vehicle strikes accounted for 3.5% (10/284) of all koala deaths between program commencement on 18 March, 2013 and significant de-collaring of koalas, after 31 August, 2016. (For statistical rigour, most mortality analyses have data-sets constrained to those derived during the main *KTMP* period prior to significant de-collaring of project koalas.)

**Table 8.9** below summarises the vehicle strike koala deaths and circumstances.

| Koala name | Date of death | Cause of death | Location/circumstances |
|---|---|---|---|
| **The Captain** | 14/08/2013 | Stuck by train - Petrie | Struck by train near Petrie Stn; rescued and taken to local veterinarian for euthanasia by wildlife rescue group. |
| **Mark** | 10/09/2013 | HBC* - Petrie | Hit by car on Gympie Rd adjacent to Amcor mill entrance. Found dead. |
| **Buffy** | 21/10/2013 | HBC - Petrie/Lawnton | Found dead near BP on Gympie Rd, Petrie/Lawnton |
| **Layla** | 15/11/2013 | HBC - Kippa-Ring | Hit by car on Anzac Avenue adjacent to Southern Cross School. dead on arrival at MKH. |
| **Nuelli** | 18/04/2014 | HBC - Narangba | Ex-*KTMP* koala. Found dead on Narangba overpass (well outside of program operational area) |
| **Noey** | 29/09/2014 | HBC - Murrumba Downs | Found dead on corner of Brays Road and Anzac Avenue by Pine Rivers Koala Care Association. |
| **Sage** | 03/01/2015 | HBC - Petrie | Hit by car Gympie Rd, Petrie on 08/12/2014. Taken to AZWH for fracture repair and treatment. Euthanased due to iatrogenic conditions. |
| **Kay9** | 23/06/2015 | HBC - Petrie | HBC on Gympie Rd, opposite Amcor entrance on 21/06/2015, rescued and taken to BVSC then AZWH. Euthanased on 23/06/2015 |
| **Rambo** | 29/06/2015 | HBC - Rothwell | Ex-*KTMP* koala. HBC on Anzac Ave Rothwell/Kippa-Ring 100m east of roundabout. Found dead. |
| **Diana** | 11/10/2015 | HBC - Petrie | Found dead on Anzac Ave, Petrie 100m north of road-over-rail bridge. |
| **Kylie** | 25/03/2016 | HBC - Murrumba Downs - presumed | Presumed HBC on Anzac Avenue bridge over Bruce Highway. No body or tags recovered, but some fragments of tag enclosure found on road. |
| **Igor** | 10/11/2016 | HBC - Rothwell | Hit by car Anzac Avenue, Rothwell near Harvey Norman. Died shortly after rescue by MOP*. |

**Table 8.9**: Summary of vehicle-strike related koala death between 18 March, 2013 and December 2016.*HBC: hit by car; MOP: member of the public.


**Plate 8.17:** Koala *Mark* hit and killed by motor vehicle strike on Gympie Rd, Petrie in September, 2013.

The “black spots” for koala mortalities on roads are at:

1. Gympie Road, Petrie, where significant koala habitat corridors transect the major linear infrastructure, at Wyllie Park, near the Amcor entrance;
2. South of the Pine River bridges at Lawnton, where a significant koala movement corridor transects the major linear infrastructure;
3. Anzac Avenue between Rothwell and Kippa-Ring.
4. Anzac Avenue at Murrumba Downs, near Brays Rd - Bruce Highway

Significant improvements in koala mitigation measures, including fauna fencing and crossing structures, would considerably reduce koala mortality in those areas. EVE has previously made recommendations about retrofitting some mitigation measures to local roads in a number of areas close to the rail corridor, as a component of the holistic offsets and compensatory package for the MBR or other infrastructure projects. (See *Appendix 12 -Impact mitigation measures to reduce translocation requirements for koalas along the Moreton Bay Rail (MBR) project corridor*).

## 8.4.11 Domestic dog attack

A diagnosis of domestic dog attack was made in two cases of koala deaths (*Adrianna* and *Penny*), and three deaths were equivocal (*Setchy, Moon Unit* and *Friar Tuck*) with respect to wild or domestic dog attack, during the main koala monitoring period between 18 March 2013 and 31 August 2016. After that period (during de-collaring of koalas) an additional two koalas (*Disco* and *Henderson*) were killed by domestic dogs. All koalas were in good health at the time of their attacks. A tabulated summary is provided in **Table 8.10**, below.

| Koala name | Date of death | Location | Circumstances |
|---|---|---|---|
| **Setchy*** | 18/08/2013 | Kippa-Ring | Found dead during scheduled tracking. Carcass found entire with no visible lesions. |
| **Adrianna** | 17/10/2013 | Petrie | Carcass found in a wheelie bin at Young Road, Petrie. Body put into bin by offending dog's owner. Found by scheduled tracking on 18/10/2013. |
| **Moon Unit*** | 20/12/2013 | Lawnton | Found dead in Leis Park, Lawnton and taken to MKH by PRKC. Necropsy conducted by MKH. Cannot exclude wild dog. |
| **Friar Tuck*** | 15/08/2014 | Kippa-Ring | Found dead on ground; tracked due to low LX *K-Tracker* activity datum; patchy fur loss and extensive saliva visible. |
| **Penny** | 29/10/2014 | Kippa-Ring | Attacked by two Staffordshire bull terriers, Amersham Rd, Kippa-Ring. Attack heard by owner of dogs, but not reported. Carcass found by scheduled tracking on 30/10/2014. |
| **Disco** | 20/09/2016 | Petrie | Rescued alive from address on Anzac Avenue, Petrie by PRKC. Transferred to Pet ER, North Lakes for emergency treatment. Transferred to EVE and euthanased due to penetrating cranial injury and brain injury. |
| **Henderson** | 27/09/2016 | Murrumba Downs | Found during scheduled tracking beside Bickle Rd, Murrumba Downs. LX *K-Tracker* tag found with chew-marks in backyard of house with two large dogs, in Chestnut Drive, Murrumba Downs. |

**Table 8.10**: Summary of domestic dog attack koala deaths. * Three equivocal domestic dog/wild dog cases

**Plate 8.18**: Equivocal dog attack deaths *Setchy* (left image) and *Friar Tuck* (right image) as found in the field. Both were found in the Kippa-RIng bushland without any ingestion or caching of the carcass.


**Figure 8.20**: Aerial photograph of the Kippa-Ring bushland to the south of the MBR corridor, showing locations of the carcasses of *Friar Tuck* and *Setchy.* Both are well away from walking tracks generally used by people, a finding suggestive of killing by wild dogs, but neither carcass was cached or partially consumed - a finding more typical of domestic dog attack. In all other wild dog predation cases *in Kippa-Ring,* carcasses of koalas were partially or essentially completely consumed, or parts were cached. (Prey caching behaviour is common in wild dogs.)

The cases of *Setchy* and *Friar Tuck* were given the equivocal cause-of-death diagnosis of *Trauma - domestic or wild dog* for the following reasons:

1. Both were found well away from usual walking tracks in the Kippa-Ring bushland: a finding more typical of wild dogs;
2. Neither was in any part consumed or cached: a finding more typical of domestic dog attack (with the exception of the "Amcor Dog"), and not typical of all other wild dog predation deaths in Kippa-Ring;
3. In the case of *Setchy* the main injury was a bite to the thoracic area, causing significant soft-tissue trauma and pulmonary collapse, without multiple other bite wounds: a finding more typical of wild dog predation;
4. In the case of *Friar Tuck*, the injuries were messy, multiple, and there was extensive saliva-matting of the fur: a finding more typical of domestic dog attack.

Experienced wild dogs are likely to kill efficiently, using generally a thoracic bite or cervical bite and shake, whereas domestic dogs tend to kill koalas with multiple, poorly aimed bites that involve multiple areas of the body, including the head. Necropsy findings are not necessarily definitive for one or the other, but add to the circumstantial evidence supporting one diagnosis over the other. More discussion of wild dogs is contained in the following chapter - ***Chapter 9 - Wild dogs***.

In the case of the koala *Moon Unit,* the koala was taken to the Moggill Koala Hospital where a necropsy was conducted, and a diagnosis of *"Trauma - domestic dog"* applied. Given the location (near the Amcor site) and the fact that an EVE veterinarian did not conduct the primary necropsy examination, the possibility of wild dog predation cannot be ruled out.

## 8.4.12 Miscellaneous causes of death

### European honey bees

One sub-adult female koala (*Goldie*) was killed by swarming European honey bees, having been stung some 255+ times. The unfortunate incident was witnessed by one of the koala tracking team, who was unable to intervene because the koala was high in a tree. The koala was located some time later on the ground and *in extremis* and perished during transport to the EVE clinic. On clipping of the fur, 255 bee stings were counted and were distributed over most exposed surfaces, with only the dorsal midline free of stings (where the fur is the most dense). Necropsy findings were consistent with acute toxicity.

**Plate 8.19:** Overview photograph of the clipped carcass of the koala *Goldie* showing numerous bee-sting lesions

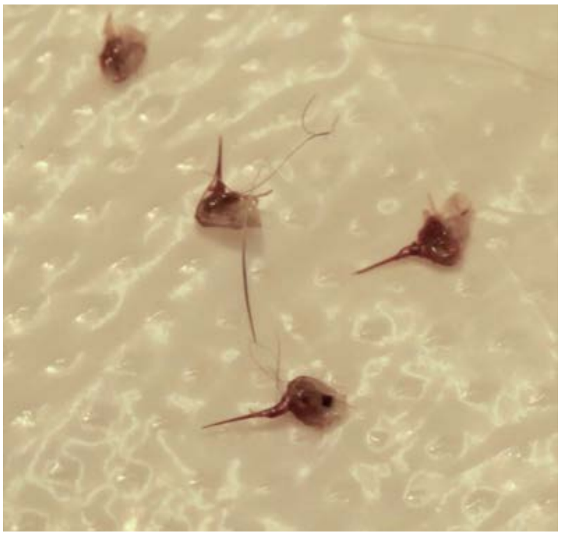


**Plate 8.20:** Bee stings removed from *Goldie* (left image) and multiple bee stings still attached to the right ear (right image).

### Inter-male fighting

Five koala deaths were attributed to inter-male fighting after necropsy examination (koalas *Belvedere, Old Eye, Sheriff, Petro* and *Cailan*), and showed injuries typical of koala fight wounds observed in living koalas (see ***Chapter 4 - Veterinary management of koalas***). Typical bite locations included the shoulders, thighs and pelvis, arms and lips/cheek. Death in these cases was attributable to pathological sequelae: shock and dehydration in the case of *Belvedere* and *Sheriff.* The koala *Old Eye* was euthanased due to old age and a pathological fracture of the humerus secondary to chronic infection of a bite wound. *Petro* had suffered pneumonia and severe septic thromboembolic necrosis of the cloaca and penis, and *Cailan* was found in a dam, and may have drowned.

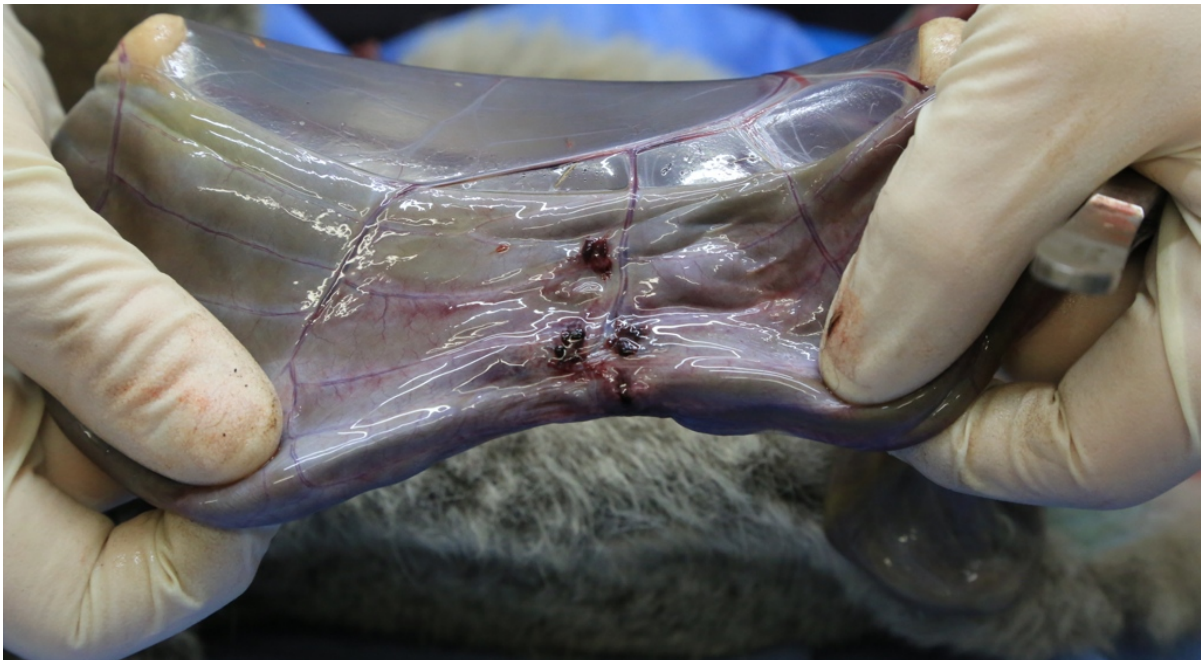


**Plate 8.21**: Acute traumatic injury to the large bowel in the koala *Sheriff* detected at necropsy examination. The injury is caused by a bite from another male koala to the abdomen, entrapping and crushing that section of bowel (without penetration).

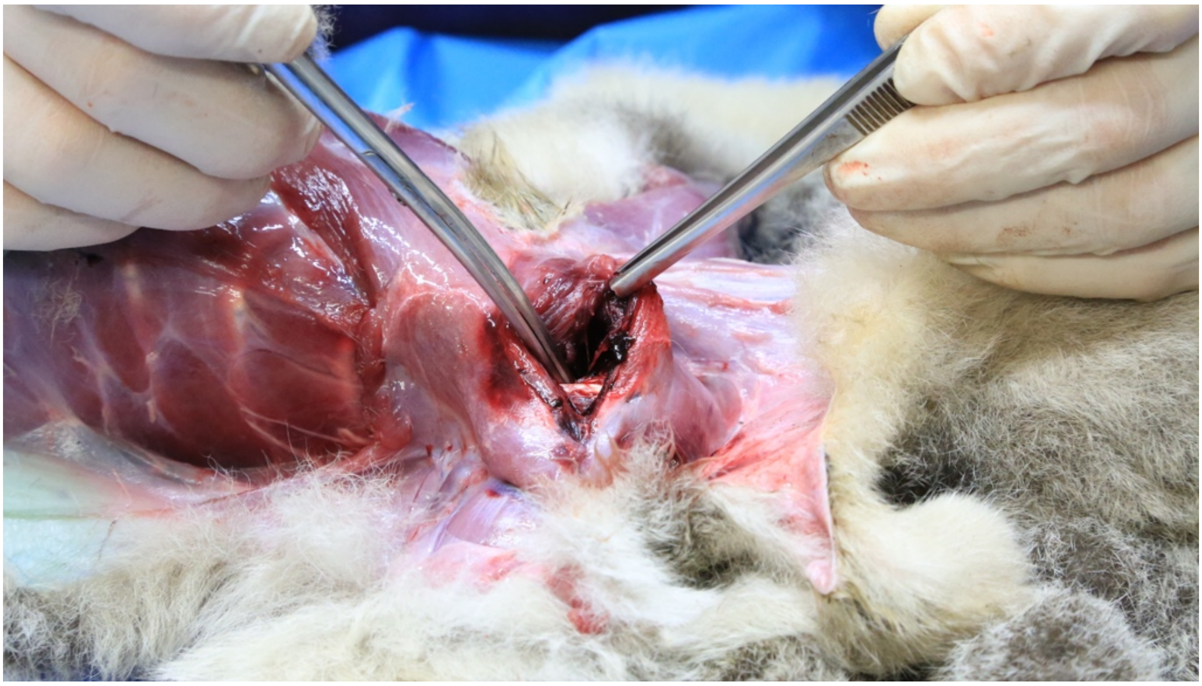


**Plate 8.22**: Deep penetrating injury to the left shoulder in the koala *Sheriff* detected at necropsy, caused by a bite wound inflicted by another male koala. The shoulders and upper forelimbs are common sites of inter-male fight injuries (see ***Chapter 4 - Veterinary management of koalas***).

### Sudden death associated with acute/peracute septicaemia/toxaemia

Over the duration of the program six koalas were found to have died suddenly with few or no premonitory signs. The circumstances and necropsy findings were consistent with an acute or peracute infection or toxaemia, such as the clostridial toxaemias (enterotoxaemia, tetanus, botulism etc.). In these cases death was very rapid, necropsy findings were non-specific and subtle, and predisposing factors were not identified. These cases are somewhat frustrating because a definitive diagnosis is difficult or impossible to achieve and predisposing factors are usually not apparent. These sorts of deaths tend to affect well-nourished, otherwise healthy individuals, and are sudden to very sudden (<24 hrs of illness), and often the premonitory signs are subtle, minimal and mostly not observed.

Koalas falling into this category included: *Burbridge, Butter, Daria, Frankie G, Hazzard,* and *Red Queen.*

### Maladaptation after release into the wild - hand-reared orphans

Two (11%) hand-reared orphans (*Rocket* and *Xoryan)* succumbed some weeks after release back into the wild following the completion of their foster care. Both had lost body condition and were dehydrated, and may have finally succumbed in part due to inclement weather. In the case of *Xoryan*, there was secondary typhlo-colitis/caeco-colic stasis. Both koalas had relatively unremarkable hand-rearing phases, and there were no predisposing factors or apparent explanation for their maladaptation to life in the wild. For comparison, 16 (89%) other hand-reared joeys were released back into the wild over the course of the program and thrived after release.

### Neoplasia and bone marrow disease

Cancers are relatively common in koalas, with neoplasms of lymphoid origin most commonly reported. The koalas *Barnacles*, *One-Tee* and *Deb* succumbed to lymphoid cancers. The koalas *Tyler* and *Gecko* had lesions consistent with myelodysplasia, a fatal condition of the bone marrow related to leukaemia.

The koalas *Jeremy* and *Kas* were euthanased due to development of osteochondroma (a tumour of mixed bone and cartilage), and in the case of *Jeremy* there was concurrent pleural mesothelioma. These cancers may be caused by the koala retrovirus (KoRV), but this has not been proven.

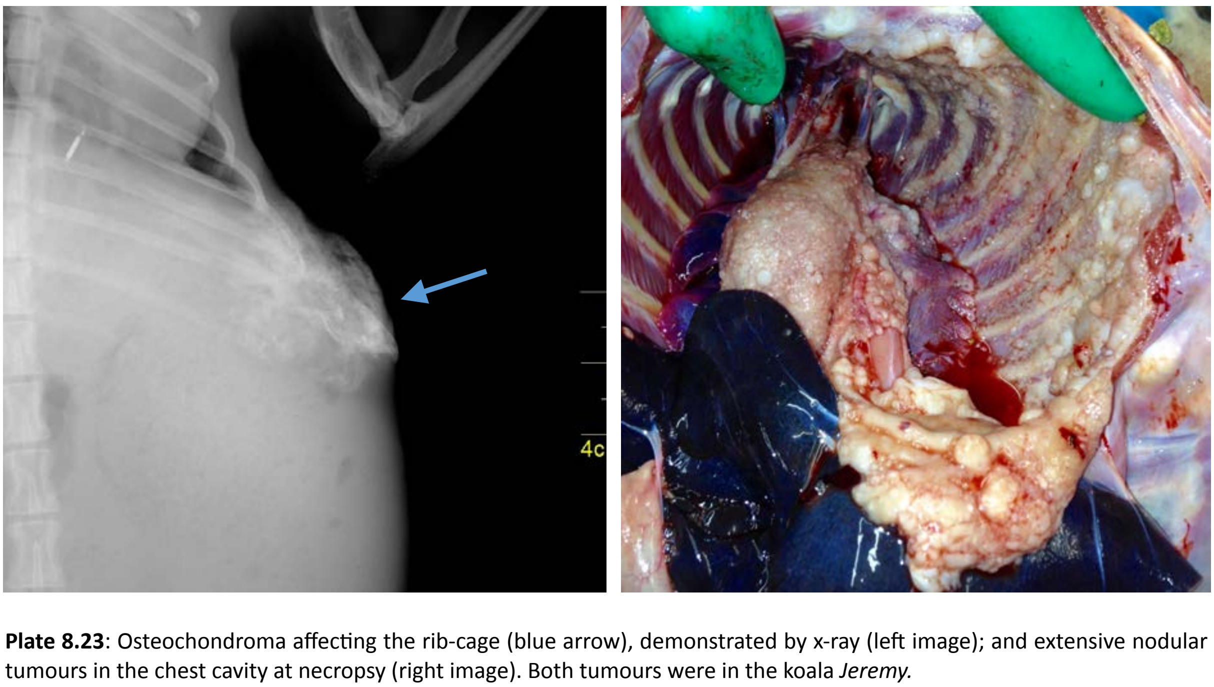


**Plate 8.23**: Osteochondroma affecting the rib-cage (blue arrow), demonstrated by x-ray (left image); and extensive nodular tumours in the chest cavity at necropsy (right image). Both tumours were in the koala *Jeremy.*

The koala *Hera* succumbed to a haemorrhagic condition associated with myelodysplasia and a paraneoplastic condition affecting the macrophage/reticulo-endothelial cell lineage. This condition has not been previously described in koalas.

### Other causes

A variety of other causes of death were noted, and can be reviewed in *Appendix 6 - Summary of necropsy findings*.

**Plate 8.24**: Advanced post-mortem decomposition of the remains of koala *Tom* precluded definitive diagnosis of cause of death. There is advanced skeletonisation due to the action of microbes and arthropods - in this case primarily fly larvae. This koala was last seen alive and well only four days prior (28 March, 2014), and death was detected by routine tracking on 1 April 2014. This demonstrates the extreme rapidity with which *post-mortem* decomposition of a carcass can occur in suitable conditions. Based on the absence of abdominal content (typical of evisceration by wild dog(s)), other circumstances and the absence of premonitory signs observed at the last field tracking event, the death was attributed to wild dog killing and categorised as *suspect wild dog predation*. This case demonstrates the critical importance of a frequent monitoring schedule when cause-of-death diagnosis is an objective. In the MBR project this was achieved by twice-weekly field tracking of koalas tagged with standard VHF transmitters, and daily remote monitoring of koalas tagged with LX *K-Tracker* collars. (The VHF transmitter collar is visible in the right of the image, and the VHF transmitter anklet in the lower left of the image.)

## 8.5 Discussion and recommendations

The primary causes of the high mortality rate observed in the MBR koala population during the first two years of the program were wild dog predation and chlamydial disease. Both of these were significantly reduced by the third year, and were not contributing significantly to mortality by the latter stages of the program. Annualised mortality rates, based on 90-day window and 2-day frame-shift analysis of data exceeded 100% between late 2013 and early 2014 due to the combined effects of wild dog predation and disease-related deaths. From then it declined rapidly, with the exception of a peak during August-November 2014, attributable largely to contributions made by the "Amcor Dog". At the time of writing, the annualised mortality rate was around 10% - 15% - a much more acceptable and sustainable level. (If koalas all died from old age at around 12 years-of-age, average annual mortality would be approximately 8.5%)

The improvement in mortality rate is substantially due to disease and wild dog control efforts, which were key compensatory measures implemented to offset the MBR project's residual impacts on the koala population. A wild dog, presumed to be the "Amcor Dog" was captured and removed from the Griffin site in late February 2017, as part of the *AKHO* program. Scars on the wild dog's face were consistent with those of the "Amcor Dog", and a broken canine tooth was consistent with necropsy findings in koalas suggestive of punctures caused by the sharp edge of a broken canine tooth. DNA analysis to confirm the identity of the dog as the "Amcor Dog" was pending at the time of writing.

The success of treatment of chlamydial disease was high (considering the chronic nature of the disease), with 69% of treated koalas surviving and released back into the wild. However, some koalas with relatively minor conditions (that certainly would not naturally have led to their deaths) perished or were euthanased due to iatrogenic conditions - related to treatment or captivity. Hence, treatment and captivity should not be considered to be entirely benign; and factors such as population health objectives, experience and expertise of potential care-providers, and risks of treatment and captivity should be considered prior to admitting/referring wild koalas for treatment.

The mortality data are crucial in informing mitigation and conservation strategies, evaluating program success and defending against unfounded or spurious criticism. The definitive method enabling collection of accurate and robust mortality data, derived from astute necropsy examination of deceased animals, is by high-intensity radio-telemetry or remote bio-telemetry. The results presented herein validate our methodological approach and the conservation management actions implemented during the project. They also comprise critical inputs for the population viability analysis, and have facilitated the adaptive management approach proposed during development of the koala management plan.

Our recommendations are as follows:

1. Cause-of-death determination is a very valuable data-set for population viability analysis, which should guide mitigation and offset measures. Therefore, appropriate investigation of causes of premature death in declining or at-risk wildlife populations should be considered a high priority for infrastructure projects likely to create additional impacts or worsen exisiting impacts. This facilitates the design of effective mitigation measures supported by robust scientific evidence.

2. Accurate determination of cause of death requires intensive monitoring, astute veterinary investigation and representative sampling of the population. Therefore, wildlife management programs which seek to determine causes of death must carefully consider the applicability of technology, appropriate allocation of resources and access to expertise to achieve that objective.

3. Accurately determining cause of death in subject wildlife is an important risk mitigation measure if project-related activities are likely to cause, or be blamed for, deaths. It is sobering to contemplate the prospect of providing an explanation for the nearly 290 koala deaths occurring during the koala management program had causes of death not been determined by necropsy examination.

# CHAPTER 9: WILD DOGS


## Key points

- Wild dogs were the most important threat to koala survival and population viability
- Only determined because of intensive monitoring and other *KTMP* methods
- *KTMP* guided appropriate management response - mortality rate declined from 152 in first years of *KTMP* down to 2 in last year. (Average 51 per year in first three years, 2 in last year)
- Single dog can have disproportionately high impact - *KTMP* and camera monitoring characterised the “Amcor Dog”
- Significant variation in wild dog impact over time and spatially
- The “Amcor Dog” captured and removed February 2017 as part of *AKHO* program

# Chapter 9: Wild Dogs

**Plate 9.1**: The "Amcor Dog" captured on a trail camera at the Amcor paper mill site in February 2014

## 9.1 Presence and monitoring of wild dogs

From the commencement of the MBR *KTMP*, the presence of wild dogs within the project area was detected, with numerous records of direct observations, scats and tracks, and high levels of koala predation in the first two years. For example, EVE field personnel recorded 35 observations of wild dog presence between 14/2/2014 and 27/1/2015 while conducting koala monitoring in the field. Nine of these records were direct observations of dogs with the remainder consisting of scats and dog tracks. Regular and widespread wild dog presence was also confirmed though thousands (approximately 3760) of camera trap nights using infra-red trail cameras. In addition to wild dog monitoring and control work conducted by MBRC under contract for the MBR project (not reported here), EVE deployed cameras at the the following sites within the project area to detect the presence of wild dogs following high levels of koala predation:

- Kippa-Ring – 3 cameras for one night on 12 February 2014;
- Scouts site – 5 cameras from 6 May to 20 May, 2014
- Griffin offset site – 5 cameras from June 2014 to February 2015; and
- Amcor site – 6 cameras from January 2014 to February 2015.

Most monitoring and control of the wild dog population in the broader area of the MBR project was conducted by MBRC dog control officers, contracted by the MBR project. The predominant control method used by MBRC to target wild dogs was soft-jaw foot-hold traps and humane destruction. At the time of writing, over two dozen wild dogs had been caught and removed from the project area and surrounds, resulting in a significant reduction in koala mortality in the final two years of monitoring.

**Plate 9.2**: Wild dogs on the marine flats at the Kippa-Ring bushland (Photograph courtesy of Paul Turner).

**Plate 9.3**: Large intestine of an adult koala that had been freshly killed by a wild dog at the Amcor mill site. This was an untagged koala. Field staff frequently found the remains of untagged koalas that had been predated by wild dogs at the Amcor site and in the Kippa-Ring bushland during early search and capture efforts - evidence that wild dog predation of koalas was occurring at a relatively high frequency prior to the commencement of the koala management program.

**Plate 9.4**: Older remains of wild dog predation of a koala at the Amcor site: left image shows decomposing stomach and stomach contents (growing white mould), and right image shows the large bowel - caecum and proximal colon. Complete decomposition of the gastro-intestinal tract and its contents can take many weeks or months, depending upon environmental conditions. (See also **Plate 9.6** below.)

In the early stages of the koala search and capture effort (prior to capture of significant numbers of koalas), EVE field personnel regularly encountered the remains of wild-dog-predated koalas (such as those shown in the photographs above), particularly at the Amcor site, during field tracking. This provides compelling evidence of the significant level of predation of koalas by wild dogs *prior to the commencement* of the koala management program. The assertion that the koala management program itself caused or contributed to the high level of wild dog predation upon koalas is neither plausible with regard to the circumstances, nor consistent with the evidence.

## 9.2 Koala mortality from wild dog predation and attacks

### 9.2.1 Overall statistics

Over the course of the *KTMP* (for data analysis purposes: 18 March, 2013 - 31 August, 2016), 284 koala mortalities (247 '*dead*' and 37 '*presumed dead*') were recorded. The leading cause of death overall was *wild dog predation* or attack, with 154 koala mortalities (54% of all deaths) attributed to wild dogs. Generally, in urbanised areas within SEQ, the assumed important causes of death of koalas are anthropogenic (vehicles, domestic dogs, etc) and chlamydial disease. Therefore the magnitude of the impact from wild dogs on the MBR koala management population was unexpected, and unprecedented in terms of previously documented evidence.

The pie chart below shows causes of mortality over the life of the program showing the very substantial contribution of wild dogs to total koala mortality. The figures do not include collateral loss of dependent joeys.

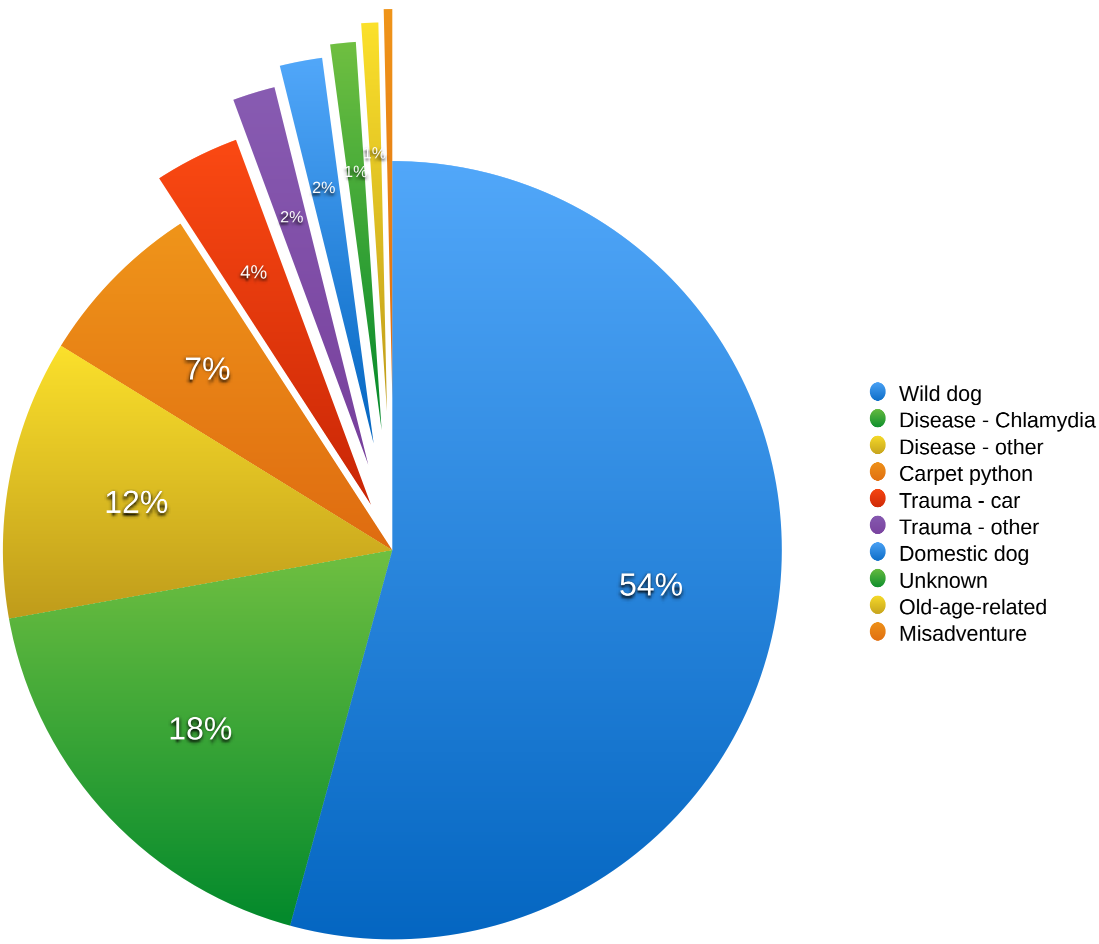



**Figure 9.1:** Causes of MBR koala mortality over the life of the program (18 March 2013 - 31 August 2016). The legend to the right indicates causes of death, starting at the 12 o'clock position and working clockwise.

