MANAGEMENT OF URBAN COMMON BRUSHTAIL POSSUMS (*TRICHOSURUS VULPECULA*)

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Declaration

This thesis is presented for the degree of Doctor of Philosophy at Macquarie University 2006.

The work described is original and has not been submitted, in any form, for a higher degree at any other university or institution. All of the presented work was undertaken during my PhD candidature, which started in August 2002.

None of the papers in this thesis are sole-authored. The concept for this thesis is my own, and I performed the data collection, data analysis and writing for each of the chapters/manuscripts, unless otherwise stated. Hence, it is appropriate that the work be included in this thesis. However, I have obtained help in this process from various other people, and their contribution is acknowledged in the role of co-authors.

Chapter description

Cathy Herbert had considerable input into every chapter. Cathy gave advice on appropriate handling of brushtail possums, discussed the design of the experiments with me, gave feedback to my interpretation of results, and helped with the editing process of all manuscripts. The particular contribution to each chapter is described below.

Des Cooper was my main supervisor for the first 2.5 years at Macquarie University. Hence, Des initiated some contents of this thesis, and his intellectual property is reflected in some chapters. Des also encouraged the preparation of publications.

Chapter 1:

I reviewed the literature and wrote this chapter entirely by myself, with helpful comments from Cathy Herbert.

Chapter 2:

I designed the experiments, collected all the data with assistance from AgResearch staff (see below), processed all sera samples, collected, analysed and interpreted the results and wrote the entire chapter. In this process, I received helpful feedback from Cathy Herbert as described above and the other co-authors as follows:

Doug Eckery supervised my research stay at AgResearch, Wallaceville, New Zealand. Doug gave helpful feedback with the design of the experiments, assisted with the data collection for the GnRH challenge, and commented on my interpretation of the results.

Brian Thomson made me familiar with the working procedures and handling of the brushtail possums in the breeding unit of AgResearch, Wallaceville, New Zealand. Brian assisted greatly with the serum collection for the intense 3-month trial and monitored some animals for potential offspring beyond my first stay at AgResearch.

Tim Trigg generously contributed the slow-release implants containing deslorelin, which are the intellectual property of Animal Peptech Health Pty Limited.

Chapter 3:

I designed the experiment, organised access to private properties, collected all the field data, analysed and interpreted the results and wrote the entire chapter. I received helpful feedback from Cathy Herbert as described above.

Chapter 4:

I designed the experiment, collected all the field data, initiated the collaboration with Dr JP Dubey , applied for and was awarded a PGRF grant from Macquarie University to fund my stay at the US Department of Agriculture, processed all samples in Dr JP Dubey's laboratory, analysed and interpreted the results and wrote the entire chapter. I received helpful feedback from Cathy Herbert as described above and from Dr. JP Dubey as follows:

J. P. Dubey from Animal Parasitic Diseases Laboratory at the US Department of Agriculture generously offered his facilities, means and training by dedicated staff to allow the processing of brushtail possum sera samples. JP Dubey also helped with the interpretation of the results and the editing process of the manuscript for Chapter 4.

Chapter 5

I designed the experiment, collected all the field data, initiated the collaboration with Lee Smythe, analysed and interpreted the results and wrote the entire chapter. The sera samples were processed at the WHO/FAO/OIE Collaborating Centre for Reference and Research on Leptospirosis, Queensland. I received helpful feedback from Cathy Herbert as described above and from Lee Smythe as follows:

Lee Smythe from the WHO/FAO/OIE Collaborating Centre for Reference and Research on Leptospirosis, Queensland generously offered the processing of brushtail possum sera samples. Lee helped with the interpretation of the results and the editing process of the manuscript for Chapter 5. Meegan L. Symonds, Michael F. Dohnt and Leonie J. Barnett are staff members of the institution and were involved with the processing of the sera samples.

Chapter 6

I wrote the entire final discussion to the previous chapters, with helpful feedback from Cathy Herbert.

Appendices description

Appendix A

I observed the adult female brushtail possum with two young when conducting the field work for Chapter 3. I collected all the data, analysed and interpreted all results, and wrote the entire manuscript. I received helpful feedback from Cathy Herbert as described above and the contribution of Mark Eldridge and Linda Neaves is described below:

Linda Neaves processed the brushtail possum tissue samples of the female and the two young, analysed the microsatellite and haplotype data and added the results of the genetic analysis to the manuscript.

Mark Eldridge extracted the DNA from the brushtail possum tissue samples of the female and the two young, helped with the interpretation of the genetic analysis, gave advice on how to present the genetic data and provided feedback to the entire chapter.

