At the Senate Environment Committee hearing yesterday Senator Cameron requested information about my expertise in Koala management. I did not have an opportunity to respond at the time so I have attached a brief CV which I hope will suffice. I have also attached a pdf of my paper on the history of Koala management in Victoria.

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**Peter Menkhorst BSc (Zoology and Botany)**

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Peter has over 35 years experience as a scientist with Victorian Government environment agencies (including Museum Victoria, Parks Victoria and Department of Sustainability and Environment or their predecessors). He has worked throughout Victoria in the fields of biodiversity survey, wildlife research, threatened species management and conservation policy development. He is a recognised authority on Victorian mammals and was editor and primary contributor to the authoritative book on that subject (item 8 in the list below). He has also written a field guide to Australian mammals and edited a field guide to Australian birds. Peter has a strong interest in threatened species recovery and has been a leader, since the 1980s, of several high profile and complex recovery programs in Victoria, including those for the Orange-bellied Parrot, Helmeted Honeyeater, Regent Honeyeater, Mountain Pygmy Possum and Brush-tailed Rock Wallaby. A 10-year stint in the Threatened Species Policy and Programs section of DSE, including a period as Manager, has given Peter a clear understanding of the legislative and policy contexts for achieving recovery of threatened species.

Peter's expertise in management of the Koala derives from his role in coordination of Koala management and conservation activities in Victoria for 12 years between 1995 and 2007. This included playing a central role in the development of the National Koala Conservation Strategy (Commonwealth of Australia 1998) and Victoria's Koala Management Strategy (DSE 2004), and representing the Department on Victoria's Koala Technical Advisory Committee. In these roles Peter was instrumental in leading the significant changes made during the last 15 years to the management of over-abundant and unsustainable populations of the Koala in Victoria. Following successful field trials of contraceptive implants in the Koala (see item 5 below), the Victorian Government has now adopted the technique in its Koala Management Strategy. Large-scale population control programs based on levonorgestrel implants have now largely replaced the previous, ethically-questionable translocation program in Victoria. As well as providing an ethically and financially suitable solution to a serious ecological problem, this work has overcome an intractable political issue for the Victorian Government.

Peter now works part-time as a consultant at the Arthur Rylah Institute for Environmental Research (DSE) on a number of projects relating to biodiversity monitoring, accounting for the needs of fauna in the development of planned fire regimes and ecology and monitoring of waterbirds. He is also part of a team preparing a new field guide to Australian birds for CSIRO Publishing.

**Ten career best scientific publications (selected from more than 80 scientific publications). Those directly related to Koala management are indicated with an asterisk.**

1. Smales, I. J., Quin, B., Menkhorst, P. W. and Franklin, D. C. 2009. Demography of the Helmeted Honeyeater (*Lichenostomus melanops cassidix*). *Emu* 109: 352-359.

Analysis of a long-term population dataset, providing important insights for management of this critically endangered taxon. Maintaining funding for this research project over an 18 year time period is a major achievement.

2. *Menkhorst, P. 2008. Hunted, marooned, re-introduced, contracepted: A history of Koala management in Victoria. Pages 73-92 in 'To 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.

Reviews and documents Australia's longest-running and most intensive wildlife management program, including significant recent advances in the regulation of over-abundant Koala populations.

3. N.L. McKenzie, A.A. Burbidge, A. Baynes, R.N. Brereton, C.R. Dickman, G. Gordon, L.A. Gibson, P.W. Menkhorst, A.C. Robinson, M.R. Williams, J.C.Z. Woinarski. 2007. Analysis of factors implicated in the recent decline of Australia's mammal fauna. *Journal of Biogeography* 34: 597-611.

Assessed the explanatory value of eight faunal and environmental factors thought to have contributed to Australian mammal extinctions on a continental scale. Provides an explicit basis for setting conservation priorities amongst regions and species.

4. *Baxter, P. W. J., McCarthy, M. A., Possingham, H. P., Menkhorst, P. W. and McLean, N. 2006. Accounting for management costs in sensitivity analyses of matrix population models. *Conservation Biology* 20: 893-905.

Uses Victoria's Koala and Helmeted Honeyeater management programs, both of which I led for extended periods, to explore methods for including financial costs of proposed management actions in models designed to assess efficacy of management options.

*5.* *Middleton, D. R., Walters, B, Menkhorst, P. & Wright, P. 2003. Fertility control in the koala, *Phascolarctos cinereus*: The impact of slow-release implants containing levonorgestrel or oestradiol on the production of pouch young. *Wildlife Research* 30: 207-212.

Provided a cost-effective and ethically-acceptable means of controlling over-abundant Koala populations. Now routinely applied to the Koala populations in Victoria where Koala over-browsing is the greatest problem.

*6.* *Melzer, A., Carrick, F., Menkhorst, P., Lunney, D. and St John, B. 2000. Koala distribution and abundance: an overview, critical assessment and conservation implications. *Conservation Biology* 14: 619-628.

A global conservation and management assessment of this high-profile and contentious species.

7. Franklin, D., Smales, I., Quin, B. and Menkhorst, P. 1999. The annual cycle of the Helmeted Honeyeater: a sedentary inhabitant of a predictable environment. *Ibis* 141: 256-268.

Based on detailed study of a marked population, provides a rare level of insight into population processes in an endangered species, particularly the relationship between breeding, moult and dispersal.

8. Menkhorst, P.W. (Ed). 1995. *'Mammals of Victoria: Distribution, ecology and conservation'*. Oxford University Press, Melbourne. 359 pages.

The most comprehensive review of the mammals of any Australian region, based on the records of the Atlas of Victorian Wildlife and a comprehensive review of the literature. Still has a high citation rate 15 years after publication.

9. Menkhorst, P.W., Weavers, B.W. & Alexander, J.S.A. 1988. Distribution, habitat and conservation status of *Petaurus norfolcensis* (Marsupialia: Petauridae) in Victoria. *Australian Wildlife Res*earch 15:59-71.

An early and important contribution to knowledge of this poorly-known (at the time) species.

10. Menkhorst, P.W. 1984. The application of nest boxes in research and management of possums and gliders. Pp. 517-525 in '*Possums and Gliders*' ed. by A.P. Smith and I.D. Hume, Australian Mammal Society, Sydney.

Stimulated many studies using nest boxes as a tool to gain access to hollow-using fauna.

# Hunted, marooned, re-introduced, contracepted: a history of Koala management in Victoria


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ABSTRACT

The management history of the Koala *Phascolarctos cinereus* in Victoria is unique and spectacular. Management of Koala populations began in Victoria in about 1910, at which time the species was undergoing a severe decline in population number and distribution. The fortuitous transfer of small numbers of Koalas to two coastal islands in the late 19th Century allowed intensive conservation management to begin in 1923, and it has continued almost unabated for the subsequent 84 years. Initially, Koalas were marooned for conservation purposes on four other large coastal islands, and several smaller ones, including two in the Murray River. These island populations were then used to re-introduce the species to remaining habitat across the former natural range of the species in Victoria and south-east South Australia. In the process intractable over-browsing problems were inadvertently created at ten sites. Since about 1985, the sole reason for translocation has been to protect natural values from the impacts of Koala over-browsing. Since 1995, considerable research effort has been directed at finding suitable in-situ population control mechanisms. During the 84 year program more than 24 000 Koalas were translocated to about 250 release sites and Koala populations have been successfully re-established in most areas of suitable habitat in Victoria. The genetic costs of using inbred populations as the source of animals for re-introduction are perhaps yet to be fully realised.



**Key words:** Koala, *Phascolarctos cinereus,* wildlife management, over-browsing, marooning, re-introduction, fertility control


## Introduction

### Koala conservation – perception and reality

The Koala *Phascolarctos cinereus* is amongst the most widely recognised and loved animals in the world. Its beguiling appearance and apparently docile nature result in a level of attraction and affection afforded to few other wild animals (Le Souef and Burrell 1926; Barrett 1937; Pratt 1937; Phillips 1990; Martin and Handasyde 1999). The annual benefit of this attraction to the Australian economy, via the role of the Koala as a tourism icon, was estimated in 1996 to total $1.1 billion (Hundloe and Hamilton 1997). Yet, it is not widely understood that, in parts of southern Australia, the Koala is responsible for one of the most intractable wildlife management problems, consuming a significant proportion of the wildlife management budgets of the Victorian and South Australian Governments.

Amongst the Australian public there is a widespread perception that the Koala is threatened with extinction. This is largely the result of a campaign run by a single special interest group, the Australian Koala Foundation (AKF), over a twenty year period. The AKF believes that the Koala can 'raise huge sums of money for conservation' (Tabart 1996). The effectiveness of the Koala as an 'icon' for conservation would be enhanced if it was officially listed as a threatened species. However, the reality is that two nominations (in 1995 and 2004) to have the Koala listed under Commonwealth legislation have failed because it did not meet the listing criteria at the national level (DEH 2006)[1]. This is not to say that the conservation of the Koala is assured – declines in Koala population numbers and distribution are still occurring in parts of coastal eastern Australia in the face of intensive agricultural and urban developments which result in the loss and fragmentation of forest and woodland cover (Melzer *et al.* 2000; US Fish and Wildlife Service 2000). Consequently, the Koala is listed as vulnerable in New South Wales and in the Southeast Queensland Biogeographic Region. Elsewhere throughout its extensive range, Koala populations remain in a reasonably sound conservation state (ANZECC 1998; Melzer *et al.* 2000; DEH 2006), although, like most taxa of Australian flora and fauna, there are good reasons for concern about future population trends, and for adopting a conservative approach.

[1] The 1995 submission failed despite the inclusion of gross under-estimates of the total Koala population and the numbers in each State. The real population figures for Victoria in 1996 were probably at least an order of magnitude greater than the 10 000 -15 000 claimed in the submission (for example, Martin (1997) estimated that the Koala population on the Strathbogie Plateau alone was in excess of 100 000 animals.)

Important conservation issues for the Koala in Victoria are the continuing incremental loss of mature trees through deliberate felling associated with land development and land-use change, and the declining health of remnant trees in rural landscapes. The potential for increased frequency of wildfire associated with climate change is also a serious concern for the Koala.

