Unique and Valuable but Untouched Research Opportunities Using Exotic Mammals in Australasia

G. L. Blackwell* and W. L. Linklater[1]

The Institute of Wildlife Research, School of Biological Sciences, AO8

The University of Sydney, Sydney, NSW, 2006 Australia

Ph: +61 2 9351 8580 Fax: +61 2 9351 4119 Email: gblack@bio.usyd.edu.au

*Corresponding author

[1]Center for Reproduction of Endangered Species, Zoological Society of San Diego

P.O. Box 120551, San Diego, California 92112-0551, U.S.A.

ABSTRACT

Ecology is often criticised as a soft science that suffers from a lack of theoretical underpinning, predictive ability and empirical validation, where the synthesis of these components is a key imperative for the science. Several New Zealand and Australian ecologists have championed the role that research on exotic mammals in their countries (which are often more abundant and of lower conservation value than native mammals) could play in this process, and highlighted their potential as model systems within which to evaluate and advance contemporary ecological theory. We searched the Web of Science database to examine the focus of scientific articles on exotic mammal ecology in New Zealand and Australia between 1990 and 2000, and investigated the degree to which Australasian ecologists have met this challenge. For comparison, we selected six 'taxa' of exotic mammals (*Capra*, Cervidae, *Felis*, Lagomorpha, Muridae and *Sus*), and excluded agricultural (Animal Production) and laboratory-based studies. The majority of published studies surveyed focussed on the conservation impacts of exotic mammals and their management, while very few articles used exotic mammals to address broader ecological questions. Studies that did address ecological questions tended to focus on more 'traditional' areas of ecology, such as population regulation and niche theory. Fields such as behavioural ecology, ecological biogeography, chemical and molecular ecology, and ecological endocrinology and immunology were under represented. We discuss reasons for this publishing trend, and identify, with examples, eleven research fields in contemporary ecology in which the study of exotic Australasian mammals could prove insightful. We illustrate how this exotic fauna could be used to make advances in our understanding.

Key words: Australia, conservation, ecology, exotic mammal, pest, New Zealand.

Introduction

Ecology is a young science. Nevertheless, a large number of ecological concepts and ideas have already been proposed as hypotheses, theories (Peters 1991) and laws (Lawton 1999). However, questions of the lack of operational definition, spatial and temporal scale, complexity, semantic and methodological confusion, and lack of experimental validation continue to hamper the development of the science (Roush 1995; Ulanowicz 1997; Ghilarov 2001). Consequently, ecology continues to be considered a soft science (descriptive, not predictive) by critics and practitioners alike (Ulanowicz 1997). The synthesis of theory, prediction and empirical validation continues to remain one of the key imperatives for the discipline (Roush 1995), and the search for relatively simple or pliable model systems to test prevailing theories continues (Thompson *et al.* 2001).

Several Australasian ecologists have recognised the role exotic mammals can play in this process. When considering exotic species in Australia, Kitching (1986; p 3) wrote that they:

"*… give us the opportunity to predict limits of distribution, impacts on the receiving community, population fluctuations, short-term evolutionary changes and the like … we can and should take advantage of the special opportunities presented by the accidental arrival and spread of exotics.*"

Similarly, in the first edition of the *Handbook of New Zealand Mammals*, King (1990; p 20) recognised the role exotic mammals introduced into New Zealand could also play as model systems, when she suggested that:

"*The opportunity to compare the biology of a familiar species in an alien environment is irresistible to the evolutionary biologist. New Zealand therefore provides a vast natural laboratory for observing the processes of adaptation…Mammalogy in New Zealand is a young science but its horizons are wide*"

With these calls, Kitching (1986) and King (1990) proposed an exciting, challenging, and potentially fruitful approach to research on exotic mammals. Exotic mammals in Australasia are well suited to empirically testing many ecological questions for the following reasons:

1. Few exotic species. The exotic mammals present in Australia and New Zealand represent a very small subset of the total potential donor species pool. This is especially true in New Zealand, where no ground-dwelling terrestrial mammals were present prior to human colonisation (King 1990).
2. Different origins. The exotic mammals present in Australasia come from disparate sources, reflecting the origins of human colonisers. In many cases, unique species combinations have resulted. For example, Himalayan tahr *Hemitragus jemlahicus* from the Indian sub-continent and chamois *Rupicapra r. rupicapra* from Europe and Asia Minor are now competitors in the Southern Alps of New Zealand (Forsyth and Hickling 1998). Consequently, there are opportunities to study ecological properties and relationships between species without the confounding variables associated with common co-evolutionary histories, or the 'ghost of competition past' (Connell 1980).
3. Rich historical knowledge and extensive baseline data. The mammals introduced into New Zealand and Australia were game species, closely and abundantly associated with humans, or of conservation or commercial value, particularly in their endemic ranges. Consequently a large body of literature, and intellectual and practical capacity, exists that provides a useful resource from which to launch frontier studies in ecology using exotic mammals.
4. Pest status. The majority of exotic species are classified as pests in both countries (State of the Environment Advisory Council 1996; New Zealand Department of Conservation 2000), and in many cases they pose major conservation threats (e.g. Environment Australia 1999; New Zealand Department of Conservation 2001). Thus, they are abundant and accessible for use in field and laboratory manipulations of population or community composition, with fewer limitations and difficulties than those associated with experimentation on species with high conservation value. Moreover, approvals for research from community-based non-government organisations are, in practice, less stringent for pest species, although any research must still comply with appropriate animal ethics and statutory regulations.

In this paper, we survey the scientific literature published on six exotic mammal taxa common to both Australia and New Zealand. We examine the focus of this literature, to determine if Australasian ecologists have taken up Kitching (1986) and King's (1990) challenge, and the opportunities these species provide. We also discuss the ways exotic mammals in Australian and New Zealand ecosystems are or could be used to advance knowledge in contemporary ecology.

Table 1. Mammal species introduced into both Australia and New Zealand used in the current study (From King 1990; Strahan 1995).

Scientific Name	Common name
Order Lagomorpha	
Oryctolagus c. cuniculus	European rabbit
Lepus europaeus occidentalis	Brown hare
Order Rodentia	
Mus musculus domesticus	House mouse
Rattus exulans	Kiore/pacific rat
R. norvegicus	Brown/Norway rat
R. rattus	Black/ship rat
Order Carnivora	
Felis catus	House cat
Order Artiodactyla	
Sus scrofa	Feral/domestic pig
Capra hircus	Feral/domestic goat
Cervus elaphus scoticus	Red deer
C. elaphus nelsoni	Wapiti[1]
C. nippon	Sika deer[1]
C. u. unicolor	Sambar deer
C. timorensis	Rusa deer
Dama d. dama	Fallow deer
Odocoileus virginianus borealis	White-tailed deer[1]
Alces alces andersoni	Moose[1]
Axis axis	Axis deer[2]
A. porcinus	Hog deer[2]

[1] Only found in New Zealand [2] Only found in Australia

Methods

Six taxa of exotic mammal (goats, deer, pigs, lagomorphs, rodents and cats) were chosen because they are common to both New Zealand and Australia (Table 1). The species present in both countries are the same for each taxonomic group with the exception of deer. Within this taxon, eight and six species are found in New Zealand and Australia respectively, of which four co-occur in both countries. The species chosen in this comparison had similar conservation status as pests (with recognised economic and/or conservation impacts) in both countries, thus excluding, for example, marsupials, which have conservation status in Australia but pest status in New Zealand. The species selected came from a variety of niches including predators, herbivores and omnivores.

The literature search was conducted using the Institute for Scientific Information (ISI) Web of Science database (ISI Research Software 2002). Using the available search options, we restricted our search to "articles" written in "English" and published from 1990 to 2000, to cover the period between the publication of the first edition of the Handbook of New Zealand Mammals in 1990 (King 1990) and the publication of the first update in 2001 (King 2001). "New Zealand" and "Australia" were used to specify Address (location), and the genera (*Capra*, *Cervus*, *Sus*, *Oryctolagus*, *Lepus*, *Rattus*, *Mus*, and *Felis*) used to specify the Topic. Genera were used to search for articles on each taxa because it avoided much of the large literature on domestic animals in medical and veterinary journals that often do not specify a study species Latin name in their articles. Results of searches for each taxa included document title, type, author addresses, keywords, and abstract fields, and were imported into Endnote version 4 (ISI Research Software 1988-2000) for closer examination.

