A systematic review of the impacts of feral, stray and companion domestic cats (*Felis catus*) on wildlife in New Zealand and options for their management

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1 Summary

Stray and companion (pet) cats are common in New Zealand and present a substantial threat to both native and non-native wildlife, especially in areas close to stands of mature trees or native bush. Conservative estimates created within this review suggest that the pet and stray cat populations in New Zealand may prey upon between 19-44 and 15-33 million animals per year respectively. The stray cat population albeit substantially smaller (~196,000) may have a comparable predation impact to the significantly larger companion cat population (~1.4 million). This is driven by the increased likelihood that a stray cat will be compelled to hunt to survive whilst the impact of companion cats is reduced by regular feeding.

Currently there is no national strategy for cat management in New Zealand. After reviewing the evidence it is clear that any management approach should address two distinct aspects of the problem: 1) identify appropriate management methods for New Zealand to reduce stray cat numbers and prevent predation; and 2) identify methods for improving ownership practices and social value as they relate to companion cats in New Zealand.

The stray cat population appears to be growing both internationally and in New Zealand. Although some stray cats are cared for directly in colonies, most are unlikely to receive appropriate or timely veterinary care, protection from harm, or regular feeding, and so have shortened lives and reduced welfare associated with injury, disease and malnutrition. Continued survival also necessitates that animals hunt, which implies a likely greater impact on wildlife for stray than pet cats. The literature

evaluated suggests that a Trap-Neuter-Return (TNR) strategy would not be judicious for the majority of stray cats as it is costly, does not stop predation of wildlife by cats and has little effect on the spread of diseases amongst cats. There is also little evidence that clearly shows TNR improves cat welfare overall or results in population decline on a broad scale. Although TNR is already used informally for small groups of stray cats (colonies), it is highly unlikely that it is applicable to stray cat populations on a large geographical scale. Therefore, any long-term strategy to manage stray cats should consider a suite of available methods including adoption and euthanasia, both of which are already employed within New Zealand. Any strategy should be collaboratively developed, formalised and rigorously monitored by all stakeholders if it is to have a clear effect. To protect stray cats that have identified carers (i.e. people who feed them but do not consider the cat to be 'theirs') a strong promotion of the benefits of transitioning stray cats into an ownership model may be useful. An option to minimise any negative emotional impacts of population management on carers may be that managers and carers of existing stray cat colonies in ecologically appropriate areas should perhaps be required to formally register. Managers and carers should also be required to adhere to procedures and processes (e.g. routine sterilisation, removal of newcomers) which will result in the eventual extinction of that colony.

Effective management of stray cats will require that they can be definitively identified. Visible identification for companion cats may allow this and may also reduce predation rates if collars with bells are used. Consideration of other methods of companion cat management should perhaps address formal mechanisms by which ownership can be established and improved. This may include registration of pet cats, restriction of ownership in areas of environmental value and promoting a partial or complete indoor-cat lifestyle. Contrary to popular belief, cats can live indoor lifestyles.

Questions as to how society should manage a growing cat population to protect other species, but also to improve cat welfare, are problematic. Cats are loved by many New Zealanders and are an important component of New Zealand families/whanau. This report in no way seeks to suggest this importance be ignored, in fact this dynamic is of great significance to many stakeholders including the New Zealand Veterinary Association.

2 Introduction

Human habitation is strongly linked to the decline of many species not adapted to urban environments (Radeloff *et al.* 2005). Alongside fundamental changes in habitat, and inability to adapt, myriad anthropogenic factors place significant pressure on natural or native populations of animals within the human landscape (Purvis *et al.* 2000). One such factor is the introduction of mammalian predators closely linked to human social systems. Domestic cats are an important part of society providing, for many, a sense of attachment and emotional support (Zasloff and Kidd 1994) even if not directly owned (Centonze and Levy 2002). However, they are also cited as having a potentially negative impact upon local ecologies (e.g. van Heezik *et al.* 2010). Currently estimates of the worldwide population of the domestic cat (*Felis catus*) suggest that it now exceeds 600 million (Peterson *et al.* 2012) and is showing signs of increasing (Dabritz and Conrad 2010) as the urban human population grows. In the United Kingdom (UK) this growth now outstrips the available financial resources for managing the un-owned population (Stavisky *et al.* 2012). In light of this population growth and limited resource, the welfare, environmental impact and population management of cats have gained significant attention in recent years. This review aims to assess both the wildlife predation risk posed by cats in New Zealand and the potential effects of any predation on wildlife populations. It will also explore available methods for cat population management.

For the purposes of this review cats are defined as three distinct groups as per the Animal Welfare (Companion Cats) Code of Welfare (2007), those being: companion, stray and feral. ‘Semi-owned’ cats, those that have their basic needs met by people but are not regarded as ‘owned’ are considered to be a subset of the stray cat population.

2.1 Cats in New Zealand

New Zealand's cat population is likely no exception to this growth trend. New Zealand has an estimated companion cat population of 1.4 million and a household cat ownership level reported to be approximately 48% (MacKay 2011). These statistics suggest a substantial and dense population of cats in urban areas showing potential signs of growth (Aguilar and Farnworth 2013) despite a sterilisation rate of approximately 87% for companion cats in some regions (Farnworth *et al.* 2010a). These numbers also indicate that almost half of all New Zealanders can be considered to be supportive of keeping cats as companion animals. This is in contrast to the fact that New Zealand's mammal-naïve ecology is vulnerable to introduced mammalian predators and it is likely this that has led to a schism in public opinion as it relates to cats and their management (Farnworth *et al.* 2011).

2.2 Cat populations

It is important to note that the domestic cat population of New Zealand is not limited to the 1.4 million companion cats estimated by MacKay (2011). There are no absolute or estimated statistics on New Zealand's total cat population which include not only companion but also un-owned stray and feral cats. Within the scientific literature very few studies attempt to quantify the total population, including un-owned cats, and any proposed value ranges are therefore large, representing high levels of uncertainty. For example, in the United States of America (USA) it is estimated that the un-owned cat population accounts for 10-50 million individuals and therefore, at the very least, un-owned cats attribute an additional 14% to the owned population (~75 million) but this contribution could be as high as 67% (Mahlow and Slater 1996). If this situation applied more widely, the New Zealand cat population could be conservatively estimated at 1.5 million, but might be significantly more. Indeed, in one year in Auckland alone, 8,573 stray cats were collected by a single welfare charity (Aguilar and Farnworth 2012). Despite the seemingly high rate of desexing for companion cats in Auckland (McKay *et al.* 2009) it is not known what proportion of uplifted stray cats are desexed. It is plausible, assuming that the population of cats continues to grow in New Zealand, that the stray population may be a significant source of kittens in urban areas. In Australia, where desexing rates are also high for companion cats (>90%), researchers identified that 96% of 15,206 strays entering a shelter in Melbourne were entire, almost half of which were mature adults (Marston and Bennett 2009).

