

**The ecology of the koala
(*Phascolarctos cinereus*) in over-browsed
habitats on Kangaroo Island, South Australia**

SOOLIM CARNEY

A thesis submitted for the degree of Doctor of Philosophy in the
Faculty of Sciences

School of Earth and Environmental Sciences

University of Adelaide

November 2010

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying, subject to the provisions of the *Copyright Act 1968*.

I also give permission for the digital version of my thesis to be made available on the web, via the University's digital research repository, the Library catalogue, the Australasian Digital Theses Program (ADTP) and also through web search engines, unless permission has been granted by the University to restrict access for a period of time.

Soolim Carney

28 November 2010

“Latin binomials do not simply eat other Latin binomials...”

Janzen 1979

Acknowledgments

This project would not have been completed without the support and assistance of many people and organisations.

Firstly I would like to acknowledge the valuable support, advice and guidance provided throughout the project by my supervisors, Associate Professor David Paton and Professor Hugh Possingham. In particular, I would like to thank David for his valuable input on drafts of this thesis and his long hours of support in the field at all hours of the day and night.

The project was funded by the South Australian Department for Environment and Heritage, the Australian Research Council and the Earthwatch Institute.

Considerable in-kind support was also provided by the South Australian Department for Environment and Heritage. I would like to specifically acknowledge the following people from the Department: Steve Berris; Toni Duka; Bob Inns; Drew Laslett; Pip Masters; Barbara StJohn; and Robin Storr. Thanks also for the field support provided by the koala catching teams including: Mark Mills; Scott Redden; Sheree Marx, and Madelaine Heuson. David Ball provided valuable advice on assessment of tree defoliation levels. Heather Mitchellmore generously provided support with feeding observations at the Cleland Wildlife Park.

Thanks to Greg Johnsson and Nadia Jackson for undertaking health assessment and ageing of koalas. Their assistance and cooperation with this project is very much appreciated.

Additional support for the project was provided by the Earthwatch Institute. I am grateful to the numerous Earthwatch Institute volunteers who assisted with components of the fieldwork that would have been impossible to complete without their contribution.

Invaluable field assistance was also provided by University of Adelaide staff and students, including: Colin Bailey; Stephen Ball; Kurrily Blaylock; Piers Brissenden; Tamra Chapman; Emma Crossfield; Anthony Freebairn; Jody Gates; Brydie Hill; Melissa Horgan; Richard Saunders; Helen Vanderwoude; and Nigel Willoughby.

Jason Philips and Leonie Heard from Planning SA provided assistance with mapping and habitat characterisation in the initial stages of the project.

Special thanks go to Andrew and Tracie Heinrich from Ella Matta and Ian and Libby Kelly from Pioneer Bend for allowing access to their properties over a period of almost four years. I am especially thankful to Andrew and Tracie for their generous hospitality. Thanks also to numerous other landholders who also kindly allowed access to their properties including: Robyn and Andrew Kelly, Colin Tremaine, Russel and Shirley Ross, Peter and Helen Lock, Mervin and Meryl Tremaine, Chris Windham and Barbara Halfpenny, Simon and Tessa Dennis, Alan Cosmer (PIRSA), Phil Cooper, Tom Giles, Philip and Jennifer Freebairn, David Pratt, Mary and Dennis Perkins, Ron Mumford, Roger Cass, Chris and Regina Beckwith, Ray Kingham, Snow Dennis, Dean Dennis, Simon and Madeline Kelly, Dean Bell and the Victor Harbor Council.

Graham and Judy Rees generously provided accommodation at Vivonne Bay Outdoor Education Centre.

Thanks to Cathy Cox (Trees For Life), Alistair Christie (Inman River Landcare Group), Scott McKenzie (Greenhills Adventure Park) and the South Australian National Parks and Wildlife Service at Flinders Chase National Park for assistance in identifying potential field sites for the tree defoliation experiments.

Thanks to Lucio Della Martina, Troy Hayden and Mark Watson for encouraging me to complete this project and for generously giving me the time to do so.

Again, thank you all.

Abstract

Over-abundant koala populations and resultant over-browsing of vegetation has presented an ongoing challenge for wildlife managers in many areas of south-eastern Australia for almost a century. In 1996 over-browsing by koalas became evident in many areas of Kangaroo Island, and in riparian areas where preferred tree species occurred; the majority of food trees were severely defoliated. This project was one of a number of concurrent research projects which focussed on key aspects of koala ecology in order to better inform development of koala management strategies on Kangaroo Island. The main focus of the project was to investigate:

- koala foraging behaviour
- tree response to extent and pattern of defoliation
- habitat use and tree preference in preferred and non-preferred habitats
- regenerative potential of over-browsed tree species,
- effect of sterilisation and translocation of koalas on tree health.