Appendix B

I observed the problem with failure of PIT tags in individual brushtail possums when conducting the field work for Chapter 3. I collected all the data, initiated the collaboration with Lee Webley, analysed and interpreted all results, and wrote the entire manuscript. I received helpful feedback from Cathy Herbert as described above and the contribution of Lee Webley is described below:

Lee Webley processed part of the brushtail possum tissue samples collected (most had been already processed for Appendix C) and performed the genetic data analysis. Lee matched the identical genotypes, calculated the P(ID) and gave helpful feedback to the manuscript.

Appendix C

Appendix C is exceptional in that it contains a manuscript that is not first-authored by me. However, I was greatly involved in the work for it: I chose the field sites, collected all the tissue samples and field data, helped with the interpretation of the results and wrote parts of the introduction, materials and methods and discussion. I also reviewed final drafts.

Adam Stow is an expert in the use of genetic techniques to investigate genetic diversity and dispersal. Adam suggested the use of GenAlEx V5 and performed and interpreted major parts of the data analysis. Adam also wrote and reviewed great parts of the manuscript and hence, made the major contribution to its contents.

Nadia Minarovic was an honours student at Macquarie University in 2003. She processed the brushtail possum tissue samples and included the results of the genetic analysis partly into her Honours thesis which substantially differs from this publication.

Lee Webley was supervising the genetic work of Nadia Minarovic and performed and interpreted major parts of the data analysis. Lee also wrote parts of the manuscript and hence, substantially contributed to the contents. Lee also took care of the correspondence with the journal.

Appendix D

This conference abstract was entirely written by me, reviewed by all other co-authors, peer-reviewed by conference participants and published in the Extended Abstracts of the XXVIIth Congress of the International Union of Game Biologists, Hannover 2005. DSV-Verlag Hamburg, pp. 78-79.

Appendix E

I added the description of the study sites and the awards won during my candidature.

Numerous other people have made this thesis possible, and their contributions are outlined in the acknowledgements of each chapter.

Signed: ……………*J. Eymann*……………….. Date: ……31-March-2006…………

(Jutta Eymann)

Abstract

The common brushtail possum (*Trichosurus vulpecula*) is indeed a common inhabitant of many Australian cities, and one of the few marsupials that has adapted well to the urban environment. Their close proximity to people provides a great opportunity to experience native wildlife in the backyard, however, their utilization of house roofs, bold behaviour and appetite for garden plants often leads to conflict with householders. Population numbers are sufficiently high to require ongoing management to minimise negative impacts for humans and brushtail possums alike in a socially acceptable manner. The aim of this thesis was to identify current management issues and address the need for improved and novel management strategies. The potential of slow-release implants, containing the GnRH agonist deslorelin, as a contraceptive agent for brushtail possums was tested on a captive population. Males appeared resistant to treatment, but deslorelin was found to inhibit reproduction in female brushtail possums for at least one breeding season, making it a promising tool to control fertility in some wild populations. A further aim was to trial deslorelin implants on a wild urban population, to collect more information about the urban biology of this species and to point out issues which have previously not been addressed. Close proximity and interaction of urban brushtail possums with humans and their domestic animals can increase the risk of disease exposure and transmission and influence the health of wild populations. Serosurveys showed that animals were readily exposed to *Leptospira* spp. and *Toxoplasma gondii*. This thesis also provides the first data on brushtail possum dispersal in urban areas, knowledge which is highly relevant to the development of management strategies such as fertility control. The findings from this research broaden our knowledge about urban brushtail possums and should assist wildlife authorities in developing alternative or improved management procedures.

Acknowledgements

Over the last few years, I have been meeting many people who I owe a big ‘thank you’. This thesis would not have been possible without their assistance, support and encouragement.

Dr. Cathy Herbert deserves the warmest thanks. Her ongoing support and enthusiasm for the project has always been there, and her advice was invaluable throughout all stages. With the help of her husband Paul, a brushtail possum expert, I was introduced to my study animal and their proper handling. Cath and I not only worked well together on many occasions, but we also had some wonderful times attending conferences and meeting native wildlife.

My other supervisor, Prof. Des Cooper, has introduced me to the world of marsupials upon my arrival in Australia. Des has been very supportive of this project and given free play to pursue different ideas. He was always generous in providing means for research and conference visits and provided me with many wonderful opportunities.

Dr. Mariella Herberstein jumped in as my official supervisor at Macquarie University, when Cath and Des changed workplace. Mariella has my deepest respect as a supervisor. She always had time for me, and has the cunning ability to understand the core of any problem immediately. Her response time was always extremely swift and apart from great advice on statistical issues, we managed to win an award for the postgraduate research fund application within the university.