Each taxa's Endnote library was searched using "ecolog", "populat" and "feral" terms to identify and remove any remaining purely agricultural, medical and laboratory studies. All studies that did not meet the search criteria using the keywords above were visually checked to confirm their classification before being discarded. The resulting libraries were then searched to remove any remaining works not conducted in New Zealand or Australia (e.g. South-East Asia), work on native species (e.g. work on native rodents in Australia), or work relating to domestic stock or animal production (e.g. farmed deer).

Remaining articles were independently classified by both authors into one of the following four categories:

1. Pest impacts and conservation implications. This category includes papers that specifically address the impacts of exotic mammals on native species, populations, communities or ecosystems. Papers in this category state explicitly that the investigation of exotic mammal impacts is the primary rationale for the study. Such studies may use either an observational or experimental approach (for

Table 2. Bird species introduced into both Australia and New Zealand used in the current study (From Bull *et al.* 1985; Simpson and Day 1986).

Scientific Name	Common name
Family Phasianidae	
Meleagris gallopavo	Wild turkey
Pavo cristatus	Indian pea fowl
Phasianus colchichus	Common pheasant
Family Odontophoridae	
Callipepla californica	California quail
Family Anatidae	
Anas platyrhynchos	Mallard
Cygnus olor	Mute swan
Family Columbidae	
Columba livia	Feral pigeon/rock dove
Family Alaudidae	
Alauda arvensis	Skylark
Family Passeridae	
Passer domesticus	House sparrow
Family Fringillidae	
Carduelis carduelis	European goldfinch
C. chloris	European greenfinch
Family Muscicapidae	
Turdus merula	Common blackbird
T. philomelos	Song thrush
Family Sturnidae	
Acridotheres tristi	Indian myna
Sturnus vulgaris	Common starling

example, see Cree *et al.* 1995; May and Norton 1996; Norbury and Norbury 1996; Choquenot *et al.* 1997; Stronge *et al.* 1997; Risbey *et al.* 1999).

2. Pest control and monitoring. Studies in this category included those outlining specific methodologies (see Risbey *et al.* 1997; Hone and Martin 1998; Mahon *et al.* 1998) or pest management strategies (for example McIlroy and Gifford 1997; Alterio 2000), and studies evaluating the efficacy and consequences of different control techniques (see Innes *et al.* 1995; O'Donnell and Phillipson 1996; Bowen and Read 1998; Murphy *et al.* 1998; Murphy *et al.* 1999; Ratz 2000).
3. Descriptive ecology. Studies that examined aspects of the study species biology or ecology, but that did not focus on any conservation implications of the study were placed in this category. Studies that investigated topics such as habitat use (for examples see King *et al.* 1996c; Caley 1997; Dexter 1998; Cox *et al.* 2000), population biology (see King *et al.* 1996a, b; Moriarty *et al.* 2000), or home range use (Dowding and Murphy 1994; Saunders and Kay 1996) were included in this category.
4. Fundamental Ecology. Any studies that used exotic mammals to address fundamental ecological questions, with no consideration of the conservation status or "worth" of the species were included in this category (for example see Dawson and Ellis 1996; Fraser 1996; Valsecchi *et al.* 1996; Powell and King 1997; Matisoo-Smith *et al.* 1998). Studies could address topics in conservation biology, the only requirement was that the study species was used as a model to test a prevailing theory, and was not given an anthropogenic worth as an exotic species (for example Frankham 1995).

To compare whether Australasian mammalogists were alone in their approach to research, we also investigated the focus of research on 15 bird species introduced into both Australia and New Zealand (Table 2). We used the same search and classification criteria as for the exotic mammal searches. We also compared papers published in both countries on the brushtailed possum *Trichosurus vulpecula*, and on bats in New Zealand, to see whether the research focus depended on the status of the species as native or exotic. Again, the same search criteria were used.

