Literature review: responses of Koalas to translocation

P. Menkhorst

February 2017

Arthur Rylah Institute for Environmental Research

Technical Report Series No. 279

Arthur Rylah Institute for environmental research

Department of Environment, Land, Water & Planning

State Government Victoria

Literature review: responses of Koalas to translocation

Peter Menkhorst

Arthur Rylah Institute for Environmental Research
123 Brown Street, Heidelberg, Victoria 3084

February 2017

Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
Heidelberg, Victoria

Report produced by: Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
PO Box 137
Heidelberg, Victoria 3084
Phone (03) 9450 8600
Website: www.delwp.vic.gov.au

Citation: Menkhorst, P. 2017. Literature review: responses of Koalas to translocation. Arthur Rylah Institute for Environmental Research Technical Report Series Number 279. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Front cover photo: Releasing French Island Koalas from the transport crate, Tallarook State Forest, 8 November 2016. Photo, author.

ISBN 978-1-76047-569-7 (Print)
978-1-76047-570-3 (pdf/online)

Accessibility

If you would like to receive this publication in an alternative format, please telephone the DELWP Customer Service Centre on 136 186, email customer.service@delwp.vic.gov.au or contact us via the National Relay Service on 133 677 or www.relayservice.com.au. This document is also available on the internet at www.delwp.vic.gov.au

Contents

Acknowledgements 2

Summary 3

1 Introduction 4

2 Methods 7

3 Results 7

4 Discussion 24

References 25

Acknowledgements

This report was commissioned by Barwon South West Region of the Department of Environment, Land, Water and Planning. I am grateful to Andrew Pritchard and Gary Peterson for their support. I thank Jemma Cripps, Tim O'Brien and Vural Yazgin for helpful comments on a draft of this report.

Summary

A review is presented of published and unpublished literature relating to the responses of individual Koalas to translocation. Despite the decades-long history of Koala translocation in southern Australia, only seven studies document the outcomes of Koala translocation. The seven studies are in general agreement on the high survival rate of translocated Koalas when they are released into habitat patches of adequate size and quality. Koalas released into agricultural land or small (<100 ha) patches of forest have lower survival rates. All studies found that translocated males tend to move longer distances than do females, and that this can result in lower survival rates for males. Climate, soil fertility and density of understorey vegetation are habitat characteristics that should receive greater attention when release sites are being selected.

Lowest survivorship occurred in animals that had been surgically sterilised shortly before being translocated and this practice is not recommended: levonorgestrel-based contraceptive implants have been the method of fertility control used on Koalas in Victoria since 2004 (DSE 2004).

The apparent absence from French Island of the *Chlamydia pecorum* types commonly found in Victorian Koalas, and the recently discovered presence of a novel *C. precorum* type from a small number of French Island Koalas, raises new concerns regarding the acceptability of translocation as a means of controlling that Koala population.

1 Introduction

In the field of wildlife management translocation is defined as 'the human-mediated movement of living organisms from one area, with release in another' (IUCN SCC 2013). Translocation may be carried out for many purposes but most often flora and fauna conservation is the imperative.

In Victoria, translocation has been an important component of Koala management for more than 90 years (Menkhorst 2008). In that time, some 40 000 individual Koalas have been captured, transported and released at an unfamiliar location and often into a novel vegetation community. The purpose of translocating Koalas has evolved over the decades as the conservation status of the species has changed: originally, the sole purpose was to create island safe havens (i.e. marooning) for what was then considered to be a seriously threatened species; once island populations had been established, the purpose changed to a re-introduction program, which has been remarkably successful (Menkhorst 1995, Martin and Handasyde 1999, Menkhorst 2008). Finally, since the mid-1980s, the aims of Koala translocation have been twofold: to yield a measureable conservation benefit to the flora and fauna community being degraded by an over-abundance of Koalas, and to reduce the suffering of affected Koalas due to food shortage and other stressors associated with high population densities (Menkhorst 2008).

Despite the huge scale and duration of this management strategy, there has been little effort to determine its efficacy or the impact on individual Koalas. The fact that the Koala is now widespread in Victoria (Menkhorst 1995; Martin and Handasyde 1999) attests to the success of the marooning and re-introduction phases of Koala management (DSE 2004; Menkhorst 2008). Indeed, a major review of mammal translocation in Australia concluded that translocations of Koalas have the highest reported success of all vertebrate translocations attempted in Australia (Short 2009). However, there have been few science-based investigations into the fate of individual translocated Koalas and no compilation of the results of such studies that can inform future management strategies. Additionally, public attitudes to animal welfare are becoming more informed and closer public scrutiny of wildlife management can be expected. This is reflected in the recent creation of a Translocation Evaluation Panel within the Department of Environment, Land, Water and Planning (DELWP) charged with assessing proposals to translocate threatened fauna. The Koala is not listed as a threatened species in Victoria (DSE 2013) and so does not fall within the purview of the panel, however, given the high public profile of the Koala, it seems appropriate that Koala translocations receive a similar level of scrutiny to that applied to proposed translocations of threatened species.

In the context of the need to develop a plan to manage an existing Koala over-browsing issue at Cape Otway, and with evidence of impending Koala over-browsing at other sites in south-western Victoria (DELWP in prep.), the Barwon South West Region of DELWP commissioned a review of the scientific literature relating to the outcomes of Koala translocation.

The scope of this review is to examine the effects of management translocations on individual Koalas. It does not consider the case of individual animals rehabilitated after injury or illness and then returned to the wild.

1.1 Koala natural history relevant to translocation

Koalas are large and robust animals: in Victoria adult males frequently weigh more than 11 kg and adult females more than 9 kg – only kangaroos, large wallabies and the Common Wombat are heavier. Koalas have a robust and muscular body structure with a short, somewhat rigid trunk and relatively long limbs (see cover photo) (Strahan 1978).

Koalas feed almost exclusively on eucalyptus foliage, a poor quality food that requires them to expend considerable energy in digestion (Moore and Foley 2000). Koalas tend to prefer feeding on a small number of eucalypt species in a given location, but have been recorded feeding on a wide range of eucalypt species across Victoria – at least 26 (DSE 2004). Eucalypt foliage is also the main source of water for Koalas.

Koalas in southern Australia (i.e. Victoria and south-east South Australia) are larger and heavier, and their fur provides greater insulation, than Koalas from further north (Briscoe et al. 2015). Despite this, they are still sensitive to hot and cold weather and they show behavioural responses by seeking sheltered sites – shade and cool trunks in hot weather (Briscoe et al. 2014), and the lee side of branches and dense foliage in wind and rain.

Koalas are sedentary, patchily distributed and tend to browse on a group of 10-20 usually large trees. Maximum population densities and home range sizes are probably determined by the number, size and dispersal of preferred tree species at a given locality. Feeding, social behaviour and moving between trees occur mostly at night.