The research on the effects of deslorelin on brushtail possums was conducted at the AgResearch institution in Wallaceville, New Zealand. Dr. Doug Eckery was very supportive of my visit, and I am very thankful for having been given the opportunity to work in their breeding unit and getting so close to the brushtail possums. Brian Thomson also gave great support, showing me handling procedures and helping with the data collection. Michael Beaumont did a wonderful job in looking after the animals and also helped with their handling. Dr. Janet Crawford’s advice was invaluable for the hormone assay procedures, and Brigitta Mester helped as well. Leanne and Mark Phillips generously accommodated me during my first stay and Jenny Juengel for my second stay, and both were great hosts. Many other staff of AgResearch always offered a helping hand, and overall, I had a truly great New Zealand experience.

Two weeks of my Ph.D. were also spent at the ‘Animal Parasitic Diseases’ Lab in Beltsville, Maryland, USA. I need to thank Dr. J. P. Dubey for welcoming me into his lab, Dr. Sam Shen for accommodating me during my stay and Dr. Oliver Kwok for showing me the lab procedures – they all made my stay truly enjoyable!

My field work back in Sydney would not have been possible without the help of many householders who allowed me to trap brushtail possums on their properties. They deserve a really huge ‘thank you’. Many have been extremely supportive over the years, helping as much as they could, and spoiling me with cups of tea and biscuits. Their enthusiasm and support for the brushtail possums has driven my motivation immensely. In particular, I thank Debra Birch and Peggy and Juha Havukainen for accommodating me in their fantastic little boat sheds on Scotland Island. Special thanks to Jan Tent for taking brushtail possum pictures and even proof-reading a couple of chapters in this thesis, and also a big ‘thank you’ to Ron Bradner, Susan Medworth, Evelyn Hadfield, Struan Lamport, the Pulvers family, Sarah Johannson, Michelle Coady, Anne and Dave Cornford, Wendy Cousins, Izabela Konzac-Islam, Don Camble, Marianne McMillan, Maryvonne McKeyDoyle, Claire Bennet, Margo and Brian Pickering, Allison Payne, Terry and Catherine Insley, Mary Lilith, Jay Ekers, Sorbi Smith, Janet and Paul Boocock, Erica Mills, Renee Rawson, Teena Cooper, Jenny Donald and many more. A special mention to Tracey Adams, Cilla Norris, Audrey, Marjolaine, Bridget and many other students who also gave much support with the fieldwork, and to Dan Lunney from NSW National Parks and Wildlife Service (NPWS) who provided valuable advice on aspects of this work and gave his support for this project in general.

The Department of Biological Sciences, Macquarie University has been overall a very friendly place to work in, and I owe thanks to staff members and other students that have been there with me. The ‘Cooper Lab’ and the Behavioural Ecology lab group welcomed me warmly. Special thanks to Lee

Webley, who helped me to identify animals with PIT tag failure, and to my office-mates Jenny Kingston, Sarah Wilks and Anne Gaskett who have all been great company. Thanks also to the international student office which awarded two travel scholarships for going overseas, and the research office which generously extended my scholarship.

Lastly, my partner Pete deserves special mention for his companionship over the last few years. He has provided much support, climbing up and down the trees looking for brushtail possums, reading chapters of this thesis, and he made my Australian experience truly complete.

Just one final thank you – to the brushtail possums! They have treated me very well over the last few years, it has been a privilege to work with them and thoroughly enjoyable, and I will keep looking out for them.

Conference Presentations and Awards

Conference poster presentations

Eymann, J., Herbert, C.A., Lunney, D., Trigg, T., and Cooper, D.W. (2003). Researching urban management problems of brushtail possums. 49th Australian Mammal Society Meeting, Sydney, New South Wales, Australia.

Webley, L., Minarovic, N., Stow, A.J., Eymann, J., and Cooper, D.W. (2005). Male-biased dispersal in urban populations of brushtail possums (*Trichosurus vulpecula*). 18th Australasian Wildlife Management Society Conference, Hobart, Tasmania, Australia.

Conference oral presentations

Eymann, J., Herbert, C.A., Lunney, D., Trigg, T., and Cooper, D.W. (2003). Management and conservation of brushtail possums in urban and native environments in Australia. 3rd International Wildlife Management Congress, Christchurch, New Zealand.

Eymann, J., Herbert, C.A., and Cooper, D.W. (2004). Brushtail possums in urban areas: a management challenge. 17th Australasian Wildlife Management Society Conference, Kangaroo Island, South Australia, Australia.

Eymann, J., Smythe, L., Herbert, C.A., and Cooper, D.W. (2005). Serologic survey for selected disease agents in urban brushtail possums (*Trichosurus vulpecula*) from Sydney**.** International Wildlife Disease Association Conference, Cairns, Queensland, Australia.

Eymann, J., Smythe, L., Herbert, C.A., and Cooper, D.W. (2005). Serologic survey for selected disease agents in urban brushtail possums (*Trichosurus vulpecula*) from Sydney. 51st Australian Mammal Society Meeting, Albany, Western Australia, Australia.