**Plate 9.5**: One of the original wild dog inhabitants of the Amcor site. This dog was never seen again or captured on trail cameras after the arrival of the "Amcor Dog". These photos were taken in June 2013.

Of the 154 koala mortalities attributed to wild dogs, 116 were *confirmed* wild dog predations with 38 were classified as *suspected* or presumed wild dog predations. Criteria used to classify such mortalities are contained in **Table 9.1** below.

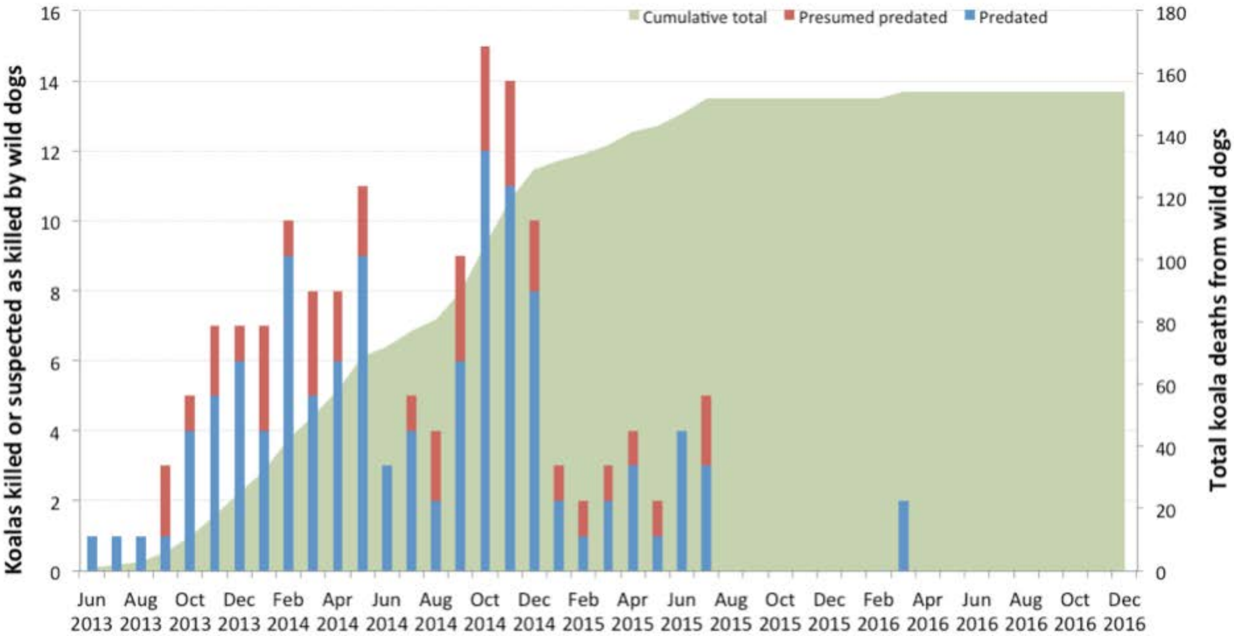



**Figure 9.2:** Confirmed (blue bar section) and suspected (orange bar section) koala mortality caused by wild dogs. Cumulative total is shown as the solid shaded area. Note that wild dog-related deaths reduced to an insignificant level in mid 2015, with only two deaths of monitored koalas occurring after that. Our assessment criteria and diagnosis of *suspected wild dog predation* are supported by the finding that *suspected wild dog predation* cases only occurred in months in which *confirmed* wild dog predation cases also occurred - never in months in which no confirmed wild dog predation cases occurred.

**Plate 9.6**: Remains of a wild dog-predated koala (untagged): the stomach (left image) and large intestine (right image). These remains were found in bushland at the Amcor site early in the intensive koala search and capture phase.

| Category | Sub-category | Burden of proof | Explanation |
|---|---|---|---|
| 1. Wild dog attack/ predation | 1. Direct observation of wild dog killing koala.<br>2. Body intact with no other lesions or pathology (other than trauma from wild dog) to indicate other cause of death and koala definitively identified (with tags intact).<br>3. Body predated but carcass definitively identified (with tags on). Unable to determine by necropsy that no other lesions or pathology (other than trauma from wild dog) contributed to death.<br>4. Tags and untagged body parts in close proximity to each other, but cannot definitively identify the remains as belonging to a particular koala.<br>5. Untagged joey found dead with or within the vicinity of dead attacked/predated mother. Joey's death is a direct or indirect consequence of attack/predation and joey was not nearing independence (seen with mother within 2 weeks of mother's death). Mother died from wild dog attack/ predation or suspected wild dog predation. | Evidence beyond reasonable doubt of wild dog attack or predation. | Strong or overwhelming direct or circumstantial evidence for wild dog attack, with or without the consuming of remains by the/a wild dog. |
| 2. Suspected wild dog predation | 1. Tags dropped with obvious bite marks.<br>2. One or both tags found well outside the home range of a koala with a stable home range.<br>3. Body or body parts with confirmed identification (microchip, ear tag or tracking tags), but remains too decomposed for definitive cause of death, found well outside the home range of a koala with a stable home range.<br>4. Both tags found within normal home range but where the circumstances indicate that it is unlikely that the removal of the tag is by anything other than a wild dog (e.g. being caught on a tree branch or snagged on vine is highly unlikely).<br>5. A tag being found in a known wild dog area, or wild dog 'graveyard' or resting area.<br>6. Untagged joey missing, presumed dead as not nearing independence (seen with mother within 2 weeks of mother's death), mother died from wild dog predation or suspected wild dog predation. | On the balance of probability, wild dog predation is highly likely. | Evidence is suggestive of wild dog predation, but without the strong evidence required for category 1. |
| 3. Lost koala | 1. Circumstances suspicious of wild dog predation (e.g. koala tracked daily and disappeared or koala had a stable home range and disappeared).<br>2. Unknown disappearance. | On the balance of probability, there is not sufficient evidence to determine that the disappearance of the koala was a consequence of wild dog predation. | Wild dog predation is a possible explanation for disappearance of the koala, but other causes are equally likely. |

**Table 9.1:** Criteria used to assign cases to wild dog predation categories

### 9.2.2 Variation in wild dog impact by polygon

Of the 152 confirmed and suspected wild dog predation cases, the first was recorded in June 2013 at the Amcor site and last was recorded at the Griffin site in March 2016. The Amcor site had the highest level of wild dog predations, with 80 koala mortalities, followed by Kippa-Ring with 42. The Amcor site was also the only site within the project area where mortalities were recorded consecutively on a monthly basis from June 2013 to December 2014. The first wild dog-related koala death was recorded at Kippa-Ring in September, 2013. A summary of deaths by polygon and month is shown graphically in **Figure 9.3**, below.

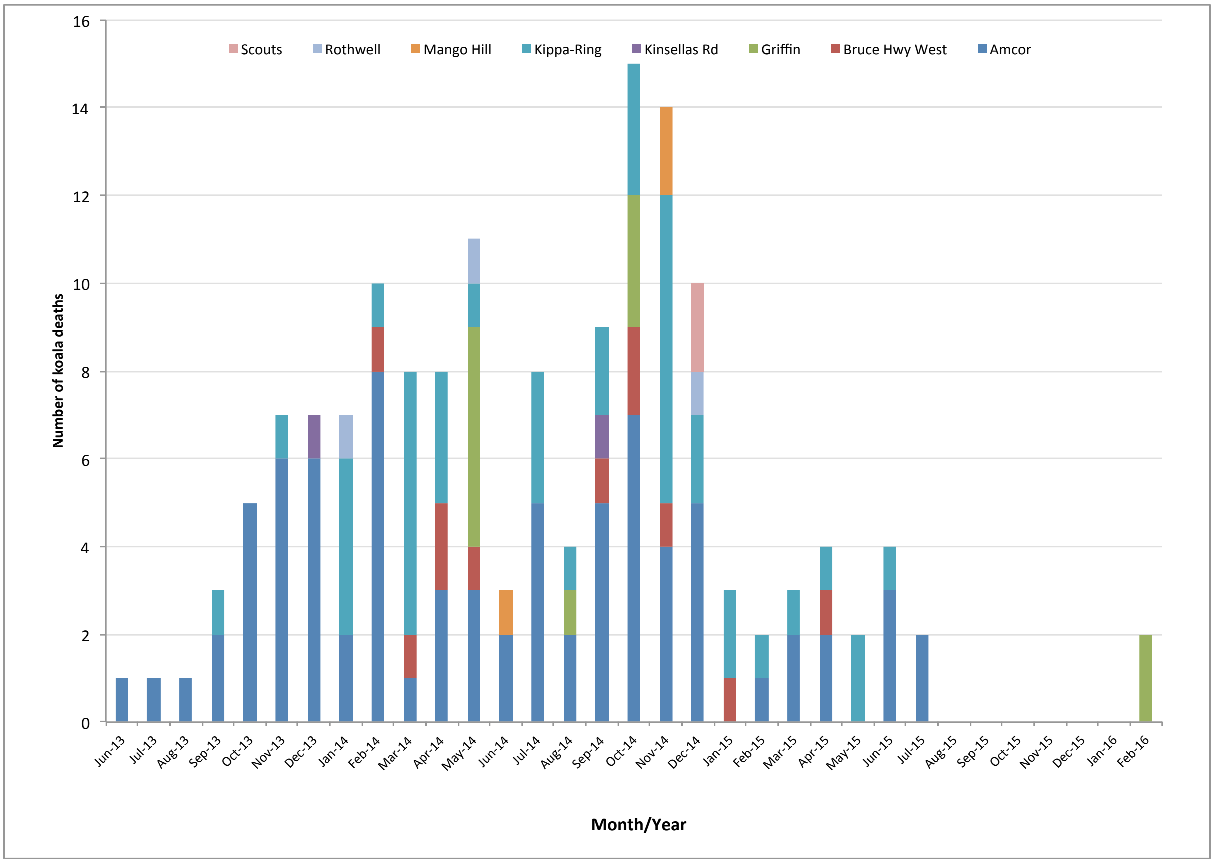



**Figure 9.3**: Confirmed and suspected koala mortalities for each polygon (koala search area) by month.

Koala mortality from wild dogs occurred every month, with the exception of January and May 2015, at the Amcor site for two years until July 2015. From the last four recorded mortalities in July 2015 at the Amcor site, none had been recorded up until the time of writing. July 2015 was also the last time a wild dog was detected at Amcor.

Total koala mortalities per month from wild dogs ranged from 1 in June, July and August 2013 at Amcor, to 15 in October 2014 where the *Amcor, Kippa-Ring, Bruce Hwy West* and *Griffin* polygons had 7, 3, 2 and 3 mortalities recorded, respectively (see **Figure 9.3**, above). The greatest monthly number of wild dog-related koala mortalities at any site was 8 recorded deaths of monitored koalas (excluding dependent young) at the Amcor site in February 2014.

### 9.2.3 The "Amcor Dog"

The "Amcor Dog" was a large, male wild dog that resembled a dingo and was active in the Amcor site and occasionally the *Bruce Hwy West* koala search area from late 2013 until July 2015. This dog is believed to be responsible for 55 of the 69 (80%) confirmed wild dog-related koala deaths at the Amcor polygon, and all eight confirmed deaths in the *Bruce Hwy West* polygon - a total of 63 confirmed koala deaths.

Of the 38 *suspected wild dog predation* deaths of koalas, he was probably involved in approximately 13, based on the location of those koalas' home ranges and their dates of death coinciding with his periods of activity. At the Amcor site, wild dog-related koala deaths between program commencement (18 March 2013) and mid-late 2013 (the time of first detection of the "Amcor Dog") are likely to have been caused by other wild dogs using the site, and the finding of limited remains was more typical of other wild dogs. Of the two or three dogs using the site prior to the arrival of the "Amcor Dog", one was removed by MBRC officers in November 2013 and others (**Plate 9.5** above) were never seen again after the arrival of the "Amcor Dog".

An image of the "Amcor Dog" recorded from a fixed IR camera in September 2014 is shown in **Plate 9.7** below. He was last recorded on a trail camera near the Amcor site on 19 July, 2015 and his location was unknown for a long period. He was subsequently captured at the Griffin site in late February 2017, as during activities conducted for the *AKHO* program.


**Plate 9.7:** Image of the"Amcor Dog"captured on an infra-red trail camera in September, 2014.

Of the eight koala search areas, the Amcor site was:

(a) the first site in which wild dog koala mortalities were detected during the *KTMP*;
(b) the site recording the greatest number of total mortalities (80);
(c) the site which recorded the most continuous and persistent koala mortalities over time (two-year span); and
(d) the greatest monthly total (8) of any site;

The "Amcor Dog" appeared to be responsible for nearly all these koala deaths. Although astounding, this conclusion is well supported by the data and was based on three main forms of evidence:

### 1. Camera trap evidence

Following thousands of IR camera-trap-nights by both EVE and MBRC, only one wild dog was ever recorded on the Amcor site between January 2014 and the koala management program end in January 2017. (Occasional domestic dogs were recorded on the site but were usually accompanied by their owners.) With this level of survey effort, it would be reasonable to conclude that if additional wild dogs were active in the area, it is likely that they would have been detected. As a comparison, more than one dog (usually two; occasionally three) were observed at other sites such as Kippa-Ring and Griffin where the survey effort using IR cameras had been comparable to that applied at the Amcor site. For example, **Plate 9.8** below, shows three different wild dogs at the site of a kangaroo carcass at Kippa-Ring within a single 24-hour period.


**Plate 9.8:** Three different wild dogs recorded in a 24-hour period at Kippa-Ring by trail cameras surveilling the carcass of an eastern grey kangaroo. One of the dogs in the left image is tagged with a GPS collar (for research not associated with the MBR project).

### 2. Evidence from *post-mortem* (necropsy) examination of deceased koalas

When koala deaths occurred and remains were recovered, a detailed necropsy examination was carried out to determine cause of death. Koala remains following predation on the Amcor site often shared striking similarities with respect to the method of killing and the state of the remains when they were discovered. This *modus operandi* differed significantly from koala remains in other areas (such as the *Kippa-Ring* koala search area).

When wild dogs were determined to be the cause of the death, the remains were classified into three categories:

- Entire carcass – defined as finding the koala carcass intact or entire;
- Partial carcass – defined as recognisable portions of a carcass, such as limbs, torso, but at least some disembowelling or dismemberment has occurred; and
- Limited remains – defined as fur, gastrointestinal tract, fragments of bone but not limbs or torso.

From the total number of koala mortalities attributed to the “Amcor Dog”, 26 carcasses were classified as entire with often the only signs of injury being subtle puncture wounds on the dorsal cervical region and rump, evidenced by small areas of blood-stained fur and saliva on the back of the neck. **Plate 9.9** below shows an example of this - koala *Hendo* who was found dead in February, 2014.

**Plate 9.9:** Koala *Hendo* (Amcor site) - wild dog predation. The finding of an intact carcass with minor punctures to the rump (sometimes not visible) and the “kill bite” to the neck, were typical of killing by the"Amcor Dog”. Note the matting of fur on the neck by dog saliva and small amounts of blood. In three cases (*Fern, Demeter* and *Mungo Jerry*) the victim was found alive by field personnel. In a number of other cases, necropsy examination findings indicated that death was not immediate and some koalas had been alive for some hours after the attack. This pattern of behaviour was not observed at sites in which other wild dogs were active.

Typical findings during necropsy examination of a koala suspected to have been killed by the “Amcor Dog” were:

1. A number of relatively minor punctures, abrasions and contusions caused by (presumably) a “positioning bite”: that is, a bite which we hypothesised was used by the “Amcor Dog” to position the koala to facilitate the “kill bite” to the neck. (See **Plate 9.10** overleaf);
2. A very accurately-placed and consistent “kill bite” to the neck, presumably with a shake, resulting in massive soft tissue trauma, and cervical dislocations and/or fractures around vertebrae C2 - C5. (See **Plate 9.11** overleaf);
3. An absence of any other significant bite injuries;
4. An intact, or substantially intact carcass.

The number of entire carcasses (24) represents one-third of all koala mortalities caused by wild dogs on the Amcor site, and one quarter (2) of confirmed deaths at the adjacent *Bruce Hwy West* polygon. Entire carcasses were not recorded at any other site where wild dog predations occurred (with the exception of the equivocal cases of *Friar Tuck* and *Setchy* at Kippa-Ring). Nearly half of all koala remains at the Amcor site were categorised as *partial carcass,* with ten of these being essentially intact but with the chest and abdominal cavity open and internal organs absent (**Plate 9.12**).

**Plate 9.10:** Punctures and contusions on the rump of the koala *Lucas* observed during necropsy examination after clipping of the fur. (February, 2014) The lesions are typical of the "positioning bite" used by the "Amcor Dog". The injuries showed no signs of massive damage associated with shaking by the dog, but were more consistent with a quick bite to aid in positioning the koala for the "kill bite". (See images below.)

**Plate 9.11**: Images taken during necropsy examination of the koala *Kev* in August 2014. He was the victim of an attack by the "Amcor Dog", and suffered injuries typical of that dog - "positioning bite" injuries to the rump area, and the "kill bite" shown in images above: the left image shows staining and clumping of the fur associated with bleeding from puncture wounds and dog saliva, and massive soft tissue damage and haemorrhage apparent after reflection of the skin of the head and neck (right image) during necropsy examination. The neck injuries are typical of a "bite and shake" technique often used by dogs (both domestic and wild), in which the external injuries belie the massive internal damage. In many cases attributed to the "Amcor Dog" the cervical spine was fractured and/or dislocated by a single bite - testament to the massive jaw and neck strength of wild dogs.

**Plate 9.12:** Koala *Rowland* - "partial remains", in which the carcass was largely intact with evisceration of chest and abdominal organs. He was a victim of the "Amcor Dog" in October 2014. The injuries on the rump and neck were typical of the "Amcor Dog". (See also **Plates 9.10** and **9.11**)

Our interpretation of these findings is that this was an experienced dog, who practised a deliberate and careful technique in his killing of koalas, which showed remarkable (almost surgical) precision and consistency between cases. He was somewhat "casual" in terms of ensuring a "clean" kill, with some adult victims and a number of joeys left alive. He was well nourished, as evidenced by the trail camera photographs, and frequently neither consumed nor cached his prey - although certainly he did in some cases. The frequency of killing during some periods suggested that his killing of koalas was not entirely opportunistic and probably involved some planning with respect to detection of koalas prior to their descent from a tree. It seems less likely that he encountered all of his koala victims entirely by chance as they moved on the ground between trees, which we hypothesise is the more usual scenario when koalas are predated by wild dogs.

### 3. Circumstantial evidence

The third body of evidence supporting the existence of the "Amcor Dog" and his involvement in the deaths of so many koalas is that trail camera data demonstrating his presence at the site coincide with the deaths of koalas; and conversely, the periods during which there were no koala deaths on the site coincide with periods during which he was not detected by camera traps. The most notable early period of absence, during which no wild dog-related koala deaths occurred was in January 2015. He then reappeared for some months, during which time the killing of koalas recommenced with the typical injuries, and then stopped in July 2015. The "Amcor Dog" was last captured on MBRC trail cameras at the Amcor site on 19 July, 2015. Two days prior, the last wild dog-related koala death was recorded at the site - *Neptune,* who was killed on 17 July, 2015. Thereafter, there were no wild-dog-related koala deaths at the Amcor site or *Bruce Hwy West* polygon. At the time of writing (January 2016) there had been no wild-dog-related deaths, or detections, for 18 months at the Amcor site.

Taken together, the most plausible explanation for the data and three bodies of evidence described above, are the existence of a single dog - the "Amcor Dog". While there are other possible explanations for the data and evidence, the most likely is as we have described above - a single wild dog with an inclination for killing koalas. Other explanations are implausible, inconsistent with the data, or at the very least, far less likely.

From the 19 July, 2015, the “Amcor Dog” was never seen again at the Amcor site. This may be the result of habitat changes to the site following completion of the rail line or increased human and construction activity associated with site remediation that was being conducted on the Amcor site. He was finally captured and removed in February, 2017 as part of the *AKHO* program.

**Plate 9.13**: Series of images showing the well-concealed caching site and exhumation of the 11-month near-independent joey *Marty,* joey of *Jahnie*, both of whom were killed by the “Amcor Dog”. Their bodies were found approximately 50m apart. Arrows show the approximate location of the body, which was only found because of the recently attached VHF telemetry collar.

## 9.3 Wild dogs vs domestic dogs

The magnitude of the impact of wild dogs on the koala population documented by the *KTMP* has resulted in some skepticism from members of the scientific community and general public. Part of the basis for this skepticism seems to be that domestic dog impacts on koalas are relatively well documented by comparison with wild dog impacts; also, those expressing such views have not had access to the data and evidence that have led us to our conclusions. However, the apparent disbelief that wild dogs could have such a profound impact over such a short period of time demonstrates a lack of understanding of their behavioural ecology. They are intelligent generalist predators and scavengers who will take advantage of opportunities, such as readily available food resources. Their intelligence also allows them to specifically target opportunities that they have learned exist and provide a readily available and valuable source of nutrition - in this case koalas.

Wild dogs are very capable of locating the general area of a koala by smell; even koala ecologists are able to detect the smell of recently-excreted koala urine, with far inferior olfactory capabilities. It is entirely plausible that a wild dog, such as the "Amcor Dog" would become an expert hunter of koalas, particularly in high-density populations, by determining their general location by smell, and then simply waiting or listening out for sounds of their descent from a tree, which is more likely than not, of an evening. Other dogs may not have the patience, and/or find other food resources less challenging to use or prey upon. The "Amcor Dog", in his killing of koalas, differed from other wild dogs (such as those at the Kippa-Ring bushland site) in that he excelled at it, such that his frequency of killing was in excess of what might be expected of opportunistic killing (such as the dogs at Kippa-Ring practised). In other words, he appeared to target koalas, and also his killing of koalas appeared to be well in excess of his physiological need for nourishment. However, it is naive to suggest that this is abnormal or implausible (as has been suggested) given the well-documented propensity of wild dogs to kill "for fun" or at least to kill far more of an easily-targeted prey species than they need to, often without caching of the excess food resource.

Domestic dogs were responsible for a number of deaths of koalas over the course of the koala management program, of which four deaths were unequivocally the result of domestic dog attacks, and three were associated with less compelling evidence. In general, a diagnosis of *wild dog predation* as a cause of death was based on some or all of the following features:

1. The killing of a koala in a bushland site;
2. Necropsy findings consistent with dog attack injuries;
3. The consumption of some or all of the carcass;
4. The caching of some or all of the carcass;
5. The evisceration or dismemberment of the carcass;
6. The "expertness" of the kill, with respect to injuries documented at necropsy.

With respect to the last feature (6.): wild dogs (except for juvenile or young dogs) are expert killers, and therefore tend to be efficient with respect to their targeting of bites and effectiveness in achieving a rapid kill or disabling injury. Often such injuries are targeted on the cervical and thoracic spine, achieving rapid death or significant disabling of their prey through paralysis and/or respiratory failure. Domestic dogs *tend* to be less expert and less targeted with their bites, resulting in multiple bites and injuries over many areas of the body, limbs and head. Domestic dogs *tend* not to dismember, eviscerate, consume and cache wildlife that they have killed, whereas wild dogs *tend* to do all of those things.

This is not to say that those features, if found, are absolutely definitive for wild dog attack vs domestic dog attack; but they *are* strongly suggestive and provide the most plausible explanation for cause-of-death diagnosis. Diagnosis of cause-of-death often requires careful consideration of all of the circumstantial and necropsy data/evidence, and determination of the *most plausible* explanation or diagnosis for the findings. In other cases, the evidence is compelling and the diagnosis definitive.

As previously mentioned, domestic dogs were occasionally recorded by EVE and MBRC through camera trap monitoring and observation by field personnel, however, on most occasions they were accompanied by their owners. If domestic dogs had been contributing significantly to the koala mortality that we attributed to wild dogs, then their detection by camera traps would have been much higher. For comparison, **Table 9.3** below shows both wild and domestic dog activity records across the project area over a three-month period from March to May in 2015. In this period, a total of 237 wild dog observations were recorded compared with a total of 12 domestic dog records, in 8 of which the domestic dog(s) was accompanied by its owner during daylight hours.

| Dog Type | March 2015 | April 2015 | May 2015 | Total |
|---|---|---|---|---|
| Wild | 126 | 32 | 79 | 237 |
| Domestic | 0 | 2 | 10 (8 with owners) | 12 |

**Table 9.3:** Wild dog and domestic dog records from camera traps from March to May 2015

**Plate 9.14**: Wild dog scat collected from the Kippa-Ring bushland site during the *KTMP*. The scat contains a clearly identifiable koala claw (arrow) and fur resembling koala fur.

The frequency of wild dog deaths declined profoundly over the course of the program, and correlated with the frequency of detection of wild dogs by camera traps, providing further evidence that these deaths were not due to domestic dog attack. Preliminary testing of the DNA recovered from the remains of 12 koalas, such as koala tags, fur at wound sites or other remains, shows definitive support for attack by wild dogs, rather than domestic dogs (Gentle *et al* in prep. 2017). Recovered canine genetic profiles were tested against purebred dingo allele data to determine whether the genetic profiles reflected dingo, dingo hybrids or domestic dogs. Dog profiles were classified as wild dogs, consisting of either dingo (61%) or dingo hybrids (39%). No domestic dog profiles were recovered.

## 9.4 Conclusions and recommendations

The information provided above, in combination with that provided in ***Chapter 8 - Causes of death of koalas***, and a following chapter, ***Chapter 11 - Population viability analysis*** provides compelling evidence for two important conclusions with respect to wild dog impacts on koalas:

1. Relatively few wild dogs can have a profound and dramatic impact on koala populations, and significantly reduce population viability;

2. Spatial and temporal variation in wild dog impacts on koala population is considerable.

The magnitude of the loss of koalas attributed to wild dog attacks and predation during *KTMP* for the MBR project was unexpected. Certainly, *some* wild dog predation upon koalas was expected, but not to the extent that it was subsequently detected. The *KTMP* provided unequivocal evidence of the potential importance of wild dogs as a threat to koala population survival, particularly those under significant threat from other factors, such as disease and urban development.

The use of near-real-time telemetry devices and/or frequent field tracking of koalas enabled the rapid detection of mortality and facilitated recovery of koala carcasses for diagnostic necropsy examination. Without the application of this technology, many of those deaths would not have had definitive causes assigned, and therefore would have provided opportunity for criticism of the project as having caused those deaths. In short, the application of appropriate technology and astute veterinary management and cause-of-death investigation was critical with respect to both achievement of the key objectives and mitigation of reputational risk to the project and associated entities.

An important data-set supporting the conclusions outlined above was that derived from camera traps - infra-red motion-triggers cameras ("trail cameras"). These provided critical data on the presence and abundance of wild dogs and the frequency of use of monitored sites. Those data were critical in the determination of the "Amcor Dog" as a single dog, validating conclusions reached from necropsy data suggesting a unique *modus operandi* in the deaths of dozens of koalas in and near the Amcor site.

The *KTMP* and wild dog monitoring program were successful in achieving the objective of guiding the adaptive management approach: the wild dog impacts on the koala population were rapidly detected and robustly determined, and appropriate resources and management responses were applied to address the problem. This, and the departure of the "Amcor Dog", resulted in a dramatic decline in the koala mortality rate attributed to wild dogs, and a significant drop in the detection of wild dogs in the project area. At the time of writing (January 2017), there had been no koala deaths attributed to wild dogs for 10 months, and only two deaths in the previous 18 months. (For comparison, there were 135 koala deaths attributed to wild dogs in the first two years of the *KTMP*. )

With respect to wild dogs, we make the following recommendations:

1. That future community infrastructure projects likely to impact on koalas or other wildlife consider the potential impact of wild dogs on those populations with respect to population viability, and as a target for offsets or compensatory measures for residual project impacts on those populations;

2. That appropriate technologies and expertise are applied to the investigation and management of wild dogs in future projects, given the potential magnitude of their impact on species of significance.

# CHAPTER 10: KOALA REPRODUCTIVE SUCCESS


## Key points

- Early data show poor koala reproductive rates due to chlamydiosis
- Reproductive rates at most sites improved markedly by end of *KTMP* due to treatment and management of chlamydial infection
- Findings provide strong support for ongoing development of the *Chlamydia* vaccine
- 350 joeys born during koala monitoring program through to August 2016 (more since)
- First ever documentation of natural adoption of a joey in the wild - *Sammy* adopted by *Karen*
- Reproductive data and joey survival a critical input into PVA, therefore robust findings and projections

**Plate 10.1**: Juvenile koala *Jordii* waits during the first veterinary examination of her mother *Adrianna* in August 2013. Two months later her mother was killed by a domestic dog, and her body dumped in a wheely bin. *Jordii* was independent at the time, but later removed from the *KTMP* in February 2014 because she consistently lived in habitat out of the *Amcor* koala search polygon.

# Chapter 10: Koala reproductive success

## 10.1 Introduction

Recruitment rates (births + immigration) are one of the key population parameters required for any ecological study to determine population trends and viability. Quantifying the number and frequency of births, or the fecundity of females of breeding age in a population is key to this understanding, yet this rate can be difficult to accurately assess in natural populations. This is because it relies on knowledge of the age of females at sexual maturity to determine breeding age, and determination of the rate of breeding. In lieu of these data, indices of age for wild koalas are based on body measurements or behavioural benchmarks, most commonly derived from captive koalas. Depending on the time of the census, and unless females are captured and physically examined, small pouch and front young may go undetected, underestimating the true fecundity of the population. Also, reproductive disease, a critically important factor in low koala population fecundity, is not apparent overtly, rather it requires ultrasound examination for diagnosis, requiring capture and sedation of koalas.

Koalas are generally seasonal breeders, with peaks in koala births generally in the spring and summer months. While there is a distinctive seasonality to koala births in Queensland, koalas can conceive and give birth to young throughout the year, and will often cycle shortly after the premature loss of a joey. Koalas have home ranges that overlap with multiple males and females, and choice of mates is thought to be relatively opportunistic. Gestation is between 32 and 35 days after which time the female will give birth to an underdeveloped neonate, weighing less than 1g and the size of a jellybean. The joey will stay with its mother for up to a year before independence, with no paternal input. After a year, and at the weaning of the last joey, a healthy female can give birth to another joey, and most fecund females produce at least one joey every year.

This chapter provides analysis and discussion of a range of data related to breeding success and joey survival derived from the MBR koala management program.

**Plate 10.2**: Eight-month old joey *Mostyn* urinates shortly after the release of his mother *Fiona* at the Amcor site following a scheduled health check in July 2013. His head was well buried in the pouch. She had four more joeys over the course of the *KTMP*, 3 of which survived to the age of independence. *Mostyn* was killed by a wild dog in December 2014.

## 10.2 Methods

### 10.2.1 Koala monitoring

The *Koala Tagging and Monitoring Program* (*KTMP*) facilitated the protection and management of koalas in the rail corridor prior to, during and after construction, as well as guiding compensatory and mitigation measures. Almost every koala within and adjacent to the rail corridor was captured, given a thorough veterinary examination, and, if healthy, tagged with VHF and/or bio-telemetry tags for monitoring. We estimate that at least 95% of koalas residing in the search areas were captured and tagged by the commencement of vegetation clearing for the MBR project. Koalas with VHF tags were tracked every third or fourth day, when data relating to health, breeding status, tree details, and GPS location were collected by field personnel. Breeding status for females included information on the presence or absence of young; if present, the size class of the young; if absent, when the young was last seen and its fate – presumed dead, or the date when the joey reached independence. Many of these joeys were tagged as late dependent young and monitored to independence and adulthood.

**Plate 10.3**: Sequential photos from **Plate 10.2**, above, showing joey *Mostyn's* head deep in his mother *Fiona's* pouch. Joeys are well-adapted to clinging on securely during the sometimes agile and vigorous movements of their mothers.

## 10.2.2 Koala health assessment and ageing of joeys

Veterinary examination provided data on the health status of each koala, including an assessment of a female's reproductive status.  Age, weight and other morphometrics were recorded and an ear tissue and blood sample were collected for genetic studies and/or diagnostic purposes. The developmental stage and approximate age of a joey with a female was noted at each examination. Routine ultrasound of the reproductive tract of female koalas was performed at each veterinary examination to detect pregnancy or structural changes in the reproductive tract indicating infertility or sterility. Pregnancy could be detected as early as 1-2 weeks, and a foetal heartbeat detected in mid to late-term pregnancy using ultrasound. Koalas were captured at a minimum of 6-monthly intervals for routine health assessment allowing the growth of joeys to be observed. Likewise, as juveniles and sub-adults were captured more frequently (generally at 45 day to 2 monthly intervals to ensure correct fit of tags), the timing of breeding could be determined with a high degree of accuracy.