Koalas rely solely on the foliage of *Eucalyptus* trees for food. Further, they show distinct preferences for the foliage of a small number of tree species at a given site (Hindell and Lee 1991), and often prefer the foliage of individual trees over other individuals of the same species (Hindell and Lee 1991). Consequently, the number of Koalas that a given area can support is a function of the density of preferred browse tree species and the frequency of palatable or nutritious individuals of those species.

Koalas are long-lived – in Victoria many individuals reach 12-15 years of age (Martin and Handasyde 1999) and a few tagged and translocated animals are known to have lived for over 20 years (DSE unpublished data). Koalas are also highly fecund with many southern Victorian females producing a single young in most years of their 8-10 year breeding life (Martin and Handasyde 1999). Further, predation now plays only a very minor role in population regulation. Consequently, populations can increase rapidly. Populations that are free of Chlamydiosis, which can cause infertility in females, may double every three years; populations in which Chlamydiosis is active can still have a doubling time of about 12 years (Martin and Handasyde 1991). As a result, in southern Australia, populations of Koalas in patchy or isolated habitat have a history of reaching unsustainable densities leading to over-browsing of forage trees, widespread tree death and, in extreme cases, mass starvation of Koalas (Kershaw 1915, 1934; Anon 1944; McNally 1957; Warneke 1978; Martin 1985a; Martin and Handasyde 1999) (Figures 1A-1D).

The dichotomy in the reality and perception of the conservation status of the Koala, and the value of the Koala as a 'flagship species', has generated fierce debate and distracted wildlife managers and concerned members of the public from tackling the important issues facing the Koala, for example continuing incremental loss of trees and habitat fragmentation, (e.g. Martin 1997; Tabart 1997; ANZECC 1998; Phillips 2000).

In this paper I describe the history of active management of the Koala in Victoria, including the management of over-browsing, and the evolution of management responses as the conservation status of the Koala changed through the 20th Century. Finally, I provide an assessment of the achievements of 84 years of active Koala management in Victoria.


**Figure 1.** Examples of over-browsing damage (all photographs by the author). A – Coastal Manna Gum *Eucalyptus viminalis* ssp *pryoriana,* Snake Island, 22 June 2000. B – Manna Gum, Framlingham, April 2001. Acacias, River Red Gum *Eucalyptus camaldulensis* beside the Hopkins River and Messmate *E. obliqua* in the far distance are unaffected. C – Pure stand of Manna Gum, Framlingham, September 1998. D – a mixed woodland of Coastal Manna Gum and Saw Banksia *Banksia serrata* has been converted to an open woodland of Saw Banksia by Koala over-browsing of the Manna Gum, Raymond Island, September 2004.

## Methods

### Information sources

In my role of coordinating Koala policy and management in Victoria since 1996, the published literature on Koalas and their management was extensively reviewed, as were files and other records of the Victorian Government wildlife agency in its various guises. Information on individual translocation events was taken from Appendix 1 of Martin (1989) for the years 1923-1988 and from departmental databases for subsequent years.

### Definitions

In this document the following definitions are adopted for describing the purposes of moving wildlife from one point to another: translocation is a generic term to describe the deliberate movement of an organism from one place with free release at another. Thus, translocation covers 1) introduction, where the release site is outside the historically-known range of the taxon, 2) re-introduction where an attempt is made to establish a taxon in an area that was once part of its historic range, but from where it has been extirpated, and 3) re-stocking which involves the addition of individuals to an existing population (also known as re-enforcement). Important localities mentioned in the text are mapped in Figures 2Aand 2B.

## Results

### Development of a policy and knowledge-base for Koala management in Victoria

Management of the Koala has been a major component of the wildlife management program in Victoria since the 1920s, but there appears to have been little documentation of the aims, strategies, effort or cost. Consequently, it is difficult to gain a clear understanding of the work undertaken in Koala management before the 1950s, although several authors have provided broad outlines (Lewis 1934, 1954; McNally 1960; Warneke 1978; Martin 1989; Phillips 1990; Menkhorst 1996; Martin and Handasyde 1999).

For the first 50 years of Koala management in Victoria a clear policy statement about its aims and strategies seems to have been lacking. A wildlife policy statement covering Koala management and procedures was drafted in October 1976 (Fisheries and Wildlife Department 1976) but was never promulgated. In 1988, in recognition of the need for a stronger scientific basis and improved coordination for Koala management, the Department of Conservation, Forests and Lands contracted Roger Martin to prepare a management plan for the Koala in Victoria. Although never formally adopted, this plan helped focus attention on the need to develop new approaches to the control of over-browsing, and placed

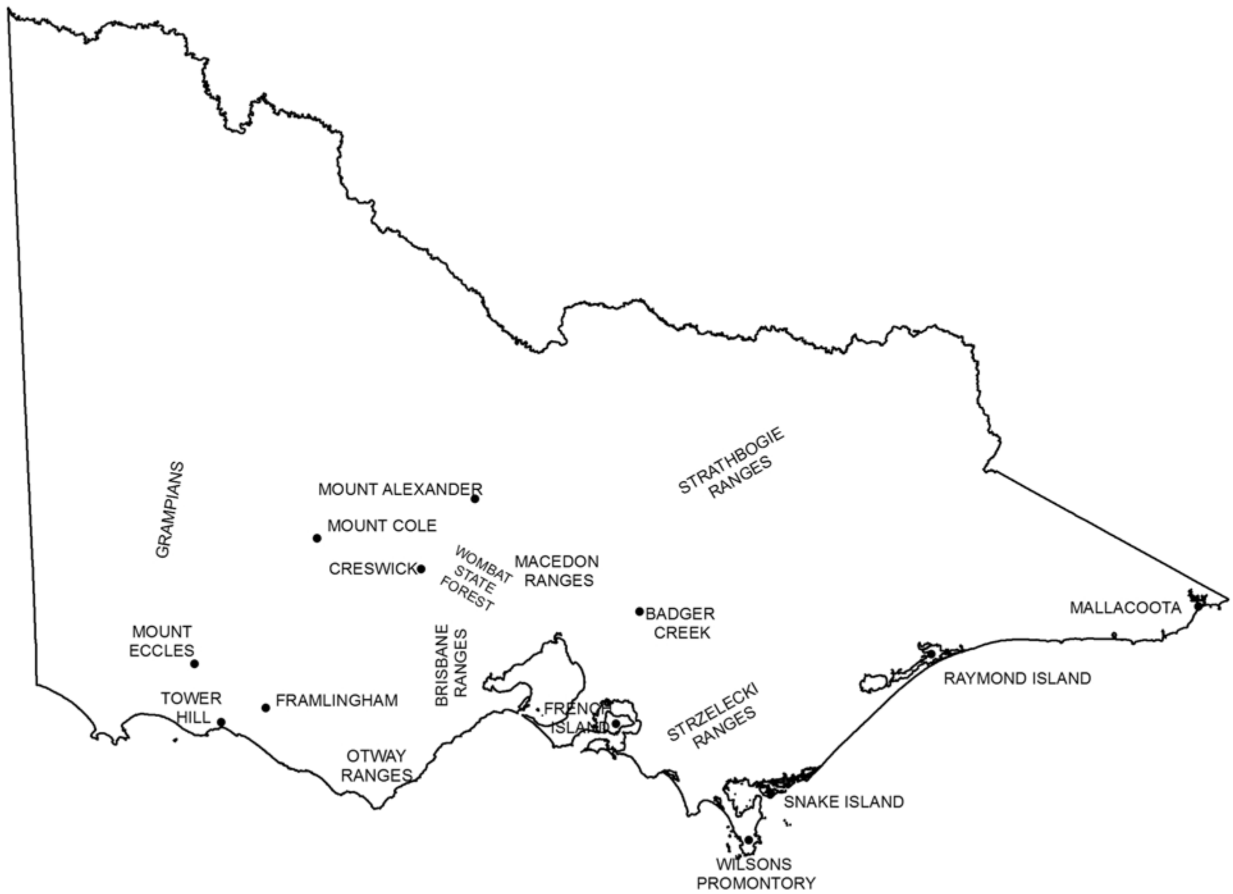


Figure 2. A - Localities of important places mentioned in the text.