Results

Our search of the six mammal taxa common to both countries generated 108 New Zealand and 164 Australian articles that met our search criteria. The different taxa studied were not evenly represented in the sample. Rodents received a large amount of attention in the literature in both countries (50.4% of New Zealand and 38.5% of Australian articles). More lagomorph and feral pig research was published in Australia than New Zealand (Lagomorphs: 15.0% of articles in New Zealand, 23.5% in Australia; Feral Pigs: 5.5% in New Zealand, 19.3% in Australia) but more work on deer was conducted in New Zealand than Australia (8.2% in New Zealand, 1.2% in Australia). Similar proportions of work have been published in both countries on feral cats (18.2% in New Zealand and 11.5% in Australia) and goats (2.7% in New Zealand, 6.0% in Australia).

The focus of articles published on exotic mammals in New Zealand and Australia was different ($\chi^2 = 9.67$, df = 3, $P < 0.05$; Figure 1). In New Zealand, 65.7% of the articles published focused on the quantifying pest impacts or management of pests, compared to 50.0% of

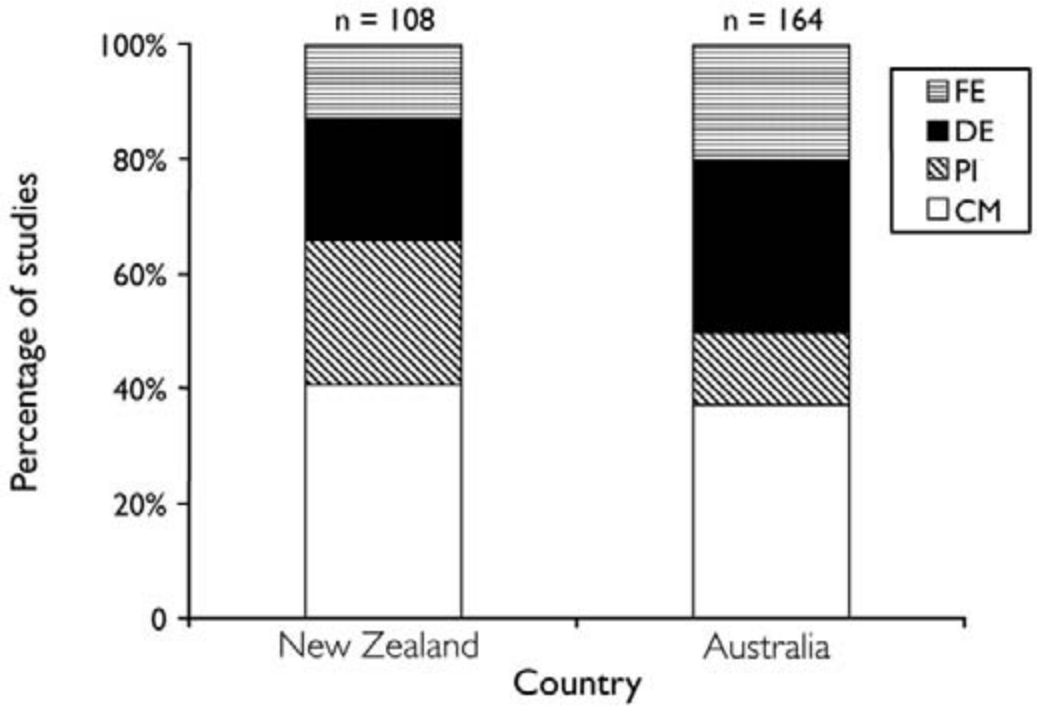

Figure 1. The proportion of research papers published on the six taxa of exotic mammals common to New Zealand and Australia. The four categories were: studies outlining pest control and monitoring techniques (CM); those quantifying pest impacts (PI); those focusing on descriptive ecology (DE); and those using exotic mammals for 'pure' research (FE; fundamental ecology).

studies published in Australia. Studies that investigated theoretical problems in ecology using these species were in the minority, comprising 13.0% of articles in New Zealand and 20.1% in Australia. New Zealand mammalian ecologists published relatively more papers on pest impacts and control than those in Australia, but less on basic descriptive ecology and theoretical investigations.