Koalas are mostly solitary within their home range and, although home ranges often overlap, trees are not normally shared. Tree-sharing does occur in the lead up to mating, and when food is scarce. Males are aggressive towards other males and access to females is determined, to some extent at least, by a dominance hierarchy based largely on body weight. Sex ratios (male:female) usually show a slight male bias (rations of between 0.55 and 0.60) and males are polygynous.

Koalas have good dispersal capabilities and can travel overland for many kilometres, including through inhospitable habitat such as farmland and *Pinus* plantations. However, dense understorey at ground level seems to present something of a barrier to movement and Koalas take advantage of tracks made by other fauna or people. Koalas are vulnerable when crossing roads, and to attack by dogs and (allegedly) cattle. Koalas cannot escape fast moving fire and are susceptible to radiant heat from even ‘cool’ burns. They cannot survive on scorched foliage following a fire.

Koalas are seasonal breeders and most births in Victoria occur in November, December or January. Except in rare cases of twins, only a single young is born per year. By about 36 weeks of age (usually late summer-autumn) the cub spends much time outside its mother’s pouch riding on her back. Cubs remain with their mother until about 11 or 12 months old, at which stage they weigh about 2 kg. They become steadily independent and have usually left the mother’s home range by age two.

Figure 1. Immediately after release at Tallarook State Forest, this French Island Koala began eating the first eucalypt leaves it encountered, juvenile leaves of *Eucalyptus globulus bicostata*, a taxon with which it was presumably completely unfamiliar. It consumed almost all leaves on the branch shown. Photo, author.

2 Methods

Reference material relating to Koala management has been collated by the author over several decades, including published and unpublished documents. This hard-copy material was searched and backtracking through the reference lists of those publications was used to source further information. This source of references was supplemented by a search of on-line scientific literature databases (ScienceDirect, Scopus, GoogleScholar) with the search string ‘koala and translocation’.

3 Results

Only seven studies of the fate of translocated Koalas were found (Table 1). They are documented in 4 unpublished reports, 2 theses and 4 papers. Two BSc (Hons) theses from South Australia are not included because only the abstracts could be sighted. Of the 7 studies, 4 were conducted by university-based researchers and 3 by Government agencies. Study 7 differed from the others in that it was an ‘in-situ’ translocation in which animals were moved only a few kilometres to a different part of French Island, meaning that habitat and climate at the release site were very similar to those of the capture site.

Study	Source population	Release site(s)	Years and duration
1. A.K. Lee et al.	French Island	Lysterfield Park, Phillip Island, Mt Alexander	1983-85 18-20 months
2. Santamaria PhD	French Island	Creswick State Forest, Enfield State Forest, Lal Lal State Forest	1997-99 26 months
3. South Australian Government	Kangaroo Island	Lower south-east South Australia	1997 8 months
4. Parks Victoria, Mt Eccles	Mt Eccles National Park	Drajurk State Forest, Lower Glenelg National Park	2002 up to 6 months
5. Parks Victoria, Snake Island	Snake Island, Corner Inlet	Gellions Run, South Gippsland	2002 5 weeks
6. Whisson et al. 2012	Kangaroo Island	Lower south-east, South Australia	1997-2007 variable
7. V. Lee 2013	French Island	French Island	2012 12 months

Table 1. Summary of the seven published studies of the outcomes of Koala translocations.

The following report reviews the ten primary documents, drawing out the major themes and conclusions, and then presents a summary of the management implications.

Study 1: Experimental translocation of Koalas to new habitat (1983-1985)

This series of studies, conducted by Professor A.K. Lee, Dr Roger Martin and Dr Katherine Handasyde from Monash University Department of Zoology, was the first science-based investigation of the outcomes of Koala translocation, 60 years after the Victorian Government began its re-introduction program. It investigated the criteria for successful translocation of Koalas by monitoring the results of four trial translocations of radio-tagged Koalas from French Island during 1983-85: two groups went to Lysterfield National Park and one group to each of Phillip Island and Mt Alexander Forest Park. The results are presented in an unpublished report (Lee and Martin, no date) and in the proceedings of a conference on the Koala (Lee et al. 1991). Information derived from both sources is summarised together here.

Methods

At Lysterfield, the two groups were translocated into forest in which unfamiliar eucalypt species were dominant, including areas of eucalypt plantation. This trial also tested whether social familiarity influences the success of a translocation. The Phillip Island translocation placed Koalas into a woodland of a familiar tree species, *Eucalyptus viminalis*, and into contact with a resident Koala population known to carry the disease Chlamydiosis. The Mt Alexander trial released Koalas into tall *E. viminalis/E. obliqua* woodland near the Koala's assumed altitudinal limit.

Lysterfield NP

Two groups were released in November 1983 and monitored until June 1985 (i.e. for 18 months), each with 5 males (3 adults, 2 sub-adults) and 7 females (all parous and 6 in each group had a back young). One group of 5 males and 7 females came from a discrete stand of *E. viminalis* on French Island and was assumed to represent a socially cohesive group (based partly on behavioural studies conducted there by Peter Mitchell, a PhD student of A.K. Lee at the time). The other group was assembled from individuals captured at different locations on French Island and therefore assumed to not form a social unit. The release area contained seven *Eucalyptus* species known to provide forage for Koalas – *E. camaldulensis, E. tereticornis, E. globulus, E. botryoides, E. viminalis, E. ovata* and *E. goniocalyx*. Both groups were released into stands with *E. ovata* as the dominant eucalypt, approximately 2 km apart. The Koalas were located every few days initially, then monthly. They were captured bimonthly for health assessment, including the taking of a blood sample. To obtain information on diet and day-to-day movements, each animal was located twice per day for five consecutive days approximately one month after release. Analysis assumed that the tree occupied during the day was the tree in which feeding occurred during the preceding and following nights, an assumption that is no longer considered valid (Woosnam-Merchez et al. 2012).

Phillip Island

Seventeen Koalas, 6 males and 11 females, were released on 21 November 1983 into Oswin Roberts Koala Reserve after all Koalas within the reserve had been moved to other parts of the island. Koalas were recaptured monthly until March 1985 (i.e. 18 months). This site had similar eucalypt species to the source site on French Island; it differed in that Chlamydia was present in the local Koala population.

Mt Alexander

Thirteen Koalas, 6 males and 7 females, 4 of which had dependent young, were released in December 1984 into the fenced Leanganook Koala Park – a 73 ha fenced reserve at 600-740 m altitude – where the Forests Commission of Victoria had attempted to establish Koalas over several decades (>500 released since 1941) but population density was low at the time of this release. Animals were located monthly but only recaptured at the end of study in August 1985 (20 months after release).

Results

Lysterfield

Once the Koalas had settled 'an appreciable proportion' of them used *Eucalyptus camaldulensis* and *E. goniocalyx*; species they were unfamiliar with. There was no evidence that the animals were impaired either as a result of translocation or as a consequence of this change in diet. Survival of adults and their back young was high following their release; 12 of the 14 females had dependent young when translocated and all back young were successfully weaned. Most adults maintained body weight, and growth rates of juveniles and sub-adults were at least comparable to similar-aged animals on French Island. Blood parameters generally improved.