Eymann, J., Herbert, C.A., Lunney, D., Trigg, T., Eckery, D., and Cooper, D.W. (2005). Management issues of urban common brushtail possums (*Trichosurus vulpecula*) – a loved or hated neighbour. XXVIIth Congress of the International Union of Game Biologists, Hannover, Germany.

Conference proceedings (see Appendices)

Eymann, J., Herbert, C.A., Lunney, D., Trigg, T., Eckery, D., and Cooper, D.W. (2005). Management issues of urban common brushtail possums (*Trichosurus vulpecula*) – a loved or hated neighbour. XXVIIth Congress of the International Union of Game Biologists, Hannover, Germany.

Awards (see Appendices)

Macquarie University Deputy Vice Chancellor (Research) commendation for outstanding postgraduate research fund application, July 2005.

1st prize for best oral presentation in the student award competition held on the occasion of the XXVIIth Congress of the International Union of Game Biologists, Hannover, Germany, September 2005.

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Preface

Introduction to wildlife management

Wildlife managers primarily are occupied with the management of wildlife populations (Caughley and Sinclair 1994), but may also deal with people, education, or law enforcement. Until recently, wildlife management has been a rural issue, but with a growing human population and expanding cities, some species have adapted well to urban environments (Knuth *et al.* 2001). This has led to greater human-wildlife interactions, and the management of wildlife nuisance situations, threats to health and safety, and economic damage is a growing area.

In its core, wildlife management targets manipulation or protection of a population (Caughley and Sinclair 1994). Manipulative management aims to change the population numbers, either directly or indirectly such as altering habitat, density of predators, food supply or prevalence of disease. Manipulative management is applied when a population has an unacceptably low density or, contrastingly, too high a density. Custodial management on the other hand is aimed at protecting a population and its habitat. Four management aims are available – to make a population increase or decrease or harvest it in a sustainable manner or simply leave it alone, but monitor it.

The common brushtail possum (*Trichosurus vulpecula*) is a solitary, nocturnal, arboreal marsupial native to Australia (Kerle 2001). This species is a challenge for wildlife managers. In Australia, brushtail possum populations are in decline throughout much of their natural range (Goldingay and Jackson 2004). However, their decline in some rural areas contrasts with their abundance in urban environments and on some islands e.g. Magnetic Island (Isaac 2005), Kangaroo Island and Tasmania. Ironically, while some brushtail possum populations are in decline, others are considered locally 'overabundant' and create problems. It is a dilemma if a species is in need of protection over most of its natural range, while in other native areas, such as Tasmania, they are killed to prevent damage to plantations (McArthur *et* *al.* 2000). In New Zealand, brushtail possums are entirely out of place, having been introduced for fur trade in the late 1800s (Cowan 1990). Now, they are considered a major pest and eradication is the ultimate goal of New Zealand wildlife managers (Montague 2000).

Management of these different brushtail possum populations will differ significantly, and intervention is required if they are in decline or if they are 'overabundant'. But what does 'overabundance' really mean? Can wildlife ever be too abundant? Overpopulation may be defined as too many animals in four scenarios (Caughley 1981): a) the animals threaten human life or livelihood, b) the animals depress the densities of other favoured species, c) the animals are too numerous for their own good and d) the animals are not in equilibrium. In the case of the brushtail possum, urban animals are often viewed as a nuisance to people if they live in their roof or browse on garden vegetation; in Tasmania, they inflict commercial forestry damage by browsing on *Eucalyptus* plantations (le Mar and McArthur 2003); and in New Zealand they are a major non-native pest, spreading bovine tuberculosis, damaging native forests and preying on eggs and chicks of native birds (Montague 2000). Therefore, wildlife managers deal with quite varying problems, such as animal welfare, vegetation protection, or commercial damage.

All management actions may be restricted by the availability of funds and are directed by the urgency of the problem. In New Zealand, approximately NZ$ 58 million was spent on research and management of brushtail possum populations in 1993/94 alone (Cullen and Bicknell 2000). The cost of knocking down a high density population was estimated at NZ$ 20 to $ 30/ha and for eradication of an island population more than NZ$ 61/ha would have to be spent. However, effective management of any brushtail possum population requires knowledge of the basic biology of the species. Any attempts at managing a population may be futile if we do not know about the species life history, demography and population dynamics.

Population ecology of the common brushtail possum

The reproduction of the brushtail possum has been extensively reviewed (Tyndale-Biscoe and Renfree 1987; Fletcher and Selwood 2000). It is a polyoestrous species, having successive oestrus cycles of about 26 days until conception occurs. The gestation period, from copulation to birth, is 17-18 days and about 8 days shorter than the oestrous cycle. Oestrus and ovulation are usually suppressed by lactation, but females can ovulate again about 8 days after loss or removal of the pouch young. Females are usually strictly monotocous (presenting one offspring at a time) and monovular with ovulation occurring spontaneously from either ovary. Brushtail possums are seasonal breeders and in Australia most females give birth in autumn, with a second minor peak of births in spring. The onset of the breeding season may vary depending on the geographical location; for the Sydney area March to May are considered the major breeding months (Bolliger 1940 in Tyndale-Biscoe 1955; Lyne and Verhagen 1957). The young exit the pouch for the first time at about 140 days and permanently leave it by 170 days (Kerle 2001). They are weaned at around 240 days and become independent.