Dependent young were assigned to an age class of monthly increments ( e.g. 0-1 month old, 1-2 months old, 2-3 months old, etc.) based on the developmental stage/size/weight of the joey. The age of neonates was estimated as an age in weeks, up to 1 month or 4 weeks of age and thereafter as an estimate of age in months. Ageing was often very accurate if a late-term or newborn joey was detected on examination, resulting in a joey of known age +/- 2 weeks. Koalas were recaptured at a maximum of 6-month intervals for scheduled health checks, but were often caught more frequently to check VHF and biotelemetry tag fit in growing animals, to replace dropped tags, to tag joeys nearing independence or for treatment of illness or injury, allowing more frequent opportunities to observe the development of joeys.

**Plate 10.4**: Some joeys seem to push pouch-life a bit far.  *Emmie Rose* and her 7-8-month joey *Brock* from Kippa-Ring at their first veterinary check in November 2013.

## 10.3 Results

### 10.3.1 General statistics

There were 350 joeys born to 169 female koalas during the *KTMP* program (between 18 March 2013 and 31 August, 2016), or on average, 2 joeys per female. This is based on the assessment of 283 females at 1862 collective veterinary examinations. Approximately 60% (n=169) of females had at least one joey while being monitored and 40% (n=114) were not observed with a joey or a pregnancy during monitoring. The two primary causes of non-breeding were reproductive tract disease or sexually immaturity (**Figure 10.1**, below). Fifty-seven percent (57%) of non-breeding females had, or were suspected to have had, reproductive tract disease. Females that were not yet of breeding age accounted for 34% of non-breeding females – many of these koalas died before reaching breeding age. The remaining 9% (n=10) of females showed no signs of disease, but were not observed with a young. Many of these females were monitored only for a short duration.

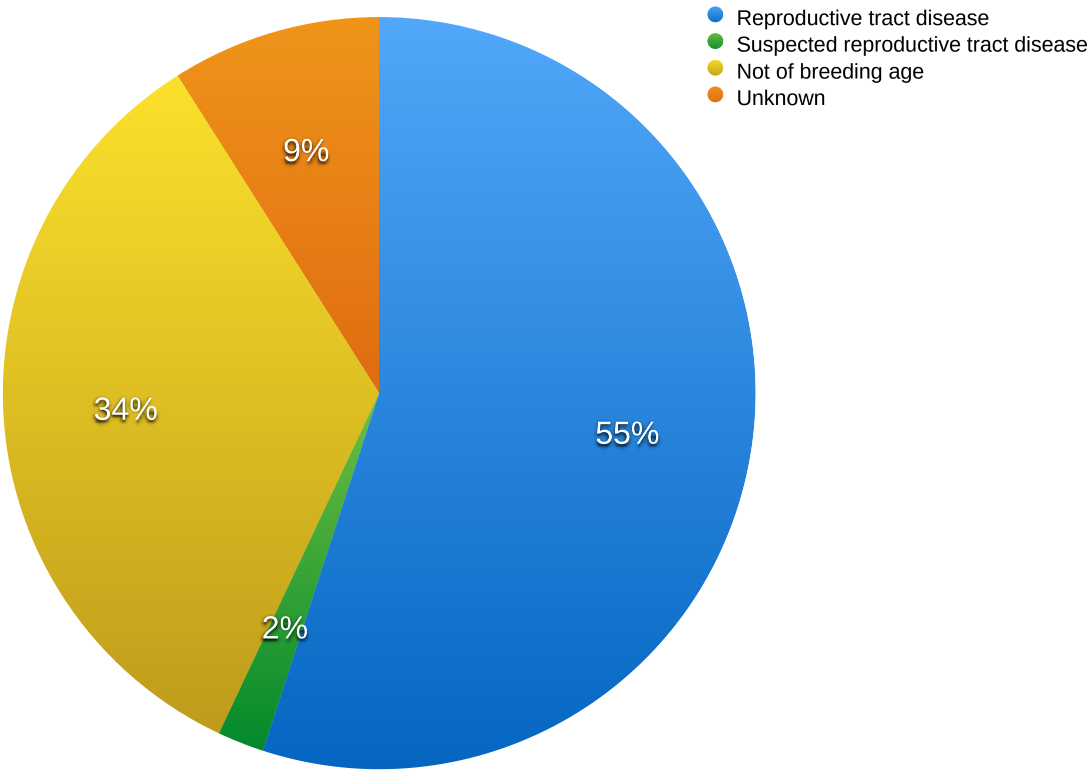



**Figure 10.1**. Reasons for females not to have young. The most common reasons for absence of a joey at a vet exam was because the female was sexually immature, or had reproductive tract disease. In less than 10% of cases the cause was not determined definitively. Most fertile female koalas conceived just prior to or shortly after weaning their previous joey, or relatively soon after the loss of a dependent joey. Legend items start at the 12 o'clock position and work clockwise. "*Suspected reproductive disease*" was assigned when subtle structural changes in the reproductive tract were detected by ultrasound examination, but not the definitive changes more commonly seen, like ovarian bursal cysts.

## 10.3.2 Fecundity

Although the terms fertile and fecund have similar meanings, for the purposes of this discussion we will use “fecund” to relate to the production of joeys, and “fertile” to relate to the capability of a female to breed. Hence, a fecund female is a female who is breeding, and a fertile female has the capability to breed, but is only fecund when she has mated and produced a joey. Also, the terms infertility and sterility have similar meanings, but for the purposes of this discussion, we refer to female koalas who are rendered permanently infertile (incapable of breeding) as “sterile”.

Fecundity in breeding-aged females varied considerably with age-class and year. In general, the proportion of females of breeding age observed with young was lower at the beginning of the project in 2013. The proportion of fecund females of breeding age in 2013 was 63% compared to 73% in 2016. If only those females that were of breeding age (and not having been ovario-hysterectomised (OHE)) are considered, 66% of females were breeding in 2013 and around 90% of females were breeding in the last two years of the project (**Table 10.1**).

| Year | Overall fecundity of females of breeding age (%) | Fecundity of entire breeding -age females (%) (excludes OHE females) |
|---|---|---|
| 2013 | 63 | 66 |
| 2014 | 65 | 77 |
| 2015 | 72 | 90 |
| 2016 | 73 | 89 |

**Table 10.1**: Percentages of fecund females by year. Note that in the latter two years, fecundity had improved to around 90% of breeding-age females (excluding surgical OHE cases), compared with less than two-thirds of breeding age females at the commencement of the program. This marked improvement is due to intensive management of chlamydial disease through early detection and treatment of cases, facilitated by high monitoring frequency and 6-monthly veterinary examinations.

**Plate 10.5**: Neonatal joey of the koala *Cherry* (left image) and *Winky* (right image) at their final veterinary examinations in December, 2016. The newborn joeys are attached to the teat, and eye-spots are just visible. The right image shows the well-developed fore-limbs that the joey uses to climb, unaided by the mother, from the birth canal to the pouch.

### 10.3.3 Timing of births

There was marked seasonality in the timing of births in the monitored population of koalas. Koalas were born in every month of the year, however, 71% of births were in late spring and summer, in the months of October to January (**Figure 10.2**). At the western end of the corridor, the Amcor koalas showed a peak in births in the months of October to December, while at the eastern end of the corridor, births still peaked over three months, but the peak was delayed by one month from November to January (Figure 3). The slight peak in the births of joeys at Kippa-Ring in April and May was caused by: first-time breeding sub-adults (46%, n= 7); adults that had previously lost young (33%, n= 5); and for reasons unknown as it was the first veterinary examination for the animal with no prior joey history (20%, n=3). Young that were lost before the age of independence were typically born in the peak birth months. Thirteen females gave birth to joeys in June, July and August. First-time mothers (15%, n=2) or those that lost previous young (23%, n=3) were more likely to breed and give birth outside of the peak birth months. Of the remaining eight females one was ill, one had a previous out-of-peak-season joey, and for six the cause was unknown, as it was their first veterinary examination with no prior joey history.

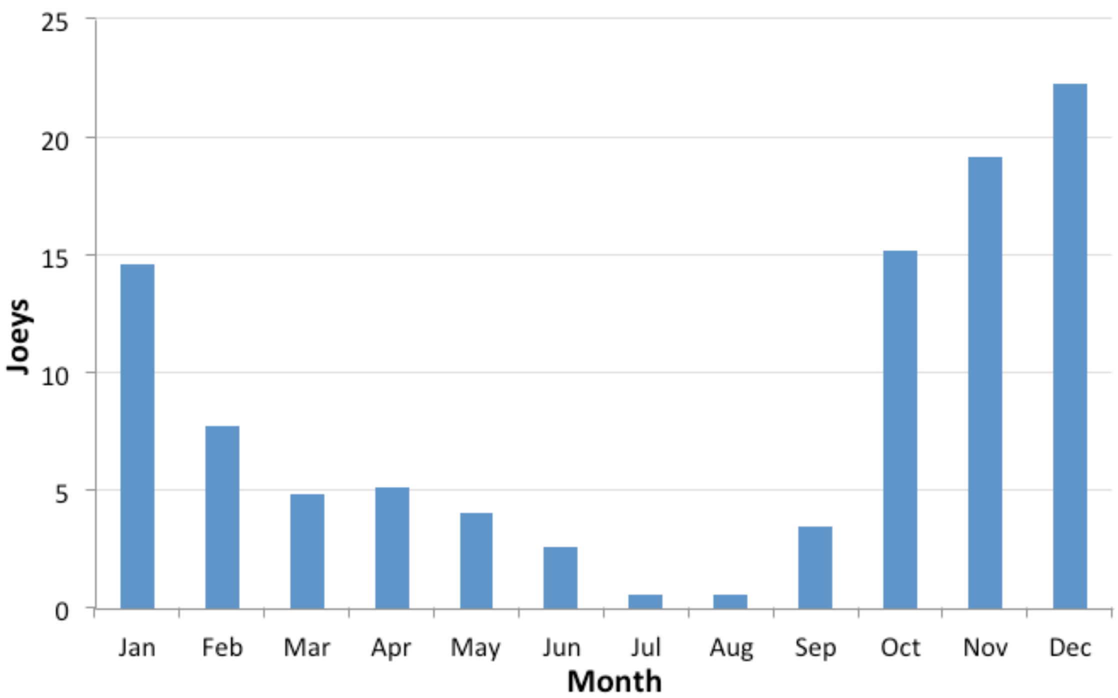



**Figure 10.2**: Number of births of joeys by month (all years combined), showing marked seasonality in births, although births occurred in every months of the year. Around 71% of births were in the months of October to January.

**Plate 10.6**: Joey of *Susan* at approximately 2-3 weeks of age. Eyes and ears are undeveloped and the hind-limbs just visible on the right of the photograph are poorly developed. The joey is approximately 25mm long.

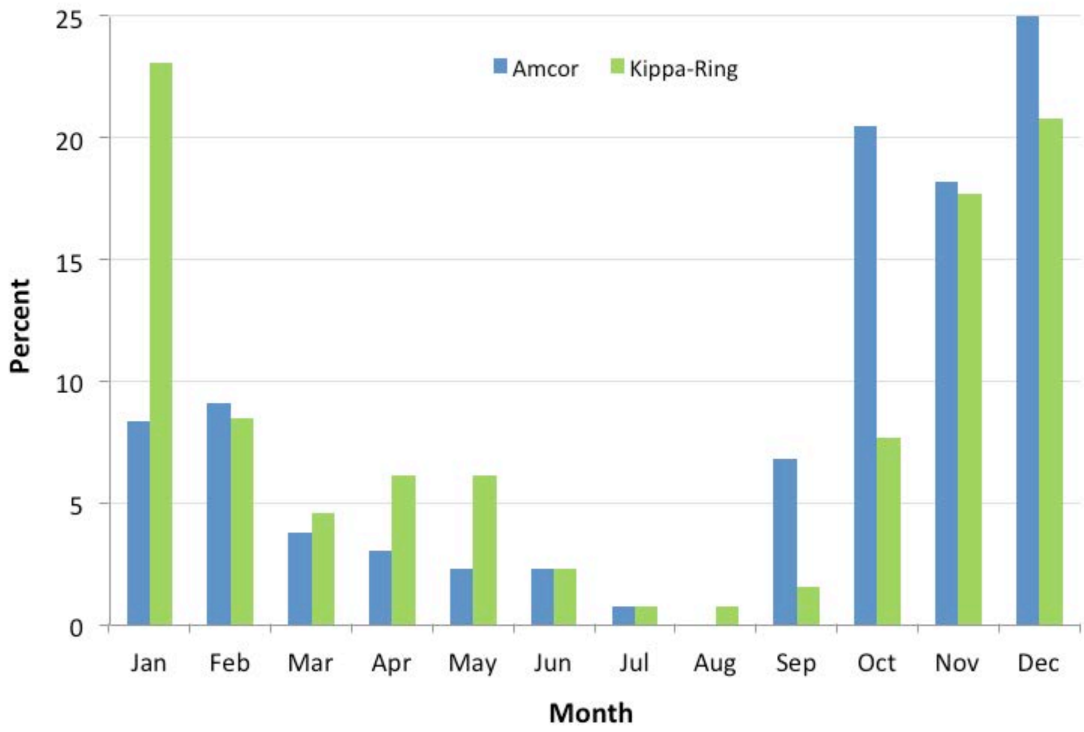



**Figure 10.3**: Seasonal variation in births - comparison of Amcor and Kippa-Ring births. There is a clear trend for Amcor births to peak one month earlier than Kippa-Ring births. The reason for this is unknown. Both polygons had a three-month peak in the birth of joeys over which time nearly two-thirds of joeys were born.

**Plate 10.7**: *Eva* and her approximately 7-month-old joey *Athena*, during *Eva's* first veterinary examination in June, 2014. *Eva* is yawning due to the sedative. Joeys were often kept with their mothers during veterinary examinations to avoid separation anxiety.

## 10.3.4 Developmental stages of joeys

Joeys progress through a number of developmental phases from birth to the age of independence at around 10-12 months of age. These are:

1. Pouch life
2. Transitional phase (between pouch life and out-of-pouch dependency)
3. Out-of-pouch dependency - often described as "back-rider" joey
4. Transitional phase (between close maternal dependency and age of independence).

In early pouch life, the joey is unfurred, unpigmented, and permanently attached to the teat. Later in pouch life, pigment and fur appear, and the joey periodically disconnects from the teat and may rarely exit the pouch. During the transitional phase from pouch life to out-of-pouch dependency, at around 6 months of age, the fur become longer and denser and the joey makes regular forays out of the pouch onto its mother's front or back. At around 8 months of age, the joey is permanently out of the pouch, but feeds regularly from the teat, and rarely makes forays off the mother into branches on which she is resting. Joeys may sample leaf during this period. From 9-10 months of age, the joey spends an increasing amount of time off the mother, eventually reaching an age where dependency on the mother is minimal, usually between 10-12 months of age.

Joey koalas were aged according to a variety of criteria based on the size, weight (if not in the pouch) and physical characteristics. Newborn joeys were easily distinguished by size. With increasing age there was greater variation in the size and weight of joeys in each size class and less confidence in the accuracy of ageing. However, many of these joeys were of a relatively well-known age, having been detected as a pregnancy or observed in the pouch at a young age. Based on the weight and characteristics displayed by these known-age joeys, an ageing chart was developed (*Appendix 13 - Joey development chart*). Joeys were only weighed if they were out of the pouch, usually when caught for tagging at 9-12 months of age. Some joeys caught with their mothers were opportunistically tagged as young as 8-9 months old if they weighed more than 1kg. At this stage, the range in weights varied considerably (**Figure 10.4**, below). For example, 9-10 month old female koalas averaged 1.39kg (range 1.17kg to 1.75kg), while male koalas averaged 1.3kg (range 0.71kg to 1.8kg). One male joey, *Slick*, was significantly under the average weight, at 0.71kg, probably as a consequence of his mother also being in poor body condition.

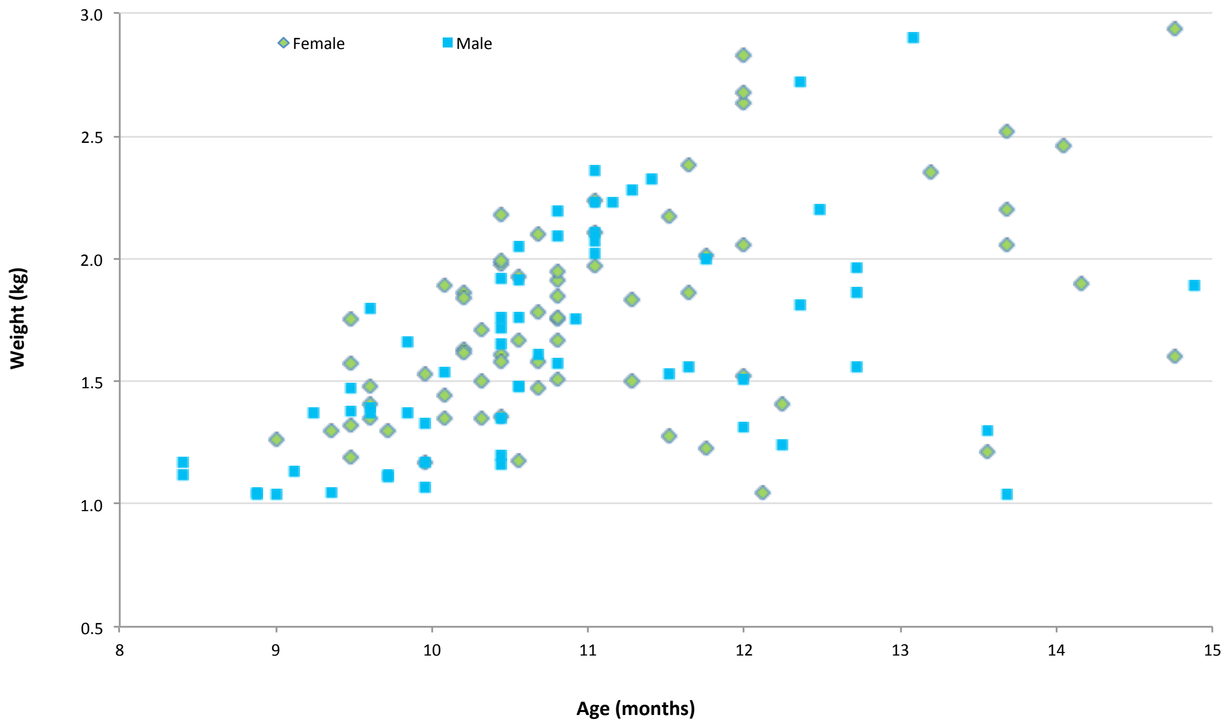



**Figure 10.4**: Scatter graph showing distribution of age vs weight for a number of MBR koala joeys

### 10.3.5 Age at first breeding

The average age of koalas at the time of first breeding was 18 months, however, the range was considerable: from 13.5 to 28 months (2.4 years) (**Figure 10.5**, below). Females tended to be around 3kg or more in weight at the onset of breeding. The oldest females (10+ years) in the study consistently produced joeys, and survival was on par with females in the other age classes (See **Figure 10.6**, two pages overleaf). When comparing koalas that remained alive through the rearing of a joey, females of 4 to 6 years old were the most successful at raising joeys to independence, with an 83% success rate, while sub-adult and mature adult koalas were the least successful with around two-thirds (65%) of joeys surviving.

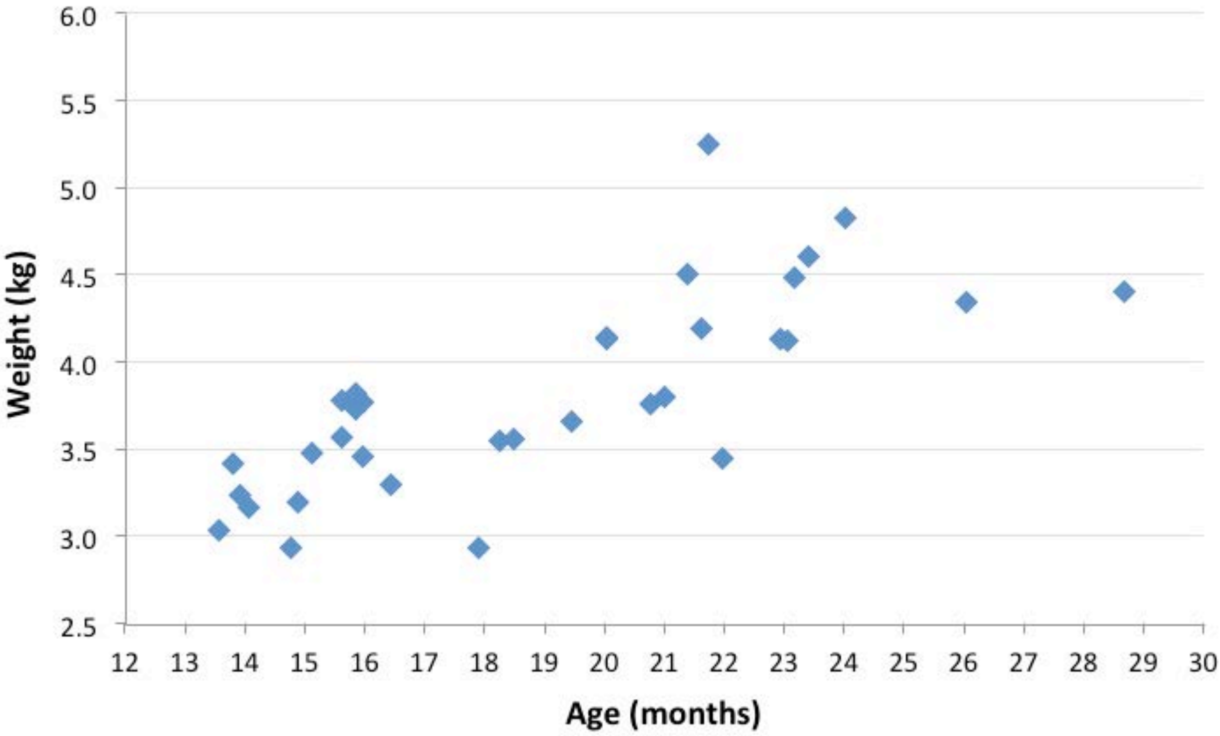



**Figure 10.5**. Age and weight of females at first breeding. The youngest female was 13.5 months of age and 3kg in weight.

**Plate 10.8**: Koala *Cindy* from Kippa-Ring was one of the most successful breeders. Over the 3.5 years of monitoring in the *KTMP* she raised four joeys to the age of independence, and had a 2-3 week pouch young when she was de-collared in December, 2016. Her joeys *Lou*, *Krystal*, *Ireland* and *Barney* all survived to the age of independence.

### 10.3.6 Survival to weaning and independence

There were 125 deaths of dependent joeys, ranging in age from newborn to near independent. Survival to independence was analysed for six age classes: newborn (<2 weeks old), pre-pouch emergence (2 weeks to 6 months), pouch emergence intermediate-sized joey (6-8 months), back-rider joey (8-10 months), near independent (10-12 months) and newly independent (12-14 months) (**Table 10.2**, below). Approximately two-thirds (66%) of joey deaths were not associated with death of the mother, the other approximately one third (33%) of joey deaths were as a consequence of the death of the mother.

The major cause of death of dependent juveniles was "*unknown*" for 57% of joeys (**Figure 10.7**, overleaf). All joeys in this category went 'missing' and were at some stage not detected with their mother during routine monitoring or at a subsequent veterinary examination. Approximately half (54%) of these joeys were never observed out of the pouch and were less than 6 months old in the newborn or pouch age class at the time of their deaths (**Table 10.2**, below). Wild dog predation, or suspected wild dog predation of the mother accounted for 28% of joey deaths. While five joeys were found alive and taken into care as orphans when their mothers were predated or killed by wild dogs, many joeys were never found, even after extensive searching. These joeys were either killed directly from predation, or perished as they were still dependent on their mothers' care for survival. Carpet python predation of females with pouch joeys, or of the joeys themselves, resulted in the deaths of six joeys (5%). Two orphaned joeys required euthanasia after their mothers died from non-*Chlamydia*-related disease, one was too small to be viable for hand-raising and one was euthanased due to gastro-intestinal complications during the hand-rearing period.

| Cause of death | Age class | | | | | |
|---|---|---|---|---|---|---|
| | Newborn (<2 weeks) | Pouch (2 weeks - 6 months) | Intermediate (6-8 months) | Back-rider (8-10 months) | Near independent (10-12 months) | Newly independent (12-14 months) |
| Unknown - other | 10 | 32 | 14 | 17 | - | - |
| Predation - wild dog | - | 9 | 5 | 4 | 2 | 5 |
| Suspect wild dog predation | - | 4 | 4 | 3 | 3 | 5 |
| Predation - carpet python | - | 1 | 1 | - | 4 | 6 |
| Trauma - other | - | 2 | - | - | - | - |
| Euthanasia | - | 3 | - | - | - | - |
| Trauma - domestic dog | 1 | - | - | - | - | - |
| Trauma - road | - | - | - | - | - | 1 |
| Misadventure | - | - | - | - | - | 1 |

**Table 10.2**: Causes of death of joeys by age-class. (Data span 18 March 2013 - 31 August 2016.)

Eighteen juveniles died shortly after independence, at 12 to 14 months old. Over half (56%) were predated or suspected to have been predated by wild dogs, one third (33%) were predated by carpet pythons, one died from vehicle trauma, and another from misadventure (*Goldie*) suffering massive bee sting envenomation.

Joey survival in different age-classes of females showed some variation which is unlikely to be of statistical significance (analysis not performed). A graphical representation of the data is shown in **Figure 10.6**, below.

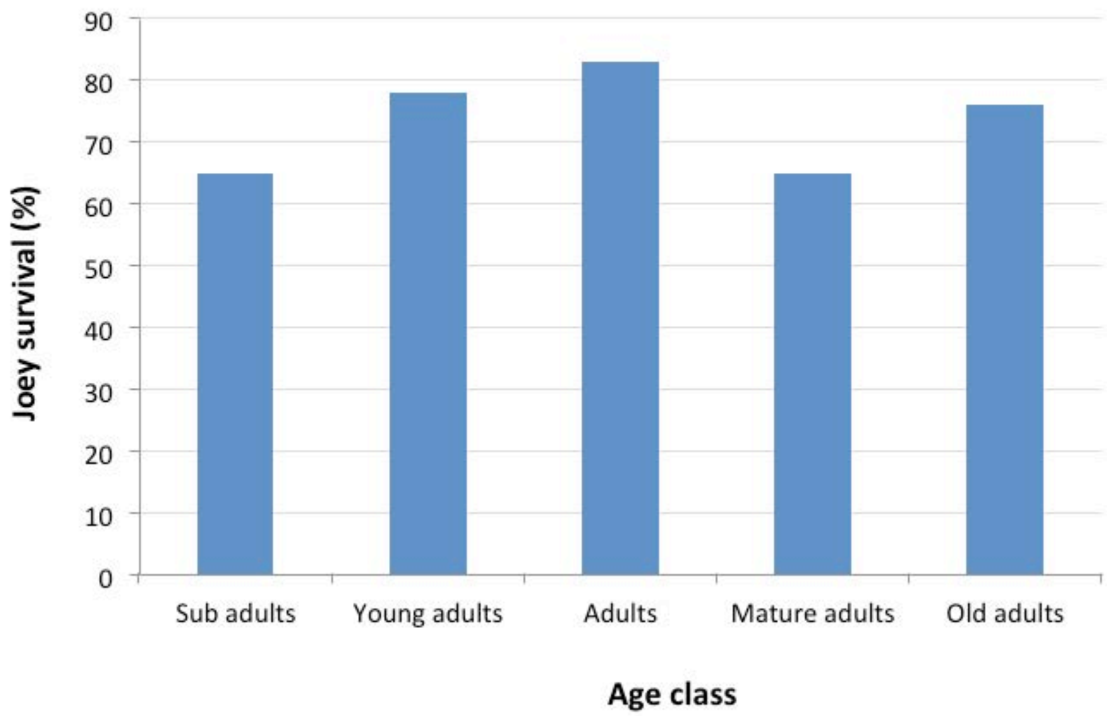



**Figure 10.6**: Percentage survival of joeys of mothers of different age-classes. Differences are probably not statistically significant, and any real differences directly associated with the age of mothers may be confounded by considerable loss of mothers to wild dogs in the first two years of the program.

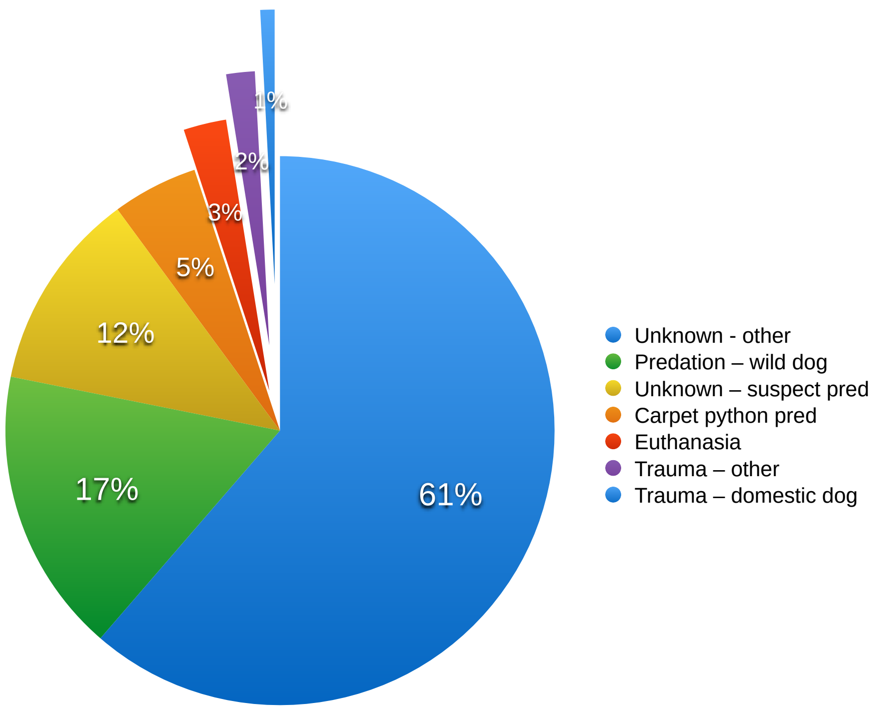



**Figure 10.7:** Pie chart showing proportionate causes of death of joeys (excluding recently independent juveniles). Two-thirds of deaths were solely the death of the joeys, and the remainder were attributed to the death of the mother.

### 10.3.7 Survival from dependence to breeding-age

Approximately two-thirds (64%) of the joeys born during the project survived to the age of independence (**Figure 10.8**). Of joeys monitored at *independence*, 76% survived to 1.5 years of age, however this equated to less than half (48.7%) of koalas surviving from *dependence* to 1.5 years. Further mortality reduced the survival to 2 years of age to 44.5%. There was a further 5% loss of koalas between 2 and 2.5 years, and no mortality of koalas between 2.5 and 3 years of age. The overall survival of koalas from the original group of dependent joeys to 3 years of age was 39%.