Fecundity in the first breeding season after release was high but declined in the second, associated with an increasing seriological antibody titre to Chlamydia. From this the authors concluded that the success of translocations of Chlamydia-free Koalas will be appreciably reduced where they are released into areas where infected animals are present.

At least one third of the animals eventually settled into the north-east corner of the park in natural forest containing *E. viminalis* and *E. ovata*, species they browse upon on French Island. However, the dispersal of the other two thirds from *E. ovata* into areas with unfamiliar eucalypt species suggests that dietary fastidiousness was not the sole cause of dispersal. Based on tree species availability, the translocated Koalas showed a preference for *E. ovata*; *E. camaldulensis* was used roughly in proportion to its availability.

There was no evidence that social familiarity had any influence of the success of the translocation or on subsequent dispersion, except for a single observation of one female, presumed to be in oestrus, moving 2 km to the vicinity of two males from her familiar group.

At the end of breeding season after release (April 1984) 10 of the 11 females still being monitored had pouch young. The female that failed to breed had antibodies to Chlamydia by mid 1984. Of the 10 young at least 5 were weaned. Growth rates of these young while in the pouch were similar to those on French Island, but were superior to French Island once they had left the pouch.

At end of the 1985 breeding season, 5 of 8 females (63%) still being monitored had pouch young but the study ended before these were weaned.

Growth rates were obtained for two 2-year-old males and one 3-year-old male. Growth rates of the 2-year-olds were similar to equivalent animals on French Island, the 3-year-old grew more rapidly than French Island animals.

Males tended to disperse further than females in the first few weeks. By Jan 1984 [~2 months after release] most animals had settled into a home range of 1-2 ha, and in most cases remained there for the duration of the study. Five animals (2 males, 3 females) settled into natural forest, 7 into *E. camaldulensis* plantation (2 males, 5 females). The remaining 3 had home ranges that included both habitats. There were no obvious differences in condition or fecundity between animals in either habitat.

Note that the effectiveness of the trial was reduced by the high failure rate of the radio collars, due to defective moisture sealing. This was resolved in the other trials which began later.

Phillip Island

Females settled in the vicinity of their release site. Female daily movements were small compared to animals released at Lysterfield – probably reflecting the abundance of the familiar food trees (notably *E.*

viminalis). Males, on the other hand, dispersed from the release site and their survival (66.7%) was lower than for females (100%).

Most (71%) females bred successfully in the season after release and five resulting young reached independence. In the second season after release only 23% of females bred and two of these showed antibodies to Chlamydia by April 1984, but the other 4 had not seroconverted by March 1985. The two infected females probably became infected when they mated with local males that by this time had invaded the release site. This is a further illustration that the presence of infected Koalas at a release site will reduce the effectiveness of the translocation [note that this conclusion assumes that the aim of the translocation is to establish a new or enhanced population]. The mortality rate of the entire group was 12%.

All nine females with continuous records throughout the study either maintained or increased body weight, 3 surviving males maintained body weight. Growth rates of 5 pouch young did not differ from those on French Island in the first 9 months of life.

Seventeen days after release all adult males had dispersed, up to 2 and 2.5 km. 60 days after release a sub-adult male and most females remained within 200 m of release point. One 2 yr old female had moved 1.4 km and the remaining 4 adult males had moved 0.5, 1.7, 1.9 and 4 km.

Mt Alexander

Two animals died during the study, an old female and a male; another old female failed to breed and lost body weight. Breeding success was poor, however, sub-adults and juveniles grew at similar rates to their French Island equivalents. Four animals 'escaped' from the park despite the presence of a Koala proof fence, and dispersed between 500 m and 3 km to more sheltered sites.

Study conclusions

- Koalas did not appear to be impaired by translocation, or as a consequence of a change in diet.
- Survival of adults and back young was high following release and 'in no instance was mortality directly attributable to the effects of translocation.'
- Most adults retained body weight and growth of juveniles and sub-adults was similar to or better than animals in the source population.
- Mixed-species eucalypt forests containing known browse species, even as minor components, are suitable as release sites.
- Changed blood chemistry may be indicative of improved nutrition after translocation, and may relate to deficiencies on French Island where the soils are old, leached sands, impoverished in trace elements.
- Fecundity in the first breeding season after release was high but declined subsequently as an increasing proportion of the animals were infected with Chlamydia.
- The likelihood of successful establishment of a new population will be significantly reduced if animals become infected with Chlamydia.
- Even populations in which Chamydia infection has reduced the fertility rate to 40% can increase to the point where they defoliate their food trees, for example, on Phillip Island between 1930 and 1978.
- Males disperse more – they may have a stronger site attachment and go looking for home. Handasyde (1986) reported that a number of the Koalas removed from Oswin Roberts Reserve to elsewhere on Phillip Island recolonised the reserve over the subsequent 15 months.
- Females search for familiar tree species but successfully adapt to unfamiliar ones.
- Koalas may be able to detect one another over considerable distances via male bellowing – 2.6 km at Lysterfield – so it is likely that resident and translocated individuals will come into contact.
- Animals less than 10 yrs old [tooth wear class IV or less] should be selected for translocation.
- Winter weather may affect growth and survival of pouch young in Koalas translocated in early autumn.

Study 2: Outcomes and implications of a Koala translocation in the Ballarat region (1997-1999)

In this PhD study Flavia Santamaria investigated the hypothesis that 'translocation does not impact on Koala's health and/or survivorship'. The approach was to monitor the fate of 30 radio-collared Koalas translocated from French Island to forests in the Ballarat area in October 1997. Results are presented in a thesis (Santamaria 2002) and two papers (Santamaria et al. 2005; Santamaria and Schlagloth 2016).

Methods

The study group comprised 20 females - 10 sub-adult and 10 adult (5 had a back young and 1 had a pouch young) and 10 males - 5 sub-adult and 5 adult [sub-adult refers to independent animals between 1 and 3 years old]. Health status, including *Chlamydia* status, was checked at time of capture on French Island and at recapture after 6 months (April 1998); 19 months (May 1999) and 26 months (Dec 1999). The three release sites were:

Creswick State Forest - 5 ad (2 females, 3 males), 5 sub-ad (3 females, 2 males)
Enfield State Forest: - 5 ad (3 females , 2 males), 5 sub-ad (3 females , 2 males)
Lal Lal State Forest: - 5 ad (4 females, 1 male), 5 sub-ad (4 females, 1 male)
Adults were released at a separate site to sub-adults, 2 km apart.