Table 1. Summary of key definitions in population ecology.

Key definitions (after Campbell et al. 2006)

- **Life history**: the series of events from birth through reproduction and death.
- **Demography**: the study of statistics relating to births and deaths in populations.
- **Population**: a localized group of individuals that belong to the same biological species and are capable of interbreeding and producing fertile offspring.
- **Population dynamics**: the study of how complex interactions between biotic and abiotic factors influence variations in population size
- **Population ecology**: the study of populations in relation to the environment, including environmental influences on population density and distribution, age structure, and variations in population size.

Life history

The term 'life history' refers to the stages of life undergone by an individual from birth to death, with particular reference to strategies influencing survival and reproduction (Campbell *et al.* 2006, see Table 1). The course of life is defined by factors such as age at sexual maturity, first mating and reproduction, fecundity, inter-birth interval and age specific mortality. Life history strategies are largely determined by the species size and physiology, and by climatic conditions, habitat type and food quality (Kerle 2001). Density-dependent factors such as intra-and inter-specific competition for resources (including food and den sites) may interact with density-independent factors such as climatic and environmental pressures (Isaac 2005). The brushtail possum has an especially flexible life history strategy that is influenced by the carrying capacity and suitability of the various habitats they occupy, and populations are able to alter fecundity, behaviour and diet (Kerle 2001). Natural selection often determines which individuals survive and reproduce, but even strong selection on any trait is unlikely to make a marked difference to population dynamics in a population that is limited by the availability of resources such as nest sites (Saccheri and Hanski 2006).

Population dynamics

By measuring life history parameters and estimating the population size it is possible to consider a range of questions (Sutherland 1996). "What determines the level of abundance? Why does the population fluctuate from year to year? How strong is density dependence and at what life stage does it operate? What are the consequences of competitors or predators on the population?" The use of observational data in answering such questions poses considerable problems; instead it requires density manipulation, for example by adding or removing animals (Sutherland 1996). The mechanistic paradigm (contrasting to the density-dependent paradigm) ignores density dependence, but focuses directly on mechanisms of regulation and addresses rather the impact of disease, predators and food shortage on population dynamics (Krebs 1995).

There have been numerous population studies of brushtail possums in Australia and New Zealand (for review see Kerle 1984, Kerle 2001; Goldingay and Jackson 2004; Efford 2000), and most studies describe basic population parameters (such as fecundity and densities) that vary considerably between different populations. However, the factors that control brushtail possum populations and what really drives their population dynamics is not clearly elucidated. Some of this variation in populations seems to be related to habitat quality (Kerle 2001). Generally, population growth is driven by key factors such as mortality rates, birth rates, migration and there are other factors which influence these. It has been suggested that resource-dependent factors are of much greater importance in the regulation of common brushtail possum populations than external factors such as predation (Kerle 2001). For example, population densities of northern brushtail possums (*T. vulpecula* arnhemensis, a subspecies) in the wet-dry tropics of Australia's Northern Territory appeared to thrive because of the ready availability of food resources that enabled females to breed continuously (Kerle 1998). On Magnetic Island, Queensland, the absence of large predators and apparently low competition for dens seemed to promote a higher density of animals than in any other reported Australian population. Food availability appeared to potentially constrain population densities (Isaac 2005). Brushtail possum populations in New Zealand reach higher densities than any recorded in their native Australia (Efford 2000). There has been great effort trying to understand the population dynamics of the brushtail possum in New Zealand because of its status as a major pest. Higher densities in New Zealand may be attributed to a combination of factors such as the absence of large predators, a lower range of parasites, higher digestibility and nutrient content of foliage and no competition with other folivorous marsupials.

Brushtail possums have adapted well to most urban areas, possibly because they provide additional resources not seen in natural habitats, such as artificial den sites and an abundant food supply (Statham and Statham 1997; Kerle 2001). The numerous studies on Australian and New Zealand populations (Kerle 1998, Isaac 2005; for reviews see Kerle 1984, 2001; Efford 2000) may not necessarily be applicable to the life history of urban brushtail possums as there is wide variation between the different populations. The population dynamics of brushtail possum populations in general are not entirely understood to date (Efford 2000), and it remains uncertain why some populations thrive while others are in decline (Isaac 2005; Goldingay and Jackson 2004). There is also a paucity of knowledge about the biology of brushtail possums in urban areas. The few studies that involve urban brushtail possums mainly address home range and use of den sites (Harper 2005, Statham and Statham 1997). Astoundingly, urban brushtail possum population dynamics have not been investigated yet, nor are the basic urban population parameters (such as sex ratio, age structure, fecundity, mortality) readily available.