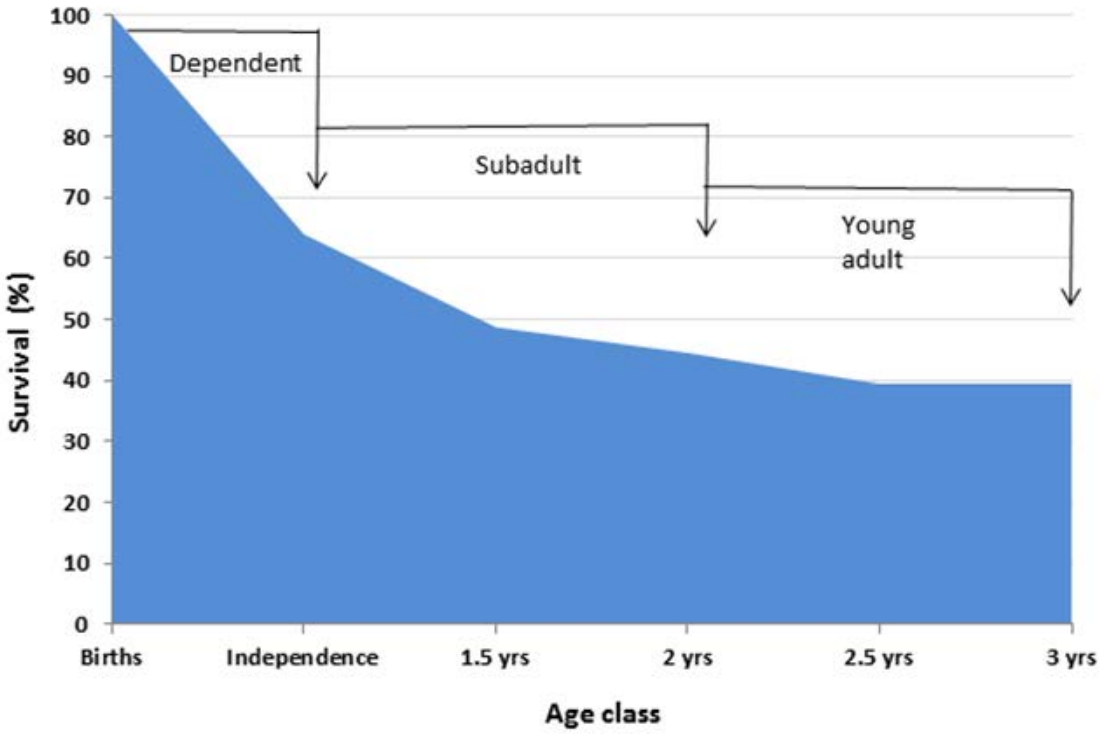



**Figure 10.8:** Survival of joeys from dependence to young adult age-class. From the total known births (100%), 64% of joeys survived to independence. Sub-adult animals between 1 and 1.5 years old had a 76% survival rate, with survival improving as the group of newly-independent juveniles aged. The overall survival of joeys to age 2.5 and 3 was 39% overall, but was significantly improved over time as wild dog and *Chlamydia* impacts were reduced. Age of independence varied between joeys, and was defined as the age of the joey on the first day that the joey was observed in a separate tree from its mother on consecutive field tracking events over a 2-week period.

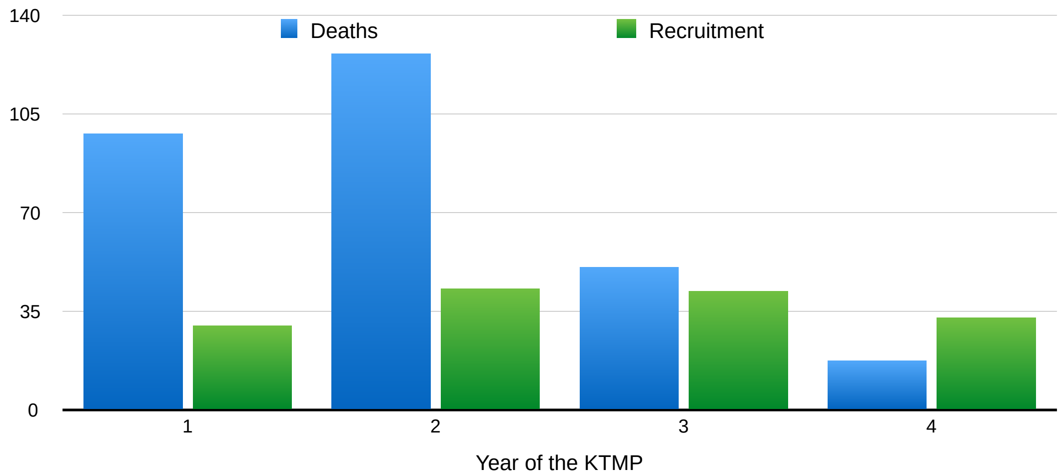



**Figure 10.9**: Number of total koala deaths (blue bar) vs recruitment (joeys reaching independence) (green bars) by year of the *KTMP* program, showing the relative reduction in deaths and improved recruitment over time. Note that total numbers of monitored koalas was less in the final year. For population growth, recruitment must exceed deaths.

## 10.3.8 Age of independence and establishment of home ranges

The age at which joeys were deemed to be independent varied considerably between 10 and 12 months of age.  We defined the age of independence as the *age of the joey on the first day that it was observed in a separate tree to its mother, and continued to be in a separate tree on consecutive tracking events for a minimum of two weeks*. In an analysis of 134 joeys that reached independence from their mother, the average age in days at the time of independence was 355, the range was 292-416 days and the standard deviation was 24.2 days. **Figure 10.10**, below, shows the bell-shaped distribution of ages at independence.

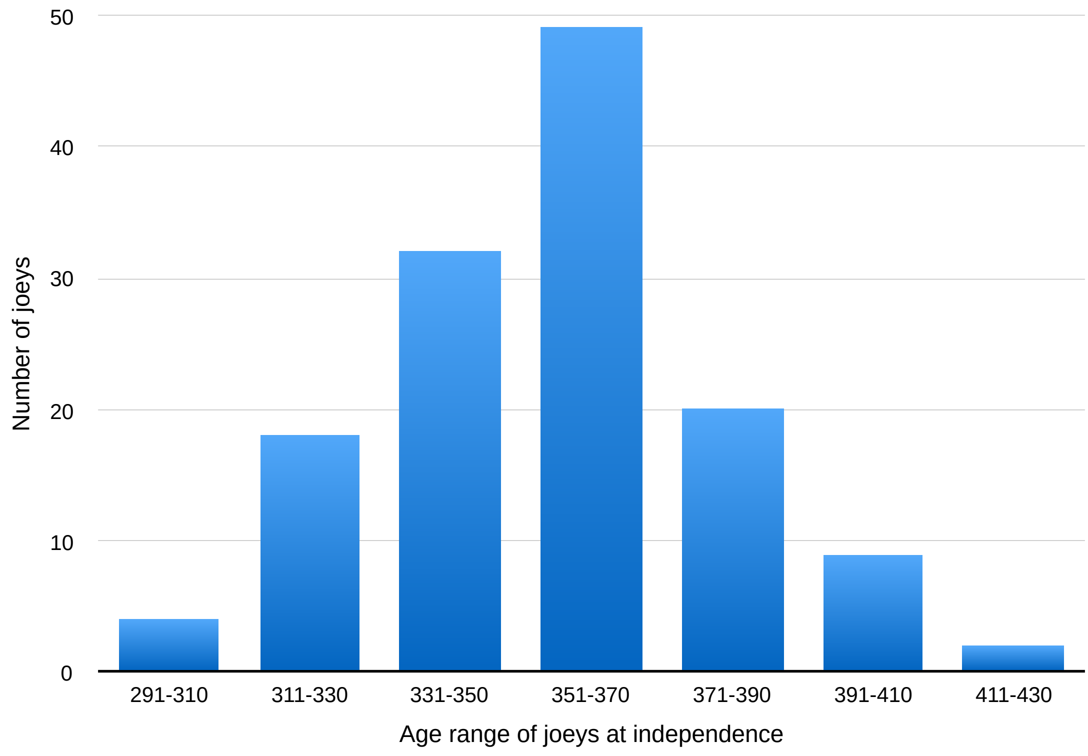



**Figure 10.9**: Bar graph showing ages of independence (in days) of a group of 134 joeys

Newly independent joeys stayed in their natal home range in the short term, expanding their ranges gradually. Initially, joeys would start spending time away from their mother in the same tree while transitioning to independence. As joeys became more independent, they would be found at greater distances from their mothers, either in the same tree, or in separate trees. In the months after independence, joeys were occasionally located in the same tree as their mother, but more usually, they were sitting in separate trees within their mother's home ranges.  Many of these sub-adult koalas dispersed away from their natal home range before breeding.

### Case study: Home range establishment by koala *Aerona*

Koala *Aerona* initially had a small 5.4ha home range and stayed within the bounds of her mother *Rhonda's* home range once living independently (**Table 10.5**, below, **Figure 10.10**, overleaf). She was often located greater than 50m from Rhonda, but *Aerona* was seen in the same tree as *Rhonda* on two occasions during this time. *Aerona* significantly expanded her range before breeding. After the birth of her first joey she showed exploratory movements to the north of her usual locations before returning to her former home range. On losing her joey *Sammy* (see case study below) she displayed typical sub-adult koala dispersal behaviour, making large movements around the site before showing a defined dispersal path. She dispersed to the south east over a month and a half (January to February 2016) and established a stable home range of 16.7ha (**Figure 10.10**, overleaf). She reproduced almost immediately and remained in the area until being untagged in June 2016.

| Koala | Life stage | Home range (ha) |
|---|---|---|
| **Rhonda** | Adult | 12.4 |
| **Aerona** | Independence | 5.4 |
| **Aerona** | Independence to breeding | 14.1 |
| **Aerona** | Breeding | 19.6 |
| **Aerona** | Dispersal | N/A |
| **Aerona** | Post-dispersal/adult | 16.7 |

**Table 10.5**: Home range establishment of koala *Aerona*, from independence to adulthood (95% KDE). Mother *Rhonda* is included for comparison. (See also **Figure 10.10**, below.)

**Plate 10.9**: *Aerona* and her biological joey *Sammy* after being reunited. (See case study below.). She failed to produce sufficient milk and was a poor mother behaviourally, so *Sammy* was removed and successfully hand-reared.

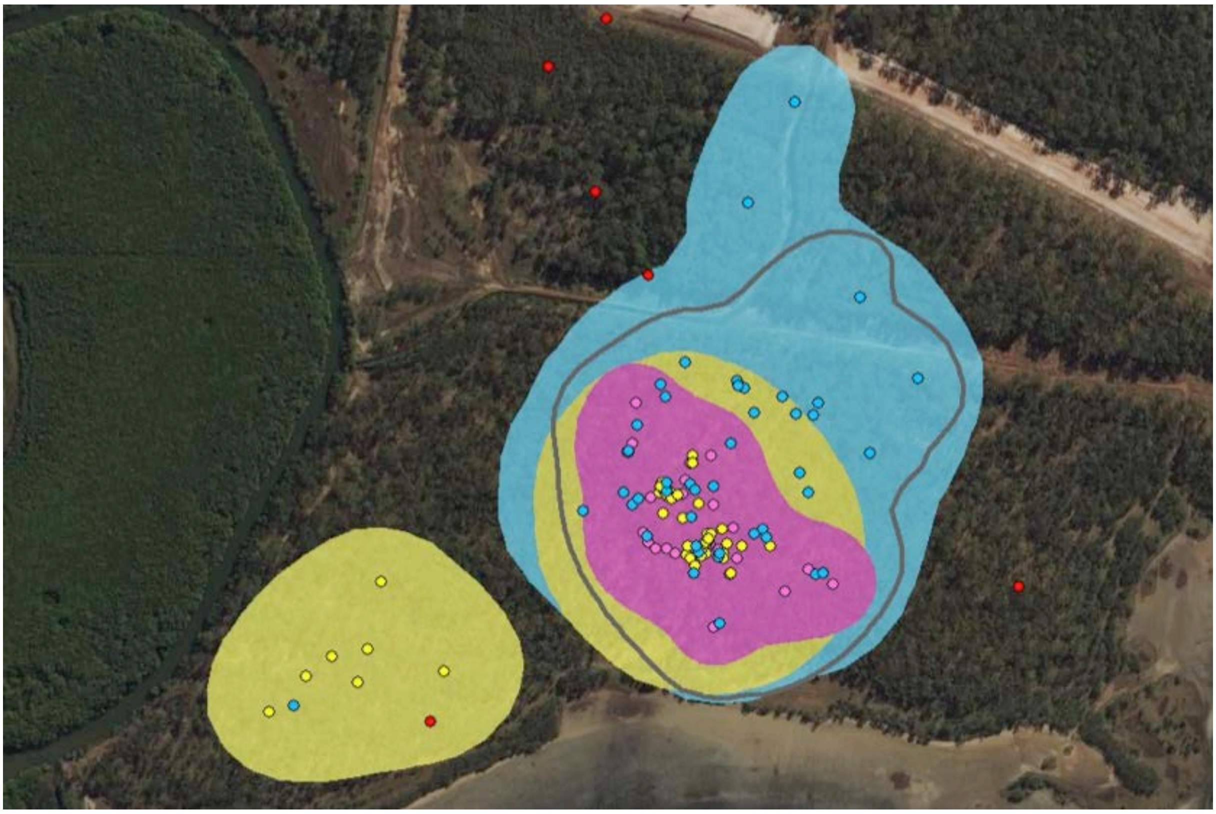


**Figure 10.10**: Home range establishment of newly independent joey *Aerona* shows initial ranging within her mother *Rhonda*'s home range (grey outline). Prior to (yellow home range polygon and yellow tracking location dots) and during breeding (blue home range polygon and blue tracking location dots) she expanded her range before losing her 6-month-old joey (*Sammy*) and dispersing to the south east.

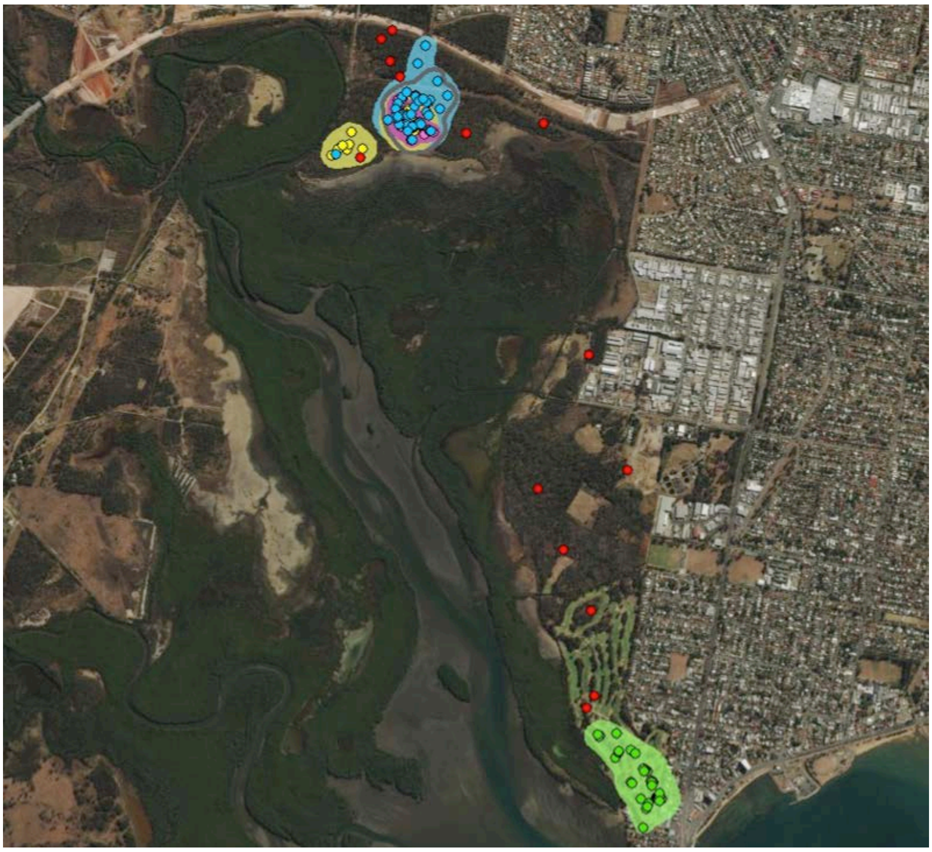


**Figure 10.11**: Home range establishment of the sub-adult *Aerona* shows her dispersal path from the vicinity of her natal home range (blue polygon) to the south-east, indicated by red tracking location dots. She reproduced almost immediately, establishing a stable 16.7ha home range (green polygon KDE 95% and green tracking location dots) where she resided until the completion of the *KTMP*.

### 10.3.9 Case study of natural adoption of a joey

Koala *Karen* was an approximately 6-year-old female that had been monitored since the start of the *KTMP*. She had been observed with 5 young during the study (**Table 10.6**, below). Koala *Aerona* was over 2 years old and was first captured and tagged as a 9-10 month old juvenile on 18/11/2014. A scheduled health examination of *Aerona* on the 22/5/2015 at 16 months of age detected an approximately 1-week-old pouch joey - her first young (**Table 10.6**).

| Koala | Capture date | Joey age | Joey status |
|---|---|---|---|
| Karen | 28/3/13 (scheduled exam) | 3-4 months | Dependent pouch young (unnamed joey) |
| | 9/6/13 | 5-6 months | Dependent backrider (unnamed joey) |
| | 8/10/13 | N/A | Missing (unnamed joey) |
| | 4/4/14 (scheduled exam) | 3-4 months | Dependent pouch young (*Igor*) |
| | 29/7/14 (tag attachment/check) | 7-8 months | Dependent backrider (*Igor*) |
| | 19/9/14 | 10-11 months | Dependent backrider (*Igor*) |
| | 17/10/14 (tag attachment/ check) | 11-12 months | Near independent (*Igor*) |
| | 22/1/15 (sick or injured) | Pregnancy | (*Keanu*) |
| | 9/2/15 (mid treatment check) | 0-1 month newborn | Dependent pouch young (*Keanu*) |
| | 19/2/15 (mid treatment check) | 0-1 month | Dependent pouch young (*Keanu*) |
| | 19/5/15 (scheduled exam) | 3-4 months | Dependent pouch young (*Keanu*) |
| | 24/9/15 (scheduled exam) | 8-9 months | Dependent backrider (*Keanu*) |
| | 2/12/15 (joey tagging) | Pregnancy (late-term) + 6-7 months + 10-11 months | Pregnancy, dependent backrider (*Sammy*), near independent (*Keanu*) (separated) |
| | 21/1/16 (health recheck) | 1-2 months | Dependent pouch young (unnamed joey) |
| | 24/3/16 (scheduled exam) | 3-4 months | Dependent pouch young (unnamed joey) |
| | 8/6/16 (tags removed) | 5-6 months | Dependent pouch young (unnamed joey) |
| Aerona | 18/11/14 (tag attachment before independence) | N/A | Not breeding |
| | 21/1/15 (tag check) | N/A | Not breeding |
| | 22/5/15 (scheduled exam) | 0-1 month newborn | Dependent pouch young (*Sammy*) |
| | 22/7/15 (tag check) | 2 months | Dependent pouch young (*Sammy*) |
| | 8/9/15 (tag check) | 3-4 months | Dependent pouch young (*Sammy*) |
| | 3/12/15 (scheduled exam) | N/A | Missing (*Sammy*) |
| | 20/4/16 (tag check) | 2-3 months | Dependent pouch young (unnamed joey) |
| | 7/6/16 (tags removed) | 3-4 months | Dependent pouch young (unnamed joey) |

**Table 10.6**: Summary of the breeding history of koalas *Karen* and *Aerona*.

Koala *Karen* was recaptured on 2/12/15 to tag her 10-11 month old joey before his independence and separation from her. At capture, the small size of the joey was noted by the capture team and confirmed at the veterinary exam as a joey of approximately 6-7 months of age (*Sammy*). Tracking data from the field team confirmed that the large joey had not been observed with *Karen* for the previous two weeks and that a smaller joey had been observed sitting on the front of *Karen*, as is the case with young not long out of the pouch. A search was conducted for the 'missing' joey and a young koala (*Keanu)* was found and captured in the vicinity of *Karen's* capture location. *Karen's* veterinary examination determined that she had a late-term pregnancy and was lactating, but had adopted the joey *Sammy,* who was actively suckling.


**Plate 10.10**: Adopted joey (*Sammy*) with *Karen* during her veterinary examination after the adoption was detected by field personnel in early December, 2015 (left image). Right image is a sonogram showing the mid-late-term foetus (arrow) carried by *Karen* at the time. Given the short (35d) gestation of koalas, this joey would have been born only weeks after the images were taken, unable to attach to the teat due to the presence of *Sammy,* and consequently would have perished. After an unsuccessful reuniting attempt with his biological mother *Aerona*, *Sammy* was hand-reared. The foetus was born and attached successfully, and at the time of *Karen's* de-collaring and removal from the *KTMP* in June 2016, the joey was a healthy 6-month joey.

**Plate 10.11**: Approximately 1-2 month joey of *Karen* during a scheduled veterinary examination in late January 2016 (left image) and as a 3-4 month joey in late March, 2016 (right image). The joey would not have survived had her adoptee, *Sammy,* been allowed to be naturally reared by her*.*

*Aerona* was recaptured on 3/12/16 to determine her reproductive status as her joey had not been seen with her by field personnel during scheduled field tracking monitoring in the two weeks prior to her capture. Her home range overlapped *Karen's* and it was considered that *Sammy* (*Karen's* adoptee) was her missing 6-7 month-old joey. She was found to be lactating at her veterinary examination, and *Sammy* was removed from *Karen,* reunited with *Aerona* and kept in care under careful observation for a week.

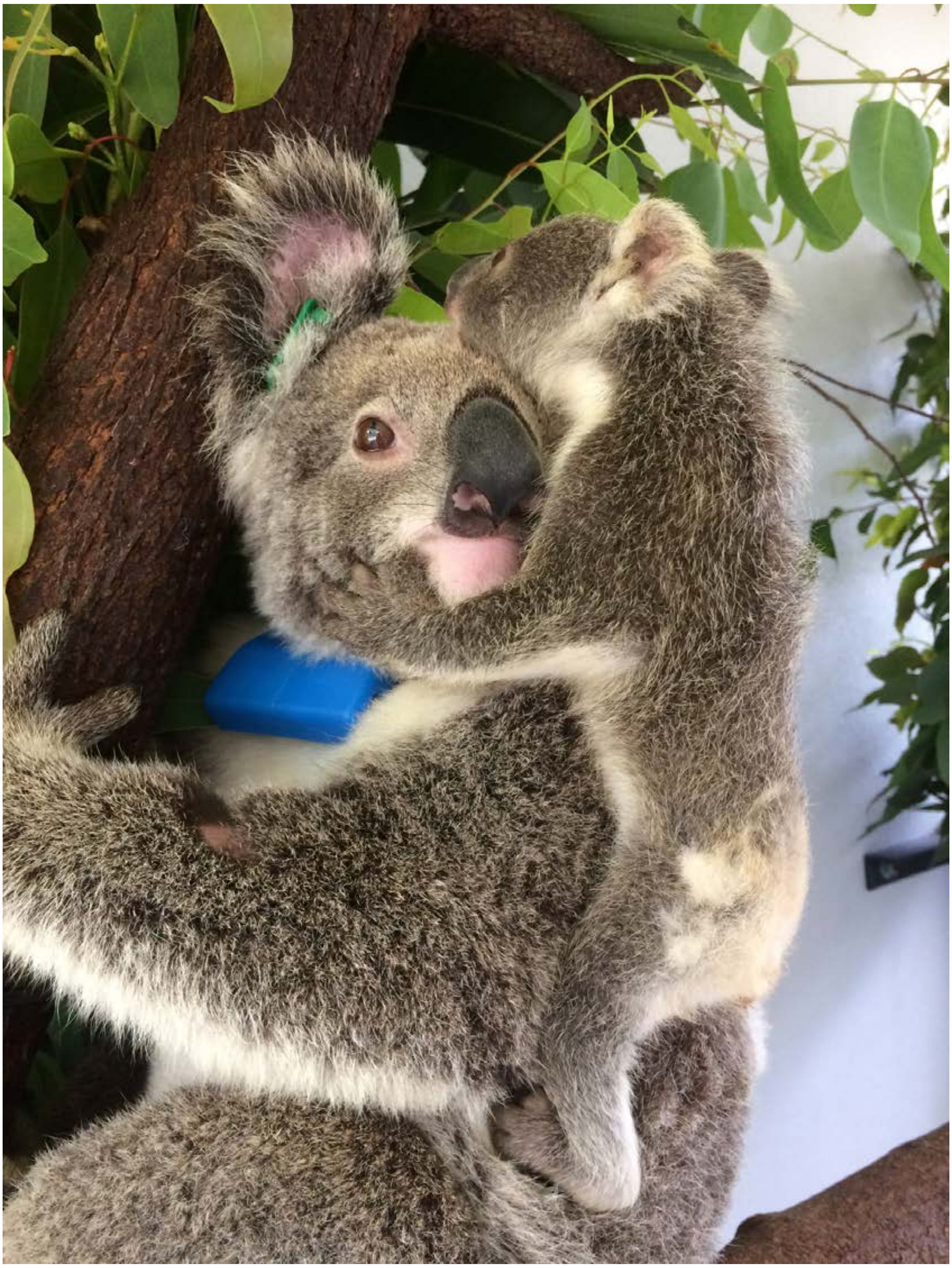


**Plate 10.12**: *Aerona* and her biological joey *Sammy* are reunited. Although *Sammy* appears to be pleased to see his mother, she seems, perhaps, less so. Aside from her poor mothering behaviour, her milk dried up, and *Sammy* was removed and hand-reared by EVE koala ecologist Dr Deidre de Villiers. He was released back at the Kippa-Ring bushland in October, 2016.

*Aerona* and *Karen* showed significant overlap in home ranges (**Figure 10.12**, below). *Karen* had a well-defined home range of approximately 10.8ha, being one of the longest monitored koalas in the program. *Aerona* had a larger home range of 37.6ha, having ranged over a greater area as a sub-adult, moving away from her mother's home range to establish her own home range after independence. Approximately two weeks prior to *Karen's* capture, both females were located within 30m of each other on two occasions. They were within 20m of each other within 12 hours on 20 and 21 November 2015, and within 30m of each other within 24 hours on 22 and 23 November 2016. Field observations showed that a large joey was sitting on *Karen's* back on 21 November and a joey of the same size was sitting at the very top of the same tree as *Karen* on 23 November (her biological joey, *Keanu*). The next day on 24 November, *Karen* was observed with a much smaller joey, and the same joey (her adoptive joey, Sammy) was observed with her until her capture on 1 December 2015. *Aerona* was noted with a joey on her or in her pouch on 9 November 2015, but thereafter field personnel were not able to see a joey due to her position in the trees (all visibility scores of 2) until her capture on 3 December 2015, when it was confirmed that her joey was missing.

**Figure 10.12**: *Aerona* (green home range polygon and green location dots) and *Karen* (pink home range polygon and pink location dots) had overlapping home ranges (95% KDE).

After *Aerona's* capture, *Sammy* was removed from *Karen* and returned to *Aerona* under careful observation. Clinic staff noted an incident during which *Sammy* became separated from *Aerona* and vocalised, but she made no attempt to rescue him, and clinic staff reunited the two. On 11 December *Aerona* was sedated for examination and was found to have ceased lactating. *Sammy* had lost weight, prompting in his removal for hand-rearing. As *Karen* was carrying a late-term pregnancy and was due to give birth, the newborn joey would have perished had *Sammy* been reunited with her. *Karen*'s near-independent joey was fostered for a short period and then released. All three joey koalas survived – *Keanu* and *Sammy* were monitored in the wild until the completion of the koala management program in December, 2016, and *Karen* was de-collared in June 2016 with a 3-4 month old pouch young.

Parentage was determined using blood and tissue samples collected from both females and their joeys. Genetic analysis of samples was conducted by The University of Queensland's Wildlife Ecology Group, and confirmed that the joey adopted by *Karen* (*Sammy*) was the biological joey of *Aerona* and that the independent juvenile was *Keanu,* the biological joey of *Karen*. As far as we are aware, this is the first confirmed and documented occurrence of the natural adoption (in the wild) of an abandoned koala joey.

## 10.4 Discussion and recommendations

### 10.4.1 Fecundity and joey survival

The MBR koala population had a relatively high level of recruitment, with around two-thirds of females of breeding age producing young each year. This was considerably higher than other koala populations in the region, where as few as 24% of females showed evidence of breeding. However, the latter statistic was derived from a broader regional population of koalas living freely in the wild that had not been subjected to the rigorous veterinary assessment employed on the MBR koala management program, hence the data are less reliable. Chlamydial disease is well recognised as the key factor limiting breeding success, reducing fecundity by contributing to reproductive tract disease and sterility in female koalas. Other work by EVE has demonstrated significant geographic variation in the impact of chlamydial disease, and this was also observed in the MBR koala population and those inhabiting the translocation recipient sites.

Healthy female koalas monitored for the MBR project produced a joey every year. Pregnancies were often detected approximately one month before the near-independent joey was weaned, which is consistent with the 35 day gestation of koalas. It also means that a fecund koala gets little respite from the physiological demands of pregnancy and lactation, and explains the generally robust and healthy appearance noted in OHE females, in which those physiological demands have been obviated. Juveniles generally became independent by the time their mother had given birth to a new joey, although on rare occasions neonatal joeys are observed attached to one teat, while the other (koalas have two teats located in the pouch) is being suckled by a near-independent juvenile. It was common for a female captured with a near independent joey to also have a pregnancy detected on examination. Observations of a lack of breeding in otherwise fertile females may have coincided with a time when a female had lost a joey in the few months before the birth of a new joey. Females who lost a joey prematurely would likely return to oestrus and be ready to breed again within one to two months.

The premature loss of a joey was a primary reason for births occurring prior to the usual birthing season in late spring and summer, between October and January. The one-month delayed peak in births at Kippa-Ring compared to Amcor is unexplained, but nonetheless an interesting observation, suggesting localised variation in breeding patterns. First-time breeding females were also likely to give birth outside of the peak birth months. Based on birth-month data, juveniles are typically between 12 and 15 months by the end of January. If they were born in January, the timing of their first breeding, when sub-adults reached 3 kg in weight at 14 to 18 months of age, would be well outside the usual birthing season. The literature suggests that females will breed at 2 years of age, however we observed numerous much younger first-time breeders.

The survival of joeys to breeding age is critical to population recruitment. Mortality of joeys was considerable, with 125 deaths of joeys recorded in the program. The proximate causes of many of these deaths was not determined, but death of the mother was the cause in one third of cases. With respect to the remainder, we did not observe consistent loss of young in particular females, suggesting that chance events or factors were more significant than maternal factors. Misadventure of pouch emerging joeys and front and back-rider joeys is certainly highly likely, as is active predation by a variety of predators taking advantage of the vulnerability of joeys at this stage of development. Mating activity can also result in the separation of mothers and young. Koala rescue groups receive many calls for orphaned koalas that are found alone without their mothers. Based on the wealth of data derived from the MBR koala management program relating to causes of mortality of near-dependent and recently depended tagged joeys, it is likely that predation of back-rider and untagged near-independent joeys by carpet pythons was also significant. Pouch infections, illness and disease may also account for the deaths of some dependent joeys.

With respect to overall population fecundity, the death of fecund females is the most damaging, and is often associated with loss of a dependent young at the same time. Breeding female koalas are the most important demographic in terms of population viability. As mentioned above, a female can breed and produce another young soon after the premature loss of a joey. Female koalas can reproduce for many years, producing a joey every year for over 10 years. We observed aged adult females (10+ years old) breeding and rearing 76% of joeys to independence. Hence, reducing premature death and maintaining fertility in breeding females is crucial to population viability. Both of these factors were successfully targeted as part of the MBR koala management program and offsets package, specifically through chlamydial disease treatment and wild dog control.

### Natural adoption of a joey - case study.

*Aerona* was a first-time mother, and as such may not have been as diligent as *Karen*, who had raised 5 young over the course of the *KTMP*. Data from this program show that first-time mothers were the least successful at raising young to independence, losing 35% of their young. This may reflect a lack of experience for first-time breeding females.

It is not uncommon in captive institutions (such as zoos and fauna parks) for female koalas to temporarily "adopt" the joey of a co-habiting female - a situation facilitated by the common practice of closely confining sometimes quite large numbers of koalas in very small enclosures . The adoption of the young joey *Sammy* by the koala *Karen*, to our knowledge, is the first documented case of such an occurrence in the wild. It may have been the result of an encounter between the two mothers, *Aerona* and *Karen* in the same tree, given that they had overlapping home ranges and came within close proximity to each other on at least two occasions, evidenced by the LX *K-Tracker* data. Alternatively, *Sammy* might have fallen, and *Karen*, being a more experienced and attentive mother, might have responded to the sounds of his distressed calling. Her joey *Keanu* might not have been with her at the time, as he was frequently observed resting separately from her in the same tree. Some female koalas immediately respond to the sounds of a joey calling, often quickly descending a tree to retrieve it. This behaviour was observed in a koala released during the *KTMP* after she left her joey in the transport enclosure at the time of her release (see **Plate 10.13,** below). Whether a female koala can distinguish between the call of her own joey and that of another, is not known, nor whether that would make a difference to her rescue response.

**Plate 10.13**: Sequence of images showing the release of *Caz* - initially without her joey, which vocalised, prompting her descent from the tree to retrieve him.

**Benefits of intensive monitoring and adaptive management**

We were able to collect and analyse a wide range of data relating to koala biology and ecology, such as joey survival to independence, dispersal behaviour, the establishment of home ranges and causes of premature death. The crucial technology used to facilitate this was telemetric monitoring devices, of which the LX *K-Tracker* system was the most valuable. Throughout the nearly four-year koala management program we monitored as many as four generations of koalas from the same lineage. Further work (by university-based research groups) was underway at the time of writing, to examine parentage and relatedness of individuals in the MBR koala population using genetic analysis of samples derived from the *KTMP*. This research will allow a more detailed examination of the breeding dynamics and genetic exchange in this group of koalas, before and after construction of the rail project.