Our search of papers on bird species introduced into both Australia and New Zealand produced 19 Australian and 25 New Zealand studies that matched our criteria. In comparison to studies conducted on mammals in Australasia, only 21.1% of Australian and 24.0% of New Zealand papers focused on quantifying pest impacts or the management of pests, while 10.5 % of Australian and 24 % of New Zealand studies described the basic ecology of the study species. Interestingly, 68.4 % of Australian and 52.0 % of New Zealand studies used introduced birds to address theoretical ecological questions, significantly more than in studies that used exotic mammals ($\chi^2 = 41.38$, df $= 3$, $P < 0.01$).

The search of publishing trends on *Trichosurus vulpecula* generated 208 Australian papers and 216 New Zealand papers, of which 53 and 174 respectively met our criteria. In both countries, the papers that were classified as not relevant used the species as a laboratory model to investigate medical, physiological or veterinary questions. For papers that did meet the criteria, the focus of research between the two countries was significantly different (Chi-square test with CM and PI categories pooled due to small sample size; $\chi^2 = 93.47$, df $= 2$, $P < 0.005$). In New Zealand, over 80% of papers investigated either control and monitoring techniques or pest impacts, compared with only 17% in Australia, while similar proportions of papers investigated basic ecology of the species (11.0% in New Zealand, 7.7% in Australia; Figure 2). Only 4.5% of New Zealand studies investigated questions in fundamental ecology, while 52.8% of Australian studies took this approach.

The search for papers published on New Zealand bats generated 25 papers that met our criteria, of which 48% described basic ecology, 8% investigated pest impacts, 4% described control and monitoring techniques, and 40% investigated theoretical issues in ecology.

Discussion

Exotic animals in Australia and New Zealand provide a valuable opportunity to make important advances in our ecological understanding. It is not our intention in this manuscript to present a specific criticism of individual ecologists and mammalogists, but rather to comment on the previous direction of the discipline as a whole, and to highlight a unique research opportunity. There are many fields, both traditional and at the frontiers of ecology (Thompson *et al.* 2001), to which exotic mammal research in Australasia could be a fruitful model system. We have listed a number of fields and sub-disciplines, from a limitless pool, along with international examples, that we think are particularly likely to yield advances in ecology through research on exotic mammals in Australasia (Table 3). The topics were selected after an investigation of publishing trends in international ecological journals such as *Trends in Ecology and Evolution*, *Annual Review of Ecology and Systematics*, *Oikos* and *Oecolgia*. The fields of investigation in which exotic mammal research might be most useful are diverse, and a number of New Zealand and Australia authors have indeed published in these