2.3 Defining cat populations

Within the literature free-roaming cat populations are described using myriad terms. In general, free-roaming cats are defined as those "not currently under direct control or [is] not currently restricted by a physical barrier" (Anonymous undated). As such, free-roaming may include both owned and un-owned individuals. Free-roaming cats may be a significant issue in New Zealand. By way of illustration, in Auckland and Kaitaia, a survey sample indicated that 95% of owned cats have free outside access (Farnworth *et al*. 2010a).

More specific to New Zealand are the definitions provided in the Animal Welfare (Companion Cats) Code of Welfare (hereinafter referred to as the Cat Code) (Anonymous 2007). The Cat Code provides definitions for stray, feral, companion and colony cats (Anonymous 2007) which are broadly delineated using anthropocentric principles as follows:

Companion Cat: *Common domestic cat (including a kitten unless otherwise stated) that lives with humans as a companion and is dependent on humans for its welfare.*

Stray Cat: *means a companion cat which is lost or abandoned and which is living as an individual or in a group (colony). Stray cats have many of their needs indirectly supplied by humans, and live around centres of human habitation. Stray cats are likely to interbreed with the unneutered companion cat population.*

Feral Cat: *means a cat which is not a stray cat and which has none of its needs provided by humans. Feral cats generally do not live around centres of human habitation. Feral cat population size fluctuates largely independently of humans, is self-sustaining and is not dependent on input from the companion cat population.*

Colony: *A group of stray cats living together*

These definitions are the ones upon which this report is based, however they are not broadly understood by the general public (Farnworth *et al.* 2010a) and do not necessarily align with terminology used outside New Zealand or within the peer-reviewed literature (Farnworth *et al.* 2010b).

The objectives of this review were firstly to assess the wildlife predation risk posed by cats in New Zealand and the potential effects of any predation on wildlife populations and secondly to explore available methods for cat population management.

3 Methodology

A systematic review of the literature was conducted using a defined protocol to retrieve, appraise and summarize available evidence relevant to the research objectives and to minimise the effect of the reviewers' own biases (Stroup *et al.* 2000). Systematic reviews also create a rigorous framework against which management actions for companion animals may be assessed (Trotz-Williams and Trees 2003). For this document the literature search was conducted by the primary author of this report, a master's-degree-qualified animal welfare research scientist with seven years of research experience. The protocol used was co-developed and reviewed by the two co-authors (PM; JB) both of whom are veterinary epidemiologists with doctorate qualifications and experience in the use of systematic reviews and meta-analyses.

3.1 Retrieval of publications

Peer-reviewed publications were retrieved by interrogating selected electronic databases subscribed to by Massey University. This included Web of Science (www.webofknowledge.com), Scopus (www.scopus.com) and The Knowledge Basket a New Zealand news and information archive (www.knowledge-basket.co.nz). Retrieved articles from each of these databases were crosschecked and combined in EndNote X5 to ensure maximal inclusion of publications. For all searches done using electronic databases, accuracy was recorded based on the number of retrieved articles that were considered potentially relevant.

Once compiled, the literature was cross-referenced against resources that had been compiled by the New Zealand Department of Conservation[1] to identify additional articles of specific relevance to this review and to explore the rigour and consensus of the search process. On reading of included articles any seminal references not previously identified were subsequently added to the resources for this work in the interests of completeness.

In addition to peer-reviewed resources 'grey literature' was included as it came to the attention of the authors. This approach was considered appropriate to ensure as broad a coverage of the literature as possible.

3.2 Search terms

The searches were conducted using keyword algorithms to maximise search specificity and sensitivity. The literature searches were conducted in consultation with Massey University library services and an eResearch librarian with extensive experience in database information retrieval. Once compiled, the following algorithms were used to search titles, abstracts and keywords:

> For predation:
>
> (cat OR cats) AND (predat* OR threat* OR risk* OR kill* OR prey*) AND (wildlife OR bird* OR "small mammal*" OR reptile* OR lizard*)

[1] Supplied by K M[c]Innes, Department of Conservation, 18-32 Manners Street, Wellington, New Zealand.

For population management:

(cat OR cats) AND (stray OR feral) AND (population* OR colony OR colonies) AND (control* OR manag*)

3.3 Inclusion criteria

Studies which addressed cat predation upon wildlife were included as were those that addressed cat ownership and cat welfare as they pertained to population management. All cat types (stray, companion, feral and colony) were included as it was considered important to have as broad a perspective as possible. However, papers which focussed solely on feral cats (as defined in section 2.3) were noted but did not comprise a major component of this review beyond simple presentation of over-arching themes. Papers which included assessment of companion, stray or colony cats or a comparison of any of these three groups with feral cats were retained for further exploration. As this report spans an array of disciplines and study types no constraints were placed on the types of studies included, or designs thereof. This is for four reasons. First, at the moment there is significant debate around the most suitable strategies to manage owned cats in New Zealand. Second, cat owners and cats may vary less between countries than do ecologies and conservation imperatives. Third, the predation impact of cats in different environments and with varying degrees of human management is still being debated. Finally, because cat management is a potentially emotive topic as broad a perspective as possible may help avoid bias brought about by the relative dearth, and potential topic bias, of regional information. Given the relative lack of information and the burgeoning nature of research in this area, no exclusion was implemented based on time of publication. For this study topic it is unlikely that older literature is less accurate or relevant and therefore the same weight was given to studies from different years. Studies from outside New Zealand were included if they were considered relevant to the objectives of the review (see section 3.4 for details) but articles had to have at least an abstract available in English.

3.4 Evaluation of relevance

Information on all retrieved articles was recorded in an Excel database and included key information such as: author(s), country of study site, year published and source type (e.g. Journal, Report). Beyond the general inclusion criteria (see 3.1) further evaluation of the relevance of the materials was made based on pre-set criteria such as relevance to the research objective.

3.4.1 Relevance to research objectives

The literature surrounding the impacts of cats on wildlife was explored and its relevance was assessed based upon the objectives of this review. As there were a number of stated objectives those were bundled into two objectives groups (i.e. Objective 1: predation risk and Objective 2: population control). Papers were able to be placed against either one or both objectives.

Objective 1: Assessment of wildlife predation risk posed by cats in New Zealand and the effects of any predation on wildlife populations

Objective 2: Assessment of available methods for cat population control.