General thesis introduction

The common brushtail possum (*Trichosurus vulpecula*) is indeed a common guest in Australian (sub-) urban neighbourhoods, but surprisingly little is known about its urban biology. Brushtail possums have a reputation both as ‘champions of the suburbs’ and ‘tormentors’ for taking up residence in house roofs and browsing on garden plants (Matthews *et al.* 2004). Their presence polarises the community into distinct parties, the possum-lovers, the -haters, and residents that are indifferent. This situation is a real challenge for wildlife authorities who are tested when community attitudes towards removing brushtail possums tend to conflict with management practices based on animal welfare and a policy of ‘living with wildlife’ (Matthews *et al*. 2004). In recent years, there has been increasing attention on managing overabundant native species (Garrott *et al.* 1993). However, brushtail possums may not get the same attention as large and charismatic native marsupials such as kangaroos and koalas, despite being one of the last native animals that live basically ‘next door’. Being one of the few marsupials that have adapted to our urban civilisation, brushtail possums offer the great potential to be a first hand opportunity to experience wildlife in your own backyard. However, it can not be denied that urban brushtail possums may cause undesirable situations, a fact that has been recognised by wildlife authorities (Matthews *et al.* 2004). There are also downsides to the animals living in such close contact with humans: the brushtail possum’s welfare in urban neighbourhoods is seriously threatened through human actions such as the illegal removal of the animals from private properties, a wide-spread and common ill-practice (Eymann *et al.* 2006). This shows that current management policies may be appropriate and animal-friendly, but are either not accepted or do not reach the entire public. This situation enhances the need for research into the biology of this species in urban areas, and the need for improved and/or novel management tools. As such, this thesis has set out to address these issues and have a closer look at these 'champions of the suburbs'.

My studies have also led me to other countries, such as New Zealand. Although the brushtail possum is not native to New Zealand, their status as a major pest has sparked huge interest into this species leading to major research projects (Cowan 2000). It seems only appropriate to utilise this knowledge and incorporate and assess if the New Zealand findings can be applied to Australia.

The central theme for this thesis is the management of urban common brushtail possums, and in pursuit of this, the key aims relevant to this topic are described as follows:

Main aims of this thesis

- To review existing management practices of common brushtail possums in urban environments, outline the current situation and give an outlook on potential future management tools (**Chapter 1**)
- To investigate the potential of the slow-release GnRH agonist deslorelin as an ethical technique for controlling fertility in common brushtail possums, a captive study (**Chapter 2**)
- To observe the effects of the contraceptive deslorelin implants on a wild population and collect basic biological information on the targeted urban population, a field study (**Chapter 3**)
- To examine the health status of urban common brushtail possums (**Chapter 4 and 5**)

Further outcomes of this thesis (Appendices)

- To report on a case of adoption in the urban common brushtail possum (**Appendix A**)
- To state technical problems encountered with field work and suggest potential improvements (**Appendix B**)

- To describe dispersal in this species, which is relevant to the application of fertility control (**Appendix C**)

These aims broadly fit together through the following rationale. The first step for this thesis was a comprehensive review, assessing and evaluating current management practices, and I have compiled this into **Chapter 1**. It was apparent that there was a clear need for improved and novel management strategies. Hence, research into a potential contraceptive agent for brushtail possums seemed a promising option.

One major focus of New Zealand research is on fertility control as a tool to control brushtail possum population numbers (Cowan 2000). Reducing the reproductive potential of a population is becoming an acceptable approach to managing 'problem' and pest wildlife (Cowan *et al.* 2003). Increasing public concern for animal welfare, together with a desire to find alternatives to culling for population control, have been major incentives for fertility control research (Rodger 2003). Although there is the desire to control brushtail possum numbers in New Zealand and in parts of Australia, these present two very different management situations. Management in Australia aims to reduce abundance to sustainable levels only in high problem areas in order to mitigate problem situations, but still aims to maintain a sufficient population size. Contrastingly, New Zealand's ultimate goal is eradication of the species (Cowan 1996, 2000). Hence, it is quite certain that fertility control techniques utilised will differ in both countries and a unique solution may not be applicable. Each unique situation requires different contraceptive attributes to achieve optimal results (Garrot 1995).