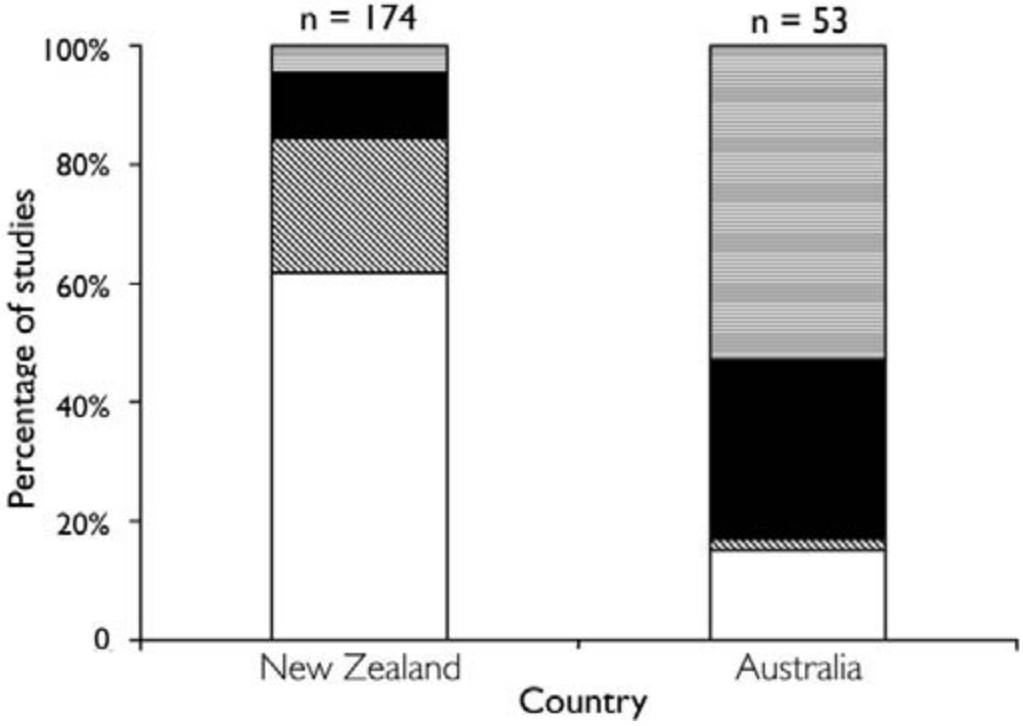

Figure 2. The proportion of papers published on the brushtailed possum *Trichosurus vulpecula* in Australia and New Zealand in the four broad research categories. For a description of the categories and an explanation of the symbols used, see Fig. 1.

Table 3. Current fields of research in ecology to which exotic mammals provide a unique research opportunity.

Research Area	Sub-discipline	Examples		
		International	New Zealand	Australia
Behavioural ecology	Models of sociality and breeding	(Ebensperger 1998; Hatchwell and Komdeur 2000)		
	Anti-predator behaviour and learning	(Bednekoff and Lima 1998)		
	Cultural transmission	(Terkel 1996)		(Valsecchi *et al.* 1996)
	Life history strategies and mate choice	(Rich and Hurst 1998; Yasui 1998)		
	Communication: signal design and interpretation	(Endler and Basolo 1998; Noble 1999)		
Chemical ecology	Communication by scent marks	(Brashares and Arcese 1999a, b)		
	Nutrition and habitat use: secondary plant metabolites, digestion and seasonality	(Owen-Smith 1994)		
Community ecology	Competition and niche theory	(Fedriani *et al.* 2000; Albrecht and Gotelli 2001)	(Fraser 1996)	(Dawson and Ellis 1996; Haering and Fox 1997)
	Diversity and structure	(Poulin 1997)		
	Effects of food web complexity on population dynamics and stability	(Morin and Lawler 1995; Marcogliese and Cone 1997)		
	Community resilience and susceptibility to invasion	(Fritts and Rodda 1998; Johnson 2000)		
	Mutualisms and community structure	(Herrera 1995)		
Ecological anthropology	Human dispersal	(Matisoo-Smith *et al.* 1998)		
Ecological biogeography	Inter and intra-specific variation in geographic range size	(Brown *et al.* 1996)		
Ecological endocrinology	Hormonal control of secondary sexual characteristics	(Owens and Short 1995)		
	Physiological mechanisms of dispersal	(Zera and Denno 1997)		
	Social facilitation of reproductive cycles	(Silverin and Westin 1995)		(Mylrea *et al.* 1999)
	Chemical cues of spatial and temporal aggregation	(Silverin and Westin 1995)		
Ecological immunology	Adaptive immune responses to novel parasites; parasites to novel hosts	Sheldon and Verhulst 1996; Sorci *et al.* 1997		
Ecology of populations	Meta-population structure and functioning	(Harrison and Hastings 1996)		(Dunstan and Fox 1996)
	Predator-prey relationships: influences on the functional response	(Harrison and Hastings 1996)	(Fitzgerald *et al.* 1996; Gibb and Fitzgerald 1998)	(Corbett 1995; Pech *et al.* 1995)
	Parasite and disease regulation of parasites, disease epidemiology	(Smith and Holt 1996; Marcogliese and Cone 1997)		(Singleton and Chambers 1996; Pech and Hood 1998)
Evolutionary ecology and ecological adaptation	Temporal scales in adaptation	(Thompson 1998)	(Powell and King 1997; Yom-Tov *et al.* 1999)	
	Phylogenetic inertia	(Linklater 2000)		
	Adaptation to macro-ecological clines	(Brown *et al.* 1996; Atkinson and Sibly 1997)	(Asher *et al.* 1999)	