Objective 2 was sub-divided into whether or not population control was assessed with regards to its effect on:

i) Predation levels
ii) Animal welfare
iii) Animal health including zoonotic risk
iv) Effectiveness and applicability in a New Zealand context
v) Stray population growth
vi) Populations of other predators and integrated pest management strategies.

3.4.2 Assessment of relative value of retrieved documents

To assess the relative value of retrieved articles a number of criteria were implemented. These did not necessarily lead to exclusion of articles but allowed the body of work to be broadly assessed (e.g. calculation of the proportion of management projects that included longitudinal studies).

The first criterion included in the assessment sheet was the group of cats on which the work was conducted. These were placed into one of four categories: companion (pet); stray; feral; and colony. These categories were defined as per the Cat Code (Anonymous, 2007). Where the term 'feral' was used in the retrieved literature to describe urban cat populations dependent upon human social structures, which is common practice in studies based in the USA, these were re-categorised as 'stray' or 'colony' dependent upon the given context. In addition, the number of cats for which information was provided was recorded because studies with larger sample sizes are less likely to be affected by chance. Similarly, the location in which the study was conducted was identified and was placed into one of five categories: 1) studies conducted in New Zealand; 2) studies in countries or on islands other than New Zealand but without significant native mammalian fauna (e.g. Hawai'i); 3) studies outside New Zealand where the country has native mammals but also a felid-naïve fauna, with cats having been introduced recently (e.g. Australia); 4) studies in countries with mammalian predators and where domestic cats are historically present (e.g. USA); and 5) studies in countries with mammalian predators, small native felids and a long historic presence of domestic cats (e.g. UK). The final criterion that was included was the duration of the study (in years) because longer studies are potentially more likely to show a credible link between interventions and effects on cat population, cat welfare and native animal populations.

4 Results

4.1 Results of retrieval of publications

4.1.1 Objective 1: Predation impact

Using the search algorithm for predation identified in section 3.2 Scopus returned 799 publications, Web of Science 623 and New Zealand Science (The Knowledge Basket) 184. Web of Science and Scopus had 277 duplicated resources bringing the combined total of articles from the three databases included in the first reading to 1329. Where duplication was identified, the Scopus citation was retained.

All abstracts were screened by the first author of this report (MF); articles that were not relevant to the objectives of the work were omitted. Where needed the decision to include or exclude an individual article was backed by one of the co-authors. Omitted articles generally included publications concerning species other than the domestic cat, veterinary case reports, and reports on diseases and parasites. Following this process a total of 243 articles were retained for further analysis, comprising 56 articles from Web of Science, 138 from Scopus and 45 from The Knowledge Basket.

Of the retained 243 publications, 175 concerned the predation impacts of feral cats only and were therefore not retained for in-depth exploration, but are briefly summarised in this report. Comparison with a database supplied by The Department of Conservation identified an additional 15 papers which were concerned with companion, stray, or colony cat predation and were therefore included.

4.1.2 Objective 2: Population management

Using the search algorithm for management identified in section 3.2 Scopus returned 329 publications, Web of Science 247 and The Knowledge Basket 183. Web of Science and Scopus had 132 duplicated resources bringing the combined total of articles from the three databases included in the first reading to 759. Where duplication was identified the Scopus citation was retained. As for Objective 1 the definition of the cats of interest was addressed relative to the definitions in The Cat Code. This was especially so for management literature from the USA where 'feral' is often used to indicate 'stray' as per the Cat Code definition.

As for Objective 1 all abstracts were screened by the first author of this report (MF) and, articles that were not relevant to the objectives of the work were omitted. Where needed, the decision to include or exclude an individual article was backed by one of the co-authors. Omitted articles generally included publications concerning species other than the domestic cat, veterinary case reports, and reports on diseases and parasites that were not related to specific population management or control practices.

Following this process a total of 188 articles were retained for further analysis, this included 20 articles from Web of Science, 158 from Scopus and 10 from The Knowledge Basket.

Of the retained 188 publications, 85 concerned the management of feral cats (as defined by the Cat Code) and were therefore not retained for in-depth exploration, but are summarised in this report. Comparison with a database supplied by The Department of Conservation identified an additional five papers which were concerned with companion, stray, or colony cat management and were therefore included.

4.2 Analysis of retrieved sources

4.2.1 Relevance to cat group

There is a substantial skew in the distribution of cat groups represented within the articles which address predation, with the majority addressing feral and companion cats and relatively few concerned with the impacts of stray or colony cats (Figure 1). However, there has recently been a substantial increase in literature around the management of stray and colony cats (Figure 2).

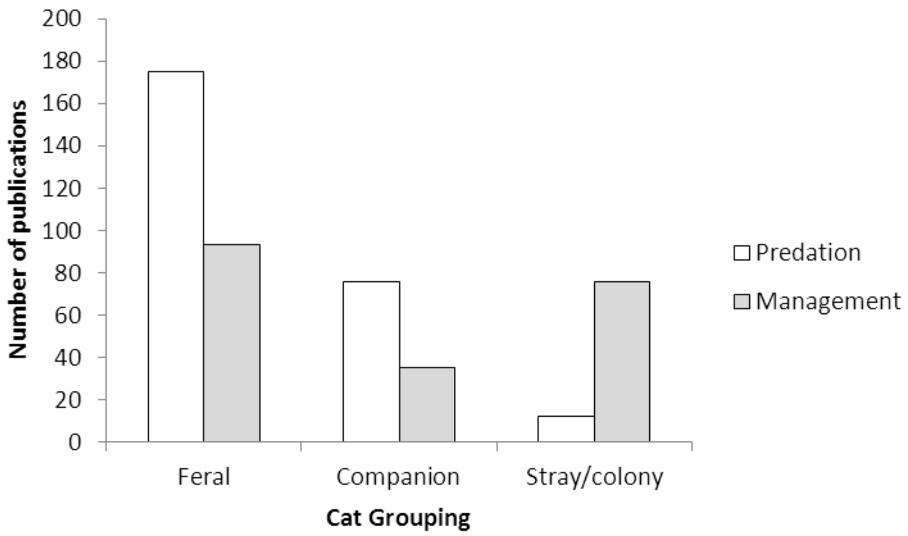

Figure 1: Distribution of retained articles for Objective 1 (predation assessment; n=256) and Objective 2 (population management; n=199) relative to cat group as defined by The Cat Code. Individual articles may address more than one cat group.

4.2.2 Year of publication

There has been a clear increase in the attention received by domestic cats in recent decades, with the evidence suggesting that cat predation impact received earlier attention than cat management.