Results

Survival and Movements

Twenty-four percent of Koalas are known to have died during the study and 47% were followed until the end of the study period. Contact was lost with the remainder – this group includes 6 of 9 males aged between 2 and 5 years, ie. not fully grown. Fourteen Koalas [12 females, 2 males] were followed for the entire study. Seven others died, 8 were lost due to transmitter failure or loss of collar, and one animal was unable to be monitored after its collar was removed due to a 'small skin abrasion'. The death rate differed between the 3 release sites – Creswick 0%, Enfield 20%, Lal Lal 50% [30% in the first 4 weeks]. The cause of death could be established in 6 cases: 2 human influence – 1 shot, 1 road kill; 2 misadventure [1 dislocated shoulder, 1 collar caught on broken branch]; 1 starvation; 1 old age.

Six of 16 females aged between 2 and 7 years were recorded with progeny after the first mating season post release, and 3 of these are known to have survived until the end of the study. During the third recapture, 19 months post release, one of the 12 females had a pouch young, another had a young dead in her pouch.

Weight changes

Six months after release, 16 of 25 Koalas showed weight increases, range 6.6-40%. Two females had lost weight (10.5 and 11.1%) and the remaining 7 Koalas were unchanged. There was no significant difference in weight change between the 3 release areas. Rates of weight increase were highest in the first 6 months post release. There was a significant negative correlation between weight change and age.

The longest dispersal distance was 25 km. Many animals did not settle into an established home range but continued to travel widely.

Chlamydia

All 30 animals were antibody –ve (ELISA<1) at the beginning of the study. After 6 months, 56% (9/16) of females and 33% (3/9) of males were antibody +ve (ELISA>1). This indicates that *Chlamydia* was present at the 3 sites, presumably in resident Koalas and was transmitted sexually. There were significant differences in seroprevalence between release sites after 6 months – 20% (2/10) at Enfield, 60% (6/10) at Creswick and 80% (4/5) at Lal Lal. Cell culture and Direct Immunoflourescence (DIF) failed to detect chlamydia organisms.

After 19 months, *Chlamydia* antibody titre had further increased in 13 of 14 Koalas. Nine of 13 animals also were +ve for DIF and/or cell culture, indicating the presence of chlamydia organisms at the uro-genital site. Although all Koalas bar one were antibody positive by the end of the study, none exhibited any external clinical signs of *Chlamydia* and all appeared healthy. However, the females failed to breed during the second breeding season post release. Both *C. pecorum* and *C. pneumonia* were detected with *C. pecorum* more common [8 of 9 animals tested compared to 2 of 9 for *C. pneumonia*]

Tree use

Release sites were chosen partially because they contained different tree species to French Island but had some scattered *E. viminalis* [but Table 4.1 in Santamaria (2002) seems to contradict this]. Translocated Koalas were found in a wide range of tree species, indigenous and exotic [and assumed to be feeding on the tree in which they were found during daytime, a questionable assumption], even though the frequencies of some of these species in the forest were low. When *E. viminalis* is present it 'appears to be highly preferred'.

The presence of a variety of potential forage species could be one way to mitigate over-browsing of a particular species by translocated Koalas. The most preferred species, *E. viminalis* and *E. ovata*, should be at relatively low density.

The released Koalas seemed to select larger trees (see also Santamaria et al. 2005). At Lal Lal mean dbh of Koala trees was 45 cm, compared to the overall mean of 30 cm. At Enfield the equivalent figures were 42 cf 26 cm and at Creswick, 49 cf 42 cm.

Study outcomes

- Of the 47% of animals followed throughout the study, only one female was chlamydia-free at the end of the study and she was the only female to successfully reproduce during the 2nd breeding season following release. The progeny of the infected females were also chlamydia positive.
- Chlamydiosis is the major concern with translocation – taking animals to the disease is just as unacceptable as taking the disease to the animals [as has been suggested for French Island].
- Translocated animals maintained or increased body weight over the duration of the study.
- Translocated animals used a variety of tree species but when present *E. viminalis* seemed to be preferred.
- Translocated Koalas preferred the larger trees in a stand.
- Survivorship was reasonable – seven of the 30 study animals are known to have died during the study but half of these occurred at Lal Lal [30% in the first 4 weeks]. The cause of death could be established in 6 cases: 2 human influence – 1 shot, 1 road kill; 2 misadventure [1 dislocated shoulder, 1 collar caught on broken branch]; 1 starvation; 1 old age.

Study 3: Koala responses to translocation to the south east of South Australia, particularly in Red Gum dominated vegetation (1997-1998)

This study took place early in the intensive Koala management program on Kangaroo Island as part of an assessment of management options. It followed the fate of 20 Koalas relocated from *E. viminalis/E. leucoxylon* habitat on Kangaroo Island to two sites in the lower south-east of South Australia in August 1997 (Clark 1998). Ten animals (5 male, 5 female) were released on a grazing property with scattered *E. camaldulensis* and the other 10 (5 males, 5 females) went to Topperweines Native Forest Reserve, a woodland dominated by *E. camaldulensis* with *E. viminalis, E. arenacea and E. ovata*. It is not stated that these 20 Koalas had been sterilised prior to translocation, so I presume that they had not, but they may have been because that was the standard procedure in the Kangaroo Island Koala Management Program.

Results

Home range analysis (70 & 90% isopleths) indicated that home range size tended to increase after translocation, particularly in males. Koalas at the grazing property all dispersed from their release site, and only two established and maintained a consistent home range. At the forest reserve, individual animals showed a preference for different habitat types – three of the 10 preferred the original release site; four used a neighbouring patch of *E. camaldulensis* and three animals left the forest reserve (no indication is provided of where they went). *Eucalyptus viminalis* remained the preferred browse species of Koalas at the forest reserve and some *E. viminalis* showed early signs of defoliation. Mortality over the eight months of the study was 15%, and most animals maintained body weight.

Outcomes

The author concluded that scattered *E. viminalis* and vegetation containing even a minor component of *E. viminalis* may not be suitable release sites.

Study 4: Post-release monitoring of surgically sterilised and relocated Koalas, Mt Eccles National, Park, Victoria (2002)

This large and ambitious study conducted by Parks Victoria assessed a Koala management regime at Mt Eccles National Park that included both surgical sterilisation and translocation (Anonymous 2003a). Two separate post-release monitoring trials were conducted in conjunction with Parks Victoria's autumn 2002 sterilisation and relocation program, and spring 2002 sterilisation program which released Koalas back to the National Park. The questions to be investigated were (but note that question 3 was not reported on):

1. What is survival rate of sterilised Koalas?
2. What are survival rates of translocated intact and translocated sterilised Koalas?
3. How do survival rates of translocated Koalas in other monitoring studies compare to this study?
4. Does the initial condition of Koalas impact on their health and rate of survival?
5. Does the health of the Mt Eccles National Park Koala population change seasonally?
6. What blood parameters and values indicate poor health in Koalas?

Key issues that, *a priori*, were thought likely to affect the health and survival of translocated Koalas were: surgery, stress of capture and translocation, suitability of habitat into which animals were released, and prevailing weather conditions at the release site.