Research Area	Sub-discipline	Examples		
		International	New Zealand	Australia
	Coevolution: novel predators-naïve prey, host-parasite, plant-herbivore	(Fritts and Rodda 1998; Abrams and Ginzburg 2000)		(Kerr and Best 1998; Blumstein *et al.* 2000)
	Speciation and hybridisation	(Dowling and Secor 1997)		
Landscape ecology	Spatial dynamics; dispersal migration and colonisation	(Silver *et al.* 2000)		(Barratt 1997; Downes *et al.* 1997)
	Ecosystem engineers	(Bangert and Slobodchikoff 2000)		
Molecular ecology and Ecological energetics	Gene flow in populations	(Harrison and Hastings 1996; Sugg *et al.* 1996; Bossart and Prowell 1998)		(Frankham 1995)
	Estimating dispersal	(Koenig *et al.* 1996)		
	Immuno-genetics	(Sorci *et al.* 1997)		(Sangster *et al.* 1998)

fields (Table 3). These studies are predominantly in the traditional core areas of ecology: population regulation, morphological adaptation to new environments, and niche theory. To date, behavioural ecology, chemical ecology, molecular ecology, ecological biogeography, ecological endocrinology and ecological immunology have not received a similar amount of attention. By and large, exotic mammals in New Zealand and Australia have not been used to explicitly address current research areas in theoretical ecology that are of global interest and application (e.g. Thompson *et al.* 2001).

Some examples of how exotic Australasian mammals could be used to address fundamental questions in ecology include: firstly, introduced *Mus musculus* and *Rattus rattus* have been shown to utilise separate microhabitats in New Zealand *Nothofagus* forests during periods of resource scarcity (Blackwell *et al.* 1998), but to utilise similar habitats when resources are abundant (Blackwell *et al.* 2003). Thus, experimental manipulation of this two-species system could provide valuable insights into the mechanisms underlying species coexistence in fluctuating environments.

Secondly, feral cats are remarkable for the diversity of social systems they exhibit in different demographic and environmental contexts, being variously solitary or colonial (Turner and Bateson 2000). A single species was introduced into New Zealand and Australia, and now has a vast geographic range, spanning a huge array of community types in both countries (King 1990; Strahan 1995). Thus, the feral cat provides an opportunity to understand micro-evolution in behaviour and sociality.

Thirdly, in both New Zealand and Australia the two lagomorphs, European rabbits and hares, are sympatric (King 1990; Strahan 1995). On the one hand, rabbits are renowned for their irruptive populations dynamics, yet this does not appear to be true for hares. Comparative and experimental studies of lagomorph ecology in Australasia could help identify what factors (such as habitat requirements, reproductive biology, and competition and predation from native or introduced species) drive irruption versus stability in populations.

From our search of publishing trends in Australasian mammal ecology, it appears that ecologists in these counties have not taken explicit advantage of these, and many other similar, opportunities. This is not to deny the important contributions applied research on exotic Australasian mammals has made to our ecological understanding. Examples of this approach include the insights into population regulation gained from work on *Mus* and the Lagomorpha in Australia, although most of these seminal works fell well outside the time limits for our study. However, we would argue that Australasian ecologists have not truly taken up the opportunities posed by Kitching (1986) and King (1990) over fifteen years ago. This is particularly true in New Zealand, where only 13% of the studies used exotic mammals to explicitly investigate fundamental ecological questions (cf. 20% Australia).

In comparison, studies published on exotic birds introduced into both countries were significantly more likely to address fundamental questions in ecology, although the small number of studies published suggests they were less likely to be studied in the first place. It is not clear from our survey if this difference reflects a different approach to the use and utility of exotic species by Australasian ornithologists and mammalogists. It may be that impacts of exotic mammals are more widely recognised and more severe than those of introduced bird species, and consequently large amounts of time, money and effort are directed towards minimizing these impacts. It is also possible that the different focus of research into exotic birds and mammals may reflect the origins of researchers. While many of the studies of exotic mammals in Australia and New Zealand are conducted or funded by Government Agencies (for example the Department of Conservation and Landcare Research in New Zealand; State Conservation Agencies and CSIRO in Australia), and thus reflect conservation concerns; exotic bird research was conducted mainly by tertiary institute-based researchers that may be more likely to conduct studies in fundamental ecology. The comparison of publishing trends on *T. vuplecula* in both countries, and the focus of New Zealand bat studies, suggest that it is the severe conservation impacts of exotic mammals that are driving the exotic mammal research focus, rather than any features of them as mammals *per se*.