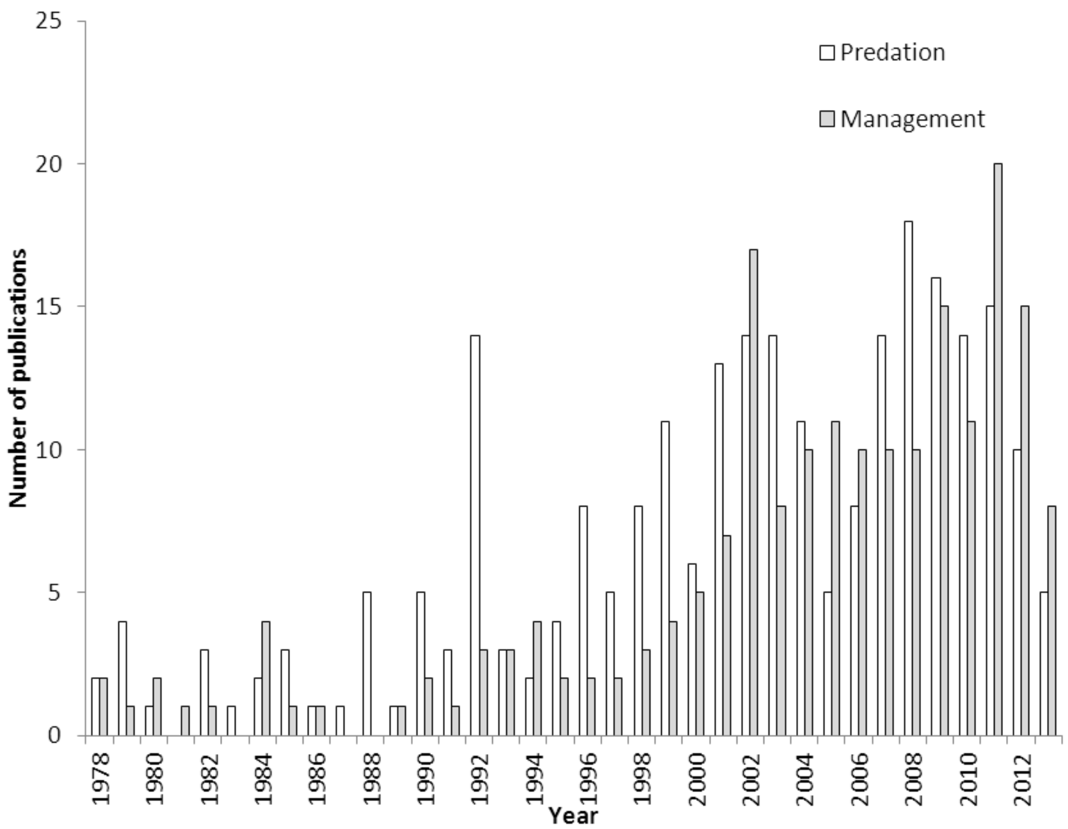

Figure 2: Distribution of retrieved and retained articles for Objective 1 (predation assessment; n=256) and Objective 2 (population management; n=199) relative to year of publication. For clarity, publications prior to 1978 were not included in the figure; however, these only total six and two resources for Objectives 1 and 2 respectively.

4.2.3 Origin of study

There is a clear difference in the origins of studies with predation studies primarily originating from countries with relatively naïve ecologies and recent cat introductions, (see Figure 3 for definitions of categories 1-5), whereas cat population management studies primarily originate from countries with a long historical association with domestic cats and ecologies which are now potentially robust to small mammalian predators.

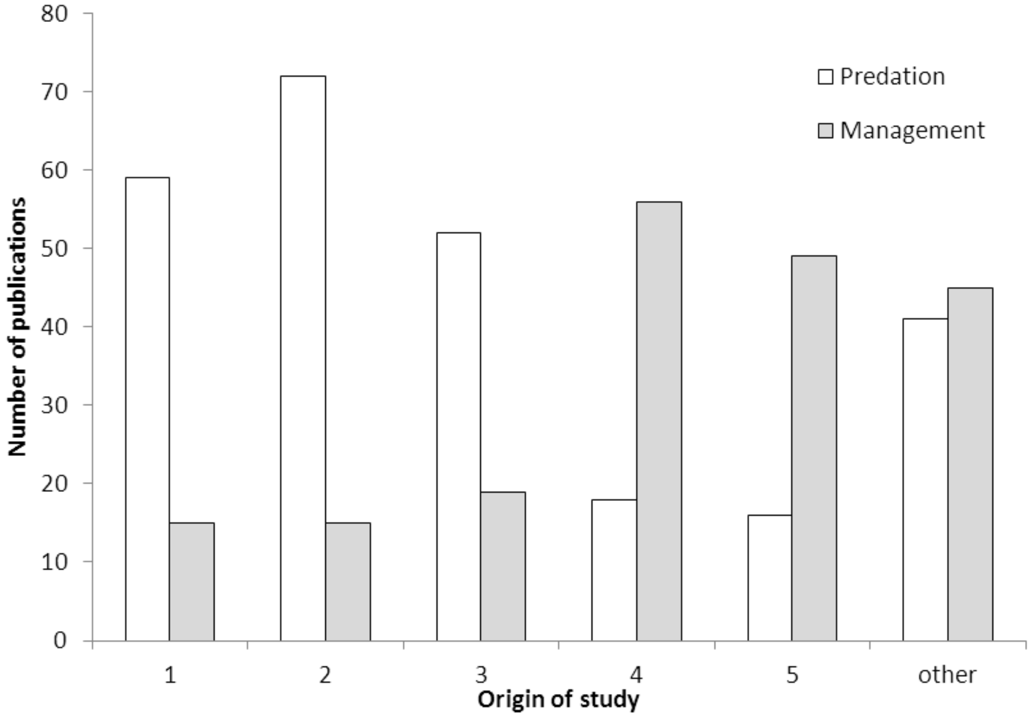

Figure 3: Distribution of retrieved and retained articles for objective 1 (predation assessment; n=256) and objective 2 (population management; n=199) relative to the country of origin of each study. Origins are defined as follows: 1) studies conducted in New Zealand; 2) studies in countries or on islands other than New Zealand but without substantial native mammalian fauna (e.g. Hawai'i) ; 3) studies outside New Zealand where the country has native mammals but also a felid-naïve fauna, with cats having been introduced recently (e.g. Australia); 4) studies in countries with mammalian predators and where domestic cats are historically present (e.g. USA); and 5) studies in countries with mammalian predators, small native felids and a long historic presence of domestic cats (e.g. UK). The category "other" includes reviews, theoretical experiments (e.g. *ex situ* exploration of immunocontraceptives), and population modelling.