The first part of the project involved conducting observations of the foraging behaviour of free-ranging koalas to better understand the spatial pattern of tree defoliation. Ten individually tagged and radio-collared koalas were observed for 24-hour periods on 34 occasions between August 1997 and December 1998. Koalas were found to restrict feeding bouts to one or two locations within the outer canopy of each tree they visited. Feeding was concentrated at these locations with browsed branches being almost completely defoliated. Based on these results artificial defoliation experiments were developed and used to determine the effect that pattern and extent of defoliation had on leaf production and recovery of trees.

Defoliation treatments were applied to 50 manna gum trees at Flinders Chase National Park and Victor Harbor. Manna gum trees showed strong compensatory growth following artificial defoliation. New leaf production was particularly high on trees that were subjected to canopy-wide defoliation. In contrast, branches which experienced localised damage produced comparatively fewer leaves than branches on trees which had experienced canopy-wide defoliation. It appears that manna gum can be highly tolerant of one-off defoliation of the entire canopy, even when substantial quantities of foliage are lost, but that branches may not be as tolerant of high levels of herbivory if defoliated in isolation. This is a crucial consideration when determining carrying capacities of riparian habitats both during the recovery phase of already heavily defoliated trees and the long-term carrying capacities of these habitats and suggests that carrying capacity may not correlate directly with the ‘standing crop’ of leaves on trees within a given area of habitat.

Between 1997 and 2000 koala numbers and tree health were monitored at Mine Creek to determine the effectiveness of sterilisation and translocation in reducing koala numbers and improving tree condition. Mine Creek has been the site of an intensive koala population control program since 1997 and presented an opportunity to test the effect of koala management techniques on tree health.

There was a decline in koala population density at Mine Creek; principally in response to translocation rather than sterilisation. The reduction in koala density at Mine Creek was short-term and did not reach the target density of 1 koala/ha. Subsequently, tree canopy condition, particularly for the preferred browse species *Eucalyptus viminalis cygnetensis*, did not improve substantially. Two years after the commencement of the management program 59% of *E. viminalis cygnetensis* trees at Mine Creek remained

severely defoliated. An increase in the population size of koalas was observed from mid-1999 onward, representing a potential doubling in the population every three years. Immigration of animals from surrounding uncontrolled areas is a potentially important mechanism of localised population recovery. An increase in koala numbers subsequent to control was unlikely to be due to *in situ* breeding, but instead immigration from surrounding uncontrolled areas of habitat (or areas where only sterilisation was undertaken and population densities remained high).

Eucalypts have a high capacity for compensatory growth and recovery if browse pressure is removed. Where over-browsing occurs the imperative for successful restoration of defoliated trees is to substantially reduce the density of koalas in the short-term and maintain reduced population levels in the long-term. Sterilisation may be usefully applied to maintain low koala densities after an initial population reduction via alternative control methods, but sterilisation alone is unable to affect much change in severely over-browsed habitats in the immediate term.

Utilisation of habitat by koalas in preferred and non-preferred tree associations on Kangaroo Island was investigated using radio-telemetry. A total of 25 koalas were radio-collared and tracked between 1997 and 2000. Preferred areas of habitat comprised of vegetation associations containing *E. viminalis cygnetensis* and non-preferred habitat typically consisted of an *E. baxteri*, *E. obliqua*, *E. cosmophylla* tree association. Observations indicated that a potentially viable, low density population of koalas occupied non-preferred habitat on Kangaroo Island. Koalas were found to use a wide range of eucalypt species and many individual koalas survived solely on a diet of tree species that were previously considered to be non-preferred by koalas on Kangaroo Island. The results of this study indicate that non-preferred areas of habitat

have significant conservation and management value, just as areas that sustain high-density populations of koalas do.

A comparison of estimated home range areas between koalas in preferred and non-preferred habitat showed that koalas in non-preferred habitat had significantly larger home ranges than koalas in preferred habitat. This was also the case within sexes with male koalas in non-preferred habitat having significantly larger home ranges than males in preferred habitat and females in non-preferred habitat having significantly larger home ranges than female koalas in preferred habitat.

The presence of a resident population of koalas in non-preferred habitat on Kangaroo Island was generally discounted until the commencement of this study. Koala management targets on Kangaroo Island were originally based on a population estimate of 3000 - 5000 koalas and the understanding that the majority of koalas occurred in the Cygnet River valley and Flinders Chase National Park. Today, methods of estimating population size on Kangaroo Island incorporate populations of koalas within high-, medium- and low quality habitats according to composition of eucalypt species. The revised koala population estimate based on this more comprehensive stratified sampling approach is $\sim 27,000$. It is now estimated that over half the Island's koala population resides in areas of low-quality habitat outside of Flinders Chase National Park and the Cygnet River catchment.