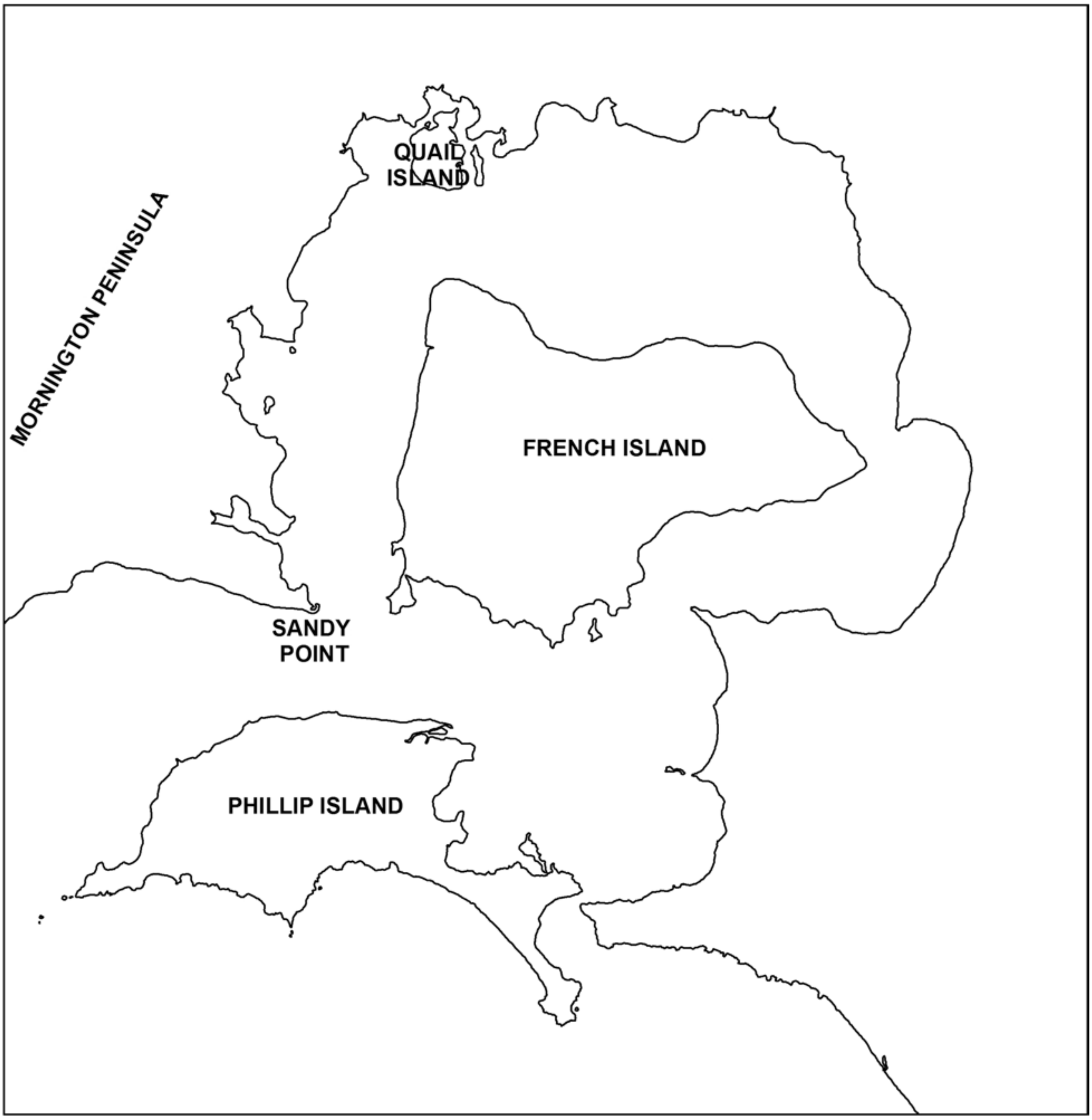


**Figure 2. B** - Key Koala sites around Western Port.

other issues, including the disease Chlamydiosis, and the genetic consequences of the translocation program, into a more scientific perspective (Martin 1989). Another very important contribution made by Roger Martin was to extract from departmental records information about all Koala translocations, allowing for the first time an appreciation of the full magnitude of this remarkable wildlife management program (see below) (Appendix 1, Martin 1989).

In 1996 the Commonwealth Government formed a National Koala Network charged with preparing a national conservation strategy for the Koala (ANZECC 1998). It was not until 2004, 80 years after active management of Koalas began, that the Victorian Government formally adopted and published a Koala management plan (Menkhorst 2004), as required under the national conservation strategy.

There was a similar lack of a scientific basis for Koala management in Victoria until the second half of the 20th century. John McNally was employed as a Wildlife Management Officer during the 1950s and, during the course of major translocation programs from French Island, undertook the first scientific study of a wild Koala population in Victoria (McNally 1957). The period from about 1977 to 1990 was very productive for research into the biology and ecology of the Koala. For southern Australian Koalas, this research was led by Professor Tony Lee from the Zoology Department at Monash University and included post-graduate studies by Roger Martin (population dynamics, over-abundance, Chlamydiosis, translocation to new habitat), Peter Mitchell (social behaviour, diseases), Mark Hindell (feeding behaviour and food preferences), and Kathrine Handasyde (reproductive physiology, population dynamics, Chlamydiosis). Subsequent studies which have influenced Koala management include those by Handasyde and her students at the University of Melbourne, notably Natasha McLean (population demographics) and Emily Hynes (fertility control), by John Emmins of the Department of Pathology and Immunology at Monash University (immunology, genetics, Chlamydiosis), and by Flavia Santamaria at the University of Ballarat (fate of translocated Koalas). Combined, this work has provided a strong foundation for the development of current Koala management programs.

The 1990s saw increased pressure to better manage over-abundant Koala populations and the beginning of research into methods of in-situ population control for Koalas to replace the increasingly problematic translocation program (Menkhorst *et al.* 1998; Middleton *et al.* 2003; Duka and Masters 2005).

## A brief history of Koala management in Victoria since European colonisation

From a review of the published literature and examination of departmental files, I discern four sequential themes in the management of Koalas in Victoria – the first, in line with the prevailing attitudes towards wildlife, characterised mostly by neglect and exploitation, the second by the concept of establishing refuge populations on islands or inside fenced 'safe havens', the third by re-introduction to suitable habitat in its former range, and the fourth by the search for cost-effective means of in-situ control of population growth. The approximate duration of these four phases of Koala management is shown in Figure 3.

*1. Neglect and exploitation – the early decades of European settlement*

The occupation of Victoria by European settlers began in the 1830s and accelerated through the 1850s when the discovery of gold across a wide area of central Victoria resulted in a dramatic influx of people to Melbourne and regional areas. By the 1860s, most of the State had been explored and much of the country suitable for the grazing of sheep or cattle had been 'taken up' by European squatters (Dingle 1984). During that period surprisingly few reports of Koalas were documented in the historical literature (Warneke 1978). The frequency of sightings increased dramatically in some regions from about the 1860s (e.g. Parris 1948) and there seems little doubt that Koala populations increased through the last decades of the nineteenth century (Warneke 1978; Strahan and Martin 1982; Lunney and Leary 1988; Phillips 1990). It has been postulated that hunting of Koalas by Aboriginal people had previously held Koala populations at low levels, but following the dramatic decline in Aboriginal populations, and the breakdown of their traditional hunting patterns, Koala populations rapidly increased (Parris 1948; Warneke 1978; Strahan and Martin 1982; Lunney and Leary 1988; Phillips 1990). The widespread poisoning of another predator, the Dingo *Canis lupus dingo* (Menkhorst 1996), would also have reduced predation pressure on Victoria's Koalas (Strahan and Martin 1982).

This increase in Koala population levels was of a magnitude that allowed the development of a major industry based on killing Koalas for their fur (Pratt 1937; Troughton 1941; Phillips 1990; Hrdina and Gordon 2004). A mammalogist at the British Museum, Robert Lydekker, wrote in 1894 that 'the Koala must be an abundant animal since from 10 000 to 30 000 are annually imported into London, while in 1889 the enormous total of 300 000 was reached' (Lydekker 1894). Many thousands of Koala skins from Victoria were amongst the millions exported from Australia (Warneke 1978).

The Koala was given legislative protection in Victoria in 1898 when it was proclaimed Native Game under the Game Act 1890, so providing a legal mechanism to declare a closed season for it (Seebeck 1988). In this case, the 'season' was closed permanently. However, this protection came too late and by the early 1900s a combination of habitat destruction, hunting, wildfire and probably disease (Le Souef 1925; Le Souef and Burrell 1926; Troughton 1941) had caused a drastic population decline. The hunting industry collapsed during the early 1900s (Phillips 1990; Hrdina and Gordon 2004) and by the 1920s there was concern that the Koala had been almost wiped out in Victoria (Le Souef 1925; Barrett 1937; Troughton 1941; Lewis 1954; Warneke 1978). Remnant populations are claimed to have occurred only in parts of the south-west, the Mornington Peninsula and South Gippsland (Lewis 1934), including Wilsons Promontory (Kershaw 1915; Kershaw 1934), but Koalas probably also persisted in East Gippsland, contiguous with those in south-eastern New South Wales, as remnant populations still do today.

*2. Island Populations to the Rescue – Phase 1, Marooning*

Fortunately for the future of the Koala in Victoria, small numbers of Koalas had been introduced by local people to Phillip Island in the 1870s and to French Island in 1890s (McNally 1960; Martin and Handasyde 1999). In contrast to the population on Phillip Island, that on French Island was free of the disease Chlamydiosis, presumably because the founder animals were sub-adult and had not been infected with this sexually-transmitted disease prior to their release on the island (Martin and Handasyde 1999). Thus, the French Island population quickly achieved a rapid rate of growth and, in the early 1920s, settlers reported high population densities of Koalas, including complaints of defoliation of trees left as windbreaks around their houses (Lewis 1934; McNally 1957).

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exploitation & neglect | X | X | X | | | | | | | | |
| Marooning on islands or mainland 'safe havens' | | | X | X | X | X | | | | | |
| Re-introduction to mainland habitat | | | | | X | X | X | X | X | | |
| Translocation to protect habitat | | | | | | | | X | X | X | X |
| In-situ. fertility control | | | | | | | | | | X | X |
| Decade | 1900s | 1910s | 1920s | 1930s | 1940s | 1950s | 1960s | 1970s | 1980s | 1990s | 2000s |

**Figure 3.** Timeline illustrating the sequence of responses to Koala over-browsing in Victoria.

Coincidently, in the early 1920s, the Chief Inspector of Fisheries and Game, Fred Lewis, initiated community-based surveys to establish the distribution of remnant Koala populations in Victoria. He did this by writing to bush schools, sawmills and other rural workplaces asking whether Koalas persisted in the district. The results of these surveys highlighted the magnitude of the decline of the Koala over most of its Victorian range and emphasised the role that extensive bushfires had played in that decline. Lewis concluded that only about 500-1000 Koalas remained in Victoria (Lewis 1934; Barrett 1937). While this population estimate is likely to have been a significant underestimate, it is clear that a drastic population decline and range contraction had occurred across most of the Koala's Victorian range. The surveys also emphasised the conservation value of the introduced population on French Island. From this information grew a plan to create further island 'safe havens', free from the threat of wildfire and disease. Requests from the French Island community for permission to cull Koalas were refused. Instead, the Victorian Government set about developing a Koala translocation program.

The practice of introducing populations of threatened species to islands where the threats operating on the mainland do not apply, known as marooning (Williams 1977), has been used successfully for many threatened species in New Zealand and for several species of mammal in Western Australia and South Australia (Abbott 2000). The earliest documented case of deliberate marooning of a threatened species took place in New Zealand in the 1890s when the New Zealand Government purchased three islands that were free of introduced predators and employed two men to capture and transfer Kakapo and other rare birds to them (Butler 1989).