4.3 Objective one: Assessment of predation risk

4.3.1 Feral domestic cats

The earliest exploration of the impacts of feral domestic cats on wildlife in New Zealand was written in the mid-20th century (Wodziki 1950). Since this date there has been significant international exploration of these impacts including a number of reviews. With the exception of only a handful of publications, the impact of feral domestic cats has been negative, leading to population declines, local extirpation, or extinction of vulnerable species (Nogales *et al.* 2004). For those studies where such declines are not evident, the lack of population declines appear to have resulted from limitation of cat population growth due to seasonal prey availability (Catry *et al.* 2007), unsuitable habitat for cats (Robertson *et al.* 2005), or the cats preying on other species (e.g. rats) which were themselves impacting upon populations of vulnerable species (Matias and Catry 2008). Population modelling has suggested that, in uncontrolled environments, feral cats may reduce extinction rates for island-based native mammal populations through predation of black rats (*Rattus rattus*) if they are also present (Hanna and Cardillo 2013). In this latter example, as in others (Fitzgerald *et al.* 1991; Medina and Nogales 2009), this results in a call for the simultaneous extermination of cats and other mammalian meso-predators. Meso-predator release was not presented as an argument against feral cat control. Broad-scale invasive species control is intended to prevent meso-predator release, a phenomenon whereby smaller predators (e.g. rats) or competitors for resources (e.g. rabbits for nest burrows), released from the predation impact of a controlled predator (e.g. cat) increase in number and therefore exert greater pressure upon another species (e.g. a seabird). The potential for meso-predator release has been further documented both in the field (Bergstrom *et al.* 2009) and through modelling (Courchamp *et al.* 1999), although it is not conclusively supported (Hughes *et al.* 2008). Notwithstanding this effect a number of studies indicate that concomitant removal of feral cats and other meso-predators from environments in which they are non-native has resulted in population recovery or reestablishment of native populations (Wanless *et al.* 2002; Rauzon *et al.* 2008; Moseby *et al.* 2009; Ratcliffe *et al.* 2010).

The significantly negative impacts of feral cats are particularly evident in environments where native fauna are mammal-/felid-naïve. As a result of a lack of selective pressure brought about through predation by cats (or other mammals) the innate behavioural and hormonal responses of native fauna to predation threats are less rapid, exposing them to greater than normal risks (Rödl *et al.* 2007). Much of the research into feral cats has taken place in felid-naïve communities, which often arise as a result of geographic isolation. It is therefore intuitive that many studies occur on islands onto which a range of invasive mammalian species have been introduced. Of those papers retained that considered the impact of feral cats, 50 addressed their impact on the endemic species found on small oceanic islands. Comprehensive reviews of these and other studies have already been conducted and reinforce the assertion that feral cats present a significant threat to wildlife, especially seabirds (Nogales *et al.* 2004; Bonnaud *et al.* 2011; Medina *et al.* 2011). Of the remainder 29 manuscripts specifically explored feral cats in either New Zealand or its islands and 22 considered Australia.

Largely the evidence indicates that feral domestic cats are generalist predators. Many studies, both in New Zealand (Langham 1990; Alterio and Moller 1997) and elsewhere (Molsher *et al.* 1999; Millán 2010), indicate a dietary preference for lagomorphs and rodents. However feral cats have been shown through observation, scat sampling, and gut content analysis, to prey upon other small native mammals (Mifsud and Woolley 2012), reptiles (Arnaud *et al.* 1993; Harlow *et al.* 2007), insects, birds (Harper 2010), and amphibians (Bonnaud *et al.* 2011). In studies which did not address a single species of concern, scat and gut samples were found to frequently include all of the taxa noted above (Catling 1988; Paltridge *et al.* 1997; Molsher *et al.* 1999; Paltridge 2002; Medina *et al.* 2006; Kutt 2011;2012).

In the absence of substantial populations of rabbits, rats, or mice, often as a result of seasonal variations in abundance (Oppel *et al.* 2011), studies indicate increases in predation of other animals, including native species (Catling 1988) which may, theoretically, have a significant impact on population persistence (Khan and Al-Lawatia 2008). Only very few articles indicated a greater likelihood that feral cats will disperse rather than switch to consumption of non-preferred prey species (Harper 2005). Modelling of the impact of feral cats suggests that increases in preferred prey populations may function to support feral cat population growth. In turn, this increases the likelihood that less preferred vulnerable species, often existing in low numbers, will come under increased predation pressure simply by virtue of increased rates of encounter (Smith and Quin 1996). This is known as the hyper-predation effect (Courchamp *et al.* 2000).

Studies of feral cats in New Zealand and its associated islands identify them as significant predators of mammals (Murphy *et al.* 2004), mainly introduced mammals but also native bats (Scrimgeour *et al.* 2012). Likewise, they have been linked to predation of both introduced and native birds including kiwi (Gillies *et al.* 2003), kakapo (Powlesland *et al.* 1995; Clout and Merton 1998), variable oyster catchers (Rowe 2008), New Zealand Dotterel (Dowding and Murphy 1993), silvereyes (Flux 2007), bellbird (van Heezik *et al.* 2010) and many species of seabird (Ratz *et al.* 1999; Dowding and Murphy 2001; Medway 2004) (see Table 2. for full list). Although cats are seen as predators of native birds they will, and do, prey upon native reptiles

(Veitch 2001; Tocher 2006) and insects (Alterio and Moller 1997). Predation by cats, although clearly not the only significant factor, has resulted in regional declines in a number of species and, in a few notable cases, extinction (Galbreath and Brown 2004). However, generally there is strong evidence that feral cats show a dietary preference for introduced mammals, especially in areas where extirpation of native species may already have occurred (Fitzgerald and Gibb 2001) or the ecosystem is severely degraded (Langham 1990). On the basis that cats are generalist predators capable of having a significant effect on native species, the feral cat is recognised as a pest in New Zealand and identified for lethal control in most of New Zealand's native species recovery plans. As an animal in a wild state, feral cats are not specifically covered by the Animal Welfare Act 1999 or The Cat Code and can legally be lethally controlled (Farnworth *et al.* 2010b).

4.3.2 Stray, colony and companion cats

Broad estimates within the USA suggest free-ranging cats account for between 1.4-3.7 billion bird and 6.9-20.7 billion mammal predations annually (Loss *et al.* 2013) although most of these can be attributed to un-owned (i.e. feral, stray) or semi-owned (i.e. those that are provided with care but not considered to be owned (Toukhsati *et al.* 2007)) cats. Of the literature that addresses free-roaming cats, and where the term free-roaming is further elucidated (i.e. ownership status is included), by far the largest amount of information concerns companion cats (see table 1) and estimates annual catch per companion cat at between 2.8 and 128 individual prey. The upper estimate in this case is based upon cat-borne camera observations which indicate that predation based upon returned prey may account for just one in four actual kills (Loyd *et al.* 2013). Other studies which have used multiple assessment methods support the notion that owner-reports of prey items likely underestimate total take (Barratt 1998; Krauze-Gryz *et al.* 2012). In broad terms the data support the assertion that cats in human environments remain generalist predators with a preference for rodents (Flux 2007) but will also scavenge substantially from human refuse (Hutchings 2003) and consume carrion (Langham 1990).