Contents

1	Introduction	1
2	Description of Study Sites.....	9
2.1	Kangaroo Island.....	9
2.1.1	General.....	9
2.1.2	Cygnet River.....	12
2.1.3	Flinders Chase.....	13
2.1.4	Little Sahara.....	17
2.2	Victor Harbor.....	19
2.2.1	General.....	19
3	Feeding Behaviour, Time Budgets and Daily Activity	20
3.1	Introduction.....	20
3.1.1	Feeding Behaviour.....	20
3.1.2	Time Budgets.....	22
3.1.3	Daily Cycle of Activity.....	24
3.1.4	Purpose of This Study.....	25
3.2	Methods.....	25
3.3	Results.....	28
3.3.1	Feeding Behaviour.....	28
3.3.2	Non-Feeding Behaviour.....	31
3.3.3	Time Budgets.....	34
3.3.4	Daily Cycle of Activity.....	36
3.4	Discussion.....	39
3.4.1	Feeding Behaviour.....	39
3.4.2	Non-Feeding Behaviour.....	42
3.4.3	Daily Time Budgets.....	45

3.4.4	Daily Cycle of Activity	46
3.5	Summary	47
4	Assessment of Koala Browse Impact Using Artificial Defoliation	49
4.1	Introduction	49
4.2	Methods	53
4.2.1	Enclosure Experiments	54
4.2.2	Captive Feeding Observations	56
4.2.3	Artificial Defoliation	57
4.2.4	Statistical Analyses	61
4.3	Results	61
4.3.1	Enclosure Experiment	61
4.3.2	Captive Feeding Observations	63
4.3.3	Artificial Defoliation	64
4.4	Discussion	69
4.5	Summary	74
5	Tree Response to Sterilisation and Translocation of Koalas	75
5.1	Introduction	75
5.2	Methods	77
5.2.1	Population Census	79
5.2.2	Canopy Condition	80
5.2.3	Tree Guards	81
5.2.4	Tree Species Preferences	82
5.2.5	Statistical Analyses	82
5.3	Results	83
5.3.1	Population Census	83
5.3.2	Tree Condition	85
5.3.3	Tree Guards	88

5.4	Discussion	89
5.5	Summary	93
6	Comparative Use of Preferred and Non-preferred Habitat	95
6.1	Introduction	95
6.2	Methods	101
6.2.1	Capture and Radio-Tracking	101
6.2.2	Health and Age Assessments	103
6.2.3	Home Range Analysis	104
6.2.4	Daily Movement.....	108
6.2.5	Tree Species Preferences.....	108
6.2.6	Population Census	109
6.3	Results	110
6.3.1	Health Assessments	110
6.3.2	Home Range Analysis	112
6.3.3	Tree Species Preferences.....	124
6.3.4	Population Census	128
6.4	Discussion	129
6.4.1	Use of Non-preferred Habitat	129
6.4.2	Home Range Size.....	130
6.4.3	Population Density	133
6.4.4	Daily Movements	135
6.4.5	Tree Species Preferences.....	137
6.4.6	Management Implications.....	138
6.5	Summary	139
7	Conclusion: Managing Over-browsing by Koalas.....	141

Figures

Figure 2-1:	Location of study sites on Kangaroo Island and at Victor Harbor, South Australia	11
Figure 2-2:	Remnant riparian vegetation along Cygnet River and tributaries.	15
Figure 2-3:	Riparian vegetation.....	15
Figure 2-4:	Remnant woodland on farmland.....	16
Figure 2-5:	<i>Eucalyptus viminalis cygnetensis</i> revegetation plot adjacent to Park Headquarters at Flinders Chase National Park.....	16
Figure 2-6:	Remnant <i>E. viminalis cygnetensis</i> (centre) at Little Sahara with mobile dune in foreground.....	18
Figure 2-7:	Hindmarsh River revegetation plot at Victor Harbor	18
Figure 3-1:	System used to record the type of branch used by a koala when recording its position in a tree.....	27
Figure 3-2:	Position in tree (based on branch type) and type of foliage consumed during feeding bouts (n = 205)	29
Figure 3-3:	Average time spent (\pm SD) per 24-hour day on various activities for all koalas during 24-hour observations (n = 33).....	35
Figure 3-4:	Average time spent (\pm SD) per 24-hour day on various activities for male (n = 26) and female koalas (n= 7).....	35
Figure 3-5:	Average percentage of time spent feeding in each hour of the day for nine koalas observed feeding over 33 days.....	37
Figure 3-6:	Average percentage of time spent feeding in each hour of the day for nine koalas observed feeding over 33 days.....	38
Figure 4-1:	Mean leaf production (\pm SE) at Victor Harbor.....	66
Figure 4-2:	Relative change in the total amount of foliage on tagged branches at Victor Harbor (Mean \pm SE).....	66
Figure 4-3:	Mean leaf production (\pm SE) at Flinders Chase.....	68
Figure 4-4:	Relative change in the total amount of foliage on tagged branches at Flinders Chase (Mean \pm SE).	68
Figure 5-1:	Mine Creek koala population and tree monitoring site..	78
Figure 5-2:	Koala census results December 1996 to September 2002.	84
Figure 5-3:	Changes in canopy condition of 97 <i>E. viminalis cygnetensis</i> trees at Mine Creek between 1997 and 1999.	87
Figure 5-4:	Changes in canopy condition of 214 <i>E. leucoxylon</i> trees at Mine Creek 1997 – 1999.	88
Figure 6-1:	Period of radio-tracking for each radio-collared koala.	106