Another, far less well-known, early case of marooning for conservation outcomes was the transfer of Koalas from the thriving colony on French Island to other Victorian islands and to Kangaroo Island in South Australia beginning in 1923 (Appendix 1A). At this time there was great pessimism about the ability of the species to survive on mainland Victoria due to fire and forest removal (Lewis 1934; Barrett 1937; Pratt 1937).

'*On the mainland of Victoria, I feel certain, the Koala is doomed to early extinction, and will never be re-established, excepting perhaps in some reserves which may be specially set apart for its protection and conservation, such as the Badger Creek Sanctuary, near Healesville. Such reserves however must be securely fenced to prevent the animals escaping*.' (Lewis 1934).

That the island to island translocations can be considered examples of conservation marooning is clear from the contemporary literature –

'*....it is hoped that on the three islands in Western Port the Koalas will have a safe home where the species will be preserved indefinitely*' (Lewis 1934).

Quail Island with about 3000 acres of Manna Gum *Eucalyptus viminalis* forest was considered to be a suitable 'retreat' (Lewis 1934).

'*Phillip Island and certain other islands off the coast are maintained as reservoirs of Koalas*' (Fisheries and Game Department 1956).

In a similar vein, the Fauna and Flora Protection Board of South Australia wrote to the Director of the National Museum of Victoria, Charles Kershaw, in 1923 offering the Flinders Chase Reserve on Kangaroo Island as a suitable site for the establishment of Koalas (Robertson 1978). This request was acted upon immediately by Fred Lewis; to the great cost of South Australian wildlife management some 70 years later (Koala Management Task Force 1996; Masters *et al.* 2004; Duka and Masters 2005). There is no evidence that Koalas occurred naturally on any of these coastal islands (Warneke 1978; Menkhorst 1996) so the maroonings should be considered introductions rather than re-introductions.

In reality, none of the three Western Port islands (French, Phillip and Quail Islands) provided adequate protection for Koalas, for differing reasons, and significant management intervention became necessary for each of them.

On French Island during the early 1930s there was considerable habitat degradation caused by vegetation clearing, fires lit by local farmers, and defoliation of eucalypts (Lewis 1934). Lewis ascribed the defoliation to insect attack and frequent fires, but it may well have been at least partly due to Koala browsing. This situation led Lewis to conclude that French Island could not act as the sole refuge for Koalas.

'*it became necessary then, in order to preserve the Koala, to select some other place for it, and the Fisheries and Game Department chose Quail Island, a Government reserve and sanctuary of about 3000 acres in the northern portion of Western Port Bay. To this retreat some 200-300 Koalas have now been transferred. There is an abundance of* Eucalyptus viminalis *on this island …*' (Lewis 1934).

Within a mere ten years the Quail Island population had increased to the point where the entire eucalypt canopy on the island was seriously degraded and a disastrous Koala population crash ensued (Anon 1944, 1945). This unfortunate event proved to be a watershed in public concern for Koalas, not least because of a failure of the Fisheries and Game Department (notably Fred Lewis) to acknowledge that the defoliation was caused by over-abundant Koalas rather than insect attack (Anon 1944, 1945; Martin and Handasyde 1999). As a result of public outcry, a major translocation program took place in 1944 aimed at removing all Koalas from Quail Island. Over 1300 surviving Koalas were removed and released into selected mainland habitat – the beginning of the re-introduction phase of Koala management in Victoria.

Meanwhile, Koala numbers on French and Phillip Islands were also increasing, resulting in eucalypt decline and necessitating removals of Koalas. Perhaps as a result of learning from the Quail Island experience, 865 Koalas were removed from Phillip Island in 1944, the same year as the huge Quail Island program, and a further 583 in 1945 – a remarkable achievement in wartime Australia where labour, fuel and other resources were in short supply. In the mid-1950s, efforts were also made to remove most Koalas from French Island because it was considered to have become unsuitable as a holding area due to 'closer settlement and frequent fires' (McNally 1960). A total of

2235 Koalas were removed from French Island between 1954 and 1957 and a further 883 from Phillip Island in 1957-58 (Appendix 1B, Figures 4A-4D).

Despite the over-browsing problems encountered on the three Western Port islands, and the re-introduction program being well established by the mid-1950s, the Fisheries and Game Department still considered that island 'holding areas' were essential to provide stocks for re-introduction. Other unsettled coastal islands were investigated to assess their suitability to replace French Island and Phillip Island as key holding areas. This led to the introduction of Koalas to Snake Island (1945) and Raymond Island (1953). Islands were also chosen as sites to assess the suitability of River Red Gum *Eucalyptus camaldulensis* forest as Koala habitat, leading to the release of Koalas onto two islands in the Murray River – Goat Island near Swan Hill (1952) and Loch Island at Mildura (1957). Conversely, Koalas were removed from two small islands, Chinaman Island in Western Port (1952) and Wartook Island in Wartook Reservoir, The Grampians (1957-1965), presumably to curtail incipient over-browsing problems.

The Department did acknowledge that there would be 'a constant need to remove surplus animals' from these island holding areas (McNally 1960), and instigated annual assessments of Koala numbers and tree condition on French Island. Presumably, it was considered that the value of the holding areas as reservoirs of Koalas for re-introduction outweighed the costs of monitoring and controlling the size of island populations.

The suggestion was even made that Quail Island be replanted and restocked. Two small plantations of Manna Gums were established in 1945 and an ecological burn was applied in 1946 to promote regeneration of Manna Gum and disadvantage bracken (Braithwaite *et al*. 1980). These efforts, along with natural recovery of the surviving Manna Gums, must have produced remarkable results because in April 1947, only three years after the Quail Island debacle, another 32 Koalas were released there. These animals from the Chlamydia positive Phillip Island population had lower fecundity than the original French Island stock and the population did not flourish. Koalas were last reported on Quail Island in 1978 (Braithwaite *et al*. 1980) and the population now seems to have died out (author, unpublished information).


**Figure 4.** Koala translocation, 1950s style (photographs from J. Cooper collection, Department of Sustainability and Environment). A – catching Koalas, French Island. B – transporting captured Koalas in sacks. C – loading Koala crates at Tankerton jetty, French Island, for transportation to the mainland. D – Phillip Island Koalas which had known only woodland of Coastal Manna Gum and Messmate, such as depicted in Figures 4A and 4B, being released into tall wet forest of Mountain Grey Gum *Eucalyptus cypellocarpa* and Manna Gum at Grey River, eastern Otway Ranges, 1958 (current release protocols do not allow the release of more than one animal into a tree (Menkhorst 2004)). This region now supports a large, high-density population of Koalas (Figure 9).

The Koala population on Phillip Island has been in steady decline since the 1970s due to declining fertility caused by Chlamydiosis combined with the impacts of a burgeoning human population (habitat loss, predation by dogs, and road deaths) (Backhouse and Crouch 1991). In contrast, and despite the gloomy predictions of Lewis and McNally, the French Island Koala population has remained free of Chlamydia and has continued to flourish – the island is sparsely settled and the road system is not conducive to high speeds. Consequently, the Koala population has a high rate of growth – doubling time roughly 3 years (Martin and Handasyde 1991) – and it is necessary to continuously remove Koalas from French Island. Since 1977 translocations have been undertaken in all but two years, at an average of 192 animals per year (n 27, range 36-591) (Appendix 1B).

*3. Island populations to the rescue – phase 2 – re-introduction*

With the need to remove large numbers of Koalas from Phillip and Quail Islands during the mid-1940s, the strategy for Koala conservation underwent an important shift – to a re-introduction program to mainland habitat that had remained vacant following the population decline in the early 1900s. It was hoped that this program would result in the 'partial re-establishment of the Koala in Victoria' (McNally 1957).

Firstly, mainland 'islands' were established to house Koalas in protected areas. These 'islands' were fenced areas of habitat at the Badger Creek Sanctuary [now Healesville Sanctuary, a zoo], and the Creswick and Mt Alexander 'Koala Parks'. The rationale for releasing Koalas into fenced enclosures is not clear and may have been driven as much by hopes of encouraging tourism to regional Victoria as by concern about protecting the Koalas from undefined threats.

The Mt Alexander Koala Park is the best documented (Widdowson 1947) – in 1941 a 50 acre fenced reserve was established in Manna Gum forest at about 600 m altitude on Mt Alexander, 10 km north-east of Castlemaine, and 54 Koalas from Phillip Island were introduced. The project was heavily supported by the Castlemaine Publicity and Tourist Association and local community service clubs raised money by public subscription. By 1944 the area of the enclosure had been doubled and a further 152 Phillip Island animals were introduced. In 1947 it became necessary to begin a program of applying metal bands to the trunks of over-browsed trees to prevent Koala access (Figure 5), and moving the band to a different tree after the original tree had recovered. Eventually, it became necessary to reduce the population within the enclosure and 100 Koalas were liberated into the surrounding forest. A similar structure was established at Creswick in 1942 and it was stocked with animals from Phillip Island in 1942 and 1943, and from Quail Island in 1944.

Little appears to have been recorded about the history of these two fenced enclosures, or about their effectiveness as tourist drawcards. Neither was entirely effective at retaining Koalas within the fenced area and some visitors expressed disappointment at not being able to find Koalas within the Mt Alexander enclosure. Both Koala Parks generated surplus animals that were released into the surrounding forest and further afield (Appendix 1C). The fence at the Mt Alexander Koala Park is still being maintained, although the density of Koalas on this high and exposed site is lower than that needed to satisfy tourists wishing to see Koalas.

**Figure 5.** Remains of a tree band applied to a Manna Gum in the Mt Alexander Koala Park during the 1940s (photographed in March 2007, author).