The urban environment is generally low quality and highly fragmented and is therefore already degraded and less able to support many species (Sims *et al.* 2008; Valcarcel and Fernandez-Juricic 2009). Although the diversity of predatory species is also reduced, urban environments do not represent safe-zones for adaptable bird species (Jokimäki *et al.* 2005). High densities of single-species introduced predators, including domestic cats, likely exacerbate local species decline (Baker *et al.* 2003). Species diversity will also be governed by habitat availability and types, as well as predator abundance (Lilith *et al.* 2010).

Studies which used bird density at the individual garden level rather than a wider population census found no effect of cat presence on bird abundance in Australia (Parsons *et al.* 2006). However, broader-scale studies in the UK indicate that the ratio of cats to 21 bird species were significantly different between urban and rural environments, suggesting that there are more cats and fewer birds in urban environments (Sims *et al.* 2008). Despite significant impacts upon bird populations, certain species (e.g. black redstarts, *Phoenicurus ochruros* in Germany) appear to be robust to cat predation pressure (Weggler and Leu 2001) whilst others are not (e.g. blackbirds (*Turdus merula*) in New Zealand; (van Heezik *et al.* 2010).

Companion cats are not all active hunters (Robertson 1998; Baker *et al.* 2005; Loyd *et al.* 2013). However, outdoor access for companion cats has been shown to increase the likelihood of predation of wildlife (Robertson 1998). There is also substantial variation amongst hunting patterns of individual cats. In some studies a small percentage of individuals may account for the majority of prey samples (Gillies and Clout 2003; Tschanz *et al.* 2011) whilst in others large percentages of included cats return relatively few prey (Barratt 1997). Cats also appear to show inter-individual preferences for prey species (Ancillotto *et al.* 2013) with prolific hunters appearing to prefer rodents (van Heezik *et al.* 2010).

Unlike feral cats, stray and companion cats exist in environments where anthropogenic food sources are either intentionally or unintentionally readily available (Finkler *et al.* 2011b). As a result, proximity to people (Ferreira *et al.* 2011) and human population density (Aguilar and Farnworth 2012) have both been strongly correlated with cat and stray cat densities. Anthropogenic food sources reduce, but by no means remove, the likelihood that cats in the urban environment will hunt (Silva-Rodriguez and Sieving 2011). The prey intake of feral cats is approximately four times that of a companion cat (Liberg 1984) but within the companion cat population the degree to which cats were fed by people also impacted upon the likelihood that they caught and consumed prey. Poorly-fed cats are 4.7 times more likely than well fed cats to have wild animal remains in their faeces (Silva-Rodriguez and Sieving 2011) and an early study indicates that cats not fed meat may also hunt more frequently (Robertson 1998). Stray cats are typically provided with less food and care than companion cats and, although this is not yet substantiated, may therefore be more likely to exert significant predation pressure on populations of prey species. Stray cats also live longer and breed more successfully than their feral counterparts (Schmidt *et al.* 2007).

A survey of free-roaming companion cat owners indicated that bird predation levels did not significantly differ between cats living in urban, suburban and rural areas (Lepczyk *et al.* 2004), however the species of birds taken in each area was not provided and this has been shown to differ between urban and suburban environments (Gillies and Clout 2003). Domestic cats show strong seasonal variation in prey types and quantities, often correlating with peak reproduction in their prey (Ancillotto *et al.* 2013). Within the companion population this also extends to the proportion of wild animals in the diet; in one study approximately 50% of scat samples by weight derived from pet food in summer but this rose to 85% in winter, the remainder being non-anthropogenically-derived (Liberg 1984). By far the greatest increase in predation is observed during the summer months (Baker *et al.* 2005). Domestic cats also show age-related changes in predation rates, with younger cats (those under 7 years of age) generally returning more birds and lizards (but not mammals) than older individuals (Woods *et al.* 2003). A longitudinal study of a single cat supports this hypothesis, indicating an overall decline in the number of prey taken annually beyond the age of 11 years (Flux 2007).

Within New Zealand specifically, companion cats have been shown to prey on a wide range of both native and non-native species (see Table 2) and the diversity of prey species appears closely linked to the environment in which the cat resides, with more native species being preyed upon by cats living adjacent to native bush (Gillies and Clout 2003) or large gardens with mature trees (van Heezik *et al.* 2010). Studies of companion cats within New Zealand are relatively few compared to those on feral cats and there appear to be no studies that specifically assess the impacts of either stray or colony cats on wildlife. However, in studies where predation levels have been quantified (see Table 2) there is evidence that those companion cats which do hunt do so opportunistically. Although companion cats in these studies kill rodents in larger numbers they also take significant numbers of birds, reptiles and invertebrates. The species taken most appear to be those which are most common. In one Dunedin-based study (van Heezik *et al.* 2010), cat predation was at a high-enough level to threaten the persistence of six urban bird species suggesting that the city population may persist only as a result of immigration from reproductively viable city fringe populations. Gillies and Clout (2003) showed significant variation in species caught depending upon the location of an Auckland suburb (i.e. urban or semi-urban). Most prey caught were rodents, especially those caught in the forest fringe; however native birds, insects and reptiles were also more likely to be caught in the forest-fringe as compared to more urban areas. In urban areas insects were the predominant prey and birds were caught in equal numbers between the two suburbs but tended to be non-native species in urban areas. In Hamilton the domestic cat was found to be the only major predator regularly identified within the city itself (Morgan *et al.* 2009a). The city of Hamilton also had a relatively high nesting success rate for four bird species, two native (fantails and silvereyes) and two non-native (blackbirds and song thrushes) (Morgan *et al.* 2011), possibly due to low rat numbers outside gullies. However, this study also suggested that the impact of cats may be more significant at fledging making nest success a potentially less robust measure of the impact of cats.

4.3.3 Free-roaming cat density

Studies in New Zealand indicate that the vast majority of companion cats are free-roaming (Farnworth *et al.* 2010a). Outside urban environments the density of cats is curtailed to some degree by the availability of prey; this is why cat density is typically low in areas without dense human habitation. For example, Hawke's Bay farmland has approximately 2-3 cats/km^2 (Langham 1990), estimated densities on Kangaroo Island, Australia were 0.7 cats/km^2 (Bengsen *et al.* 2011), and rural areas in the Mediterranean report densities of 0.26 cats/km^2 (Ferreira *et al.* 2011). In human-mediated environments this pressure is removed and predation pressure may not decline as prey species abundance declines (Shochat 2004) especially since urban cats may not be subject to optimal foraging requirements (i.e. efficiency based on capture rates and energy returns) (Maclean *et al.* 2008). As a result, companion domestic cats (excluding stray and colony cats) are able to live at extremely high densities within urban environments with estimates for Dunedin being 223 cats/km^2 (van Heezik *et al.* 2010).