Figure 6-2:	Influence of sample size on harmonic mean estimates (90% isopleth) for koalas in preferred habitat (5 male: 4 female).....	113
Figure 6-3:	Influence of sample size on harmonic mean estimates (90% isopleth) for koalas in non-preferred habitat (4 male: 6 female).	114
Figure 6-4:	Influence of sample size on fixed kernel estimates (90% isopleth) for koalas in preferred habitat (5 male: 4 female).	114
Figure 6-5:	Influence of sample size on fixed kernel estimates (90% isopleth) for koalas in non-preferred habitat (4 male: 6 female).....	115
Figure 6-6:	Frequency distribution of distance travelled by koalas in preferred habitat (4 male: 5 female)	122
Figure 6-7:	Frequency distribution of distance travelled by koalas in non-preferred habitat (4 male: 6 female)	122
Figure 6-8:	Observed use by koalas and availability of eucalypt tree species in preferred habitat based on 710 observations (5 male: 4 female).....	126
Figure 6-9:	Observed use by koalas and availability of eucalypt tree species in non-preferred habitat based on 634 observations (4 male: 6 female).....	126
Figure 6-10:	McLoughlin <i>et al.</i> (2001) space-use model.....	132

Tables

Table 1-1:	Reports of tree defoliation by koalas in Australia	2
Table 3-1:	Number of 24-hour observations of koalas at various sites and times of year	26
Table 4-1:	Proportion of leaves removed from tagged branches by koalas in enclosures.....	63
Table 4-2:	Proportion of leaves removed from tagged branches by captive koalas at Cleland Wildlife Park.	64
Table 5-1:	Numbers of sterilised and translocated koalas at Mine Creek 1997-2000.....	76
Table 5-2:	Koala sex ratios and fertility rates observed during censuses at Mine Creek, 1996 - 2002.	86
Table 5-3:	Condition of guarded and control trees Oct 98 – Nov/Dec 99	89
Table 6-1:	Regionally preferred food tree species throughout Australia	96
Table 6-2:	Comparison of reported koala home range sizes from various studies throughout Australia.....	100
Table 6-3:	Criteria used in age assessment of koalas	104
Table 6-4:	Health and weight data for koalas included in final home range analysis.....	111

Table 6-5:	Home range estimates for koalas in preferred and non-preferred habitat types.	117
Table 6-6:	Comparison of home range area and core area estimates for male and female koalas in preferred habitat (5 male: 4 female)	118
Table 6-7:	Comparison of home range area and core area estimates for male and female koalas in non-preferred habitat (4 male: 6 female)	118
Table 6-8:	Comparison of home range areas and core area estimates for male and female koalas in preferred and non-preferred habitat (9 male: 10 female)	119
Table 6-9:	Daily distance travelled for each radio-collared koala.....	121
Table 6-10:	Statistical comparison of daily distance travelled by radio-collared koalas	123
Table 6-11:	Tree preference for individual koalas in preferred and non-preferred habitat types.....	127
Table 6-13:	Summary of population census results. Censused areas (column five) consisted only of vegetated areas and did not include cleared areas (i.e. pasture) between patches of vegetation	128
Table 6-14:	South Australian Department for Environment and Heritage annual census results for Mine Creek and Deep Creek 1996-1998.....	129
Table 6-15:	Koala population densities reported in various studies throughout Australia.....	134
Table 6-16:	Comparison of reported average daily movements of koalas.....	136

Appendices

Appendix A: Tree Guard Photo Points

Appendix B: Home Range Area Plots

Appendix C: Data Analysis – Tree Preferences

Appendix D: Media Statement on KI Koala Issue