Methods

Two programs were run:

1. Autumn 2002 sterilisation and relocation program – involved the translocation of surgically sterilised females and intact (fertile) males.
2. Spring 2002 sterilisation program – both sexes surgically sterilised and released into Mount Eccles National Park [not clear whether this was at site of capture or not – therefore, I suspect it was not]

Sterilisation of females was achieved via laparoscopy transection and cautery of fallopian tubes. Male sterility was achieved by vasectomy. All animals were relocated within 30 hrs of capture and surgery.

Program 1

Between 9 and 19 April 2002, 22 animals (11 sterilised females and 11 intact males) were translocated to each of 2 sites – *E. camaldulensis* woodland in Drajurk State Forest, and tall mixed lowland forest in Lower Glenelg NP. Dominant tree species in the tall mixed lowland forest included *Eucalyptus willisii, E. baxteri, E. obliqua* with some *E. viminalis*. This vegetation was also characterised by an 'extremely dense layer of shrubs and small trees and a dense ground layer of heathy sub-shrubs and bracken'. Eleven sterilised females were also released at point of capture in Mount Eccles National Park. All females were without young. All 55 animals were radio-collared and tracked until October 2002 (i.e. for 6 months through the winter and spring).

All Koalas were recaptured at 1 week post release, 3-4 weeks post release, and then at ~2 month intervals. Recaptured animals were weighed, measured [head length], blood sampled and breeding condition was assessed. Koalas that lost >10% of original body weight were taken into care and then returned to Mount Eccles National Park if they regained condition. In the analysis these animals were treated as mortalities.

Program 2

In September 2002, 39 females were captured, given one of 3 treatments (see below) and their movements, health and survival monitored for 6-8 weeks.

Sterilised group – 13 females captured, transported to surgery, anaesthetised, measured, radio-collared, surgically sterilised, held overnight and released the following morning at their site of capture.

Handled group – 13 females captured, transported, anaesthetised, radio-collared, held overnight and released the following morning at their point of capture, i.e. not surgically sterilised.

Control group – 13 females captured, radio-collared and immediately released.

All Koalas were located via radio-telemetry once a week for 6-8 weeks. Following some mortality in the sterilised group all remaining animals in that group were recaptured and those requiring veterinary treatment were taken to Melbourne Zoo.

Results

Survival of sterilised Koalas

Surgical sterilisation affected the health and survival of Koalas, regardless of whether or not they were translocated. In program 1, 45% of sterilised but not translocated females died or were taken into care within 30 days of release. In Program 2, 46% of females in the sterilised group had died or lost >10% body weight (and been taken into care) within 30 days of release. There was no evidence that operational procedures involving capture, transport and holding of animals overnight had adverse effects on survival. Many of the dead animals had empty stomachs at death and it was considered that, in 20 of the 26 mortalities, the cause of death was consistent with 'Koala stress syndrome' (Obendorf 1983) – dehydration, loss of appetite, and loss of muscle mass.

The effect of habitat on survival

There was great variation in survivorship between release habitats – survival to 30 days was 95% at the *E. camaldulensis* site, but only 14% at the mixed forest site.

One animal released at the *E. camaldulensis* site travelled a minimum of 53 km over 6 months. Both males and females travelled through a wide range of unfamiliar habitats and were not impeded by large areas of unsuitable habitat including 'forestry plantations' [it is not clear whether this term refers to pine plantation, eucalypt plantation or both], farmland and *E. baxteri* forest. At the mixed forest site it was suggested that the dense heathy understorey impeded dispersal to other habitats and many animals may have died from a combination of starvation and exhaustion as they tried to disperse to more suitable habitat. Both sterilised females and non-sterilised males suffered similar mortality rates.

Changes in body weight and body condition

Changes in body weight and condition varied substantially within and between treatments. Animals released at the Red Gum site showed no significant mean difference in body weight between intitial and first recapture, for either sex, while those at the mixed forest site and those returned to their site of capture showed significance declines in body weight.

Study conclusions:

- Koalas that were nutritionally compromised and/or in poor body condition were less likely to survive the impacts of sterilisation and translocation.
- Surgical sterilisation had the greatest direct impact on the health and survival of Koalas from Mount Eccles National Park, but the quality of the habitat at the release site was also critical. There was no evidence that capture, handling and transport caused mortality.

- Characteristics of the release site are critical to survival – habitat selection by Koalas may be more complex than recognised by current criteria, e.g. the abundance of preferred browse species and density of understorey should receive closer attention.
- Across all treatments the majority of Koalas that died had lost weight, were in poor condition and had empty stomachs – the factors that caused the Koalas to be in that condition could not be determined.
- Koalas are capable of dispersing long distances and little is known about the factors that influence whether or not an animal will settle at a site – the size and quality of habitats outside the release site may also influence long-term survival.

Study 5: The impact of relocation on the health and survival of sterilised adult female Koalas (*Phascolarctos cinereus*) at Snake Island and Gellions Run, Nooramunga Marine and Coastal Park (2002)

This study, conducted by Parks Victoria, aimed to monitor the effects of capture, transport and relocation on the health and survivorship of adult female Koalas from Snake Island that had been sterilised in previous management programs (Anomymous 2003b). The Koalas were relocated from Snake Island to Gellions Run – an area of 3,244 ha on the nearby coast. Gellions Run was considered an ideal release site because of its proximity to Snake Island (minimises travel time), comparable climate and vegetation (coastal barrier heathy woodland with *E. viminalis pryoriana* dominant) and the 'natural' Koala population was 'very small'[1].

Methods

Sixteen females that had been surgically sterilised in either spring 2000 (3 animals) or spring 2001 (13 animals) were recaptured on 15-16 October 2002, held in crates overnight, then measured and scored for body condition, blood sampled and radio collared. Eight of these were translocated; the other 8 controls were released at site of capture. The study animals were tracked and monitored weekly, beginning on 21 Oct 2002, and were recaptured beginning on 25 November 2002 for the control group and 3 December for the treatment group. Morphometric data, condition scores and blood samples were taken. The authors then compared the total distance travelled after 34 days and mean daily distance travelled, both within and between treatment and control groups.

Results

All animals survived the study period. Blood values for all Koalas were normal at the start of the trial and remained so in all but one translocated animal, however, the changes in this animal were considered mild.

Most animals in both treatment groups lost weight during the trial but in most cases this was <10% and considered to be within the limits of normal variation. One animal had lost 12% of body weight by the end of the trial (49 days; 15 October to 3 Dec for translocated animals). Changes in muscle and coat condition scores were minor for both groups. After 34 days, relocated Koalas had, on average, travelled over 3 km, almost twice as far as the control animals. Mean daily distance moved was 84 m for translocated Koalas and 51 m for the control group.