It should also be noted that by confining our study to mammalian taxa introduced into both Australia and New Zealand, we have excluded several exotic mammal species that have been the focus of much research in one or both countries. For example, one New Zealand study, although one that did not meet our criteria for inclusion, is the work by Lentle and colleagues, investigating the physiology and ecology of feeding behaviour in captive and free-living tammar wallabies (for examples see Lentle *et al.* 1998a, b; 1999). There are also examples of the use of over-abundant native mammals with pest status in Australia to investigate fundamental questions in ecology (for example Caughley and Gunn 1993; McLeod 1997; Fisher and Owens 2000). There is no reason why the approach we espouse cannot be applied to these and other mammal species. However, it is our contention that these studies are, unfortunately, currently in the minority.

The majority of studies on exotic mammals that we investigated tackled an applied problem, relating to an exotic species impact on a local scale. This emphasis reflects the social, political and economic context that Australasian ecologists work in (Linklater *et al.* 2002). Exotic mammals are one of the root causes of a conservation crisis for endemic species that warrants immediate attention (Burbidge and McKenzie 1989; Craig *et al.* 2000). Nevertheless, tackling these problems does not preclude concurrent and concomitant investigations in theoretical ecology. Indeed, conservation management and research programs of pest, or endangered, species can benefit in the long-term from being conducted in tandem with research answering basic questions in ecology (Berger 1994; Linklater *et al.* 2002). With this approach, assumptions are more likely to be explicitly understood, testable hypotheses formulated *a priori*, and experiments conducted to establish causative relationships. In this way, the theoretical framework and practical outcomes of an applied research program, and our understanding of ecological systems, improve together, thus providing a sound basis for adaptive management (Armstrong *et al.* 1994; Lancia *et al.* 1996). Moreover, once a research program is funded and established, economies of scale mean any additional fundamental research is a relatively inexpensive complement. Research addressing theoretical questions augments the consideration of applied questions.

Any particular study will fall somewhere on a continuum from wholly applied to purely theoretical in its approach, with a number of possible applications of the same dataset. As previously noted, many applied programs on exotic mammals have already made invaluable contributions both to conservation management and our theoretical knowledge. It is our contention that many untapped opportunities still exist to achieve both these aims. Moreover, the adoption of a targeted research framework involving a complement of fundamental and applied research objectives offers a greater potential for 'win-win' outcomes for researchers, public, funding agencies and conservation stakeholders alike.

Conclusions

The recent update to the Handbook of New Zealand Mammals (King 2001) once again draws attention to the role Australasia's exotic mammals can play in contemporary ecology. The studies in Table 3 indicate that Australasian ecologists have not taken full advantage of the opportunities and challenges posed by these species. In this paper we have identified the features of exotic mammalian species and assemblages that make them eminently suitable to such investigations and presented the fields of investigation in ecology in which we think the study of Australasia's exotic mammals could prove insightful (Table 3). We reiterate the call of Kitching (1986) and King (1990) for Australasian ecologists to utilise this untapped resource. Although we have largely confined our discussion to mammals, because they have been the subject of similar previous calls (King 1990; Kitching 1986), and are perhaps the most apparent conservation problem (Atkinson 2001) and the most visible research opportunity, our thesis is equally applicable to all exotic flora and fauna.

Acknowledgements

Thanks to Suzanne Bassett, Elissa Cameron, Mike Joy, Ed Minot and Kevin Stafford, for discussions on this and related topics over the past few years. Thanks also to Dr Peter Banks and two anonymous referees for comments on later drafts of the manuscript. Over the period that the ideas for this article were developed, GLB was funded in part by a Massey University Doctoral Scholarship, while WLL was funded by a New Zealand Department of Conservation Research Contract (No. 1850).

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