The slow-release GnRH agonist deslorelin has previously been shown to be a successful contraceptive in other marsupial species such as tammar wallabies (Herbert *et al.* 2004, 2005) and kangaroos (Herbert 2004; Herbert *et al.* 2006; Woodward *et al.* 2006). Hence, deslorelin seemed to be promising as a potential contraceptive agent for brushtail possums, and we decided to investigate its effects on the reproduction of the brushtail possum (**Chapter 2**). This research was conducted in cooperation with

AgResearch, and I was fortunate to be able to work in their brushtail possum breeding unit at Wallaceville in New Zealand.

I also initiated a field trial to test the efficacy of deslorelin implants to inhibit reproduction in wild urban brushtail possums in Sydney (**Chapter 3**). The field trial not only enabled us to compare findings with those from the captive study, but also was a unique opportunity to collect information on basic biological parameters of the targeted population such as age structure, sex-ratio, reproductive output and the health of the animals. In the past, these fundamental life history traits have been poorly recorded in urban brushtail possum populations. An appreciation of these characteristics is essential prior to any fertility control agent being applied on a large scale.

Dispersal is a fundamental issue for the success of any control operation as immigration has the potential to swamp the effects of fertility control (Cowan 2003; Ramsey 2005). In New Zealand, possums tend to disperse even at very low densities, and the potentially large distances moved by juveniles mean that buffer zones around control areas are likely to be 'leaky' (Cowan and Clout 2000). This thesis provides the first data on dispersal of brushtail possums in the urban environment and hence, will contribute towards resolving management issues for this species in urban areas (**Appendix C**).

There can be further major issues with wildlife living in urban areas (apart from residential complaints about noisy brushtail possums living in the roofs) that are important on a more widespread scale. The proximity to urban areas and contact with humans and their domestic animals can increase the risk of disease exposure for wild populations and influence their health (Deem *et al.* 2001; Riley *et al.* 2004). For example, marsupials are highly susceptible to toxoplasmosis and infection can prove fatal in captive and free-ranging populations (Canfield *et al.* 1990). **Chapter 4** shows that urban brushtail possums are readily exposed to this parasite in the urban environment. There is also concern that the close association of wildlife with humans and their domestic pets may result in 'spill over' of diseases, and infectious diseases of wildlife can also be a threat to human health (Daszak *et al.* 2000). Hence, in **Chapter 5** I examined the notifiable zoonotic disease leptospirosis.

Working in the field has also its practical challenges, and some problems may not have been expected beforehand, such as a certain percentage of failure in the marking of the animals (**Appendix B**). Luckily, there was a way to back up and ensure the correct identity of each brushtail possum.

Additionally, the field studies on urban brushtail possum populations resulted in the surprising observation of an adult female which had adopted a second young (**Appendix A**).

Last but not least, the final Appendix gives an impression of the captive breeding unit in New Zealand and from the field sites within Sydney's North Shore suburbs (**Appendix E**).

Field sites

The main part of this thesis builds on the data collection from private properties within Sydney metropolitan area that were nearby the facilities of Macquarie University in North Ryde, New South Wales (all chapters except no. 2). Householders within the different communities responded to a media campaign which asked for volunteers in a university based brushtail possum research project. The campaign involved posters on the noticeboard of the local shopping villages, a report in the local newspaper and an interview on a local radio station. Also, staff members from Macquarie University living in the particular areas volunteered and were happy to become involved in our studies.

After the establishment of the different field sites, numerous properties were visited and traps set to verify the presence of brushtail possums. Brushtail possums were investigated in the garden area of about 35 residential houses from five localities within the Sydney metropolitan area (Fig. 1). Locations included four North Shore mainland suburbs (Beecroft, Chatswood West, North Epping, and Pymble) and Scotland Island, a 52.4 ha land mass located at Pittwater (D. Van Den Bosch, GIS officer Pittwater council, pers. comm.). These areas are characterised by the presence of native trees and significant areas of remnant native bushland contributing to the landscape quality, which makes them highly attractive not only to people, but also to brushtail possums and other native species (see Appendix E for detailed description of the field sites). In the end, trapping was conducted over 124 nights, giving a total of 1,202 trap nights and a total of 350 animals (including recaptures) caught.