Study Conclusion

Despite small sample sizes, it is reasonable to conclude that relocation of previously sterilised female Koalas does not pose a significant risk to individual animals in the short term, when conducted under strict criteria governing capture, handling and transport.

[1] Note that this release site does not meet the criteria applied in Victoria's Koala Management Strategy (DSE 2004) (which was not in force at the time the translocations took place) because the it is within the South Gippsland exclusion zone and is dominated by *E. viminalis*.

Study 6: Whisson, D.A., Holland, G.J. and Carlyon, K. Translocation of overabundant species: Implications for translocated individuals (2012)

This study analysed post-release densities, survival and movements of Koalas that had been surgically sterilised (tubal ligation and vasectomy) and moved from Kangaroo Island to the lower south-east of South Australia between 1997 and 2007. Native forest covers ~7% of the lower south-east region so suitable release sites were difficult to find.

Methods

Thirty-five release sites were selected in the lower south-east of South Australia that were considered to be of high habitat quality – forest blocks of at least 10 ha dominated by healthy *E. viminalis* [2]. Translocations took place from January to May in most years, and sometimes in the preceding December.

Survival and density

1. Selected a random subset of 16 release sites for annual monitoring – 2001, 2002, 2004-2007. A single observer systematically searched 'a 5 ha area' and recorded the number of Koalas. No information is provided on how the 5 ha area was selected and I assume that only one 5 ha sample was taken per site across the 16 sites.
2. During 2006 surveys of Koala density were conducted 3 months before releases took place and 1 month after, at 11 of the 16 sites plus 14 others where releases occurred.

Effect of immediate vs delayed translocation after sterilisation on short-term [12 week] survival and movement.

Delayed translocation – used 6 females and 4 males surgically sterilised >1 year before translocation. Immediate translocation – used 6 females and 9 males translocated on the same day that they had been surgically sterilised. Only animals with good muscle condition and a tooth wear class of IV were included in the study. Animals were translocated on 17 Dec 2004 and 21 Jan 2005, with Koalas from each treatment group represented in each translocation. They were radio-tracked daily in first week, then bi-weekly, then weekly until April 2005 (~3 or 4 months post release) when surviving animals were captured for weighing and assessment of muscle condition.

Translocated animals vs residents on Kangaroo Island

Compared the survival of intact animals on Kangaroo Island (8 females, 5 males) to that of Koalas surgically sterilised and translocated on the same day (8 females 8 males). Animals were translocated on 20 April and 2 May 2007. All individuals were located daily for the first week, weekly for next 7 weeks, then monthly until collars were removed in June 2008.

Results

Population density at release sites

Each year, densities were <0.3 Koalas/ha throughout the region and ≤0.4/ha at sites where Koalas had been released in the corresponding season. Densities remained low despite consistent releases, comprising 1686 individuals, between 2005 and 2007.

[2] Note that the Victorian guidelines for selecting Koala release sites (DSE 2004) require that the forest be at least 1000 ha in extent, have treed links to other forest areas and that *E. viminalis*, if present, is not the dominant species of *Eucalyptus*.

Immediate vs delayed translocation after sterilisation (2004/05)

All Koalas survived the first 4 weeks after translocation but 2 deaths were recorded for the immediate group at 3 months post release (8% of all translocated animals (2/25) and 13.3% of the immediate group (2/15). Treatment was not identified as a significant factor in distance moved. Over the 12 weeks of the study males moved greater distances than females. At 4 weeks post translocation, 56% of Koalas had moved >1 km from their release site (41.7% of females; 69.2% of males). This increased to 76% at 12 weeks (58.3% of females; 92.3% of males). One male had moved 8.5 km after 12 weeks.

Translocated individuals vs residents

Six of 16 animals (37.5 %) sterilised and translocated to the mainland died during the 12 month radio-tracking period. Two deaths occurred within the first 3 months, the other 4 occurred 3-12 months after translocation.

Over the same period, no deaths of the intact animals returned to their home range occurred. Therefore, mortality was greater than expected in the surgically sterilised and translocated group. Animals that were sterilised and translocated moved at a greater rate over time than those left intact on Kangaroo Island: 18.8% had moved >1 km after 4 weeks compared to 7.7% of animals monitored on Kangaroo Island.

Biochemical and haematological parameters of Koalas at first capture were within the range of reference values for healthy Koalas as defined by Canfield et al. (1989) and did not vary between survivors and non-survivors.

NB: in the Discussion it is admitted that unseasonably [their word – the releases were in April and May] cold weather (minimum temps <8°C) occurred in the week following the releases in the 2007-08 study. Four out of 6 translocated Koalas died at this time. Therefore, the high mortality rate could have been due to the combined effects of the invasive surgical sterilisation procedure combined with unseasonably cold weather experienced by the translocated animals.

Study 7. An investigation on *in-situ* management of overabundant koala populations in Victoria (2013).

The relevant aim for this MSc study (Lee 2013) was: to understand welfare outcomes and broad movement patterns for koalas after *in-situ* translocation as part of management.

In-situ translocations were defined as the transfer of individuals on a very local scale so that habitat and climatic conditions are very similar to the source habitat, i.e. in this case transfer within French Island. An ex-situ translocation would involve removing animals from French Island.

Methods

Twenty adult females all with back-young (i.e. fertile) were captured, contracepted and radio-collared during Aug-Oct 2012. All animals were in good condition and had tooth-wear categories between II and IV. Half the animals were released at point of capture, the other half translocated to one of several alternative habitat patches on French Island. Attempts to recapture all study animals were made after approximately one month, 6 months and 12 months.

Results

No mortality was recorded in either the control or treatment groups while they were being monitored via radio-telemetry. Further, at the end of the study there was no significant difference between the control and translocated groups in percentage change from initial body weight.

After 12 months most of the translocated individuals appeared to have settled at a new site. The translocated group were a mean distance of 3062 ± 1522 m from their release site; the equivalent figure for the control group was 100 ± 21 m from their release point after first capture. Two individuals in the treatment group moved large distances for females – 7.18 km to its original capture site and 8.36 km. Most back young from both groups were estimated to have reached independence – 7 of 9 young of females in the control group and 9 of 10 young of females in treatment group.

Study Conclusions

- This study found high survival in both adults and dependent juveniles that were translocated.
- Translocated adults moved greater distances from their release point before settling into new habitat compared to control animals that were returned to their original capture site.
- In terms of potential impact of management intervention on the survival and health of koalas, the present study could be considered a 'best case scenario', because animals are translocated *in-situ* (locally) into known good quality habitat and familiar climatic conditions.
- Despite the small sample size and relatively short term of this study, the resultant high survival rates indicate that *in-situ* translocation of adult female koalas following contraceptive treatment is an appropriate and more humane management strategy for koalas than *ex-situ* translocation.

3.1 Insights derived from the seven studies

3.1.1 Selection of individual animals to translocate

Tooth Wear Class

Only animals with a tooth wear class of ≤4 should be translocated (Lee and Martin no date, Lee et al. 1995).