The early detection and management of chlamydial disease, also facilitated by the *KTMP*, increased the reproductive capacity of the koala population significantly. The management of disease and wild dogs reduced the premature mortality of koalas; and both of these responses dramatically improved the viability of the MBR koala population, such that it is now (at the time of writing) demonstrably, on a growth trajectory. While the proximate causes of death of a subset of joeys was not determined, the improvement in maternal survival in the latter stages of the program had substantial benefits for the survival of dependent young.

## 10.4.2 Recommendations

Population survival and persistent relies upon births and immigration exceeding, or at least being equal to, deaths and emigration. Ignoring immigration and emigration for argument's sake, if the birth rate is consistently lower than the mortality rate, then a population will decline towards extinction. Koala populations in Queensland are affected by high prevalences of chlamydial disease which commonly results in permanent infertility - sterility - in females. This causes significant reproductive loss and lowers the capacity of koala populations to sustain high mortality rates from factors such as predation and anthropogenic threats.

With respect to transport infrastructure projects and koala reproductive success, we make the following recommendations:

1. That the reproductive status of koalas be thoroughly investigated in populations exposed to impacts from transport infrastructure projects, through veterinary management and monitoring programs, like the *KTMP.* This allows key factors affecting population viability to be targeted, improving the cost-effectiveness of offset and mitigation measures.

2. High disease prevalence in koala populations allows offset measures to provide significant benefits to population viability by chlamydial disease management. Therefore, we recommend that management of disease, through treatment and vaccination, be considered as a component of offset packages. If appropriately implemented, these would result in significant improvements in population resilience to impacts such as transport infrastructure-associated mortality, as well as other causes of premature death.

# CHAPTER 11: POPULATION VIABILITY ANALYSIS


## Key points

- Koala population in rapid decline due to wild dogs and disease at commencement (well prior to vegetation clearing and construction)
- *KTMP* and *KTrans* programs guided adaptive management of key threats using innovative technology
- Koala population decline reversed by year 3 of program - establishing a growth trajectory
- Fecundity (reproductive) rates improved and mortality rates decreased through MBR management responses
- Clear benefit to koala population, but duration of benefit depends on future management.

# Chapter 11: Population viability analysis

**Dr Hawthorne Beyer, University of Queensland**

## 11.1 Introduction

Population viability analysis (PVA) is an ecological tool that helps to guide decisions about how to manage wildlife populations for conservation. In simple terms, PVAs model the trajectories of wildlife populations based on a number of variables, such as mortality rate, birth rate, immigration and emigration and so on. PVAs may indicate that a population is growing, declining or stable, and, depending on their complexity, also make predictions about the medium and long-term likelihood of persistence of the population under various scenarios, including implementation of specific conservation actions.

PVAs require the input of data collected from the target or similar wildlife populations. The more high-quality data that can be input into a PVA, the more likely it is that the conclusions drawn from the model will be accurate. When data are not available for input, or predictions need to be made about future events (such as bushfire, flood, disease impacts), assumptions are included in the model. Sometimes such assumptions are just educated guesses, which can reduce the rigour of the model. In the worst cases, PVA models rely heavily on assumptions, and if these are not based on solid data or well validated information, then the model can give very misleading outputs.

The data used for the PVA for the Moreton Bay Rail koala population are some of the most comprehensive and high-quality data ever used in a wildlife PVA. This means that the reliance on assumptions is minimal and the model is very robust, and therefore we can be reasonably confident in the conclusions and predictions that arise from the PVA.

This section sets out the results of population viability analysis under three broad scenarios:

1. What was the koala population trajectory before any work for the MBR project commenced, and what would it have done in the future if the rail project had never gone ahead?

2. What would the koala population trajectory have looked like had the rail project gone ahead, but no koala protection and mitigation measures were implemented?

3. What is the likely koala population trajectory in the short-medium term, now that the MBR project is essentially complete, and a variety of koala protection, mitigation and compensatory measure have been implemented?

**Plate 11.2**: Koalas are susceptible to attack by wild and domestic dogs when moving across the ground between trees. This sequence of photos is of koala *Sammy* taken at his release back into bushland at Kippa-RIng after his final veterinary examination at the end of the koala management program.

Some important caveats with respect to the koala management program for the MBR project are worth noting here:

1. Management of disease and wild dogs commenced early. In the ideal scenario, the initial phase of data collection for a PVA would involve no active management or intervention to help the population. This would then allow collection of data without the confounding variable of active management of threats or other variables, and allow a true assessment of the population trajectory as it was. In the circumstances of the MBR project, this was not an acceptable option from an animal welfare or conservation perspective. Therefore, some assumptions are made about what the likely impacts of disease would have been had we not provided active veterinary population health management from the start. The confounding impact of wild dog control is perhaps less significant, partly because of the disproportionate contribution of the "Amcor Dog", which was only captured (in February 2017) long after his departure from the site, at which time koala monitoring had been completed.

2. Assumptions about the loss and/or retention of koala habitat, had the MBR project not gone ahead are highly speculative, and therefore difficult to resolve robustly in the model. For example, had the MBR project never been proposed many decades ago, it is very likely that much of the habitat that persisted up until the time of its construction, may have been developed for urban purposes many years ago. However, for the purposes of the model, we have assumed that the habitat would have largely remained as it was, but without the impact of the rail construction project. This is a very conservative assumption, because it is very likely that much of the habitat present at the time of commencement of the MBR project would have been developed, and will be in the future.

## 11.2 Methods

### 11.2.1 Overview

PVA is based on data describing the survival and reproduction of individuals, derived from the timings of observed births and deaths. Birth and death rates often vary substantially as a function of age, so it is important to estimate age-specific rates. However, analysis of the koala monitoring data is complicated by the asynchronous entry of koalas into the monitoring program, the time that animals spend in care receiving treatment and unknown outcomes for some animals. Survival analysis is a rigorous approach to analysing data characterised by these sorts of complexities. Here, we use survival analysis to develop robust estimates of survival rates, which are then coupled with an analysis of birth rates to inform the PVA. We are able to gauge the impact the MBR project has had on the koala population by estimating how survival and fecundity rates have changed over the course of the project as management efforts intensified and had greater cumulative impact.

PVA's are simulations of birth and death processes in order to develop predictions about how population numbers may change over time. They explicitly account for random, natural variation ('stochasticity') by sampling from probability distributions. This means that each PVA simulation is different and, by running the simulations many times, we can estimate not only the average population trajectory but the confidence intervals around that trajectory representing this uncertainty.

Although survival analysis and PVA are conceptually straightforward, there are many statistical details to consider when parameterising the models. We describe these issues in detail below.

**Plate 11.3**: Vocalisation by the koala *Dennis* at his release attracted some interest from the locals. Such vocalisation occurs in 10% or so of koalas, particularly those that are "quiet stressers", and occurs almost exclusively at the time of release back into the wild, rather than during the stressful capture and period of captivity.

### 11.2.2 Detailed description of methods

Analysis of these monitoring data is complicated by the asynchronous entry of koalas into the monitoring programme, the time that animals spend in care receiving treatment (**Figure 11.1**, below) and unknown outcomes (right censoring) for some animals.

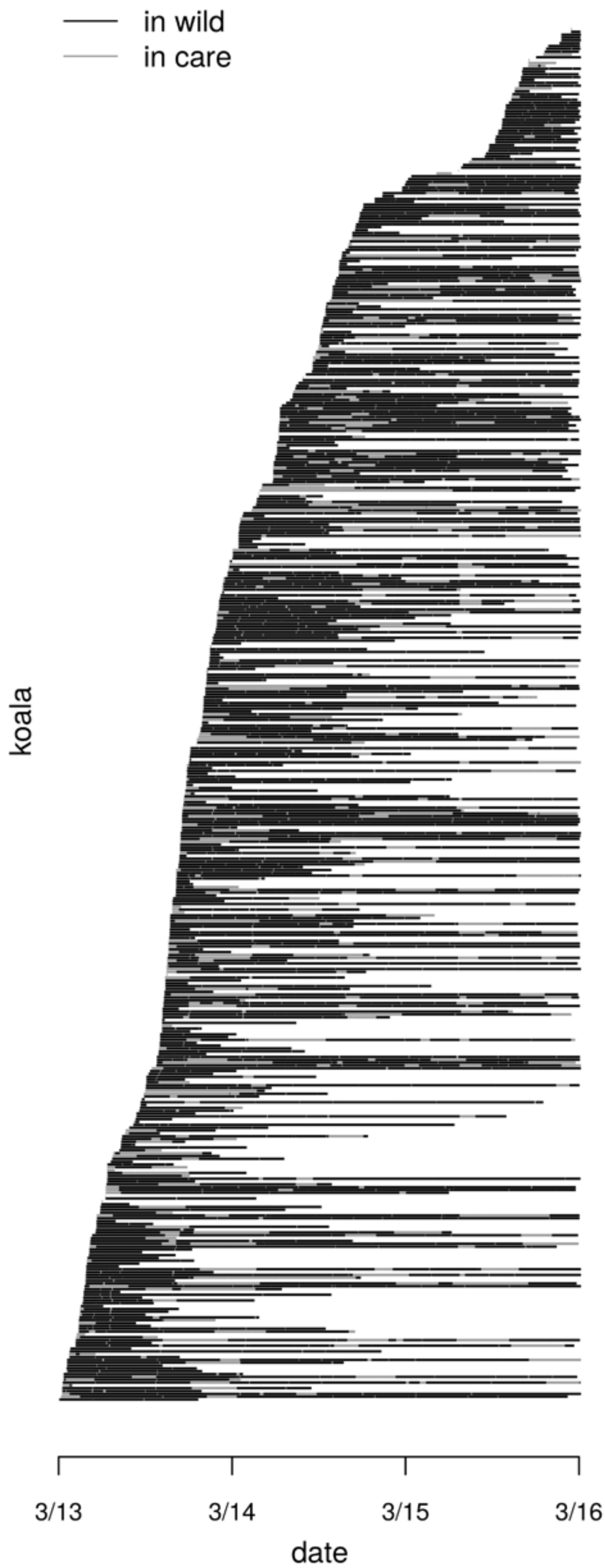



**Figure 11.1**: Monitoring history of 501 koalas (horizontal lines) between March 2013 and March 2016 (x axis). Koalas entered the study asynchronously over the course of the study and some animals spent time in a veterinary care facility to receive treatment for health issues (grey lines). Black lines represent time in the wild, which is the focus of the survival analysis.

We use survival analysis to quantify mortality rates of joeys and adults and to determine whether death rates differ as a function of age, sex, a year factor and whether the animal was at a translocation site. We quantify survival probabilities using the Andersen-Gill formulation of the Cox proportional hazards model (Cox, 1972; Andersen & Gill, 1982; Cox & Oakes, 1984), which can be expressed in matrix form as:

$$h(t) = h_0(t) \exp(\mathbf{X}\beta)$$

where $h_0(t)$ is the baseline hazard function, **X** is a matrix of covariates and does not include an intercept term, and $\beta$ is the vector of parameters to be estimated. The expression $\exp(\mathbf{X}\beta)$ modifies the baseline hazard multiplicatively, hence values of $\exp(\mathbf{X}\beta)$ greater than and less than 1 represent higher and lower mortality rates respectively, relative to the baseline function.

The Cox proportional hazards model can accommodate time-dependent covariates and right-censored records in which the outcome (here mortality) is not known. The Andersen-Gill formulation further accommodates interval censored data (Andersen & Gill, 1982), which in this case corresponds to times when koalas are housed in veterinary facilities and are not, therefore, exposed to several mortality risk factors such as predation, vehicles, domestic dog attacks and chlamydial disease.

An assumption of this modelling framework is that there is no bias in which animals are censored, and the removal of animals with severe disease or injury is a violation of this assumption. To correct for this bias we estimate survival times for the animals that were euthanased because of severe injury or illness and did not, therefore, die in the field. In 32% of these cases the injury or condition was so severe that death was imminent and estimates of the survival time had intervention not occurred are likely to be reasonably accurate (median 3.5d; range 0-20d). Examples include animals that had experienced severe trauma after being struck by vehicles or attacked by predators, or had broken bones that prevented them from climbing, or critical illness, such as septicaemia. A further 32% were assessed to have expected survival times from 20-60 days (mean 47.7d). The remaining 36% of euthanased animals were deemed to have projected survival times that exceeded 60 days (mean 235 d). All animals in the first category were treated as uncensored in the analysis and the estimated survival time was used as the observed survival time in the wild. We repeated survival analysis with and without the second group to test sensitivity of inferences to the censoring of these animals. The final group was always treated as censored.

We estimate prevalence of chlamydial disease, caused by the bacterial pathogen *Chlamydia pecorum*, and the time between loss of a joey and conception of the next joey ('breeding interval') directly from the monitoring and veterinary exam records.

### 11.2.3 Population modelling

We estimate population growth rates and simulate koala population dynamics using a female-only, age-structured model with an annual time step. There are k = 12 age classes, with the first age class corresponding to joeys (age 0-365 d) that are considered to be dependent on their mothers in their first year. Population numbers at time *t* are assumed to be censused immediately following reproduction, hence recruitment is calculated after mortality and ageing.

Survival into the second age class ($N_2$) must account for the fact that joeys are dependent upon their mothers, so the death of a mother necessarily results in the loss of the joey:

$$N_2(t+1) = s_1 N_1(t) - \frac{1}{2}\sum_{i=2}^{k}(1-s_i)b_i N_i(t) \tag{2}$$

where $N_i(t)$ is a vector of the number of koalas in each age class *i* at time *t*, *s* is a vector of annual per capita age-specific survival rates and *b* a vector of age-specific per capita birth rates. Thus, the number of animals surviving to age class 2 accounts for mortality among joeys independent of the fate of the mother ($s_1$) as well as the joeys that are lost as a result of the death of the mother. We assume an equal sex ratio among neonates (Ellis *et al.*, 2010) and the fraction 1/2 is required to remove males. In all subsequent age classes (i.e. 3,.......,12) state transitions are modelled as:

$$N_i(t+1) = s_{i-1} N_{i-1}(t) \tag{3}$$

Recruitment into the first age class at time *t* + 1 is determined from the population of adult females at time *t* + 1:

$$N_1(t+1) = \frac{1}{2}\sum_{i=1}^{k} b_i N_i(t+1) \tag{4}$$

Age-specific annual survival rates were estimated from the survival analysis by fitting a continuous function ($f(x)=a(1\text{-}\exp(-cx^{d}))$, where parameters a, c, and d are estimated using maximum likelihood) to observed adult female Kaplan-Meier cumulative survival curves (Kaplan & Meier, 1958) for each of the three years of the study. The annual survival rate for age *i* years, conditional upon having survived to age *i* -1 years, is then calculated as:

$$s_i = (p(i) - p(i-1))/(1 - p(i-1))$$

where *p(i)* is the cumulative probability of mortality (1 - survival) at year *i*, determined from $f(x)$. Survival at age class 12 is assumed to be 0. For joeys, the annual survival rate was estimated directly from the survival curve (see Results).

Annual fecundity is not straightforward to estimate for koalas. Unlike mammals in temperate climates, koalas in this region can reproduce at any time of year (Ellis *et al.*, 2010). This has important implications for population dynamics because if a mother loses a joey she can become pregnant again after a short interval. In any one year period this increases the chance that a female will successfully rear a joey as she may have more than one attempt. Furthermore, generations of young can overlap because the female can conceive before the previous joey has reached full independence. We estimate annual fecundity by simulating birth, neonate survival, and inter-breeding intervals over a 100,000 year period, based on observed empirical distributions.

Population growth rates are the leading eigenvalues of the Leslie matrices (Leslie, 1945; Caswell, 2001) constructed using equations 2-4 and the fecundity and survival estimates, for each of the three years of the study. We estimate that fecundity for age class 2 females (age 1-2 years) is approximately 80% that of more mature females based on field observations and veterinary examinations. Population simulations were based on equations 2-4 and incorporate stochasticity by assuming binomial distributions for state transitions. The initial population of adult females (*n*=100) was generated by sampling from the observed age distribution of female koalas.

Three stochastic, 10-year population simulation scenarios were evaluated. First, we use the parameter estimates from year 1 to estimate what might have happened to the population had no interventions taken place (the “counterfactual scenario”). In the next two scenarios we use the parameter estimates for each of the three years in the corresponding year of the simulation. In the “continued management” scenario we then assume that the conditions in year 3 are maintained permanently. Finally, a “phased management” scenario was designed to reflect what may happen to the population as interventions are phased out over the next few years. Specifically, the year 3 parameter estimates were applied to year 4 and the year 1 parameter estimates were used from year 7 onwards, with two interpolated (equal interval) survival curves representing the gradual transition between them in years 5 and 6. Thus, the phased management scenario assumes that the population will revert to a state of decline within three years of the project ending.

**Plate 11.4**: Sub-adult koala *Graham* climbing a large blue gum tree on his release at the Amcor site in July 2013. He was killed by the “Amcor Dog” in February 2014.

## 11.3 Results

### 11.3.1 Koala mortality

Predation accounted for at least 55.2% of mortality or 66.4% if the suspected (but unconfirmed) predation deaths are included (**Table 11.1**). Of the 140 confirmed predation deaths, wild dogs, carpet pythons and domestic dogs accounted for 83.6%, 13.6% and 2.9% of predation mortalities respectively. We believe it is most likely that the 38 suspected but unconfirmed predation events are due to wild dog predation as wild dogs are more likely to transport and bury the carcass away from the point of predation, thereby making it difficult to find. If true, the overall percentages would change to 87.1%, 10.7% and 2.2%.

A further 26.1% of mortality was attributed to disease, which included severe chronic cystitis, reproductive tract disease, hypoproteinaemia and anaemia, severe ulcerative dermatitis, acute septicaemia/toxaemia, fungal skin lesions, caeco-colic dysbiosis, severe acute bacterial enteritis and several other conditions. Of these, cystitis and reproductive tract disease associated with chlamydial infection were the most common. In the most severe cases where there was poor prognosis for return of satisfactory quality of life the animals were euthanased (n = 54). Only 7.5% of mortality events were attributable to other causes such as road and rail collisions or trauma from unknown sources.

| cause of death | year 1 | year 2 | year 3 | year total |
|---|---|---|---|---|
| predation (total) | 61 | 93 | 24 | 178 |
| predation, wild dog | 37 (20) | 66 (30) | 14 (8) | 117 (58) |
| predation, python | 9 | 5 | 5 | 19 |
| predation, domestic dog | 3 | 1 | 0 | 4 |
| suspected predation | 12 (3) | 21 (5) | 5 (2) | 38 (10) |
| | | | | |
| disease | 35 | 18 | 18 | 71 |
| trauma, road | 3 | 3 | 3 | 9 |
| trauma, rail | 1 | 0 | 0 | 1 |
| trauma, unknown | 2 | 2 | 1 | 5 |
| unknown/other | 1 | 1 | 3] | 5 |
| | | | | |
| total | 103 | 117 | 48 | 268 |

**Table 11.1**: Causes of adult koala mortality, based on monitoring of koalas with telemetry collars and necropsies. Values in parentheses are mortalities attributed to a single wild dog that evaded control efforts. (Note that some figures differ slightly from those in other chapters due to censoring of some data for modelling reasons, and use of data up to March, 2016 only, for this analysis.)

## 11.3.2 Koala reproduction and joey survival

We monitored 315 joeys across all years (259 born after the start of monitoring), observing 95 mortalities. Of these mortalities 39 were attributable to the death of the mother. For the purpose of the population modelling we treat these 39 deaths as censored records, not deaths, in order to estimate only the 'intrinsic' survival rates of the joey independent of the fate of the mother. Mortality from the loss of the mother is modelled separately in the simulations. For the survival analysis joeys born before the start of monitoring were omitted as they represent a biased sample (the subset of joeys that had survived until the beginning of the study). Overall intrinsic survival of joeys post-gestation to independence (day 365) was 70.3% (63.0-78.4%) across all animals and years. Survival rates during the 6 month pouch phase were 88.8% (84.8-93.0%), higher than 79.2% survival rates during the 6 month back phase transitioning into independence (**Figure 11.2a**). When the deaths of the mothers upon which the joeys are dependent is included, survival to independence (day 365) was 55.2% (48.1-63.3%) and survival rates during the 6 month pouch phase were 80.7% (75.7-86.0%) across all three years of the study. These survival rates do not include mortality during gestation (miscarriage), which we cannot estimate. We found no evidence that joey survival varied across years, seasons, or as a function of the age of the mother (survival analysis; **Table 11.2**).

| | coef | exp(coef) | se(coef) | z | p |
|---|---|---|---|---|---|
| mother age | 0.00 | 1.00 | 0.00 | 0.45 | 0.66 |
| season | 0.16 | 1.17 | 0.34 | 0.47 | 0.64 |
| year 2 | 0.10 | 1.10 | 0.29 | 0.33 | 0.74 |
| year 3 | -0.49 | 0.61 | 0.56 | -0.88 | 0.38 |

**Table 11.2**: Cox proportional hazards survival model of joey (*n = 259*) survival during the first 12 months as a function of the age of the mother, the season of birth (wet or dry season) and a year factor.

Mortality risk for adult males was approximately 1.54 times higher than for females (**Table 11.3**; **Figure 11.2b**). We also found a reduction in risk in each consecutive year of the study in line with expectations based on increasing levels of intervention (disease and dog control). Relative to survival in the first year mortality risk was 0.63 and 0.37 times lower in years 2 and 3 respectively (**Table 11.3**). The hazard was U-shaped with respect to age of adults (**Figure 11.2c**) indicating higher risks of mortality for the youngest and oldest individuals. There was no evidence that animals at translocation sites suffered higher mortality rates than the core study area (**Table 11.3**). For both the joey and adult survival analyses, tests of non-zero slopes in Schoenfeld residuals were non-significant for each variable and globally indicating that the assumption of proportional hazards was not violated (Grambsch & Therneau, 1994).

| | coef | exp(coef) | se(coef) | z | p |
|---|---|---|---|---|---|
| age | -0.27 | 0.76 | 0.10 | -2.67 | 0.01 |
| $age^2$ | 0.02 | 1.02 | 0.01 | 2.78 | 0.01 |
| male | 0.43 | 1.54 | 0.14 | 3.09 | 0.00 |
| year 2 | -0.46 | 0.63 | 0.18 | -2.49 | 0.01 |
| year 3 | -1.01 | 0.37 | 0.27 | -3.72 | 0.00 |
| translocation | -0.14 | 0.87 | 0.23 | -0.59 | 0.56 |

**Table 11.3**: Cox proportional hazards survival model of adult (*n = 441*) survival as a function of age (quadratic), sex, the year of the study and whether the animal was at a translocation site.

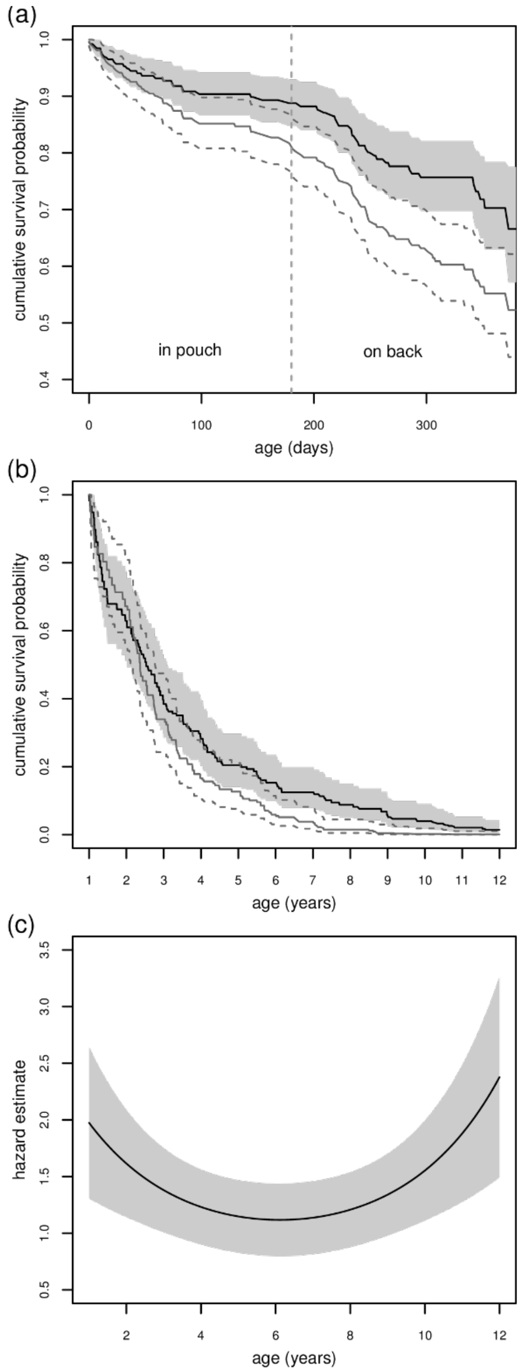



**Figure 11.2**: (a) Cumulative survival probability curves for joeys (0-365 days), quantified with and without mortality arising from the death of the mother (grey lines, dashed confidence intervals and black lines, shaded confidence interval respectively). (b) Cumulative survival probability curves for adult (>1-year-old) males and females (grey lines, dashed confidence intervals and black lines, shaded confidence interval respectively). (c) Relative hazard estimate as a function of adult koala age (for ages >1 yr).

The mean breeding interval, defined as the number of days between births conditional on the first joey surviving to independence, was 353 d (n=99, 95% quantiles 334-423 d; **Figure 11.2a**, previous page), implying a mean birth rate of 1.03 young $yr^{-1}$. However, this fails to account for the ability of females to conceive again following the death of a joey prior to independence. The mean time interval between loss of a joey and birth of the next joey was 96.6 d (n=35, median=68 d, range 0-375 d, **Figure 11.2b**, previous page). There was no clear relationship between month and the latter interval implying that the interval is not strongly related to season (**Figure 11.2b**, previous page). Based on simulations we estimated that the overall annualised breeding rate after accounting for reproduction following the death of the joey was 1.18.

We estimate the prevalence of chlamydial disease based on the initial veterinary exams of koalas, prior to treatment, in 90 d intervals. At the beginning of the study these prevalence estimates are likely to reflect prevalence in the population prior to intervention, but as the study progresses prevalence is expected to drop as infectious individuals are removed or treated. Prevalence of disease in the first 18 months of the study was approximately 21.5%, dropping to 2.6% in the second 18 months (**Figure 11.3**, below).

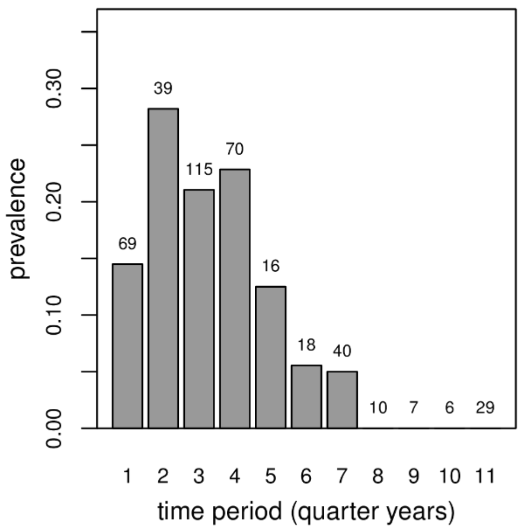



**Figure 11.3**: Prevalence estimates. Low prevalence in the second half of the study most likely arise from the suppression of transmission dynamics following treatment of all monitored koalas in the first half of the study (treatment reduces incidence in the population).

Sterility is difficult to identify. In the most definitive cases the female has clear sonographic signs of bilateral reproductive disease and is monitored frequently enough to determine that no joeys are produced. In many cases, however, clear clinical signs can be ambiguous, lacking or unilateral, and/or the animal is not monitored frequently enough to determine with certainty that no joeys are produced. At first veterinary examination, 45 adult female koalas were deemed to be sterile (advanced bilateral reproductive disease and no joey) and 201 were deemed healthy and fertile. Another 4 had unilateral reproductive disease at the first exam and 4 were suspected of developing bilateral reproductive disease but died from other causes before disease status and sterility could be confirmed. The time required for bilateral reproductive disease to develop from a state of either no sign or mild/unilateral disease ranged from 55 to 180 d with an approximate average of 4 months. Overall, we estimate that 16.3-20.1% of the total population of adult females may have been sterile at the beginning of the study (based on initial vet exams of adult females in the first year of the study).

Population growth rates were estimated to be 0.844, 0.885 and 1.04 in years 1, 2 and 3 of the study respectively. Stochastic simulations indicate that without intervention (the counterfactual scenario) the population would have declined by approximately 90% over a decade under the assumption that dog and disease risks would have continued unabated and that environmental conditions were similar among years (**Figure 11.4**, below). Conversely, under the continued management scenario the population would be projected to increase in size by approximately 8% on average over a decade relative to population numbers at the start of the project. Under the phased management scenario population numbers at the end of the project are estimated to be 75% of population numbers at the beginning of the project and, relative to the counterfactual, the population is at considerably higher levels.

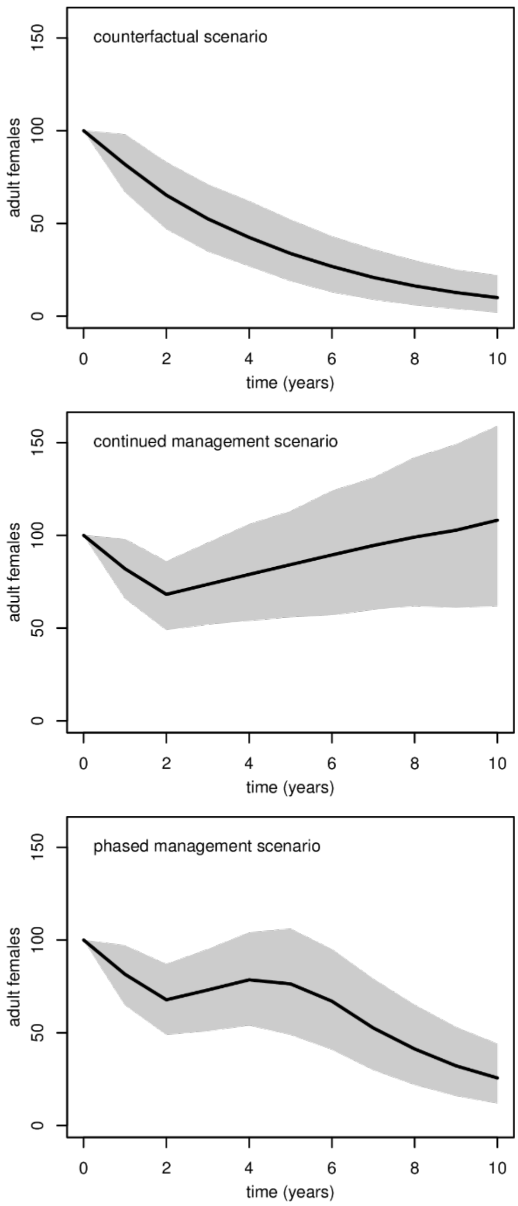



**Figure 11.4**: Stochastic simulations of adult female koala population numbers (y axis) under three alternative management scenarios. The counterfactual scenario is an estimate of population number had no intervention occurred and indicates a continued decline of 16% per year. The continued management scenario is based on the assumption that intensive dog and disease interventions are maintained indefinitely and after year 3 indicates an increase in the population at a growth rate of 4%. The phased management scenario is based on the assumption that control measures are phased out after year 4 and the population returns to prior growth rates over the following three years. Grey shaded areas are the 95% confidence intervals.

These population projections do not account for sterility resulting from chlamydial disease and, therefore, will tend to overestimate population growth rates when chlamydial disease is prevalent. This implies that if sterility were explicitly accounted for, the counterfactual projections, which are based on the first year of monitoring data when prevalence was at its highest, would indicate an even greater rate of population decline. This suggests that the estimate of the benefit of interventions (the difference between the counterfactual and the phased management scenario) may be conservative, that is, population growth is probably better than this conservative analysis suggests.

### 11.3.3 Koala detection analysis

The analysis of detection probability was based on 14,576 observations of koalas in the field over a three-year period by experienced field personnel. Each time a koala was located the visibility of the animal was scored using an ordinal ranking from 0 (unobserved) to 5 (clearly visible and easily spotted). Other variables recorded included the date, time of day, weather conditions (wind, cloud, rain), and height of the koala from the ground. All of the observed koalas wore VHF tags allowing the field crew to identify the location of koalas regardless of how visible they were. Hence there is no sampling bias in this dataset against koalas that are difficult to observe.

We assume that detection probability was linearly related to the visibility scores and ranged from 0.01 to 0.99, i.e. we assume that the most visible koalas would almost certainly have been detected by a team searching the area without the aid of VHF technology, and the most concealed koalas would almost certainly not have been detected. The mean probability of detection was 0.48. We used beta regression to identify correlates of detection probability.