The Koala Parks became obsolete with the switch to a full-scale re-introduction program precipitated by the very large numbers of Koalas that needed to be rapidly removed from Quail and Phillip Islands beginning in 1944 (Appendix 1B). The sheer numbers of Koalas requiring translocation meant that a large number of suitable release sites needed to be found. Fisheries and Game Inspectors across Victoria were asked to identify potential release sites according to specific criteria that included the presence of suitable browse tree species, the area of available forest cover, and security of tenure and management, including a capacity to respond to wildfire (McNally 1960). The last criterion meant that State Forests were favoured as release sites because the Forests Commission had primary responsibility for control of wildfire and was best equipped to perform that role.

By the early 1950s the island populations were seen as on-going sources of surplus Koalas that would provide animals for the re-introduction program:

*'Phillip Island and certain other islands off the coast are maintained as reservoirs of Koalas'* (Fisheries and Game Department 1956).

*'these island populations have since provided the holding areas for koalas from which surplus animals are transported to restock suitable localities on the mainland of Victoria'* (McNally 1960) (Figure 6).

Through the 1940s, large numbers of Koalas from Phillip and Quail Islands (Appendix 1B) were released in the Daylesford area, Macedon Range, Mt Alexander, Brisbane Ranges (specifically the Durdiwarrah Water Reserve) and Strathbogie Ranges. During the 1950s most translocations were from Phillip and French Islands (Appendix 1B, Figure 4) and favoured release areas included the Grampians, Mt Cole, Wombat State Forest, the eastern slopes of the Otway Range (Figure 4D), and riverine forests along the Murray River. All these districts now have well-established Koala populations (Menkhorst 1996, Figure 7) though the population around Halls Gap in the Grampians crashed in the 1970s due to infertility caused by Chlamydiosis and that in the Macedon Range has declined since the late 1970s, commensurate with a surge in housing development. By 1960 the Department felt confident enough to claim that the 'future of the Koala in Victoria is assured' (McNally 1960), a claim that has stood the test of time (Menkhorst 1996) (Figure 7).

Small numbers of Koalas were also translocated to other States but the documentation of these is often poor. Kershaw (1934) states that some of the surplus Koalas from Wilsons Promontory in the early 1900s were sent to New South Wales, South Australia and Western Australia, but there appears to be no further record of this. French Island Koalas were also released along the Murrumbidgee River at Narrandera, where a population persists (Parsons 1990), but there is no official record of this in Victorian departmental files. Finally, and most bizarrely, Koalas from the Mt Alexander Koala Park were used to found a colony in Yanchep National Park, Western Australia.

Despite the efforts of the Victorian wildlife agency to prevent severe over-browsing and Koala suffering, there were regular outbreaks during the late 20th Century, on islands and in isolated patches of coastal Manna Gum forest on the mainland (Table 1). Severe defoliation, tree deaths and Koala population crashes occurred at Sandy Point in the mid 1980s, on Snake Island in the mid 1990s (Figure 1A), at Framlingham in 1997-98 (Figures 1B, 1C) (Martin and Handasyde 1999), and at Raymond Island in 2004 (Figure 1D). In recent years, timely management interventions in the form of initial population reductions by translocation followed by the application of hormone-based contraception have prevented severe defoliation at Tower Hill Game Reserve and may do so Mt Eccles National Park, where more than 6000 ha of Manna Gum forest is threatened.

In the 83 years between 1923 and 2006, over 24 600 individual animals were translocated to over 250 release sites across Victoria (Appendix 1A, B, and C), probably the most sustained and extensive wildlife re-introduction program ever undertaken.

*4. In-situ population control to protect other natural values*

Although the conservation of the Koala had been a primary aim of the translocation program since 1923, it was usually not the sole reason because prevention of tree death caused by over-browsing was frequently an additional concern. However, the re-introduction program was effectively complete by about the mid-1980s


**Figure 6.** Display prepared for the Royal Melbourne Show, 1957, indicating Koala 'holding areas' (French Island and Phillip Island) and major 're-stocking areas' (Grampians, Mt Cole, Castlemaine [Mt Alexander], Stony Rises, Brisbane Ranges, Mornington Peninsula) (photograph from J. Cooper collection, Department of Sustainability and Environment).

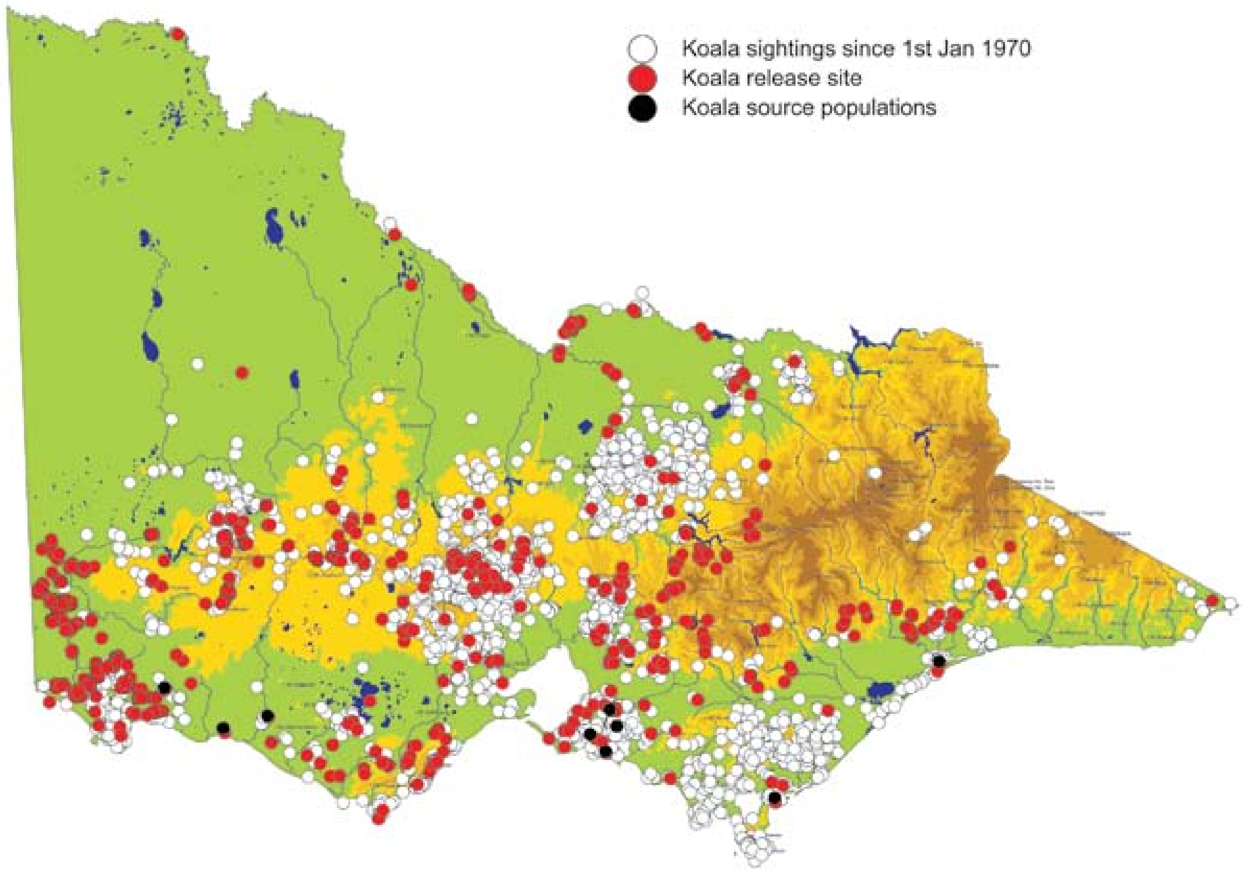


**Figure 7.** Distribution of principal source populations (black dots), all documented release sites (red), and post 1970 Koala sighting records (white). From west to east the source populations are: Mt Eccles National Park, Tower Hill Game Reserve, Framlingham forest, Sandy Point, Phillip Island, Quail Island, French Island, Snake Island, Raymond Island. Data from Atlas of Victorian Wildlife database, Department of Sustainability and Environment.

and it was clear that translocation could no longer be the sole solution to Koala over-browsing (Martin 1989). Further, there was increasing public concern over the animal welfare aspects of Koala over-browsing and the translocation program. Despite these factors, translocation has continued until the present because it is the only politically acceptable and practicable means of rapid population reduction. Most of the translocations since the mid 1980s should be considered re-stocking rather than re-introduction because there were few release areas that did not already support a Koala population. The recommendation of Martin (1989) that animals

**Table 1.** Over-browsing events that have required active management in Victoria.

| Area | Years | Management response |
|---|---|---|
| Wilsons Promontory | 1905-1910 | Translocation locally and interstate, cull |
| French Island | 1923-present | Translocation (marooning and re-introduction), research into physiological and behavioural effects and effectiveness of 3 different hormone implants in females, and vasectomy of males. |
| Phillip Island | 1941-1978 | Translocation (marooning and re-introduction). |
| Quail Island | 1944-1945 | Translocation (marooning and re-introduction). |
| Sandy Point | 1985-2000 | Translocation (re-stocking). |
| Snake Island | 1992-present | Translocation (re-stocking) of surgically sterilised animals, trial of immunocontraception (2000-2003). |
| Tower Hill | 1996-2003 | Translocation (re-stocking) followed by in-situ fertility control via hormone implants. |
| Framlingham | 1997-1999 | Translocation (re-stocking) of intact females and surgically-sterilised males. |
| Mt Eccles | 1999-present | Translocation (re-stocking) of surgically sterilised animals, in-situ fertility control via hormone implants. |
| Raymond Island | 2004 | Translocation, trial of commercial hormone implant. |
| Eastern Otway Ranges | 2002-present | May not be practicable – population very large, rugged topography, very tall trees. |

from Chlamydia negative populations not be released into areas where Chlamydia is present is unable to be met because Chlamydia is now known to be endemic and widespread through Victorian Koala populations (Emmins 1996). Further, the habitat at the three known Chlamydia-free populations (French Island, Tower Hill Game Reserve and Framlingham) is already in a state of decline due to over-browsing, and artificially increasing those populations would be counter-productive. However, clinical cases of Chlamydiosis are rare in most Victorian Koala populations and the disease is thought to have no epizootic potential (Emmins 1996).