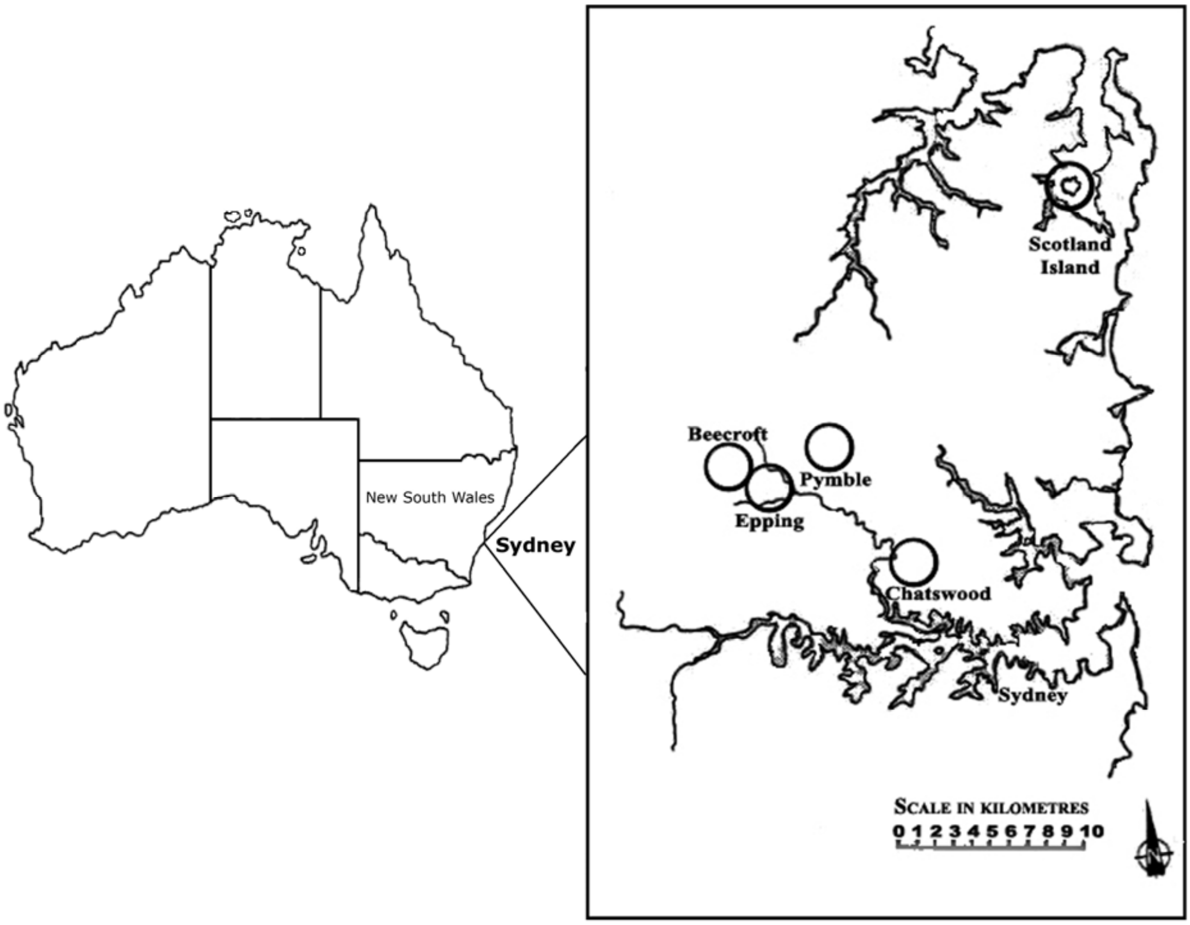

Figure 1. Map of Australia showing Sydney field sites (four metropolitan suburbs – Beecroft, Chatswood West, North Epping and Pymble; and Scotland Island) from which brushtail possums (*T. vulpecula)* were sampled.

Structure of this thesis

This thesis has been prepared in accordance with the guidelines of the Higher Degree Research Unit (HDRU), Macquarie University, NSW, Australia (HDRU 2006). All chapters of this thesis have been written for publication in relevant journals. Hence, this thesis includes papers that are in preparation for submission, have been submitted and/or were accepted for publication during the period of my candidature, or are now even in press (including a published conference abstract). The preface aims to give a brief and comprehensive introduction to the issues surrounding the urban brushtail possum and explains how the different chapters are interlinked. Chapter 1 reviews thoroughly the background to each following chapter and hence, not only provides an extended introduction, but also an integrative conclusion to the situation of the urban brushtail possum. Each chapter forms a coherent body of work focusing on a single project or a set of related questions. As each chapter is designed as a 'stand-alone paper', some degree of overlap has been unavoidable, particularly in the introduction and in the description of the materials and methods. Each chapter is formatted according to the requirement of the journal to which it was or will be submitted (including the references), and the English language has been adjusted to the journal's country of origin. All chapters and publications in the appendices are first-authored by me, except for the publication on sex-biased dispersal in brushtail possums, but do include co-authors to acknowledge their contribution. The specific contribution of co-authors to the preparation of each publication has been specified in the thesis certificate, and contributions of others have been recognised in the thesis acknowledgements.

Please note: the terms 'possum' and 'brushtail possum' relate to the 'common brushtail possum' throughout this thesis unless otherwise stated.

Amendment for the reader: this thesis has been mostly updated after receipt of the reviewers' comments which have been incorporated in the individual chapters. Hence, the individual chapters and appendices indicate the actual status in regard to publication upon re-submission of the thesis. Manuscripts in preparation or under review by the journal may be altered at a later point in time for publication purposes.

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