Beyond companion cats, large populations of stray cats can be supported through provision of food by semi-owners (Toukhsati *et al.* 2007) or colony carers. Evidence suggests that this increases the local stray cat population and concomitantly reduces the diversity of other species (Hawkins *et al.* 1999). In countries where stray and colony cats are either protected or are an accepted part of the urban environment (e.g. Israel) total cat density can exceed 2300 cats/km^2 (Mirmovitch 1995). Based on stray cats numbers collected by a single charity in one year in Auckland, stray cat density may, at the very least, range from 15-50 cats/km^2 depending on location (Aguilar and Farnworth 2012). As the data used by Aguilar and Farnworth (2012) only accounted for cats that were reported and removed, and 44% of the data on stray cats could not be used, the actual density is likely to be substantially higher. However, stray cat numbers will differ across New Zealand, and a report on a single Wellington shelter reported a much lower annual intake (Rinzin *et al.* 2008). Reasons for such variation are not evident within the research.

4.3.4 Home-ranges of cats

Feral cats have been shown to have large home-ranges which often coincide with areas of significant prey abundance (Fitzgerald and Karl 1986). Urban cats have smaller home ranges than those found either in the suburbs or in rural areas (Lilith *et al.* 2008; Loyd and Hernandez 2012). Companion cats are also found to have significantly smaller ranges than stray cats (Schmidt *et al.* 2007) with stray cats spending 14% of their time highly active (i.e. hunting) as compared to 3% in companion cats (Horn *et al.* 2011). Stray cats also have higher survival rates than feral cats and likewise higher fecundity (Schmidt *et al.* 2007). Despite high mortality rates in the first six months of life, stray cat populations have a high reproductive capacity (Nutter *et al.* 2004b). When tracked, companion cats showed preference for areas in which hunting success is improved (Loyd and Hernandez 2012). Prey that live at high density in patchy and fragmented habitat may be particularly vulnerable in this regard (Larsen and Henshaw 2001). Despite having a contracted home range there is strong evidence that urban or suburban domestic cats will incur upon surrounding rural, semi-rural, or national park landscapes (Lilith *et al.* 2008; Marks and Duncan 2009; Fandos *et al.* 2012) where prey may include remnant native species (Meek 1998). Dispersal of domestic cats is aided by sparse human settlements which act both as outposts for free-roaming stray cats and smaller centres of aggregation (Ferreira *et al.* 2011; Young *et al.* 2013).

4.3.5 Estimated predation impact of companion and stray cats

4.3.5.1 Companion cats

The total predation impact of cats on fauna in New Zealand has not yet been estimated but, in other nations, is estimated to be billions (Loss *et al.* 2013) or hundreds of millions (Woods *et al.* 2003) dependent upon the size of the cat population. It seems pertinent to attempt a rudimentary and conservative calculation based upon the data provided by three recent studies to address predation by companion cats in New Zealand (Gillies and Clout 2003; Flux 2007; van Heezik *et al.* 2010). Using the broad (and highly conservative) assumption that 35% of companion cats are active hunters this would indicate that approximately 490,000 of the 1.4 million companion cats (MacKay 2011) routinely return prey to New Zealand households. Using the mean annual return rate across the three studies (22.3 prey items per annum) this would indicate a total population annual return of some 10,927,000 individual animals. We may postulate that somewhere between 1 in 4 (Loyd *et al.* 2013) and 1 in 1.7 (Barratt 1998) prey are returned making the number of animals killed somewhere between 18.58 - 43.71 million. The breakdown by taxa, based upon mean values from Gillies and Clout (2003) and van Heezik *et al.* (2010) would be as follows: mammals 6.23-14.64 million; birds 4.7-11.06 million; reptiles and amphibians 1.45-3.41 million; invertebrates 6.21-14.6 million.

4.3.5.2 Stray cats

It is more difficult to estimate the impact of stray cats and, in this regard, this section should be considered highly speculative. Using a conservative estimate of the stray cat population, that being an additional 14% of the companion population (Mahlow and Slater 1996), stray cat numbers may be at the lower estimate of 196,000 across New Zealand. Little information exists on individual impacts of stray cats. Stray cats, or those living around anthropogenic food sources (Hutchings 2003), are likely to exploit available food, but also to supplement these with prey. One may reasonably assume that a stray cat is unlikely to be provided with its complete daily dietary needs. Include evidence that poorly fed cats are 4.7 times more likely to consume vertebrate prey than well fed cats (Silva-Rodriguez and Sieving 2011) and one may conclude that the proportion of stray cats that hunt, even infrequently, is likely 100%. Using an assumption that an individual stray cat may consume twice as many prey items as a companion cat (i.e. (22.3*2)*4 or 1.7) the annual take would be between 75.82 and 178.4 prey items per cat. Based upon total population estimates this would indicate a total take of approximately 14.86 – 32.97 million prey items. A further breakdown of the taxa is perhaps not helpful given the speculative nature of this estimate and a lack of data as to where stray cats are found but, conservatively, could be considered to be proportionally similar to that for companion cats.

4.3.6 Non-predatory impacts of domestic cats

More recently the sub-lethal impacts of urban cat populations are being explored. At high densities they are being shown to have indirect impacts upon other species. The response of birds to the presence of a cat in the locale has been directly related to an increased likelihood of nest predation by animals other than cats (Bonnington *et al.*

2013). It is indicated that this is probably due to exposure of the location of the nest as the bird responds to cat presence. Models of the sub-lethal impact of urban domestic cat populations suggest that a reduction in provisioning by nesting birds equal to one fewer fledglings per nest per year may be enough to significantly reduce urban bird abundance (Beckerman *et al.* 2007). Such reductions in provisioning may result from increased vigilance, reduced foraging time, and increased predator evasion and even well-adapted bird species are more vigilant in urban environments as compared to rural ones (Valcarcel and Fernandez-Juricic 2009).