Lethal methods of population reduction are widely used on other marsupial species throughout Australia (for example various species of kangaroo and wallaby, Common Brushtail Possum, and Common Wombat). Shooting would likely be the most cost-effective means of rapidly reducing Koala populations (Martin 1997, Tyndale-Biscoe 1997; Duka and Masters 2005), however, lethal means of population control have not been authorised for the Koala since the 1920s because of its iconic status and public image. At a meeting of the Australian and New Zealand Environment and Conservation Council (a forum of State, Commonwealth and New Zealand Environment Ministers) held in May 1996, culling was rejected as a management tool. Consequently, it was not considered during preparation of the National Koala Conservation Strategy published in 1998 (ANZECC 1998).

Counter balancing concerns for individual animal welfare is the increasing concern amongst land managers and conservationists about the ecological damage resulting from Koala over-browsing (Koala Management Task Force 1996; ANZECC 1998; Masters *et al.* 2004; Menkhorst 2004).

The search for an alternative to translocation began in earnest in 1995 when the Department of Natural Resources and Environment commissioned a review of fertility control options (Middleton 1996a). The outcome of the review was a recommendation to conduct separate field trials of the effectiveness of two techniques – slow-release implants of a progestin hormone or oestradiol to females, and vasectomy of males (Middleton 1996b). Implementation began in late 1996, despite opposition from some quarters because it was feared that the program would divert money away from other urgent wildlife research and management programs, and because of doubt about the efficacy of male sterilisation (eg. Anderson 1996). So began a decade of intensive research and adaptive management trials by the Victorian and South Australian wildlife management agencies to develop methods for in-situ population control (Table 2).

In Victoria, these trials have been guided by an expert advisory committee, the Koala Technical Advisory Committee, convened jointly by the two Government agencies with primary responsibility for

**Table 2.** Fertility control trials and population management programs other than translocation undertaken on Koalas in Victoria and South Australia.

| | | | | | |
|---|---|---|---|---|---|
| **1. Population reduction by translocation followed by hormone implant contraception of remaining females** | Tower Hill 1996-2003 (Middleton *et al.* 2003, DSE and EcoPlan Australia unpublished) | | | | |
| **2. Male sterilisation followed by release at capture site** | French Island 1996 to 1998 (Menkhorst *et al.* 1998, DSE and EcoPlan Australia unpublished)) | | | | |
| **3. Surgical sterilisation followed by translocation** | Kangaroo Island 1997 to 2001 (Duka and Masters 2005) | Snake Island 1999 (Parks Victoria 2003b) | Mt Eccles National Park 1999 (both sexes)-2000 (females only) (Parks Victoria 2003a) | Framlingham 1998 (males only) (DSE and EcoPlan Australia unpublished) | French Island 2000 (females only) (Parks Victoria unpublished) |
| **4. Surgical sterilisation followed by delayed translocation** | Snake Island 2000 to present (Parks Victoria unpublished) | | | | |
| **5. Immunocontraception** | Snake Island 2000-2003 (Kitchener *et al.* in prep) | | | | |
| **6. Hormone implants to females followed by release at capture site** | Mt Eccles National Park 2004-present – levonorgestrel (Parks Victoria unpublished) | French Island 2004-2007 – levonorgestrel and etonogestrel (E. Hynes, University of Melbourne unpublished), 2006-present – Suprelorin (A. Greenwood, University of Melbourne unpublished) | Raymond Island 2006-present – Suprelorin (A. Greenwood, University of Melbourne unpublished) | | |

Koala management, the Department of Sustainability and Environment and Parks Victoria. The committee's role is to advise the two Government agencies on technical matters relating to Koala management. Its primary focus in recent years has been to advise on adaptive-management trials to assess a range of fertility control techniques for their efficacy, ethics and cost-effectiveness.

A six-year field trial of subdermal implants containing either the synthetic progestin levonorgestrel, or low doses of oestradiol, applied to female Koalas, began at Tower Hill Game Reserve in 1997. This trial indicated that a contraceptive rate of 100% could be maintained for up to six years using levonorgestrel implants, representing at least 60% of the reproductive life of a female Koala (Middleton *et al.* 2003; DSE unpublished data). A trial of the impact of vasectomy of male Koalas was also conducted at Red Bill Creek on French Island between November 1996 and October 1998. By vasectomising all males captured on the study site (the proportion of treated males on site varied over time because the population was not a closed one) this program reduced the proportion of females carrying pouch young from 87% at the beginning of treatments to 36% over two breeding seasons (DSE unpublished data).

Meanwhile, severe over-browsing problems were emerging on Snake Island and at Mt Eccles National Park. Because the hormone implant trials had not been completed, surgical sterilisation of females, by transection and bipolar cautery of the distal oviduct, as undertaken by the South Australian Government on Kangaroo Island (Masters *et al.* 2004; Duka and Masters 2005), was initiated on Snake Island in 1999, and at Mt Eccles National Park the following year. In both these Victorian cases it was found that the combination of surgical sterilisation and immediate translocation could result in high levels of mortality (up to 90% in one treatment group) (Parks Victoria 2003a) and the practice was abandoned. On Snake Island surgical sterilisation of males and females has continued but sterilised animals are released on the island and are translocated off the island when captured in subsequent years (Parks Victoria 2003b). The aim of removing all Koalas from Snake Island, part of the Nooramunga Marine and Coastal Park, is now within sight after eight years of intensive effort in which over 1100 male and over 1600 female Koalas have been surgically sterilised. Most of these sterilised animals have also been removed from the island to adjacent mainland habitat (Parks Victoria unpublished data).

Based on the results of the hormone implant trial (Middleton *et al.* 2003), and the animal welfare concerns associated with surgical sterilisation, a large-scale trial of the efficacy of hormone implants at the population level was begun at Mt Eccles National Park in 2004. The Koala population there was estimated at 11 000 animals (Wood 2004) with a sex ratio a little below parity and female fertility rate of 38% (Chlamydia is present in the population) (McLean 2003). Therefore, it was estimated that there were about 2100 fertile females present. Over the three years to 2006, 2450 females were implanted (Figure 8), a level of treatment that is approaching the 75% of fertile females required to produce a significant population decline (N. McLean unpublished). This trial gives hope that most of the Koala populations currently causing significant defoliation can be held at sustainable population densities via a determined contraception program using levonorgestrel implants. Fortunately, three of the four current over-browsing populations (Tower Hill Game Reserve, French Island, Raymond Island) are considerably smaller than that at Mt Eccles. The Mt Eccles program also included the development of a koala-forest model to help evaluate the long-term consequences of different levels of fertility control on both the Koalas and their food supply (the Manna Gum forest) (Todd et al. in press). The model allows the assessment of the most ecologically and financially desirable target population size for the National Park (1000 adults).

There is currently no practicable response available, within the levels of resourcing provided for wildlife management in Australia, to manage larger populations that are causing serious over-browsing, such as those on Kangaroo Island (SA) (estimated 30 000 Koalas) and in the eastern Otway Ranges (Figure 9) and Strathbogie Ranges (Victoria) (population sizes unknown but likely to be many tens of thousands in each).

The potential of an anti-fertility vaccine was also investigated at Snake Island between 2000 and 2003 using as antigens both porcine zona pellucida and a constituent protein of the zona pellucida from the Common Brushtail

**Figure 8.** Veterinarian inserting sub-dermal, slow-release hormone implant between the shoulder blades of sedated female Koala, Mt Eccles National Park, October 2004 (photograph – author)

Possum. Immunisation with porcine zona pellucida led to a significant reduction in fertility in female Koalas with antigen-specific antibody still detected 33 months after initial immunisation treatment (Kitchener *et al.* in prep).

In 2004, a bid for funding under the Australian Research Council's Linkage Grant program resulted in funds for a five-year program of research into the efficacy, on large populations, of a commercially-available contraceptive implant developed for the pet industry, the GnRH super agonist Suprelorin (Peptech Animal Health Pty Ltd). A potential advantage of Suprelorin is that, as a liquid rather than a powder, it may be amenable to remote delivery via a darting system. This project will also assess the impact of fertility control on population genetics in the Koala (Herbert 2007).

**Figure 9.** Tourists drive through severely over-browsed forest dominated by Southern Blue Gum *Eucalyptus globulus* along the Great Ocean Road near Kennett River, eastern Otway Ranges, January 2008. Numerous Koalas can be readily viewed from the roadside, descendents of animals released nearby in the Grey River Reserve in 1958 (Figure 4D), 1977 and 1982.


**Figure 10.** Over-browsing at Wilsons Promontory, approx. 1905-1910, the first documented case of Koala over-browsing (from Barrett 1937).

## DISCUSSION

### Causes of over-browsing by the Koala

The capacity for Koalas to cause serious over-browsing of preferred food trees was first documented by members of an expedition to Wilsons Promontory conducted by the Victorian Field Naturalists Club in 1905. This expedition preceded the declaration of Wilsons Promontory as Victoria's first national park (Garnett 1971) and, although hunting parties had shot hundreds of Koalas for their pelts during the preceding winters (Kershaw 1934), the interior of the promontory was uninhabited, difficult to access and rarely visited. At Red Hill at the foot of the Yanakie Isthmus, the field naturalists found a dense population of Koalas that were noted to be in poor condition, in an area of Swamp Gum *Eucalyptus ovata* which had been seriously defoliated. Some years later the dead Swamp Gums were still plainly evident (Kershaw 1915) (Figure 10). Likewise, in the valley at Oberon Bay, the 1905 party attributed the decline in health of Manna Gums to Koala over-browsing (Kershaw 1934) and remedial action in the form of relocation of Koalas to other parts of the Promontory and interstate, and some culling, was instigated in about 1910-12 – the first Koala management for conservation purposes (to protect the community of flora and fauna that was threatened by Koala over-browsing).