The largest influence on detection probability was the height of the koala above the ground (range 0-35m; mean 15m), with a 34.6% reduction in detection probability when the animal was at a height of 35m compared to when the animal was on the ground. Detection probability decreased with intensity of rainfall, with a maximum difference in detectability of 14.2% between no rain and heavy rain. However, heavy rain was rare and the difference in detectability between no rain and moderate rain was only 4.6%. The maximum variation in months with lowest and highest detection probability (April and October respectively) was only 2.8%. There was a 3.0% difference in detection probability between the middle of the day (peak 11 a.m.) compared to early morning and late afternoon. Other minor effects included cloud cover (a 1.9% difference with higher detection when cloudy), wind (a 1.7% difference with detection increasing with light and moderate winds) and the diameter at breast height of the tree (a 1.7% difference with higher detection in larger trees). Finally, there was also a maximum range of 9.8% in detection probability among sites as a result of other factors not accounted for by the other covariates.

To estimate the proportion of koalas that would likely have been detected using repeated standard survey methods prior to clearing a site for development we sampled 100 records (with replacement) from the observed koala sightings for the sites through which development occurred. For each survey the koala is counted as observed if a random variable drawn from a uniform distribution is less than or equal to the detection probability. Any unobserved animals can be observed in subsequent surveys. This sampling procedure was repeated 1000 times with 8 sequential surveys each time. When only a single survey is conducted, detection rates were estimated to be 47.5% (95% CI: 38.0-57.0%). Five and eight surveys were required to detect, on average, at least 95% and 99% of all the koalas respectively.

Based on extensive experience treating koalas we estimate that roughly 50% of the animals that were not detected would have survived the fall to the ground when the tree was felled, but that 50% of the survivors would not have survived treatment, giving an overall death rate of around 75% among undetected koalas. Assuming 50% of undetected koalas were female and 65% of these females had dependent joeys, we estimate that for every 100 adult koalas in cleared land, 52 koalas (including joeys) may die using one-pass survey methods.

In the context of this project, 93ha of potential koala habitat were cleared for the MBR project and associated infrastructure. Koalas in SEQ have been known to occur in densities of up to 1.3 koalas $ha^{-1}$ (Dique *et al.*, 2004). In such circumstances, clearing 93ha of land using traditional search strategies could result in the loss of 42 koalas. In this study densities prior to clearing were considerably lower, though this would not be known prior to having performed extensive surveys. Given an empirically estimated density of 0.16 koalas $ha^{-1}$, approximately 15 koalas would have been resident in this area at the time of clearing. Using typical single-survey protocols for searching for and removing koalas prior to clearing, we estimate that approximately 8 koalas would have died using conventional survey methods. The extensive survey and tracking protocols used in this project are expected to have resulted in detection rates near 100%, and validate the approach taken to protect koalas.

**Plate 11.5**: Seven-month-old koala joey *Allan* clings to his mother *Anita's* leg during her sedation for a tag size and check. Back-rider joeys were often left with their mothers during veterinary checks and examinations to avoid undue stress from separation. These two koalas were inhabitants of Kippa-Ring, where koala detection rates were higher due to the openness of the vegetation, however in an experimental survey using wildlife spotter/catchers conducted by EVE in November 2016, only 23% of koalas were detected. The mortality rates estimated in the paragraph above are very conservative, and do not take into account death of dependent joeys, like *Allan*.

## 11.4 Discussion and recommendations

### 11.4.1 General discussion of PVA findings and implications

This work suggests that the koala population in this area was declining at a substantial rate prior to the introduction of intensive management interventions (dog and disease control) and well before construction interference. This is broadly consistent with recent regional analyses of long-term trends reporting that koala populations in south-east Queensland have been declining over the last two decades (de Villiers, 2015; Rhodes *et al.*, 2015; Adams-Hosking *et al.*, 2016). Habitat loss, habitat fragmentation, and mortality from predators, vehicle collisions, domestic dogs and disease are all factors implicated in this decline (Melzer *et al.*, 2000; Rhodes *et al.*, 2011; McAlpine *et al.*, 2015; Rhodes *et al.*, 2015). To understand the impact of the development project on koalas one must explicitly consider the dynamics of the population as any actions can have long-term, delayed effects on the system via their influence on dynamics. Based on our survival analysis and population simulations we estimate that the population would have declined by approximately 90% by 2023 in the absence of intensive management, implying that effective extinction of the population could have resulted within approximately two decades. This counterfactual, the estimate of what would have happened in the absence of intervention, establishes a reference baseline for estimating the impact of the development project (Ferraro, 2009; Baylis *et al.*, 2016). Specifically, the impact is the expected deviation from this counterfactual over a relevant period of time.

The intervention measures adopted in the first and second year of the project reduced the rate of population decline in the second year, but this was not enough to stabilise the population. Only through further intensive management were positive population growth rates achieved in year 3. The phased management scenario is a projection of koala population dynamics under the assumption that intervention measures (both disease and dog control) are phased out in year 4 and that the population returns to its original rate of decline over the following three years. The difference between the population projections under the counterfactual and the phased management scenarios is a measure of the impact of the development project. On this basis we estimate that intensive management of threats has achieved a substantial net benefit to the koala population and that this benefit was already apparent by the end of the project (year 4).

**Plate 11.6**: Koala *Jane* and her 10-month-old joey *Loki* at the revegetated translocation site in Griffin. She was a beneficiary of the koala management program, having been translocated in October 2015 from high-risk, sparse remnant habitat in Lawnton adjacent to one of the major koala black-spot roads - Gympie Road. *Loki* and an early pregnancy detected at her final veterinary examination were conceived after her translocation to Griffin.

Habitat loss has occurred (93ha of land was cleared or otherwise consumed by the project) but this is not expected to have an important impact on the koala population for three reasons. First, intensive and prolonged searching of the site and monitoring of koalas prevented direct loss of koalas from land clearing itself. Second, because koala densities were already low in this area (between 0.15 and 0.25 koalas $ha^{-1}$ in most places) relative to historical densities that have been found in similar habitats (0.2-0.6 koalas $ha^{-1}$; Dique *et al.*, 2004; Ellis *et al.*, 2013; de Villiers, 2015), the loss of habitat is unlikely to limit the population. Loss of habitat will reduce the carrying capacity of the population (the maximum number of koalas that the area could support), but if the population is well below the carrying capacity, as we suggest, then this limiting effect will not be be realised until substantial population growth occurs. Finally, crossing structures facilitate the safe movement of koalas across the rail line, thereby reducing any fragmentation effects that the rail line may have. A comprehensive analysis of the effectiveness of these crossing structures is pending, though initial evidence from camera traps and telemetry monitoring suggests they are effective at facilitating movement across the rail line.

**Plate 11.7**: Untagged koala in severely over-browsed habitat south of the Amcor site at Lawnton. This is one of the few sites in Queensland where over-browsing death of trees has occurred due to a very localised overabundance of koalas. This is a result of koalas being displaced into a very narrow strip of vegetation between a large urban development and the Pine River. Overall, however, koala populations in Queensland have declined more rapidly than can be attributed to habitat loss alone, due to concurrent and additive threatening processes.

It is important to acknowledge that we cannot definitively distinguish normal interannual variation in survival and reproduction from changes resulting directly from management interventions. This could be particularly important when trying to predict population changes in the counterfactual scenario. The approximately 16% decline observed is severe and although it is not unreasonable in the context of the predation and disease impacts on the population, it is not clear if that level of decline would have been sustained over a long period of time. It is not known, for example, whether wild dogs would have continued to inhabit this area once prey densities declined and, had dog densities declined, the survival rates of the koalas may have increased. It seems unlikely, however, that a positive population growth rate could have been achieved without intensive disease management.

A key contribution of this work is providing systematic and reliable assessments of causes of mortality. Previous estimates may have substantially underestimated the importance of predation as major sources of koala mortality as many of these analyses of causes of mortality are based on incidental sampling of koalas, particularly those struck by vehicles. The occurrence of these records typically coincides with areas of high human population density and this sampling bias is likely to result in an overestimation of the importance of vehicle strikes and anthropogenic factors such as domestic dog attacks. These records are likely to provide little insight into predation rates because, even if animals survive a predation attempt, it is difficult to detect such events in these incidental samples. Wild dog and python predation is particularly difficult to quantify without intensive monitoring because the carcass is often never found. Indeed, carpet python predation has been largely overlooked in previous work but here occurred at a rate approximately 5 times higher than domestic dog attacks and twice as high as vehicle strikes, even within this urbanised landscape surrounded by residential areas.

It is not clear how representative this koala population may be of other populations in the region as no other population has been studied as intensively. It is likely there is considerable spatial heterogeneity in both the distribution of threats and their impacts on koala populations. Anthropogenic threats will be concentrated in the intensively developed, eastern coastal areas and the prevalence of *Chlamydia* is known to vary over this region (Kollipara *et al.*, 2013; Polkinghorne *et al.*, 2013). Less is known about the fine-scale distribution of wild dogs and carpet pythons in south-east Queensland. Both are generalist predators that may thrive in remnant habitat degraded by anthropogenic influences and in urbanised landscapes. Pythons can remain in tree tops for extended periods of time, are difficult to detect and monitor, and there are few options for their control. Wild dogs can be effectively monitored and controlled, though this requires intensive fieldwork.

Camera trap data provided useful insight into some aspects of wild dog predation. A single male that long eluded capture was thought to be responsible for over 60 koala deaths. This animal appeared to kill every koala it encountered, even though it was not ready to feed, and may even have specifically targeted koalas. It is this sort of effect that may explain why a small reduction in wild dog densities may do little to benefit population dynamics as only a few effective predators are needed to maintain substantial impacts on populations. The actions of this single dog may account for the continued population declines in the second year of the project.

It is encouraging that positive koala population growth rates are achievable in south-east Queensland. With suitable management it may still be possible to ensure the long-term persistence of koala populations in some areas. More work is required to understand how to achieve stable populations cost effectively. Given the extreme impact of wild dog predation on this koala population (50-75% of all mortality) it is essential to understand how widespread wild dog predation is and how wild dogs can be effectively controlled. Camera trapping and targeted trapping and baiting involves intensive and ongoing fieldwork. In some areas it may be appropriate to consider fencing as a means of managing wild dog populations in areas that are deemed particularly important for koalas.

This project demonstrates that (i) effective control of chlamydial disease is possible, (ii) effective control of wild dog predators is possible, and (iii) together, these effects can secure koala populations in these remnant habitat patches in a heavily human modified landscape. Unfortunately, these benefits can only be realised with intensive management over multiple years, which would be prohibitively expensive to apply at large scales. Although this study was not an experimental design (there was no control, replication or randomisation) we suggest it nevertheless provides a reasonable basis for inferring cause and effect. The intensive monitoring of both koalas and dogs, and immediate investigations into koala deaths and necropsies, provided reliable insight into causes of mortality. Furthermore, the veterinary exams established that treatment was effective at clearing chlamydial infection and the camera traps and field monitoring provided evidence that dog control was effective. Thus, we argue that the management interventions (disease and dog control) were responsible for the reduction in mortality rates over the course of the study. What this study design does not allow us to address is the level of natural inter-annual variation in survival and reproduction. We speculate that the severe rates of population decline observed in the first year due to wild dog predation and disease may have been have been more modest in other years because: (i) a 16% decline is not sustainable for many years yet koalas appear to have persisted here for many years, and (ii) wild dog predation may vary among years depending on the availability of other prey, the density of dogs, or the movement of dogs to other areas.

Overall, this work constitutes the most compelling evidence to date that management actions can achieve meaningful conservation outcomes in declining populations of koalas, specifically that population growth rates larger than 1 can be achieved.

## 11.4 2 Recommendations:

With respect to the value of population viability analysis and data collection we recommend the following:

1. That the collection of high-quality, robust and comprehensive data be prioritised in the early stages of transport infrastructure project planning and development. Appropriately experienced experts should be engaged to design and implement the scientific programs that will produce the data, to ensure their quality and rigour;

2. That rigorous population viability analysis (PVA) be conducted whenever important koala populations (or other threatened species) are likely to be impacted by new or expanding transport infrastructure projects, so that avoidance, mitigation and offsetting management actions are both efficacious and cost-effective.

3. The collection of pre, during and post-impact, long-term datasets are crucial to the assessment and evaluation of threats and management measures respectively. The koala management program for the MBR project provided sufficient data to robustly assess the status of the population before, during and after the rail impact, and it therefore serves as a effective model for future koala management associated with transport infrastructure projects.

# CHAPTER 12: AKHO-CM AND GOSM PROGRAMS


## Key points

- *AKHO-CM* and *GOSMP* provided additional data and information to *KTMP* and *KTrans*
- Koala use of culverts to cross rail corridor confirmed - 31 koalas, 11 confirmed crossings
- Koala use of revegetation areas demonstrated frequently, despite young age of trees
- Eight koalas at Griffin offset site used revegetation areas during monitoring
- Use of innovative technology improved quality of data and cost effectiveness of programs

# Chapter 12: AKHO-CM and GOSM Programs

## 12.1 Introduction and background

Many large infrastructure projects implement wildlife management and protection measures but fail to adequately monitor and/or evaluate their success in terms of achieving their primary objectives or purpose. This results in a lack of evidence supporting or validating their use, and potential for wasted resources if they fail to achieve their objectives. This can be perpetuated on future projects because of a failure to evaluate, refine and improve approaches, leading to adverse wildlife conservation and protection outcomes and wasted resources for the project. Evaluation should include monitoring of target species or the mitigation devices/measures over sufficient timeframes to ensure that both short-term and long-term objectives are achieved, and should be both objective and quantitative, if possible. In most cases, such monitoring programs would need to persist well past the construction phase and into the operational phases of projects. Depending on critical objectives, repeated or long-term monitoring may be required well into the future.

This chapter provides an overview and some results from two bodies of work: the *Alternative Koala Habitat Offsets - Connectivity Monitoring* (*AKHO-CM*) program and the *Griffin Offset Site Monitoring Program* (*GOSMP*), which formed part of the koala management program for the Moreton Bay Rail project, but were not part of the *KTMP* and *KTrans* programs of work. The *KTMP* and *KTrans* programs of work commenced in March 2013, and were nominally completed at the end of June 2016, forming the main program of works designed to monitor and protect koalas during the construction and early operational phases of the MBR project, whereas the *AKHO-CM* and *GOSMP* works had different objectives and later timeframes.

These programs aimed to monitor and evaluate the success of two koala conservation measures implemented by the MBR project to offset or mitigate project-related permanent impacts: the *barrier effect* of the rail line, and the *loss of koala habitat*. In the case of the *AKHO-CM* project, this involved the monitoring of structures providing potential routes of passage for koalas to cross the rail corridor between habitat patches, using trail cameras. It also used the LX *K-Tracker* system to collect data on the movement of koalas across and near the rail corridor. The critical objective was to assess whether ecological connectivity of habitat transected by the rail corridor was maintained, i.e. whether koalas were able to continue to move across the rail corridor safely. In the case of the *GOSMP*, the critical objective was to evaluate the benefit of alternative koala habitat provided to replace habitat lost in construction of the rail project. This involved the monitoring of tree growth in revegetated areas and the monitoring of koalas' use of those areas/trees.

The *Alternative Koala Habitat Offsets- Connectivity Monitoring* program operationally commenced in March 2016 and aimed to investigate the effectiveness of dedicated fauna crossing structures and other potential crossing structures (drainage culverts and bridges) in terms of maintaining ecological connectivity across the rail barrier for koalas. The *Griffin Offset Site Monitoring Program* commenced in June 2016 and was completed in January 2017. **Table 12.1**, below summarises the various programs and their operational commencement and completion dates.

| Program | Aim | Commencement | Completion |
|---|---|---|---|
| *KTMP* (1 and 2) | Monitoring and protection of koalas, guide adaptive management and design. | March 2013 | June 2016 |
| *KTrans* | Translocation program for high-risk koalas | March 2014 | June 2016 |
| *AKHO-CM* | Monitoring of koala movement across the rail corridor | April 2016 | March 2017 |
| *GOSMP* | Monitor revegetation areas for tree growth and koala use | July 2016 | January 2017 |

**Table 12.1**: Various components of the koala management program for the Moreton Bay Rail project.

**Plate 12.1**: Koala *Ali* at his release at Kippa-Ring in May, 2016. He was one of the first koalas detected on cameras installed in the culverts as part of the ***AKHO-CM*** program. He was photographed using drainage culvert M31 at Kippa-Ring (see **Plate 12.2**).


**Plate 12.2**: Koala *Ali* investigating (left image) and then exiting (right image) the southern opening of drainage culvert M31 near the stabling yards at the Kippa-Ring end of the MBR project in May 2016. This was a "non-transit" event - *Ali* had ventured into the culvert, but not crossed the entire corridor. The photograph was taken by an infra-red motion-activated trail camera installed for the ***AKHO-CM*** program. (See also ***Chapter 3 - Koala conservation, mitigation and offset measures.***)

The overview and results described herein only relate to sections of work performed by EVE. With respect to the *AKHO-CM* program of work, some components were supplied, managed and reported by other providers: BioLink Pty Ltd provided project management services and habitat assessment, Griffith University's Applied Road Ecology Group provided data analysis and reporting, and WildSpy Pty Ltd provided wireless identification tags (WIDs), WID data-loggers, and thermal camera installation, data collection and maintenance. Their sections of work were to be reported separately.

## 12.2 Methods

### 12.2.1 AKHO-CM methods

Three approaches were used to determine the route and frequency of koala crossings of the rail corridor (after establishment of the permanent fauna/safety fence), and their use of habitat and interactions with the rail corridor. These were:

1. Telemetric monitoring of koalas using conventional and remote telemetry devices (the LX *K-Tracker* telemetry system);
2. Installation of infra-red motion-activated trail cameras at most potential crossing structures (bridges and culverts), and thermal imaging cameras at some bridges;
3. Application of wireless ID (WID) tags (ear tags) to koalas and installation of data-loggers at most potential crossing structures.

The thermal camera and WID tag/data-logger installations and data collection were not performed by EVE and are not discussed further here. Comprehensive analysis and reporting all *AKHO-CM* data were to be performed by others, and this was expected to be completed around mid-2017. Hence the methods described in this section only relate to GPS monitoring of koalas and trail camera monitoring of bridges and culverts using standard IR trail cameras - components of *AKHO-CM* performed by EVE.

#### Telemetric monitoring of koala movements

Telemetric monitoring of koalas was essentially as described in previous chapters. Approximately 110 koalas were retained in the program for the *AKHO-CM* program following the nominal cessation of monitoring for the KTMP at the end of June 2016. A firmware upgrade was performed in mid 2016 to the LX *K-Tracker* tags to create a geofencing function that caused increased GPS fix rate and uploads when the tags detected proximity to the rail corridor. This allowed finer-detail data to be collected on some fence and rail corridor interactions by koalas. *K-Tracker* data were examined weekly for evidence of koalas crossing either the rail corridor or other monitored structures.

De-collaring of these koalas commenced in December 2016 and was essentially completed by the end of January 2017.

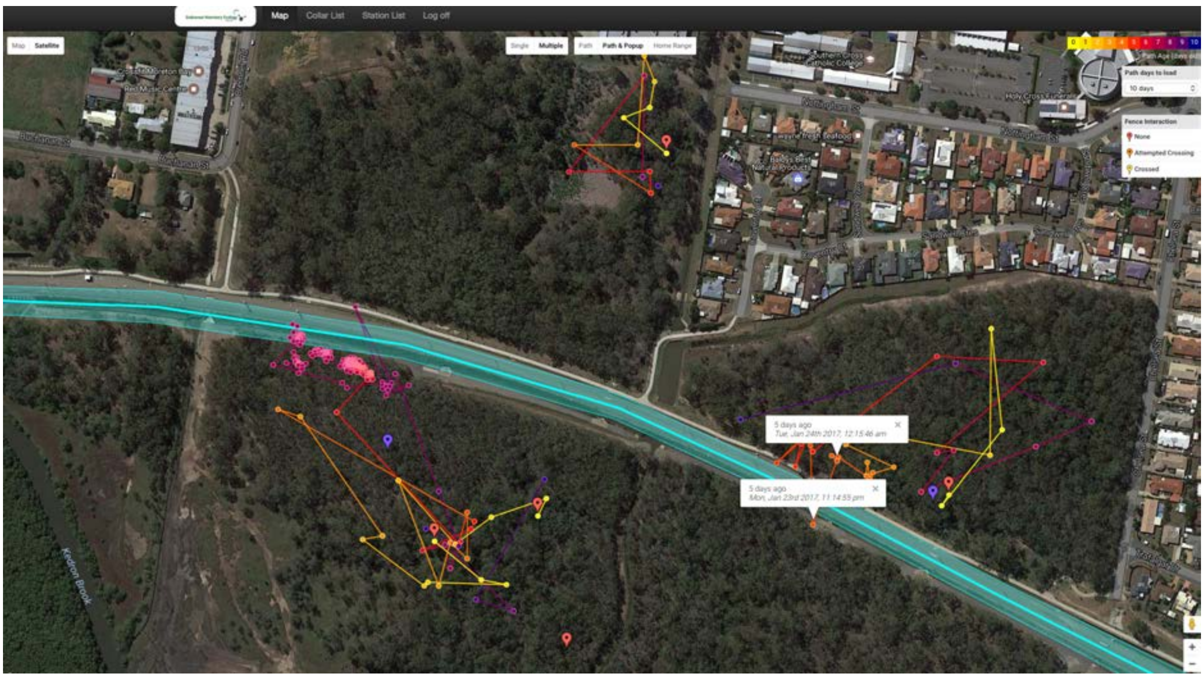



**Figure 12.1**: Screen-grab from the LX *K-Tracker* website showing some of the few remaining koalas in the program at the end of January. Note the high frequency GPS fixes near the rail corridor, and potential corridor transit event with tagged positions.

### Trail camera monitoring of culverts and bridges

Eighty-one (81) Reconyx® Professional Series PC900 trail cameras were installed at 21 structures that could potentially have been used by koalas to cross the rail corridor or associated infrastructure. A summary is contained in **Table 12.2**, below, and a more comprehensive list in *Appendix 14 - AKHO-CM List of monitored structures and camera installation positions*.

| Structure type | Number | Number of cameras |
|---|---|---|
| Dedicated fauna crossing culverts | 5 | 13 |
| Drainage culverts | 9 | 31 |
| Vehicle culverts | 2 | 4 |
| Rail bridges | 3 | 21 |
| MBR-associated road bridges | 1 | 8 |
| Non-MBR road bridge | 1 | 4 |
| **TOTALS** | **21** | **81** |

**Table 12.2**: Summary of categories and numbers of crossing structures and cameras installed.

Cameras were installed in heavy-duty security enclosures manufactured by Reconyx® and attached to monitored structures using a heavy-duty stainless steel bracket. Lock protectors were used to reduce the risk of theft. (See **Plate 12.3**, below.)

**Plate 12.3**: Infra-red motion-activated trail cameras installed on the Saltwater Creek rail bridge (left image) and M31 drainage culvert at Kippa-Ring (right image). Its paired camera can be seen at the far end of the culvert. A high level of protection and security was required to protect the cameras from vandalism. Despite that, two cameras were rendered permanently inoperable by vandalism, two were stolen and a number of others sustained minor damage over the 12 months of deployment (up until the time of writing).

## 12.2.2 GOSMP methods

### Revegetation areas

Revegetation areas covered approximate 35ha of the 65ha Griffin offset site and were planted with approximately 24,800 tube stock in four stages between September 2013 and January 2015 by a TMR-engaged contractor. Monitoring by EVE was conducted using 20 randomly selected plots over a seven-month period from July 2016 to January 2017. **Figure 12.2**, below, shows the extent of the revegetation area at the Griffin offset site.

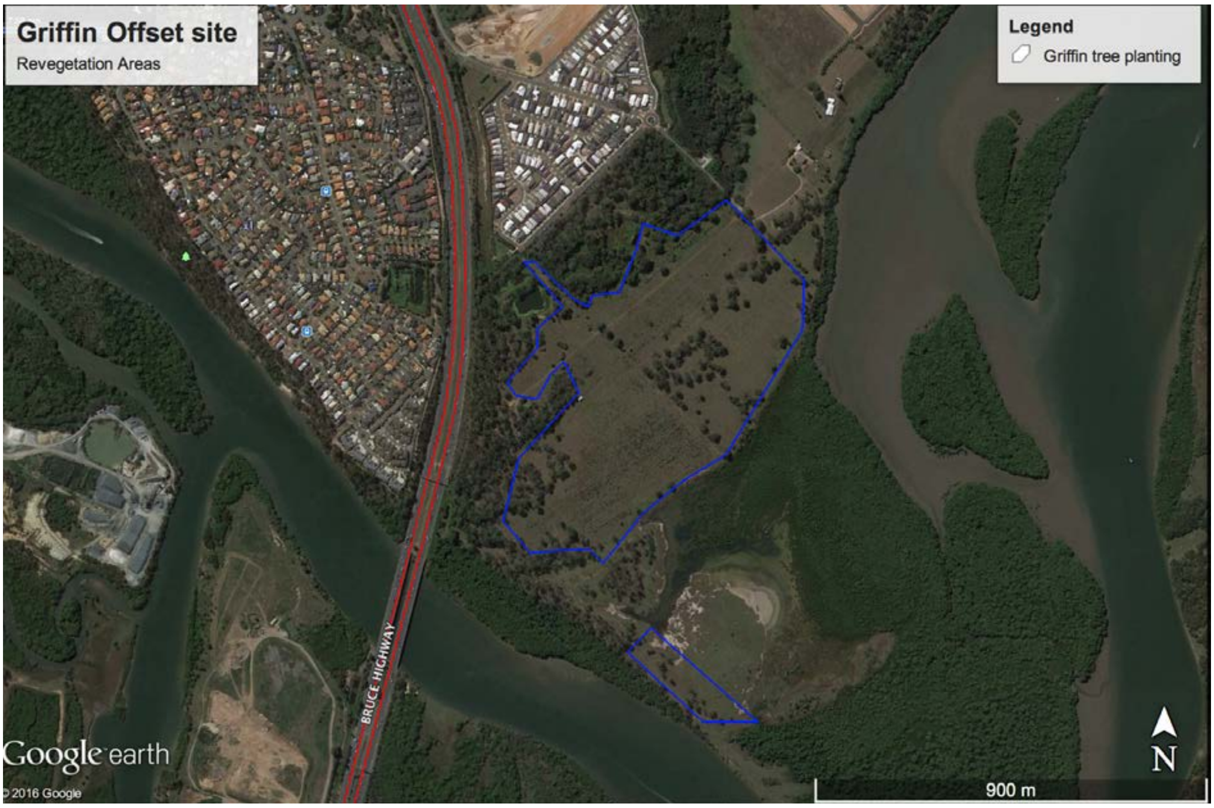



**Figure 12.2**: Aerial image of the main revegetation areas (blue polygons) at the Griffin offset site, which cover approximately 35ha in total and support approximately 24,800 planted koala habitat trees. The entire site is approximately 65ha, although the cadastral boundary encompasses 55.23ha.

### Tree surveys

The site was delineated into *Planting Areas* according to the timing of plantings by the revegetation contractor. These were overlayed with a 20m x 20m grids, and a number of plots were randomly selected in each *Planting Area*. The mapping coordinates of the centre of each 20m x 20m plot was noted and formed the centre point for tree surveys. The centre of each plot was located with a GPS unit and marked with a star picket to provide a physical reference point for subsequent monthly surveys. Each planted tree that fell within 10m of the centre point was identified with a numbered tree tag and became one of the trees monitored in that plot.

Tree growth was monitored in a total of 214 trees across the 20 plots by measuring tree height, crown size and diameter of stem or trunk at breast height (DBH). Koala usage was determined through analysis of GPS data derived from the LX *K-Tracker* telemetry system, field tracking of monitored koalas, trail cameras, and physical signs such as scratches on the trees, and scats under the tree. Measurements occurred during monthly visits to the site over seven months between July 2016 and January 2017.

### Trail cameras

Three infra-red motion-activated trail cameras (Reconyx® Professional series PC900 trail cameras) were installed to record koala activity in trees in the replanted area that had evidence of high levels of koala usage noted in early tree surveys. The cameras were installed on 12 October, 2016 and decommissioned in January 2017. Data were downloaded monthly at the time of tree monitoring visits. Koalas detected by the cameras were identified by cross-referencing against the time-referenced GPS positions in LX *K-Tracker* tag uploads. Some koalas were directly observed during tree monitoring visits or during scheduled field tracking events.


**Figure 12.3**: Aerial image showing locations of trail cameras in the revegetation areas. Cameras were installed on 12 October, 2016 and removed in January, 2017. They were successful in capturing a number of events in which koalas used the target trees for feeding, as well as detecting a wild dog passing through the area and other fauna.



**Plate 12.4**: A variety of other fauna was detected on the cameras: the left image shows a squirrel glider, and the right image an owlet nightjar. The camera is pointed at a young tallowwood tree (*Eucalyptus microcorys*), in the revegetation area (located at the *Trail cameras G1 and G2* locations in the aerial image above.)

### Koala use of the revegetation areas

There were four methods (direct and indirect) used to detect the koalas' use of replanted trees:

1. LX *K-Tracker* data: 12-hourly GPS uploads provided twice daily locations of koalas. This was an indirect method that was suggestive of, but not definitive for, use of revegetation area trees.

2. Field radio-tracking: field personnel tracked koalas during routine scheduled field tracking events and occasionally to confirm an LX *K-Tracker* datum, also noting the koala's identification and recording tree measurements and species. At such events, koalas were photographed by field personnel.

3. Opportunistic observations during tree surveys: indirect evidence of koala use of offset trees, such as scratches and pellets, and evidence of browsing, and direct evidence of koalas observed in revegetation areas, was recorded at the time of tree surveys.

4. IR trail cameras: cameras captured proof of koalas' use of individual trees. Cameras were installed at trees determined to be used frequently by koalas in early tree surveys.

## 12.3 Results

### 12.3.1 AKHO-CM

Results of trail camera data reported here span the period between April 2016 and 2 January 2017. Additional data from cameras between 2 January 2017 and 31 March 2017 (the end date for trail camera monitoring) were not available at the time of writing and were to be reported separately, as a component of final reporting for the ***AKHO-CM*** project, compiled by Griffith University's Applied Road Ecology Group. Similarly, detailed analysis of ranging behaviour and responses to rail construction and the effect of the rail corridor as a barrier to movement, using GPS and WID data was to be reported as a component of the ***AKHO-CM*** final report, due for completion around the middle of 2017.

A summary of koala detections at structures monitored by cameras is contained in **Tables 12.3** and **12.4**, below. Distribution of detections by month is shown graphically in **Figure 12.4** and **12.5**, overleaf.

| Month | Koala detections | Crossings detected | Non-transit detections |
|---|---|---|---|
| April 2016 | 0 | 0 | 0 |
| May 16 | 4 | 3 | 1 |
| June 2016 | 3 | 2 | 1 |
| July 2016 | 3 | 1 | 2 |
| August 2016 | 5 | 4 | 1 |
| September 2016 | 1 | 1 | 0 |
| October 2016 | 1 | 0 | 1 |
| November 2016 | 1 | 0 | 1 |
| December 2016 | 0 | 0 | 0 |
| **Totals** | **18** | **11** | **7** |

**Table 12.3**: Summary of koala detections by trail cameras at monitored structures along the rail project between April, 2016 and December, 2016. This includes two road bridges over creeks (Cecily Street Bridge over Freshwater Ck, and Bruce Highway road bridge over Freshwater Creek). Column one is total detections, column two is transit of the rail corridor by the koala confirmed by paired camera detections and/or GPS locations, and column three is detections of koalas in which a transit of the structure did not occur, or could not be confirmed.

| Structure name | Confirmed crossings | Non-transit detection |
|---|---|---|
| Freshwater Creek rail bridge | 8 | 0 |
| Bruce Highway road bridge (Freshwater Creek) | 0 | 1 |
| Fauna culvert F3 (Kippa-Ring) | 1 | 0 |
| Fauna culvert F6 (Kippa-Ring) | 0 | 2 |
| Drainage culvert M29 (Kippa-Ring) | 1 | 3 |
| Drainage culvert M31 (Kippa-Ring) | 1 | 1 |
| **Totals** | **11** | **7** |

**Table 12.4**: Koala detections by crossing structure. There were no koala detections by camera at any other structures.