Sex ratio

Study 1 concluded that females seem to be able to locate males, even in dispersed populations, so the sex ratio of the translocated group is not critical (Lee and Martin no date, Lee et al. 1995). However, given that males are polygynous and will fight over females, it would seem prudent to not have a strong male bias in the translocated group.

Role of social familiarity

Study 1 found that social familiarity did not increase the success of a translocation, or reduce dispersal from the release site. This suggests that a sample of animals drawn from several sites will be just as effective as animals drawn from the same site (Lee and Martin no date, Lee et al. 1995).

3.1.2 Impact of translocation on individual Koalas

Survivorship

Survivorship after release was usually high for both adults and back young, however, there were a few instances of low survivorship: these occurred when translocation closely followed surgical sterilisation, or were related to habitat quality at the release site or inclement weather following release.

Study 1 concluded that Koalas did not appear to be impaired by translocation, or as a consequence of a change in diet (Lee and Martin no date). Study 2 found that most adults retained body weight and growth of juveniles and sub-adults was similar to, or better than, animals in the source population (Santamaria 2002). This is not unexpected because the source population on French Island was inhabiting degraded, over-browsed habitat. Study 7 showed similar results (Lee 2013) but this 'in-situ' translocation would be expected to be more benign.

Study 4 showed that surgical sterilisation had the greatest direct impact on the health and survival of translocated Koalas, but the quality of the habitat at the release site was also critical. There was no evidence that capture, handling and transport caused mortality (Anonymous 2003a).

Studies 1 and 7 found no evidence of negative consequences of translocating females with pouch young or back young, as long as the mother-young pairs do not become separated (Lee and Martin no date, Lee et al. 1995, Lee 2013).

Prior sterilisation

In study 4, mortality was greater than expected in the surgically sterilised and translocated group (there was a maximum of a few hours between sterilisation and translocation) (Anonymous 2003a). When a gap of 12-24 months is left between surgical sterilisation and translocation (study 5) there was no detectable effect of sterilisation on translocation outcomes (Anonymous 2003b).

No study has specifically addressed the impact of a combination of the application of hormonal implants (rather than surgical sterilisation) and immediate translocation, but this has been standard practice in Victoria for over 12 years without any evidence of negative consequences for the animals concerned.

Health Impacts

All studies agreed that animals in poor health should not be translocated (see Lynch and McLean 2004 for health criteria and parameter values). Koalas that were nutritionally compromised and/or in poor body condition were less likely to survive the impacts of sterilisation and translocation (Santamaria 2002).

Translocated Koalas often maintained or increased body weight over the duration of a study. The authors of study 1 suggested that changes detected in blood chemistry may be indicative of improved nutrition after translocation, and may relate to deficiencies on French Island where the soils are old, leached sands, impoverished in trace elements (Lee et al. 1995).

Studies 1 and 2 identified Chlamydiosis as the major health concern with translocation; both used animals from the *Chlamydia*-naive French Island population. In study 2, fecundity in the first breeding season after release was high but declined subsequently as an increasing proportion of the animals were infected with *Chlamydia*. Of the females followed throughout the study, only one was *Chlamydia* free at the end of the study (after 26 months) and she was the only female to successfully reproduce during the second breeding season following release. The progeny of the infected females were also *Chlamydia* positive (Santamaria 2002, Santamaria and Schlagloth 2016).

3.1.3 Factors potentially affecting success

Season

Study 1 indicated that translocations should be scheduled for early or late summer when conditions favour survival of the translocated animals. In October and November the majority of young are back young but are within a month of independence (Lee and Martin no date, Lee et al. 1995) and few pouch young would be expected to be present. While weather conditions are often favourable in early autumn (March/April), females usually have small pouch young at this time. Younger pouch young may be more sensitive than older young to changes in the mother’s nutritional status, a possible consequence of translocation. Adverse weather in late autumn and winter may affect the growth and survival of the pouch young of females translocated at this time (Lee and Martin no date, Lee et al. 1995).

Weather at time of translocation

Translocations should be avoided when the ambient temperature is likely to rise above 35°C because Koalas suffer hyperthermia when captured and confined under these conditions. Koalas should not be captured on wet days and wind chill should be avoided when Koalas are translocated, particularly on wet days (Lee and Martin no date, Lee et al. 1995).

Habitat quality

Characteristics of the release site are critical to survival – habitat selection by Koalas may be more complex than recognised by historically-used criteria that mostly relate to presence of known browse tree species and climate. Abundance of preferred browse species, soil fertility and density of understorey should also be considered (Anonymous 2003).

Eucalypt species community

Studies 1 and 2 concluded that mixed-species eucalypt forest containing known browse species, even as minor components, is suitable to receive translocated Koalas (Lee and Martin no date, Santamaria 2002). Study 2 found that translocated animals used a variety of tree species but, when present, *E. viminalis* seemed to be preferred (Santamaria 2002). Study 3 reached a similar conclusion and, based on evidence of incipient over-browsing, concluded that scattered *E. viminalis* and vegetation containing even a minor component of *E. viminalis* may not be suitable release sites (Clarke 1998). Study 4 provided a seemingly anomalous result of poor survivorship (14%) in a mixed species release site, however, these animals had been surgically sterilised immediately before translocation and the quality of the habitat was suspect for other reasons, such as the dense shrub and ground layers.

Adaptability to unfamiliar eucalypt species

All studies found that Koalas readily utilise unfamiliar forage tree species. Koalas also seemed to readily adapt to trees with far different structure to those they were familiar with, for example, Koalas from French Island used trees that were much taller and of much greater girth than they had previously experienced. Indeed, Study 2 found that translocated Koalas preferred the larger trees in a stand (Santamaria et al. 2005).

Surrounding habitat matrix

Koalas are capable of dispersing long distances and little is known about the factors that influence whether or not an animal will settle at a site – the size and quality of habitats outside the release site may also influence long-term survival (Anonymous 2003a).

Dispersal after release

All studies involving both sexes found that males disperse further than females.

Koalas may be able to detect one another over considerable distances via male bellowing – 2.6 km at Lysterfield – so it is likely that resident and translocated individuals will quickly become aware of each other and will come into contact (Lee and Martin no date, Lee et al. 1995).

4 Discussion

Despite the rather low level of assessment of the efficacy and humanness of Koala translocation, there is a reassuring level of agreement in the outcomes of these six studies. In general, Koalas appear to be robust to the rigours of translocation, perhaps more so than most other Australian mammals, and no study detected a problem with the process of translocation itself. Although often considered to be dietary specialists, several of the studies provided clear evidence of a capacity to quickly adapt to unfamiliar eucalypt species. However, other measures of habitat quality need to be given greater weight in the process of selecting potential release sites. These include climate, particularly rainfall, altitude, soil fertility and understorey density.