Koala over-browsing is confined to southern Australia. It is not known to occur on Queensland islands to which the Koala has been introduced (A. Melzer, Central Queensland University pers. comm.). Most cases of Koala over-browsing have three characteristics:

1) they involve one of the coastal subspecies of the Manna Gum *Eucalyptus viminalis* ssp *pryoriana* or ssp *cygnatensis*, or the Swamp Gum, and often other palatable species of eucalypt growing nearby are ignored, or eaten only as a last resort, for example Messmate *E. obliqua* at Framlingham and on Snake Island.
2) Koala population densities are high, at least 2 per ha.
3) they occur either on islands, or in situations with poor habitat connectivity and therefore with limited dispersal opportunities[2].

This last characteristic has led to claims that over-browsing could be overcome by increasing connectivity of habitat. While increased connectivity is to be welcomed, there is ample evidence that, even in the absence of barriers to movement, Koalas are incredibly reluctant to leave favoured stands of trees – the first documented case of Koala over-browsing on Wilsons Promontory had ample habitat connectivity but trees were still killed (Figure 10) before the Koalas chose to disperse, and the current situation around Kennet River and Grey River in the eastern Otway Range (Figure 10) has contiguous forest habitat over more than 140 000 ha of the Great Otway National Park and Otway Forest Park. Therefore, lack of connectivity of habitat is not a pre-requisite for over-browsing to occur – although it has been the usual situation through the twentieth century. This may be an artefact of the translocation program combined with the extensive habitat fragmentation that has occurred in Victoria since the late 1800s.

Observations of over-browsing in a natural population at Wilsons Promontory in 1905 (Figure 9), and by Martin (1985a, b) in another natural population in South Gippsland during the early 1980s, refute recent claims that over-population, and consequently over-browsing, are products of the social disruption caused by translocation (Phillips 2000). These observations support the hypothesis

[2]Koalas are actually quite accomplished travelers and are capable of crossing many km of inhospitable habitat such as cleared farmland and pine plantations (e.g. Lee *et al.* 1991, Santamaria 2002, Parks Victoria 2003a).

that Koala populations may naturally have undergone population fluctuations in their patchy preferred habitat (Martin 1985b). Of course, fragmentation of habitat has greatly exacerbated the impact of these fluctuations on the habitat and on Koala populations by limiting the capacity to disperse, thereby increasing the necessity to take effective management action.

## Outcomes of the translocation program

Koalas are now widespread in coastal and lowland forests and woodlands across southern, central and north-eastern Victoria, roughly south of the 500 mm isohyet and below about 700 m altitude (Menkhorst 1996) (Figure 7). Populations also extend into the drier Riverina region in narrow corridors of riverine forest along the Goulburn and Murray Rivers, downstream to the Swan Hill area (Menkhorst 1996; M. Rohde pers comm). This distribution probably approximates the distributional range of the Koala at the time of European settlement (Warneke 1978; Martin 1989). However, the current distribution is far more fragmented due to extensive clearing of forest and woodland for pastoral and agricultural industries.

The claim that the translocation program has been a major conservation success is made from a population conservation perspective rather than the individual animal welfare perspective frequently adopted by its critics. It is acknowledged that large numbers of Koalas would have suffered considerable discomfort and an unknown number did not survive the translocation and release process. In most cases little or no monitoring of translocated individuals took place – it was generally impractical to do so, especially before the development of radio-telemetry technology during the late 1970s. The standard level of monitoring consisted of two follow-up visits to the release site – one and two weeks after release – to search for debilitated animals. Few were found, but no conclusions about the fate of the translocated individuals can be drawn from such unstructured and qualitative assessments. However, the fact that Koala populations have been re-established virtually throughout the remaining suitable habitat across the former range of the species indicates that enough animals survived for population establishment. Further, there can be no doubt that far greater distress and mortality would have resulted from a strategy of allowing isolated populations to crash, as clearly shown at Quail Island in 1944, Sandy Point in 1986, and Framlingham in 1997.

Studies of the fate of translocated animals have generally shown high levels of survivorship, even when released into entirely unfamiliar forest communities and forest structure (Lee *et al.* 1991; Santamaria 2002; Parks Victoria 2003b; DSE unpublished data from Raymond Island). However, there have been some exceptions, notably in south-west Victoria in 2002 (Parks Victoria 2003a). Important factors in determining the survivorship of translocated Koalas have been identified as habitat quality at the release site, the physical condition of the individual animal (M. Lynch, Veterinarian, Zoos Victoria unpublished data), avoidance of cold and wet weather during capture, translocation and release, and minimisation of time between capture and release (Martin 1989; Menkhorst 2004).

## Fertility control trials

Since the mid 1990s the Koala over-browsing problem has stimulated significant research into methods of in-situ fertility control in marsupials (Middleton *et al.* 2003, Duka and Masters 2005, Herbert 2007). Large-scale field trials of progestin hormone implants conducted in Victoria at Tower Hill (Middleton *et al.* 2003) and Mt Eccles National Park (Parks Victoria unpublished data) suggest that this technique is practicable, though costly (exact costings are not available but a reasonable estimate of the cost of a large-scale hormone implant program is around $200 per treated animal). It is now proposed that progestin hormone implants will become the principal fertility control method for over-abundant Koala populations in Victoria (Menkhorst 2004).

## Genetic issues

Unfortunately, the stock used to found the French Island population in about 1898 probably comprised only a few animals (Houlden *et al.* 1996), thereby creating a severe genetic bottle-neck. The founders for the Phillip Island population were more numerous and from a greater geographical range, but never-the-less also represent a significant genetic bottleneck. The genetic bottle-neck effect was then amplified when subsets of these populations were marooned on other islands, resulting in significant inbreeding.

An unforeseen consequence of using these populations to restock the Victorian mainland is likely to have been the genetic swamping of any remnant populations by the restricted and inbred island gene pool. Thus, the level of genetic variation in Victorian Koala populations established through translocation is significantly lower than that found in the major relict Victorian population (South Gippsland) and across comparable areas in NSW and Qld (Emmins 1996; Houlden, *et al.* 1996, 1999). Therefore, there is a higher threat of inbreeding depression in Victorian Koala populations than in Koala populations further north (Emmins 1996).

Although genetic theory predicts that populations with low genetic variation will have lower survival prospects, there is currently no evidence that the population growth potential of Victorian Koalas is being constrained by their genetic history. On the contrary, many populations derived from island stock are flourishing, for example in the eastern Otway Ranges. However, given the finding that a higher than normal proportion of male Koalas on French Island exhibit testicular aplasia (Seymour *et al.* 2001), it would be prudent to be alert to signs of inbreeding depression in Victorian Koalas (Sherwin *et al.* 2000).

In South Gippsland, including the Strzelecki Ranges, remnants of the original gene pool survive, thanks to a strong remnant population and few releases of island stock (Emmins 1996). For this reason, Koala management strategies have recommended against translocation into South Gippsland (Martin 1989; Menkhorst 2004). It is also probable that Koalas east of the Snowy River, except those immediately around Mallacoota township, are largely unaffected by the translocation program (see Figure 7).

## Assessing the effectiveness of the translocation program

Any fair assessment of the success of the translocation program using modern criteria and standards (IUCN 1998) should give due regard to the original aims of the program, and how these changed through time. It is also important to have regard for the knowledge available at a given time and the prevailing attitudes towards wildlife. In 1923, the science of genetics was in its infancy, and the concepts of inbreeding and small founder size were not well articulated. Therefore, it is perhaps not fair to point to the genetic consequences of the re-introduction program as evidence of a failure of the program. That criticism can be more fairly applied to management from about 1970 onwards when alternatives to translocation could have been more vigorously pursued.

Table 3 presents a qualitative assessment of the degree to which the important considerations in planning a re-introduction program (as defined by IUCN 1998) were considered during the three phases of management of Koalas in Victoria. Given that the program preceded the IUCN guidelines by up to 70 years, and that the science of conservation biology has developed only since about 1980, the program stands up well against these modern criteria.

The marooning phase succeeded in establishing populations on all the coastal islands to which Koalas were taken and these island populations provided ample stock for the re-introduction program. However, significant management problems were created: the on-going management of population levels on all of the islands has consumed a major component of Victoria's wildlife management budget ever since; the ecological cost to the island's indigenous floral and faunal communities has never been properly investigated or documented, but is likely to have been serious in all cases (for example Figure 1); severe genetic bottle-necks were created, and the animal welfare cost has been significant.

The re-introduction phase was clearly successful because populations have persisted and expanded over several decades (up to six) in most regions where releases took place (Figure 7). There are now many times more Koalas in Victoria than there were in 1944 when the re-introduction phase began. However, neither the animal welfare cost, nor the financial cost, was ever adequately documented, and the genetic cost is, perhaps, yet to become clear. The habitat protection phase has been successful at some sites, such as French Island, where an adequate and timely translocation program has been in place for over 50 years, but has been less successful at sites where translocations were too limited or too late, for example Sandy Point (1985), Snake Island (1992) and Framlingham (1997).

Initiation of research to develop acceptable alternatives to translocation came too late to allow a seamless transfer from translocation to in-situ population control. After a decade of research it is still not certain that a practicable method that meets animal welfare standards and expenditure targets will be found. Sub-dermal, slow-release hormone implants containing levonorgestrel provide the most promising means of limiting population growth, but, on their own, will not produce a rapid population reduction. Therefore, this technique needs to be applied long before unsustainable population densities are reached. Continuing exploration of other avenues of population control is essential.