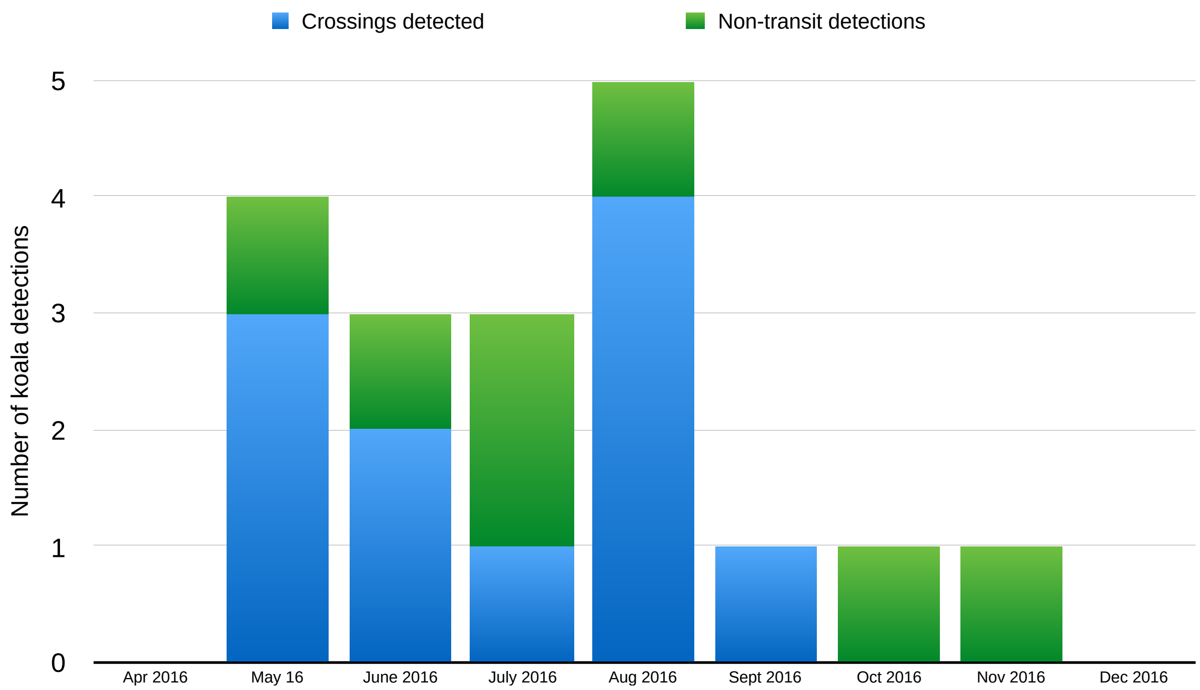



**Figure 12.4**: Number of koala detections at all cameras by month. There is a paradoxical trend of fewer detections in the breeding season (when koalas are more active), but this might be explained by the reduced detection capability of the cameras in the warmer months, because they rely upon movement in the differential thermal signature between animals moving in the detection zone and the background. Koalas are very well insulated and produce a lower thermal signature than most other mammals.

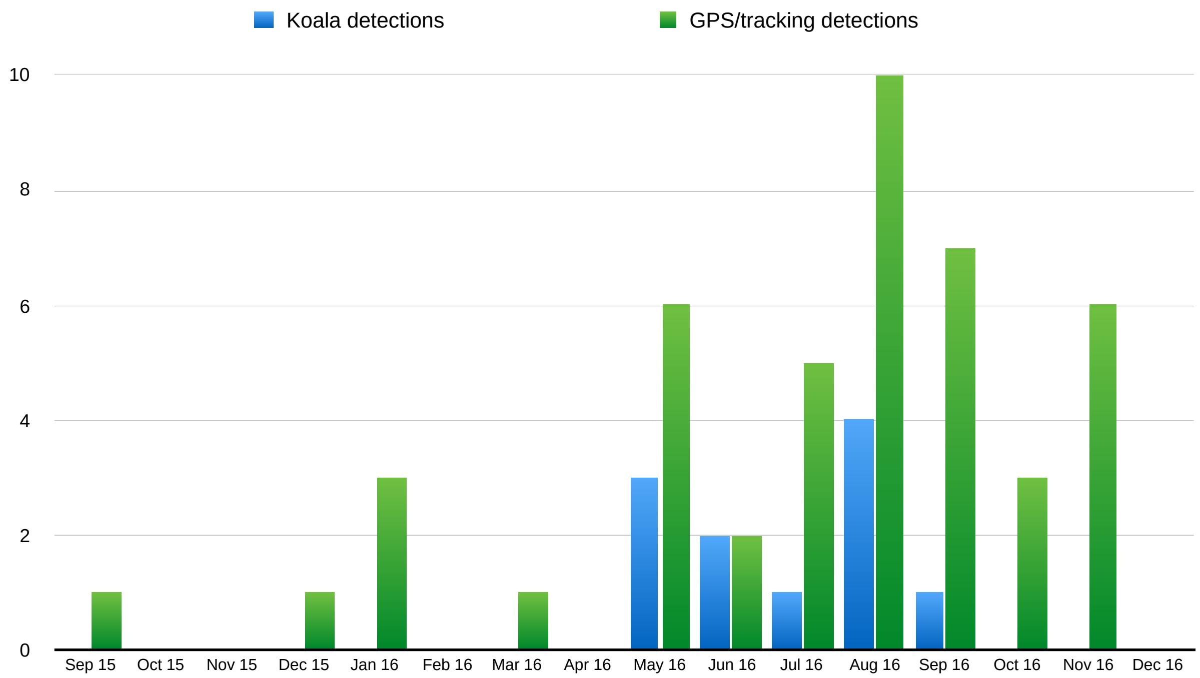



**Figure 12.5**: Number of koala crossings by GPS or field tracking detection (green bars), vs detections of koalas by camera traps (blue bars). Despite the relatively high levels of activity of koalas with respect to crossing monitored structures between September and November 2016, fewer were detected by cameras, suggesting that camera detection rates of koalas during warmer months is considerably reduced, probably due to the reduced thermal gradient between koalas and the relatively warm background. In cooler months the thermal difference between a koala and its background would be greater, resulting in a higher detection probability with the relatively crude IR detection mechanism of trail cameras (compared with thermal cameras, for example.) (Note that trail cameras were only deployed from April 2016 onwards, hence absence of data in those months.) The relatively infrequent crossings between September, 2015 and April, 2016 may be explained by the unfamiliarity of the local koalas with the potential crossing routes in the newly-established built rail line. Construction activities were a significant disturbance up until establishment of the rail corridor safety/fauna fence in September 2015, at which time the permanent (but permeable) barrier effect of the rail project commenced. The peak in the detection of crossings in the the latter half of the year (2016) is consistent with the increased activity and movements of koala during the breeding season.

In addition to those detected by trail cameras, crossings of the rail corridor or other monitored structures (Cecily Street bridge, Bruce Highway bridge) were detected by LX *K-Tracker* GPS data and/or field tracking events.  Crossings and interactions of koalas with the rail corridor were recorded from September 2015 through to completion of the koala management program in January, 2017, when essentially all koalas were de-collared.  Some examples are shown in **Figure 12.6**, below.

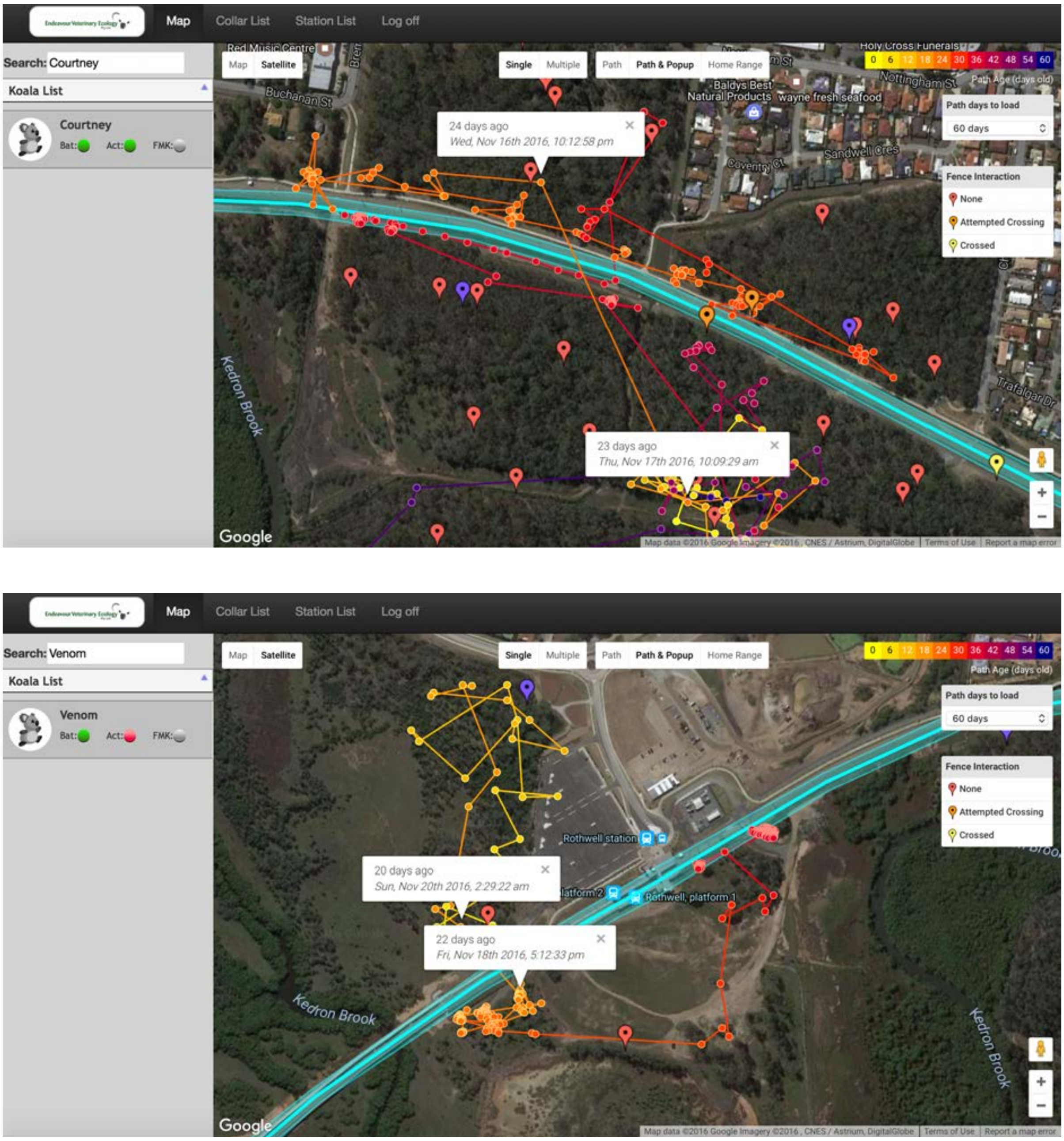



**Figure 12.6**:  Screen-grabs from the LX *K-Tracker* website, showing the movements of the koalas *Courtney* (top image) and *Venom* (bottom image) around the time of their transits of the rail corridor.  The data are often suggestive of the transit route, but camera data are necessary to confirm.  For example, in the lower image, *Venom* appears to have used vehicle culvert V1 just west of Rothwell station. Unfortunately, this transit event was not detected at the V1 cameras.

Due to the reduced frequency of scheduled field tracking facilitated by the *K-Tracker* system (only fortnightly tracking was required),  some crossings detected by the *K-Tracker* system were confirmed by field tracking immediately after the detection.  This is because GPS locations can vary in accuracy, depending on satellite orientation, and single-point *apparent* crossings could be spurious, and therefore required field confirmation.

Between September 2015 (time of establishment of the permanent barrier fencing along the rail corridor) and December 2016, there were 42 crossings by koalas of monitored structures (including road bridges at Cecily Street and the Bruce Highway, which transected the Freshwater Creek habitat corridor) detected by LX *K-Tracker* GPS or field tracking data. There were also three crossings of untagged (cleanskin) koalas detected by cameras, and 7 detections of non-transit interactions with monitored structures by tagged koalas.

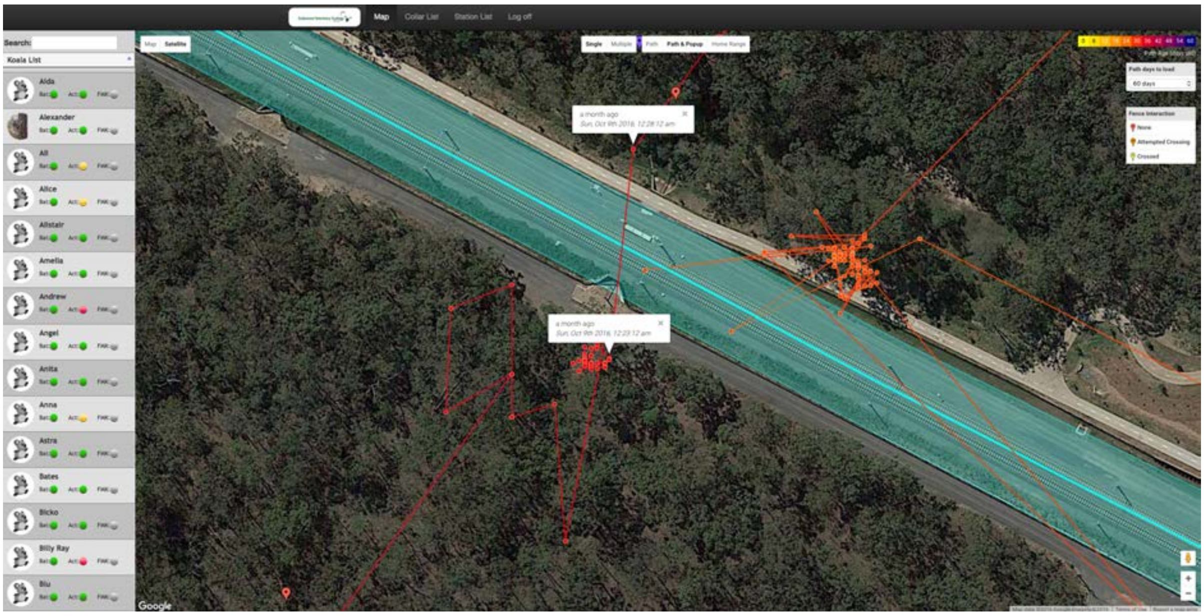


**Figure 12.7**: Apparent use of fauna culvert F5 at Kippa-Ring by the koala *Alistair* in a transit of the rail corridor from south to north in October, 2016. The geofencing function has detected proximity to the rail fence, and increased the GPS fix rate to improve the resolution of koala movements as they interact with the rail corridor - in this case, suggesting the use of culvert F5. Unfortunately, the cameras installed at either end of the F5 culvert did not detect this transit, possibly due to the high ambient temperatures reducing detection probability.

**Figure 12.8**: Screen-grab of LX *K-Tracker* data showing a north-to-south transit of the rail corridor via the Freshwater Creek habitat corridor by koala *Tuco* around 8 July, 2016. The IR photo to the left confirms the transit time as 3:48 am. GPS and camera data provided excellent complementary information on koala transits.

Thirty-two koalas crossed the rail corridor or had significant interactions with crossing structures recorded between September 2015 and December 2016. The following koalas all had more than two crossings of monitored structures: *Paper* (6 transits of the Cecily Street - Freshwater Creek corridor), *Venom* (6 transits of the rail corridor at or near Saltwater Creek), *Astra* (4 transits of the rail corridor at Kippa-Ring, and one non-transit interaction with culvert M29), *Tuco* (4 transits of the rail corridor at the Freshwater Creek rail bridge), *September* (3 crossings of the rail corridor at or near the Yebri Creek rail bridges), and *Walt* (2 crossings of the rail corridor at Rothwell, at or near the Saltwater Creek rail bridge, and one early incursion into the rail corridor prior to completion of the fauna fence).

Although the number of koalas monitored during the period varied significantly, the data suggest that between 15 and 30% of koalas residing near the corridor crossed the corridor or another monitored structure at least once.


**Plate 12.5**: Sequences of images taken by an IR trail camera at the northern openings of the M29 drainage culvert at Kippa-Ring, showing koala *Astra's* investigation of the culvert over a period of 17 minutes. The interaction did not result in a transit of the corridor, but *Astra* had successfully crossed the corridor previously in September and December 2015, and also subsequently in July 2016. This set of images is from early July 2016.

## 12.3.2 GOSMP

### Tree growth

Tree growth was assessed by measurement of DBH, tree height and crown diameter. The averages of each parameter measured in 214 trees over the seven months of monitoring is shown graphically in **Figure 12.9**, below.

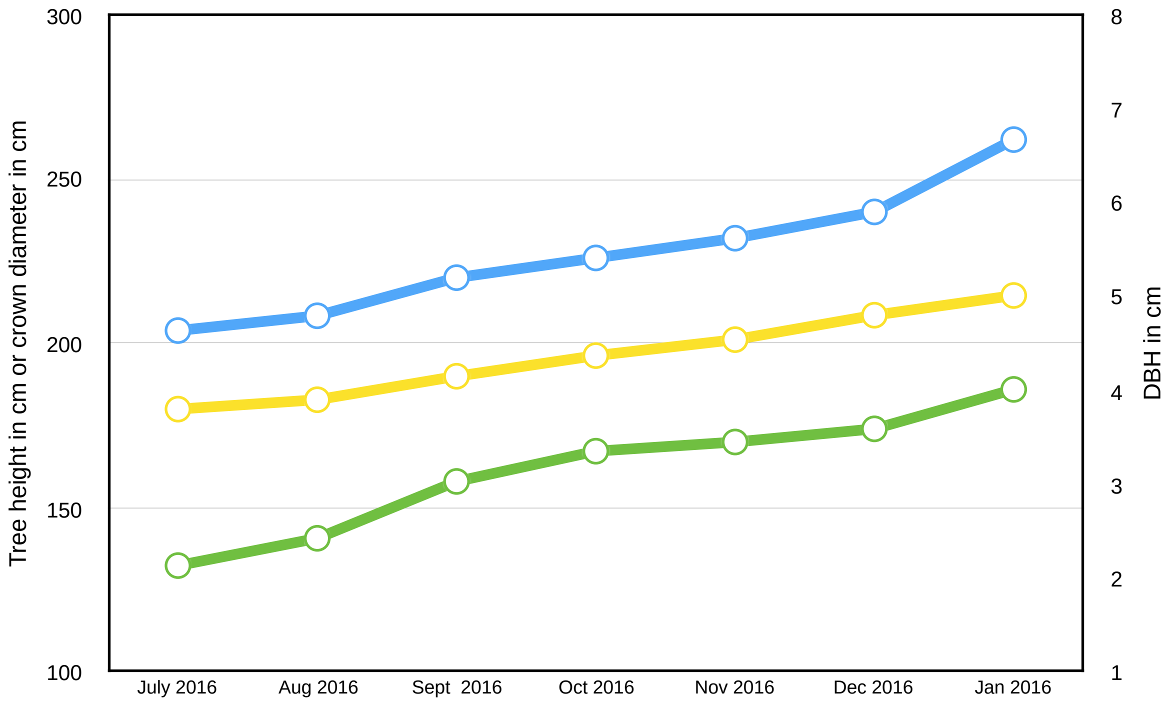



**Figure 12.9**: Growth of trees in the revegetated areas as an average of tree height (blue line), DBH yellow line and crown diameter (green line). Tree height and crown diameter are referable to the left-hand Y-axis scale, and DBH the right-hand Y-axis scale.

At the final site visit in January 2017, some of the trees had matured sufficiently to producing flower buds (**Plate 12.6**, below).

**Plate 12.6**: Buds present on one of the revegetation area trees, demonstrating sexual maturity. Left image is an *E. moluccana* (gum-topped box); right image is an *E. robusta* (swamp mahogany).

### Koala use of revegetation areas

Eight individual koalas were known to use at least one revegetation tree: they were either tracked to the tree, photographed by trail cameras, or observed during a tree survey. The following table (**Table 12.5**) lists these koalas and the method of detection. In addition to these observations, there were LX *K-Tracker* data suggesting the use of revegetation trees by three additional koalas (**Table 12.6**, two pages overleaf).

| Date | Koala | Tree species | Detection method |
|---|---|---|---|
| 07-10-15 | *Mariah* | *E. tereticornis* | Field personnel tracked *Mariah* in this tree |
| 07-11-15 | *Mariah* | *E. tereticornis* | Field personnel tracked *Mariah* in this tree |
| 11-11-15 | *Mariah* | *Eucalyptus sp.* | Field personnel tracked *Mariah* in this tree |
| 11-11-15 | *Jane* | *E. tereticornis* | Field personnel tracked *Mariah* in this tree |
| 21-11-15 | *Mariah* | *E. resinifera* | Field personnel tracked *Mariah* in this tree |
| 24-11-15 | *Mariah* | *E. tereticornis* | Field personnel tracked *Mariah* in this tree |
| 23-12-15 | *Mariah* | *Eucalyptus sp.* | Field personnel tracked *Mariah* in this tree |
| 06-01-16 | *Mariah* | *E. grandis* | Field personnel tracked *Mariah* in this tree |
| 07-10-16 | *Cox* | *E. resinifera* | Field personnel tracked and captured *Cox* in this tree |
| 21-10-16 | *Anna* | *E. microcorys* | Captured on trail camera at 9:40 pm. |
| 28-10-16 | *Michael* | *E. microcorys* | Captured on trail camera at 6:46 pm. |
| 15-11-16 | *Michael* | *E. microcorys* | Captured on trail camera at 5:21 pm. |
| 24-11-16 | *Cox* | *E. resinifera* | Field personnel tracked and captured *Cox* in this tree |
| 07-12-16 | *Michael* | *E. propinqua* | Field personnel tracked and captured *Michael* in this tree |
| 23-12-16 | *Andrew* | *E. microcorys* | Captured on trail camera at 3:39 pm. |
| 09-01-17 | *Billy Ray* | *E. tereticornis* | Field personnel tracked and captured *Billy Ray* in this tree |
| 11-01-17 | *Susan* | *E. resinifera* | Field tree survey personnel spotted *Susan* sitting in survey tree #7, Planting Area 10, Plot 20. |

**Table 12.5**: Confirmed koala use of revegetation trees by direct observation by field personnel, or by camera data validated against LX *K-Tracker* data.

**Plate 12.7**: Koala *Michael* is captured by a camera descending a well-used tallowwood (*E. microcorys*) in the early evening of 28 October, 2016. This tree was used by at least three different koalas over a 3-month period: *Michael, Andrew* and *Anna.*

**Plate 12.8**: Koala *Susan* observed in a red stringy-bark (*E. resinifera*) in the revegetation area in January 2017.


**Plate 12.9**: Sequence of camera trap photographs showing koala *Andrew* ascending the well-used tallowwood tree in December 2016, and then descending approximately 14 minutes later.

**Plate 12.10**: Koala *Cox* was located in this red stringy bark tree (*E. resinifera)* by field personnel. The broken stem in the canopy is a tell-tale sign of koala browsing and use (arrow - left image).

| Date | Koala name | Tree species | Evidence |
|---|---|---|---|
| July 2016 | *Cashew* | N/A | LX *K-Tracker* data show consecutive locations in the revegetation zone |
| July 2016 | *Pistachio* | N/A | LX *K-Tracker* data show multiple locations in the revegetation zone |
| July 2016 | *Jadore* | N/A | LX *K-Tracker* data show one location in the revegetation zone in July |
| July 2016 | *Andrew* | N/A | LX *K-Tracker* data show multiple locations in the revegetation zone |
| Aug 2016 | *Cashew* | N/A | LX *K-Tracker* data show multiple locations in the revegetation zone |
| Aug 2016 | *Pistachio* | N/A | LX *K-Tracker* data show multiple locations in the revegetation zone |
| Aug 2016 | *Michael* | *E. microcorys* | LX *K-Tracker* data show multiple locations in the vicinity of a tree showing evidence of high use. |
| Sept 2016 | *Cashew* | N/A | LX *K-Tracker* data show two locations in the revegetation zone |
| Sept 2016 | *Pistachio* | *E. microcorys* | LX *K-Tracker* data show multiple locations in revegetation zone and in the vicinity of a tree showing evidence of high use. |
| Oct 2016 | *Michael* | N/A | LX *K-Tracker* data show two locations in the revegetation zone. |
| Oct 2016 | *Maxwell* | N/A | LX *K-Tracker* data show one location in the revegetation zone. |
| Oct 2016 | *Cox* | N/A | LX *K-Tracker* data show numerous locations in the revegetation zone, solely using the revegetation trees for days at a time. |
| Nov 2016 | *Michael* | N/A | LX *K-Tracker* data show one location in the revegetation zone. |
| Nov 2016 | *Cox* | N/A | LX *K-Tracker* data show numerous locations in the revegetation zone. She was also captured in a revegetation tree. |
| Nov 2016 | *Cashew* | N/A | LX *K-Tracker* data show multiple locations in the revegetation zone. |
| Dec 2016 | *Andrew* | N/A | LX *K-Tracker* data show numerous locations in the revegetation zone. |

**Table 12.6**: Summary of indirect evidence for use of revegetation areas by koalas at the Griffin offset site.

**Plate 12.11**: Evidence of koala use of a blue gum tree (*E. tereticornis*)(left) and narrow-leafed red gum (*E. seeana*)(right). Left image shows broken upper canopy branches, and right image shows scratches in the smooth bark, both of which are consistent with koala use of those trees.

**Plate 12.12**: Swamp mahogany (*E. robusta*) showing removal of terminal leaves and stems, consistent with recent koala browsing. Koala pellets were found in and beneath the tree. LX *K-Tracker* data indicate that koalas *Pistachio* and *Cashew* may have used this tree (August, 2016).

## 12.4 Discussion and recommendations

### 12.4.1 AKHO-CM

More detailed analysis of the permeability of the rail corridor to koalas, their ranging behaviour and responses to construction, and the implications for population dynamics, genetics and viability are within the scope of the broader ***AKHO-CM*** program. This will be reported separately by others following collation and analysis of a larger body of data. The findings and discussion presented in this chapter represent an initial analysis of results with respect to the movement of koalas across the corridor using only koala GPS and tracking data, and trail camera data.

The data indicate that a number of koalas regularly crossed the rail corridor, and some, such as *Venom* and *Walt*, travelled significant distances to access crossing points. The detection of crossings by all methods suggested an increase in movements, and therefore crossings, during the breeding season (although detection of these events by cameras reduced in the latter half of the breeding season, probably due to reduced detection of koalas by the IR sensors). These sensors are relatively crude, compared with the technology contained in thermal imaging cameras, and require the movement of a body with a significantly different heat signature from the background for a detection to occur. Koalas have one of most insulative pelages of any land-based mammal, which may significantly reduce the heat signature differential between them and their background in warm weather. Future projects contemplating use of trail cameras for detection of koalas in warmer weather should carefully consider the placement and view of the cameras to improve detection probability.

The LX *K-Tracker* system, with the innovative geo-fencing function, was extremely valuable in detecting interactions of koalas with the rail corridor, including transit events. In most cases, the data were suggestive or strongly indicative of a crossing route, but in some cases this was not confirmed by camera data, probably due to the detection failures outlined above. This tag functionality was also critical in the timely rescue of the sub-adult koala *MacGyver* after he breached the rail corridor fencing during dispersal ranging behaviour (**Figure 12.10**, below), and koala *Anna* during her incursion into the fenced Bruce Highway road reserve at Griffin.

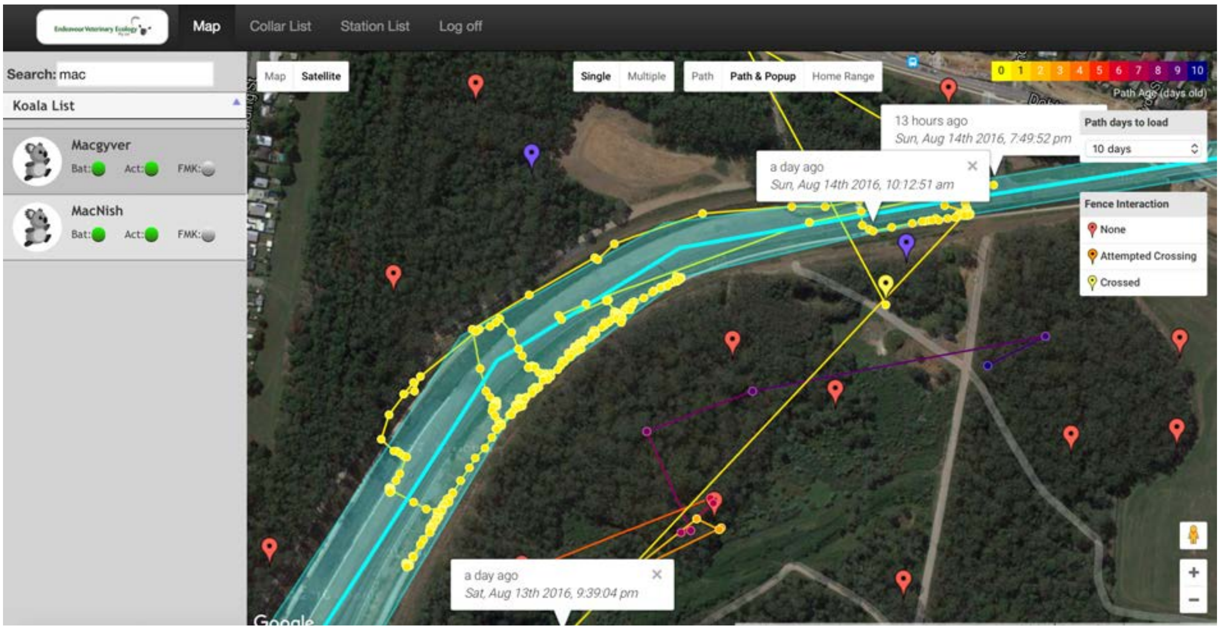



**Figure 12.10**: Screen-grab of LX *K-Tracker* data showing GPS positions of koala *MacGyver* around the time of his entrapment. He was rescued on a Sunday night after EVE personnel viewed the data uploads. The geofencing functionality gives fine detail of the movements of the koala within the fenced rail corridor.

Based on all available data, koalas used a variety of structures to cross the rail corridor including the dedicated fauna culverts, drainage culverts, habitat corridors under bridges and vehicular access culverts. On occasion, it seems they also breached the corridor fence to cross. There are too few data to allow any meaningful statistical analysis between structure types. However, it seems likely that habitat corridors extending under bridges will be readily used (such as the Freshwater Creek habitat corridor), and other structures will be used opportunistically when encountered by koalas.

The number of crossing opportunities/routes is probably an important factor in facilitating movement by koalas and increasing barrier permeability, although data are insufficient to make a statistically robust analysis in this respect. For example, the Kippa-Ring section of line provides numerous routes of transit by virtue of the five drainage culverts, four fauna culverts and one vehicular access culvert. In addition, the Kippa-Ring section bisects a large and important habitat remnant supporting a relatively high density of koalas. By comparison with the Amcor section, the Kippa-Ring section is highly permeable, which is reflected in the confirmed crossings data, whereas the Amcor section had relatively few koala crossings detected. Arguably, the Yebri Creek habitat corridor is a superior crossing opportunity for koalas, but it is the only appropriate crossing opportunity in that section of rail. The next potential crossing opportunity heading north and east is the M12 culvert, which, due to poor drainage and significant ponding of water, provides an unattractive route of crossing (**Plate 12.13**, below). These two factors probably contributed to the entrapment of the dispersal-aged koala *MacGyver,* who was unable to exit the rail corridor in the Amcor cutting section of the rail corridor after breaching the boundary fence. (See **Figure 12.10**, above, and also sections in ***Chapter 6 - Ranging behaviour and habitat use by koalas***).

**Plate 12.13**: Drainage culvert M12 at the north-eastern end of the large cutting through the Amcor site. There is significant ponding of water at either end of the culvert such that the culvert is permanently wet, reducing its likelihood and frequency of use by terrestrial fauna as a crossing route. Minor earthworks and some ballast would be sufficient to remediate the issue. Cameras detected use of this culvert by macropods (rarely) as a route of transit of the rail corridor, and it may have been used by the koala *Disco* during his dispersal north from his natal home range in the Amcor site.

## Recommended remediation - M12 and Brays Rd culverts

Remediation works to improve the effectiveness of the drainage culvert M12 and the culverts under Brays Road are warranted. Both of these structures, although not dedicated fauna crossing structures, are nevertheless very important safe passage structures for fauna moving along critical habitat corridors (Freshwater Creek) and/or between habitat blocks (north and south of the rail corridor at Amcor). Minor works would be required at M12 to reduce or eliminate ponding of water. Remediation to lift the fauna ledge in the southern box culvert of the Brays Road culverts out of its current permanent submersion should be conducted if it is to function as was intended.


**Figure 12.11**: Aerial images showing the critically important east-west habitat corridor along Freshwater Creek (blue line) and the pinch-point in the corridor at Brays Road (blue arrow)(also see inset). The significant ponding of water at the Brays Road crossing is an impediment to use of the culverts as a fauna passage. The fauna ledge constructed is ineffective, because its eastern third is permanently submerged. Remediation works are required to restore the effectiveness of this culvert as a safe passage crossing point for koalas.