Many translocated Koalas explore the area in which they have been released to select a patch of higher quality habitat. Other individuals, mostly males, undertake much longer movements and these individuals tend to have a lower survival rate.

The most problematic translocations were those in which surgical sterilisation narrowly preceded translocation (study 4), and this practice has been discontinued (DSE 2004 page 12).

Defining success in Koala translocations

The definition of success of any management action is obviously a function of the aims of the action. When translocation is used to reduce the density of overabundant animal populations, success is often measured at the source population and may include parameters such as reduced population density, improved health of remaining individuals, recovery of degraded habitat. However, Whisson et al. (2012) point out that the fate of translocated individuals should also be considered so that measured benefits at the source can be counterbalanced by the health and well-being of the translocated individuals.

Impacts of disease on translocation strategy

French Island is the only Koala population in Victoria that is considered to be *Chlamydia* free, although this assumption has recently been challenged (Legione et al. 2016). Therefore, the humanness of translocation from French Island remains a point of contention because *Chlamydia* naïve animals, particularly females, can suffer severe symptoms when they first encounter the disease. *Chlamydia*-naïve females translocated to areas where *Chlamydia* is prevalent may be rendered infertile within 12 months if they mate with local males (studies 1 and 2). Translocations from other sites in Victoria can be assumed to not involve *Chlamydia*-naïve animals.

Santamaria (2002) makes an important point regarding the disease Chlamydiosis – taking naïve animals to the disease is just as unacceptable from an animal welfare perspective as taking the disease to *Chlamydia* free populations, as has been suggested as a management strategy for French Island, but rejected in Victoria's Koala Management Strategy (DSE 2004).

References

Anonymous (2003a). Post-release monitoring of surgically sterilised and relocated Koalas, Mt Eccles National Park, Victoria. Unpublished report by Parks Victoria.

Annomymous (2003b). The impact of relocation on the health and survival of sterilised adult female Koalas (*Phascolarctos cinereus*) at Snake Island and Gellions Run, Nooramunga Marine and Coastal Park. Unpublished report by Parks Victoria.

Briscoe, N.J., Handasyde, K.A., Griffiths, S.R., Porter, W.P., Krockenberger, A. and Kearney, M.R. (2014). Tree-hugging koalas demonstrate a novel thermoregulatory mechanism for arboreal mammals. *Biology Letters* 10: 20140235.

Briscoe, N.J., Krockenberger, A., Handasyde, K. and Kearney, M. (2015). Bergmann meets Scholander: geographical variation in body size and insulation in the koala is related to climate. *Journal of Biogeography* 42: 791-802.

Canfield, P.M., O'Neill, M.E. and Smith, E.F. (1989). Haematological and biochemical reference values for the koala (*Phascolarctos cinereus*). *Australian Veterinary Journal* 66: 324-326.

Clark, S. (1998). Koala responses to translocation to the south east of South Australia, particularly in Red Gum dominated vegetation. P 14 in *Review of Koala Management Program on Kangaroo Island*, 28-29 May 1998. Biodiversity Branch, Department of Environment, Heritage and Aboriginal Affairs, South Australia.

DELWP (in prep). Strategic Framework 2017-2025, Barwon South West Koala Management Program. Department of Environment, Land, Water and Planning, Geelong.

DSE (2004). *Victoria's Koala Management Strategy*. Department of Sustainability and Environment, Melbourne, Victoria.

Handasyde, K.A. (1986). *Factors affecting reproduction in the female Koala (Phascolarctos cinereus)*. PhD thesis, Monash University, Clayton, Victoria.

IUCN/SSC (2013). *Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0*. Gland, Switzerland: IUCN Species Survival Commission, viiii + 57 pp.

Lee, A.K. and Martin, R.W. (no date) [1985?] Translocation of the Koala (*Phascolarctos cinereus*) to new habitat in Victoria. Project report 48, World Wildlife Fund, Australia.

Lee, A.K., Martin, R.W. and Handasyde, K.A. (1991). Experimental translocation of koalas to new habitat. Pp 299-312 in *Biology of the Koala* ed. By A.K. Lee, K.A. Handasyde and G.D. Sanson. Surrey Beatty and Sons, Sydney, NSW.

Lee, V. (2013). An investigation on *in-situ* management of overabundant koala populations in Victoria. MSc thesis, Department of Zoology, The University of Melbourne, Victoria.

Legione, A.R., Amery-Gale, J., Lynch, M., Haynes, L., Gilkerson, J.R., Sansom, F.M. and Devlin, J.M. (2016). *Chlamydia pecorum* infection in free-ranging koalas (*Phascolarctos cinereus*) on French Island, Victoria, Australia. *Journal of Wildlife Diseases* 52: 426-429.

Lynch, M. and McLean, N. (2004). *Assessment of animal welfare during Koala population management programs*. Guidelines prepared for Parks Victoria, 2004. Unpublished report.

Martin, R.W. and Handasyde, K.A. (1999). *The Koala: Natural history, biology and conservation.* University of NSW Press, Sydney.

Menkhorst, P.W. (Ed). (1995). *Mammals of Victoria: Distribution, ecology and conservation*. Oxford University Press, Melbourne.

Menkhorst, P. (2008). Hunted, marooned, re-introduced, contracepted: A history of Koala management in Victoria. Pages 73-92 in '*Too Close for Comfort. Contentious issues in human-wildlife encounters*', edited by D. Lunney, A. Munn and W. Meikle. Royal Zoological Society of New South Wales, Mosman, New South Wales.

Santamaria, F. (2002). Outcomes and implications of a koala translocation in the Ballarat region. PhD thesis, School of Science and Engineering, University of Ballarat.

Santamaria, F. and Schlagloth, R. (2016). The effects of Chlamydia on translocated Chlamydia-naïve koalas: a case study. *Australian Zoologist* 38: 192-202.

Santamaria, F., Keatley, M.R. and Schlagloth, R. (2005). Does size matter? Tree use by translocated Koalas. *The Victorian Naturalist* 122: 4-13.

Short, J. (2009). The characteristics and success of vertebrate translocations within Australia. Unpublished report to the Department of Agriculture, Fisheries and Forestry by Wildlife Research and Management Pty Ltd, Kalamunda, Western Australia.

Strahan, R. (1978). What is a Koala? Pp 3-19 in *The Koala: Proceedings of the Taronga Symposium* ed. by T.J. Bergin. Zoological Parks Board of New South Wales, Sydney.

Whisson, D.A., Holland, G.J. and Carlyon, K. (2012). Translocation of overabundant species: Implications for translocated individuals. *Journal of Wildlife Management* 76 (8): 1661-1669.

Woosnam-Merchez, O., Cristescu, R., Dique, D., Ellis, B., Beeton, R.J.S., Simmonds, J. and Carrick, F. (2012). What faecal pellet surveys can and can't reveal about the ecology of koalas *Phascolarctos cinereus*. *Australian Zoologist* 36: 192-200.

www.delwp.vic.gov.au