**Table 3.** Assessment of consideration given to relevant criteria during each phase of the translocation program. n – little or none; p – partially considered; y – considered; na – not applicable.

| Consideration | Phase | | |
|---|---|---|---|
| | Marooning | Re-introduction | In-situ |
| Stakeholder approvals | P | Y | Y |
| Commitment of long-term financial and political support | P | P | P |
| Access to technical advice | P | P | Y |
| Appropriate taxon – close genetic relationship to original stock | Y | Y | NA |
| Intra-specific variation considered | N | P | NA |
| Critical needs understood | P | P | NA |
| Potential ecological impacts understood | N | P | P |
| Optimal number and composition understood | N | P | P |
| Assured long-term protection of release areas | Y | P | Y |
| Habitat adequate | N | P | NA |
| Threats controlled | Y | P | P |
| Impacts on donor population assessed | N | P | NA |
| Veterinary screening process established | N | N | Y |
| Monitoring and success indicators agreed | N | N | Y |
| Decision process for revision, rescheduling, discontinuation | N | N | Y |
| Transport plan developed | Y | Y | NA |
| Release strategy in place | ? | P | NA |
| Policy on interventions agreed | ? | N | P |
| Collection and investigation of mortalities | N | P | Y |
| Documentation of outcomes | N | P | Y |

Despite the cost and the threat of problems caused by reduced genetic variation, the re-establishment of the Koala in almost all remaining habitat across most of its original Victorian distribution can be considered the most successful wildlife management program undertaken in that State. It can also reasonably be claimed to be a successful threatened species recovery program, one of very few ever achieved in Victoria, and it would not have been possible were it not for the fortuitous creation of two introduced island colonies (Warneke 1978), and the decision in 1923 to create more of them.

## Conclusion

The Koala in southern Australia provides a unique wildlife management challenge. It is declining in some regions yet is prone to extreme over-abundance in others. It causes serious ecological damage and animal welfare crises when population levels exceed food availability, yet attracts enormous public support and concern. The management of these issues by the Victorian Government over 80 years has provided valuable lessons in wildlife management. It represents a unique, long-term conservation management trial that has succeeded on one level, but has inadvertently generated several intractable population management issues which are yet to be fully resolved. The management of over-abundant Koalas has highlighted a public expectation that non-lethal control methods can be effective to manage wildlife populations. The development of practicable, ethically-acceptable and cost-effective means of meeting this expectation remains a major challenge for wildlife managers.

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# APPENDIX I

Appendix 1A. Releases of Victorian Koalas onto Islands

| Release island | Source population | Year | Number | Notes |
|---|---|---|---|---|
| French Is. | Corinella area | 1898? | ? 2 ♀ | |
| Phillip Is. | West Gippsland, Mornington Pen. | Late 1800s | ? | |
| Phillip Is. | French Is. | 1923 | 50 | |
| Kangaroo Is. | French Is. | 1923 | 6 | South Australia |
| Kangaroo Is. | French Is. | 1925 | 12 | South Australia |
| Quail Is. | French Is. | 1930 | 45 | All (1308) Koalas removed in 1944 |
| Chinaman Is. | French Is. | 1930 | 15 | |
| Quail Is. | French Is. | 1931 | 30 | |
| Chinaman Is. | French Is. | 1931 | 30 | All Koalas removed 1952 |
| Quail Is. | French Is. | 1932 | 60 | |
| Quail Is. | French Is. | 1933 | 30 | |
| Snake Is. | Phillip Is. | 1945 | 69 | |
| Snake Is. | French Is. | 1945 | 64 | |
| Quail Is. | Phillip Is. | 1947 | 32 | |
| Wartook Is. | Creswick Koala Res. | 1947 | 12 | Island in Wartook Reservoir, The Grampians. All (74) Koalas removed 1957-1965 |
| Wartook Is. | Phillip Is. | 1948 | 16 | |
| Goat Is. | Chinaman Is. | 1952 | 4 | Island in Murray River at Swan Hill. All remaining animals removed to Pental Island in 1976. |
| Raymond Is. | Phillip Is. | 1953 | 32 | |
| Chinaman Is. | French Is. | 1957 | 48 | |
| Loch Is. | French Is. | 1957 | 6 | Island in Murray River, Mildura. Population did not establish. |
| Hallstrom Is. | Stony Rises | 1962 | 4 | Island in Lake Eucumbene, NSW. |
| Loch Is. | Wartook Is. | 1963 | 6 | |
| Total | | | 573 + | |

APPENDIX I

Appendix 1B. Numbers of Koalas translocated from Victorian islands

| Year | French | Phillip | Quail | Chinaman | Wartook | Snake | Raymond | totals |
|---|---|---|---|---|---|---|---|---|
| **1923** | 56 | | | | | | | 56 |
| **1925** | 12 | | | | | | | 12 |
| **1927** | 1 | | | | | | | 1 |
| **1928** | 11 | | | | | | | 11 |
| **1930** | 62 | | | | | | | 62 |
| **1931** | 66 | | | | | | | 66 |
| **1932** | 60 | | | | | | | 60 |
| **1933** | 30 | | | | | | | 30 |
| **1935** | 38 | | | | | | | 38 |
| **1938** | 6 | | | | | | | 6 |
| **1939** | 33 | | | | | | | 33 |
| **1940** | 28 | | | | | | | 28 |
| **1941** | | 114 | | | | | | 114 |
| **1942** | | 74 | | | | | | 74 |
| **1943** | | 97 | | | | | | 97 |
| **1944** | | 865 | 1308 | 6 | | | | 2179 |
| **1945** | 96 | 583 | | | | | | 679 |
| **1947** | | 32 | | | | | | 32 |
| **1948** | | 16 | | | | | | 16 |
| **1951** | | 38 | | | | | | 38 |
| **1952** | | 106 | | 39 | | | | 145 |
| **1953** | | 160 | | | | | | 160 |
| **1954** | 711 | | | | | | | 711 |
| **1955** | | 12 | | | | | | 12 |
| **1956** | 41 | | | | | | | 41 |
| **1957** | 1483 | 425 | | | 38 | | | 1946 |
| **1958** | | 458 | | | | | | 458 |
| **1960** | 268 | | | | | | | 268 |
| **1963** | | | | | 6 | | | 6 |
| **1965** | 111(min.) | | | | 30 | | | 141 |
| **1969** | 6 | | | | | | | 6 |
| **1970** | 166 | | | | | | | 166 |
| **1971** | | 8 | | | | | | 8 |
| **1972** | 74 (min.) | | | | | | | 74 |
| **1973** | | 180 | | | | | | 180 |
| **1974** | | 29 | | | | | | 29 |
| **1975** | | 30 | | | | | | 30 |
| **1976** | | 20 (min.) | | | | | | 20 |
| **1977** | 294 | 121 | | | | | | 415 |
| **1978** | | 70 | | | | | | 70 |
| **1979** | 110 | | | | | | | 110 |
| **1980** | 111 | | | | | | | 111 |
| **1981** | 241 | | | | | | | 241 |
| **1982** | 591 | | | | | | | 591 |
| **1983** | 36 | | | | | | | 36 |
| **1985** | 182 | | | | | | | 182 |
| **1986** | 76 | | | | | | | 76 |
| **1987** | 203 | | | | | | | 203 |
| **1988** | 87 | | | | | | | 87 |
| **1989** | 208 | | | | | | | 208 |
| **1990** | 226 | | | | | | | 226 |
| **1991** | 147 | | | | | | | 147 |

| Year | French | Phillip | Quail | Chinaman | Wartook | Snake | Raymond | totals |
|---|---|---|---|---|---|---|---|---|
| **1992** | 137 | | | | | 46 | | 183 |
| **1993** | 134 | | | | | | | 134 |
| **1994** | 111 | | | | | 82 | | 193 |
| **1995** | 134 | | | | | | | 134 |
| **1996** | 158 | | | | | | | 158 |
| **1997** | 234 | | | | | 562 | | 796 |
| **1998** | 195 | | | | | | | 195 |
| **1999** | 212 | | | | | 204 | | 416 |
| **2000** | 203 | | | | | 66 | | 269 |
| **2001** | 170 | | | | | 242 | | 412 |
| **2002** | | | | | | 446 | | 446 |
| **2003** | 170 | | | | | 50 | | 220 |
| **2004** | 416 | | | | | 185 | 371 | 972 |
| **2005** | 250 | | | | | 441 | | 691 |
| **2006** | 156 | | | | | 283 | 11 | 450 |
| **Totals** | 8551 | 3438 | 1308 | 45 | 74 | 2607 | 382 | 16405 |

**Appendix 1C.** Translocations of Koalas from Victorian mainland habitat. There were no translocations from mainland habitat between 2003 and 2007. Ckp – Creswick Koala Park; Mt A – Mt Alexander Koala Park; SR – Stony Rises; BR – Brisbane Ranges; SP – Sandy Point and surrounds; Fram – Framlingham; TH – Tower Hill; Mt E – Mt Eccles.

| Year | Ckp | Mt A | SR | BR | SP | Fram | TH | Mt E | Totals |
|---|---|---|---|---|---|---|---|---|---|
| **1946** | 30 | | | | | | | | 30 |
| **1947** | 31 | 102 | | | | | | | 133 |
| **1948** | | 6 | | | | | | | 6 |
| **1950** | | 9 | | | | | | | 9 |
| **1952** | 6 | | | | | | | | 6 |
| **1955** | | 20 | | | | | | | 20 |
| **1962** | | | 4 | | | | | | 4 |
| **1966** | | 12 | | | | | | | 12 |
| **1969** | | | | 16 | | | | | 16 |
| **1985** | | | | | 23 | | | | 23 |
| **1986** | | | | | 44 | | | | 44 |
| **1987** | | | | | 136 | | | | 136 |
| **1988** | | | | | 228 | | | | 228 |
| **1989** | | | | | 263 | | | | 263 |
| **1990** | | | | | 217 | | | | 217 |
| **1991** | | | | | 167 | | | | 167 |
| **1992** | | | | | 33 | | | | 33 |
| **1993** | | | | | 45 | | | | 45 |
| **1994** | | | | | 46 | | | | 46 |
| **1995** | | | | | 67 | | | | 67 |
| **1996** | | | | | 55 | 59 | 199 | | 313 |
| **1997** | | | | | 59 | | 147 | | 206 |
| **1998** | | | | | 44 | 1077 | 41 | | 1162 |
| **1999** | | | | | 45 | 130 | | 850 | 1025 |
| **2000** | | | | | 47 | | | 683 | 730 |
| **2001** | | | | | 3 | | | 1193 | 1196 |
| **2002** | | | | | | | | 1528 | 1528 |
| **Totals** | 67 | 149 | 4 | 16 | 1522 | 1266 | 387 | 4254 | 7665 |