**Plate 12.14**: Photo of the eastern opening of the southern box culvert under Brays Road. The fauna ledge is visible at the rear of the culvert (arrow), but dives down under the water level, such that it is submerged by approximately 400mm at its eastern termination. Hence, its functionality as a dry-passage fauna ledge is completely obviated.

### 12.4.2 GOSMP

The *Griffin Offset Site Monitoring Program* (**GOSMP**) provided information on the growth of trees in revegetated areas and the utilisation by koalas of those areas. Although of only six months duration, the program was nevertheless very valuable in demonstrating the early use of young trees by both sub-adult and adult koalas, using a variety of indirect and direct detection methods. These included direct observation of koalas using trees during field tracking events and other site visits, camera-trapping, and inferred use by GPS data.

Although an important tool to determine the success of offset planting projects, monitoring appears to be rarely carried out to determine (a) growth rates and general health of planted trees and (b) whether they are being utilised by the target species – in this case, koalas. This has resulted in a dearth of informative data relating to when offset plantings (and possibly revegetation projects in general) become habitat that is 'of use or value' to the target species or other wildlife. Instead there is a general perception that offset plantings are of little or no value for many decades. While this argument may have some merit when specifically referring to hollow-dependent fauna (tree hollows can take many decades form), we found that koalas (and other arboreal species) will regularly use offset plantings that are less than three years old.

Despite the relatively short monitoring period, regular and widespread use of the revegetation areas only three years after planting indicates that they may have more value to koalas than previously thought, even as juvenile trees. It should be noted that the Griffin site contains areas of mature koala habitat, and supported approximately 10 resident koalas at the time of planting. While most koala usage of the revegetation areas appeared to be as a nocturnal foraging resource, with koalas then moving back to the mature habitat to rest through the day, there were also several occasions when koalas were recorded resting in young trees through the day. Also, one female koala ranged almost entirely within the revegetation area for approximately six days. This may indicate that koalas will not only utilise offset plantings as an occasional foraging resource, but areas of offset plantings may be incorporated into their regular home ranges, and used as a resting/roosting resource.

**Plate 12.15**: Koala *Fozzie,* a resident koala at the Griffin offset site, at her final release in December, 2016

### 12.4.3 Recommendations

#### Monitoring and evaluation of wildlife management programs

The following recommendations relate to the monitoring and evaluation of wildlife management programs or mitigation measures generally:

1. That suitable and long-term monitoring, evaluation and adaptive management are components of wildlife management programs for transport infrastructure projects when significant species are likely to be impacted;

2. That monitoring and evaluation programs are scientifically rigorous, objective, and whenever possible, quantitative;

3. That monitoring and evaluation programs have clearly defined and carefully considered objectives and metrics;

4. That past, current and future wildlife management programs associated with transport projects are considered as opportunities for offset measures with respect to ongoing monitoring of target fauna. For example: the Griffin offset site provides an extremely valuable opportunity to conduct long-term monitoring and evaluation of both the revegetation areas and also the koala population itself from the translocation perspective. It should be considered as a site at which additional monitoring work would be beneficial and could be supported by current and future infrastructure projects for which koala-related offsets are required.

#### Monitoring of the permeability of transport infrastructure to fauna - habitat connectivity

The following recommendations relate specifically to monitoring of koala (and other fauna) movement across linear infrastructure, and permeability of the MBR rail corridor specifically:

1. That the ecological cost-benefit analysis of fencing vs not fencing linear transport infrastructure is carefully considered early in project planning, and whenever possible based on comprehensive data collection from target species well prior to the impact occurring. Real-time or near-real-time telemetry provides the best solution for the acquisition of data-sets such as ranging behaviour, habitat usage and causes of mortality, which are critical inputs into mitigation planning;

2. That the use of state-of-the-art technology is incorporated into intensive wildlife management programs because of the potentially significant benefits to quality and quantity of data and cost-effectiveness, and because it provides the opportunity for innovative solutions to be applied to the achievement of key objectives (such as the geofencing functionality developed for the LX *K-tracker* telemetry system). However, the technology and methods used must always be referable to the key objectives;

3. That a *mix* of technological solutions (in this case, GPS and field tracking of koalas, and camera traps) can provide superior and corroborative data, when based on meaningful objectives, and in turn strengthen the rigour of monitoring and evaluation programs. For example: camera traps frequently appeared to miss koala crossings of monitored structures in warm weather-presumably due to the koalas' low heat signature, but GPS data detected them;

4. That remediation works be carried out to improve the utility (for fauna) of the M12 culvert at the north-eastern end of the Amcor stretch of the rail corridor. This will require minor works to prevent pooling of water on either side of the corridor, which is currently reducing the value of this critically-positioned potential fauna crossing structure. As it is the first potential fauna crossing structure in the more than 1km stretch east of the Yebri Creek bridge, it is important that it is remediated as soon as possible;

5. That remediation works be conducted on the Brays Road culvert's fauna ledge as soon as possible to remediate its submersion. The Freshwater Creek habitat corridor is a critical habitat linkage between east and west, and currently Brays Road is a significant barrier to fauna movement along that corridor. The installation of a fauna ledge in the southern box culvert was the minimum acceptable treatment to improve safe wildlife transit under Brays Road. However, it has been incorrectly constructed, fails to meet its goal of provision of dry passage and should be fixed promptly.

### Monitoring and evaluation of offset sites

The following recommendations relate to the Griffin offset site but can also be applied to other sites being used for offsets:

1. Plant mortality in revegetation areas can be extensive, reducing the ecological value of the offset and resulting in cost-ineffectiveness. This can occur for a range of reasons, and therefore regular monitoring and investigation of causes of plant mortality is essential in the immediate period following planting. Factors to consider in reducing plant mortality rates include: timing/seasons; planting tree species that naturally occur in the locality; and consideration of certain species requirements and tolerances (i.e. salinity, soil moisture/water logging) in relation to a site's natural characteristics.

2. Strict weed management controls should be incorporated into all offset revegetation projects until trees become established. Dense weed infestations, if left uncontrolled, can shade and smother immature plants, increasing the planting mortality rate. The planting of native understory and mid-storey species can significantly reduce weed infestations, thereby reducing the need for (and cost of) weed management, and also improves the biodiversity and ecological value of replanted areas (see also point 3, below).

3. While the primary purpose of an offset planting may be to fulfil statutory requirements by planting 'koala habitat trees' at the specified ratio, a broader benefit would be achieved by also incorporating understory, shrub and ground cover species into plantings. This produces a more natural and diverse floristic community once established, and therefore provides habitat to a greater number of native species, a more effective and resilient ecosystem generally and potentially reduced costs in watering and weed management.

4. Ensure an effective monitoring component is included in offset projects not only to provide data on tree health and growth rates but also to determine if the offsets are being utilised by the target species. Unfortunately the current regulatory offsets framework only requires habitat of the target species to be secured or created through physical offsets for a proponent to fulfil their obligations. For offsets to be genuinely effective though, and appropriately 'offset' the impact of a project to the particular species, they must be used by the species and contribute to its long-term conservation. Evaluation of this objective requires appropriately detailed and long-term monitoring, at a frequency and for a duration relevant to the target species.

### Barrier crossing structures - bridges and culverts

The permeability of transport infrastructure to wildlife is important, and sometimes critical, to population persistence and genetic resilience, when linear infrastructure bisects important habitat remnants. Hence the barrier effect, as well as road or rail-associated mortality, are important targets for mitigation and impact avoidance.

The following recommendations are based on preliminary data derived from the *KTMP* and *AKHO-CM* programs of work:

1. That "more" is better than "fancy" with respect to potential crossing structures for wildlife. Koalas and other wildlife used vehicular, drainage and fauna culverts to cross the MBR rail corridor, with no detectable preference for dedicated fauna structures. Hence, for rail infrastructure (narrow width), barrier mitigation can be cost effectively achieved by installing more low-cost culverts,

rather than fewer higher-cost wildlife specific structures. However, habitat corridors under bridges were the most commonly traversed of any potential rail corridor crossing structure.

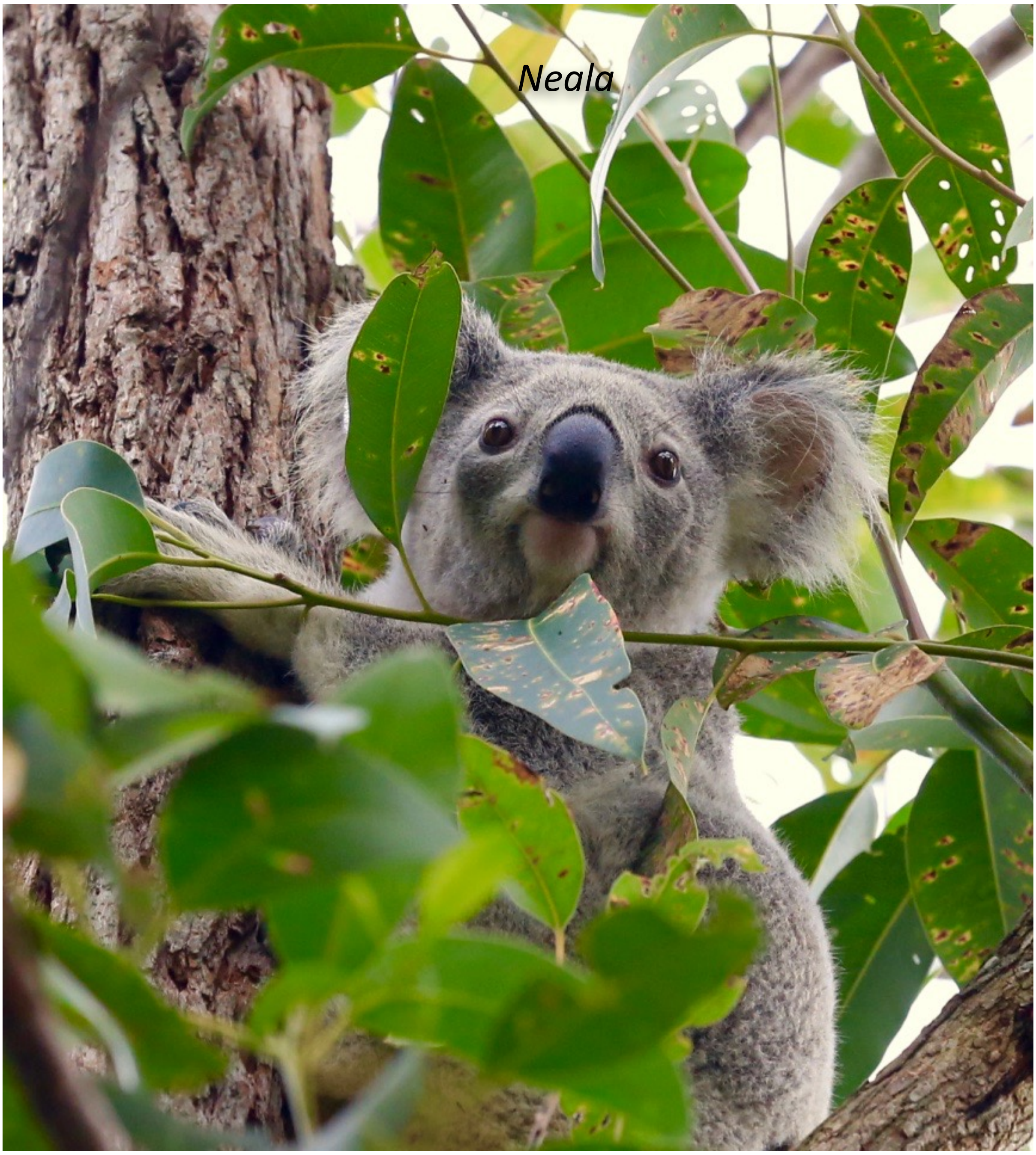
**Plate 12.16**: View of Freshwater Creek at Mango Hill showing the Redcliffe Peninsula Line rail bridge elevated well above the riparian corridor. Elevated linear infrastructure is second only to tunnelling with respect to minimising the barrier and mortality impacts of transport infrastructure. This bridge crossing allows movement of koalas and other fauna along this critical habitat linkage, without exposure to risk from vehicle strike. This crossing point was used frequently by the male koala *Tuco* whose home range spanned the rail corridor. It was also used by other tagged and untagged koalas, whose transits of the rail corridor were detected by trail cameras.

2. Whenever possible, the elevation of transport infrastructure above ground level (i.e. on pylons) provides the gold-standard for avoidance of both the barrier effect and transport infrastructure-associated mortality, when such infrastructure traverses or transects sensitive or important habitats.

3. Riparian corridors (creeks and rivers) are extremely valuable corridors for movement of koalas and other wildlife, particularly through heavily urbanised or disturbed landscapes. Whenever possible, bridges should be constructed in preference to culverts, because they allow far better ecological connectivity between habitat remnants or along habitat corridors. Bridges also significantly reduce transport-infrastructure-associated wildlife mortality when fauna fencing is not installed . Bridge spans and heights should be maximised to provide the maximum dry passage for terrestrial fauna and allow continuity of vegetation beneath the bridge.

Note: insufficient research has been conducted with respect to the likelihood of use of culverts that are long and narrow by koalas or other fauna - for example, those that cross wide transport infrastructure -. It may be that vegetated land bridges are the only suitable crossing structures for wildlife in areas such as the large cut at the Amcor site, where culverts are not suitable either for drainage or wildlife passage. This principle also applies to road infrastructure, which tends to be wider than rail infrastructure, for which long and narrow culverts may not provide sufficient mitigation of the barrier effect because target species may not use them.

# CHAPTER 13: RECOMMENDATIONS AND LEARNINGS




## Key points

- *KTMP* and associated koala management program was exemplary and provides a model for future projects
- Holistic and scientifically valid mitigation and offsets program better than just planting trees
- Proactive media communications strategy should be key component of future projects
- Establish the environmental vision early, consult and engage with key community stakeholders
- Use the best available expertise and technology to ensure benefits are maximised and objectives achieved

# Chapter 13: Recommendations and learnings

At the time of writing, the MBR koala management program was one of the most valuable long-term telemetry monitoring studies of a wild koala population and the most intensive koala management program ever conducted. There were three broad benefits that arose from the program:

1. The koala population was effectively protected from the risks associated with construction and operation of the MBR, and residual impacts were appropriately compensated for;

2. The data and biological samples from the program contributed to high-quality scientific research, and this, combined with analysis of data detailed in this report, has contributed an enormously valuable body of work to the scientific and ecological knowledge of koalas;

3. Risk to the project associated with environmental stakeholder groups, adverse national and international media arising from poor koala protection or incidents was almost entirely mitigated.

The koala management program used innovative approaches to protect and manage the koala population, developed new technologies to solve problems and ensured key objectives and milestones were met. Koalas were treated compassionately and with appropriate veterinary oversight and the methods used to protect them were effective and safe. This earned and maintained the respect and admiration of koala stakeholder groups, and ultimately transitioned the koala population from an extinction trajectory to a growth trajectory. This is an astounding achievement and one of which the project team as a whole should be justly proud. Consequently, we recommend that future projects which are likely to create significant risks for wildlife populations or habitat are similarly managed. However, such management does not necessarily evolve naturally - hence we provide below some key recommendations to ensure that future projects carefully consider and plan for the best environmental and project outcomes.

**Plate 13.1**: Koalas are under threat and need to be appropriately protected. Koala *Susan* at her final release into the Griffin offset site at the end of the koala monitoring program in December 2016. She benefited from the *KTMP* and *KTrans* programs as a koala identified as living in high-risk habitat, and was successfully translocated to the Griffin offset site, where she thrived. Her original habitat was completely obliterated by unrelated urban development.

## 13.1 Summary of key recommendations

Each of the following 14 recommendations (grouped by topic) is well supported by data and by reference to the outcomes achieved on the Moreton Bay Rail project. The project was unequivocally successful in achieving its key objectives with respect to koalas, as well as providing invaluable benefits to the scientific community. One of the most outstanding results was that community stakeholders that initially were hostile and untrusting, became, and were, at the time of writing, some of the greatest advocates of the project's approach to the protection of koalas. We suggest that the approach taken by TMR on the MBR project in respect of koala protection is best practice, and should serve as a model for all future infrastructure projects in which koalas or other significant wildlife are likely to require management.

### Establishing the vision

1. Perhaps the most critical early step in planning a major infrastructure project that is likely to cause significant impacts on wildlife or habitats, is to **clearly articulate the environmental vision** for the project. The vision statement or position should encompass the concepts of:

    (a) Best practice wildlife management;
    (b) Low-impact environmentally sustainable design and construction principles;
    (c) Prioritising *avoiding* impacts rather than *mitigating* impacts;
    (d) Open and honest engagement with environmental/wildlife stakeholders.

(The MBR was comfortably able to be open and honest with koala stakeholders because it was implementing a best practice approach to koala protection and management. Had it not, stakeholder briefings and consultations might have been considerably more adversarial and volatile.)

2. The vision must be understood, committed to, and supported at the highest level of project management. In the case of the MBR project there was consistent support from the Director General (TMR), Project Director and MBRL Steering Committee. This is essential to ensuring that proposed works are appropriately funded, which in turn, relies upon the value of the work being understood in the context of the whole project vision and whole project budget, that is, at a strategic level;

3. Proactively communicate the environmental vision to the media and community. Use every possible opportunity, of which there are many when dealing with charismatic fauna, like koalas, to communicate positive stories to the traditional media and via social media.

**Plate 13.2:** EVE General Manager, Jo Loader during filming for the SBS documentary ***Life on Us*** filmed in May 2013. Koala work often attracts media attention, which can have PR benefits for the project and promote conservation awareness. Opportunities for positive media exposure should be taken full advantage of to build positive public perceptions.

### Early engagement of wildlife consultants

4. The earlier wildlife management consultants are engaged, the better. This should be *well before* design is finalised and preferably at concept planning stage. This facilitates achievement of the best outcomes, and reduces the inefficiencies, additional cost or poorer outcomes when changes are proposed late in the design phase, or after design is finalised, and are either not implemented, or implemented at significant additional cost.

5. Early commencement of wildlife monitoring will allow for good, robust data sets to be collected prior to any project impact. On the MBR project, this was critical to showing that the koala population was heavily impacted and in decline *prior to* project impacts, and allowed early implementation of compensatory and mitigation measures, thereby achieving excellent outcomes.

6. An adequate level of pre-impact wildlife monitoring is expected by environmental stakeholders, who often have a considerable level of technical expertise. Ecological assessments, disappointingly commonly, are inadequate and inaccurate. This can lead to a cascade of poor decisions which are costly to remedy or are simply not remedied due to budgetary or time constraints. The failure by consultants to properly consider the impacts of another large infrastructure project on koalas prior to commencement of operational works led to a more rushed and reactionary response to koala protection and less beneficial outcomes than those achieved on the MBR project.

**Plate 13.3**: Untagged koalas in severely over-browsed habitat as a result of very localised overabundance of koalas trapped between a large urban development at Lawnton and the Pine River, just south of the Amcor site. There was extensive death of koala food trees as a result of over-browsing. This is a dramatic example of the consequences of poor management of koalas by developers and a failure of the regulatory authorities, including the development assessment manager, to condition the development approval to require appropriate koala management. It vividly demonstrates the desirability of proper and comprehensive koala management, and validates the approach taken to protect and manage the koala population affected by the Moreton Bay Rail project.

### Early community stakeholder engagement

7. Early and ongoing engagement of wildlife/environmental stakeholders is critical in the building of trust, dissemination of accurate information and establishment of good working relationships. In turn, this has a crucial role in management of project risk, particularly in respect of adverse community reaction to proposed projects.

8. Early articulation of environmental vision - best practice approach, comprehensive wildlife protection, robust scientific justification, trusted and expert practitioners, etc. This commences the stakeholder engagement process with a positive vision upon which future discussions and engagement can be based.

9. Seek and respect the input of community stakeholders. Their feeling of involvement and engagement with the project, particularly in terms of providing input into wildlife protection and conservation solutions, is an important component of stakeholder management. It keeps them positively engaged, focused on solutions to issues, and reduces the risk of poor PR and discontent.

**Plate 13.4**: Bi-monthly community stakeholder meetings were valuable and well-received. Koala stakeholders at a meeting in the Strathpine MBRC chambers.

### Project oversight and management

10. Contracting and oversight of the koala management program by TMR, rather than the design and construct (D&C) contractor was crucial to the success of the program. Had the program been part of the D&C contract and implemented and managed by the principal construction contractor, it is highly unlikely that the program would have been adequately funded or conducted. Construction contractors tend not to have the same approach as asset owners and managers, who have to consider the long-term legacy a project and the associated infrastructure. We recommend that all future sensitive wildlife management programs be managed and contracted by TMR to ensure that outcomes meet community expectations rather than falling victim to commercial interests and/or inadequate budgets and conflicts of interests.

11. The commitment to the project vision must be central to the manner in which operational works are conducted. A zero-tolerance approach to deviation from the vision and specifications should be clearly articulated to the principal construction contractor and all subcontractors, and an appropriate culture established early - prior to the commencement of operational works. This maximises the likelihood of smooth and efficient operational works without conflict and misunderstanding, and, to that end, those expectations should be clearly stated in specifications documents, and enforced robustly.

**Plate 13.5**: EVE field supervisor Bree Wilson conducting scheduled field tracking of monitored koalas using VHF radio-telemetry, which allows detection of signals emitted from transmitters fitted to program koalas using a directional antenna and telemetry receiver. Over 50,000 field tracking events of koalas occurred during the *KTMP* and *KTrans* programs of work.

### Science-based decision-making

12. The appropriate scientific investigation and management of impacted wildlife populations or habitat is essential. It allows the decision-making process to be well-informed, robust and comprehensively defensible. Anything less exposes an environmentally sensitive project to criticism, significant PR and political risk and a dearth of substance upon which to defend the project and/or decisions.

13. One of the great strengths of the MBR project, and a legacy of which the project team should be very proud, is the enormously valuable body of scientific knowledge on koalas that has been acquired and shared. This has not only been critical in informing robust and defensible koala management approaches for the project's purposes, but has been arguably one of the most valuable and comprehensive studies of koala biology and conservation management ever conducted. In addition, the science has unequivocally demonstrated that the koala management program has not only mitigated the impacts of the rail project, but improved population viability substantially. We therefore recommend that the approach taken on the MBR project serve as a model for future projects likely to significantly impact protected wildlife.

14. The koala management program also provided extremely valuable data and biological samples to support external research in a variety of streams, most notably the development of a vaccine to reduce the impacts of chlamydial disease. Biological samples can be collected at relatively low cost to the primary project, but can provide immense value to a research project. This collaboration not only strengthens the credentials of the project in terms of its environmental commitment, but provides a resource for researchers that otherwise would never be available. The concept of maximising the scientific benefit of koala management activities was articulated early in the design of the koala management program. It has been valuable for both the project and collaborating researchers, and is a clear demonstration of the project contributing to "the greater good", in addition to leveraging other sources of funding to support the research. We therefore recommend that a similar approach be adopted early in the planning stages of future projects.

The following sections present more detailed discussion of some specific topics relevant to the recommendations and learnings:

## 13.2 Key issues

### Wild dogs

The adverse media stories relating to high mortality of koalas, mainly due to wild dog-associated predation, were erroneous. At no time did the media report on, or note, that wild dogs are a natural predator of koalas, and that predation of wild animals by other wild animals is a normal and entirely necessary ecological process. It is worth noting here, as we have done elsewhere in this report, that there is no evidence at all that any process or procedure involved in the koala management program contributed to an increased risk of wild dog predation on koalas, nor has any logical mechanism for that been put forward. This highlights the importance of being proactive with positive media communications to avoid poorly informed, potentially adverse or critical media filling the void in public perception.

Wild dog predation of koalas was clearly occurring in the MBR corridor and adjacent areas prior to the commencement of the koala management program. It was also at a level sufficient for field officers involved in the early koala search and capture efforts to frequently find the remains of untagged koalas that had been predated upon by wild dogs. Hence, there is little support for assertions that the koala management program *caused* the high level of wild dog predation.

Wild dog control efforts over the final three years of the koala management program appear to have significantly reduced their impact with respect to koala mortality. At the time of writing, there had been only two koalas predated by wild dogs in the previous 18 months, which is in stark contrast with the predation level of around one every two days at the height of the wild dog impacts (October-November 2014). While the wild dog control program resulted in a very considerable benefit to the viability of the koala population, it must be remembered that the removal of top-level native predators from an ecosystem is not advisable, and may lead to ecological imbalances in time. In fact, there is some anecdotal evidence that fox and cat presence in areas subject to wild dog suppression may have increased. While these smaller predators have little impact on koalas, they can devastate populations of small native mammals and reptiles. Hence, the positive and negative effects of wild dog suppression should be carefully considered in the context of whole-of-ecosystem effects, both short and long-term.

**Plate 13.6**: The infamous "Amcor Dog" captured on a trail camera at the Amcor site in September, 2014 (left image) and a large and well nourished male wild dog captured on at trail camera at Freshwater Creek in January, 2017.


**Plate 13.7**: Images showing foxes carrying native prey were frequently captured on trail cameras monitoring culverts for use by koalas. The image on the left is from a camera positioned on the southern side of the Yebri Creek rail bridge, and shows a fox with a small swamp wallaby; image on the right shows a fox with a northern brown bandicoot at drainage culvert M15 near Kallangur Station. Foxes often increase in abundance in areas from which wild dogs have been removed, which can have devastating impacts on small and medium native fauna.

**Plate 13.8**: The quandary of "interfering" with nature: in this case, monitored koala *Tonia* was fortuitously found (during tracking for a scheduled capture) after she had just fallen out of a tree while being constricted by a python (February, 2015). Because of the size of the snake it was likely that she would have been a "*Carpet python predation - not consumed*" statistic had the capture team not made a timely rescue. Of 21 less fortunate koalas, only 8 (38%) were consumed. The human psychology of interference with nature is fraught with inconsistency: wild dog predation of koalas is considered worthy of lethal management, but not so for carpet python predation; both are arguably native and natural predators of koalas.

### Regarding TMR as the principal contractor for koala and other wildlife management works

When design and construct (D&C) contracts (and other major infrastructure contract types, such as public-private partnerships (PPP)) are awarded largely on *price*, wildlife and environmental impacts are at significant risk of being inadequately managed. This is particularly so when specifications and scope documents are poorly written, light on detail and/or written by personnel with limited understanding of important specifications. The combination of those two things can lead to very rudimentary efforts being applied by the principal contractor to wildlife and environmental protection to save costs. Consequently, very poor outcomes often occur if there is little oversight and enforcement by the client or a third-party auditor. In addition, the requirement for the principal contractor to perform management actions that have not been properly specified in the contract documents can lead to very substantial variation costs.

The decision by TMR to retain control of the koala management program as PC unquestionably resulted in superior outcomes for the koalas and in terms of project risk management. It is hard to imagine that the D&C principal contractor for the MBR construction would have supported the koala management program to the same extent had that program been included in the D&C contract. Consequently, we strongly recommend that special environmental and wildlife management programs on large public infrastructure projects continue to be managed directly by TMR, rather than included in D&C or other contracts with the construction contractor. This arrangement gives a sufficient level of independence to the wildlife contractor from perceived conflicts of interest with the construction principal contractor, who, naturally, is seeking to minimise costs. Furthermore, it gives a higher level of confidence to community stakeholder groups (wildlife and koala groups) that commercial interests are not interfering with the proper conduct of wildlife protection works.

### Early engagement of wildlife and ecosystem management consultants

During construction projects, it is important to make the distinction between general ecology consultants and those who have additional expertise in the "on-ground" management of wildlife. Ecology consultancy firms may have little expertise in the on-ground management of wildlife, resulting in an unacceptably poor standard of ecological investigation. Expertise spanning broad ecological principles as well as practical on-ground wildlife management should be sought early in the planning stages of major infrastructure projects so that outcomes are optimised. EVE was able to provide very limited input into the design of the MBR due to the advanced stage of design when input was sought. Nevertheless, the MBR project, overall, has mitigated koala impacts to a greater extent than any other similar project, and the project management team and Steering Committee should be congratulated on that. In addition, it has provided a demonstrable net benefit for koalas in the short-medium term through the implementation of a comprehensive management and alternative offsets program.

**Plate 13.9:** Eastern grey kangaroos - late afternoon in tidal flats of the Kippa-Ring bushland.

### Proactive positive media presence

The impact and consequences of poorly informed adverse media stories can be profound, in terms of public perception, political interference, stakeholder and staff morale, and ultimately the achievement of key objectives. A number of adverse media stories about the MBR koala management program, although entirely baseless, nevertheless got traction and resulted in erroneous perceptions becoming entrenched in some sections of the community. Essentially, these stories attributed the high level of wild dog predation to translocation of koalas, because of misleading comments made by particular wildlife commentators. While poorly informed adverse media stories cannot be prevented, the impacts of such stories can be mitigated by establishing and maintaining a positive public perception of such programs as the koala management program.

The establishment of a positive public perception is particularly important when iconic and beloved species, such as koalas, are involved and likely to be impacted by an infrastructure project. It takes very little for adverse media stories to be published and become entrenched when a void in public perception exists. Hence, we recommend that future projects develop and implement comprehensive communications plans based on saturation of the broadcast, print and social media with positive stories. This will ensure that the public perception is generally positive, and poorly informed adverse stories will be at odds with that perception, and therefore get less traction.

**Plate 13.10**: Koala *Johnny K* in bushland near the site of Kallangur Station after his first veterinary examination. He was killed three months later by the "Amcor Dog" after moving south across Dohles Rocks Road to the Amcor site.

# Program summary statistics

| Item | Date or statistic |
|---|---|
| **Key project dates** | |
| Start - first koala veterinary check - koala *Ozone* | 18 March 2013 |
| Completion date (main *KTMP*) | 31 August 2016 |
| Completion - all other koala management programs | February 2017 |
| Start of construction / habitat clearing | 29 January 2014 |
| Completion of habitat clearing | 29 May 2014 |
| **Koala statistics** | |
| Number of koalas in project | 503 |
| Males | 217 |
| Females | 285 |
| Intersex (koala *Jerilly*) | 1 |
| Sex ratio male:females | 1:1.3 |
| Weight of koalas | |
| Male (heaviest) - Koala *Hayden* - 10 years old, Amcor polygon | 9.58 kg |
| Female (heaviest) - Koala *Bev* - 10 years old, Amcor polygon | 7.9 kg |
| Joeys produced (18 March, 2013 - 31 August, 2016) | 350 |
| **Mortality** | |
| Total deaths, project commencement - 31 August, 2016 | 284 |
| Male | 131 |
| Female | 153 |
| Overall mortality rate (March 2013-August 2016) | 43.6%, 284 deaths |
| Year 1 (18 March 2013 – 17 March) | 88.8%, 97 deaths |
| Year 2 (18 March 2014 – 17 March) | 56.9%, 127 deaths |
| Year 3 (18 March 2015 – 17 March) | 23.0%, 51 deaths |
| Year 4 (6 months: 18 March 2016 - 31 August 2016) | 8.9%, 9 deaths |
| Duration of all koala management program (*KTMP*, *KTrans*, *AKHO* (*GOSMP* component and koala monitoring for *AKHO-CM*) | 4 years |
| **Major causes of mortality** | |
| Wild dog attack/predation or suspected predation | 54%, 154 koalas |
| Disease (chlamydial disease + other disease) | 29.6%, 84 koalas |
| Carpet python predation (includes one death after *KTMP* period) | 7%, 21 koalas |

| Item | Date or statistic |
| --- | --- |
| **Lesser causes of mortality** | |
| Vehicle hits | 10 koalas |
| Domestic dog attack | 5 koalas |
| Other trauma (including one train strike) | 5 koalas |
| Unknown cause | 3 koalas |
| Old age-related | 2 koalas |
| Misadventure - bee sting | 1 koala |
| **Tracking and monitoring statistics** | |
| Total field event - tracking, captures, observations, etc | 56,636 |
| Field tracking events | 50,684 |
| Koala captures | 3,285 |
| Most records for a koala - *Patricia* | 347 |
| Most individual captures - *Andrew* (koala #3 in *KTMP*) | 14 |
| Estimated koala tag/days | 220,000 |
| **Capture methods** | |
| Tree climb (75%) | 2464 |
| Ground flagging (13%) | 427 |
| Koala trap (11%) | 361 |
| Other (1%) | 33 |
| Capture-related deaths | 0 |
| Capture-related injuries requiring treatment (0.06%) (*Lou*, *Gerber*) | 2 |
| **Telemetry tag-related injuries** | |
| Collar or anklet-related deaths | 0 |
| Collar or anklet-related injuries requiring treatment | 7 |
| **Veterinary statistics** | |
| All veterinary records (events, file notes, etc) | 3962 |
| Scheduled veterinary examinations | 1525 |
| Veterinary rechecks | 198 |
| Necropsy examinations | 258 |
| Koalas successfully treated for chlamydial disease (69%) | 121 |
| Koalas euthanased or died from chlamydial disease (31%) | 51 |

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