Table 1: Summary of studies retained which contained data concerning predation by urban populations of companion and stray cats

Study	Country	Study length	Cat type (n)	% Active hunters	Sampling method (n)	Mean composition/number of prey taken during study				Estimated annual take per cat
						Mammals	Birds	Reptiles amphibia	Invertebrates	
Barratt (1997)	Australia	12 months	Companion (214)	-	Returned (1961)	65%	27%	8%	-	Prey items: 2.8 ± 0.45
Barratt (1998)	Australia	12 months	Companion (135)	~80%	Returned (-)	6.9 ± 2.3	2.6 ± 0.7	0.7 ± 0.4	-	Prey items: 10.2 ± 2.7
					Observed (-)	12.9 ± 6.2	3.0 ± 1.4	1.6 ± 1	-	17.4 ± 6.5
Baker *et al.* (2005)	UK	144 days	Companion (131)	26-49%	Returned (358)	75%	24%	1%	-	Prey items: min 7; max 21
Baker *et al.* (2008)	UK	12 months	Companion (275)	~39%	Returned (495)	66%	24%	9%	1%	-
Borkenhagen (1979)	Germany	-	Companion (54)	-	Returned (309)	62%	22.1%	0.3%	15.6%	-
Brickner-Braun *et al.* (2007)	Israel	-	Urban stray (43) Village stray (59)	-	Gut contents (102)	0% 22%	0% 4%	0% 4%	0% 2%	- -
Calver and Thomas (2011)	Australia	3 weeks[a]	Companion (15)	100%	Returned (60)	52%	38%	10%	-	Prey items: 69.3[b]
Campos *et al.* (2007)	Brazil	2 months (July; Jan)	Free-ranging suburban/rural (-)	-	Scat (97)	20.51%	12.82%	-	63.24%	mammals: 2-2.9 Kg
Flux (2007)	NZ	17 years	Companion (1)	100%	Returned (558)	58.2%	40%	1.8%	-	Prey items: 32.8
Gillies and Clout (2003)	NZ	1 year	Companion (80)	-	Returned (1674)	32%	13.5%	7.5%	47%	Prey items: 20.9
Gordon *et al.*	NZ	6 weeks[a]	Companion (45)	~80%	Returned (257)	63%	32%	<5%		Prey items:

(2010)										60.1[b]
Hutchings (2003)	Australia	2 years	Stray (-)[d]	(-)	Scat (159)	present 55/159	present 16/159	present 38/159	present 2/159	-
Kays and DeWan (2004)	USA	3 months	Companion (12)	100%	Returned (60)	86%	14%			Prey items: 20.04[c]
Krauze-Gryz *et al*. (2012)	Poland	30 months	Companion (34)	100%	Returned (1545)	69.8%	13.1%	8%	8.2%	
Langham (1990)	NZ	44 months	Rural stray[d] (-)	-	Scat (321)	74%	24%		2%	-
Loyd *et al*. (2013)	USA	7-10 days	Companion (55)	44%	Camera observation	26%	13%	41%	21%	Prey items: 124.8[e]
Nelson *et al*. (2005)	UK	1 month[a]	Companion (89)	100%	Returned (309)	58.6%	37.9%	-	-	Prey items: 41.6[b]
Thomas *et al*. (2012)	UK	8*6 weeks	Companion (348)	~75%[f]	Returned (1150)	65%	30%	-	-	Prey items: 18.3
Tschanz *et al*. (2011)	Switzerland	48 days	Companion (32)	65.6%	Returned (71) Observed (46)	76.1%	11.1%	-	4%	Prey items: 27.5
van Heezik *et al*. (2010)	NZ	12 months	Companion (144)	75%	Returned (1887)	35%	37%	8.1%	19.7%	Prey items: 13.1
Woods *et al*. (2003)	UK	5 months	Companion (696)	91%	Returned (11537)	68%	24.3%	4.8%	<3%	Prey items: 27.12

[a] Period excludes one or more identical period during which a predation deterrent was tested
[b] Cats recruited in these studies were known hunters
[c] Actual number 1.67/month in Summer; observed kills = 5.54/month (66.48/year by same calculation)
[d] Cats in this study are described as ‘feral’ however they live and scavenge around human habitation meaning they are potentially ‘stray’ under code of welfare definition
[e] Actual number 2.4 items per week, mean of successful hunters only
[f] Percentage of cats having returned prey after eight seasons

Table 2: Prey species identified following return to owner by companion cats in New Zealand. Where numbers of returns are not available, species are presented in order of most to least frequent.

Study	Birds (n)	Mammals (n)	Reptiles/Amphibia	Invertebrates (n)
Flux (2007) Cats n=1	Hedgesparrow *Prunella modularis* (48) *Silvereyes *Zosterops lateralis* (43) Greenfinch *Carduelis chloris* (30) Goldfinch *Carduelis carduelis* (22) Chaffinch *Fringilla coelebs* (17) House sparrow *Passer domesticus* (16) Blackbird *Turdus merula* (13) Song thrush *Turdus philomelos* (7) Yellowhammer *Emberiza citrinella* (7) European starling *Sturnus vulgaris* (6) *Fantail *Rhipidura fuliginosa* (5) *Grey Warbler *Gerygone igata* (4) *Kingfisher *Halcyon sancta* (1) *Shining cuckoo *Chrysococcyx lucidus* (1) Redpoll *Carduelis cabaret* (1)	House mouse *Mus musculus* (221) Rat *Rattus rattus* (63) Rabbit *Oryctolagus cuniculus* (35) Hare *Lepus europaeus* (4) Weasel *Mustela nivalis* (2)	(*) Skink *Cyclodina* spp.(9) Frog *Litoria* spp. (1)	Evident but not included
Gillies and Clout (2003) Cats n=80	House sparrow *Passer domesticus* *Silvereyes *Zosterops lateralis* Blackbird *Turdus merula* Song thrush *Turdus philomelos* European starling *Sturnus vulgaris* Myna *Acridotheres tristis* Finches *Carduelis* spp. Chaffinch *Fringilla coelebs* Domestic chicken *Gallus gallus domesticus* *Kereru *Hemiphaga novaeseelandiae* (1) *Tui *Prosthemadera novaeseelandiae* (2) *Grey Warbler *Gerygone igata* (2) *Fantail *Rhipidura fuliginosa* (1) *Kingfisher *Halcyon sancta* (1)	Rat spp. *Rattus rattus/norvegicus* (313) House mouse *Mus musculus* (207) Stoat *Mustela erminae* (4) Rabbit *Oryctolagus cuniculus* (2) Hedgehog *Erinaceus europaeus* (1)	(*) Skink *Cyclodina* spp.(117) (*)'Gecko species' (8) *Auckland green gecko *Naultinus elegans elegans* (2) Frog *Litoria* spp. (2)	*Crickets *Teleogryllus commodus* (*) Lepidoptera spp. *Cicada *Cicadidae* spp. *Tree weta *Hemideina thoracica* (Total 787)

van Heezik *et al.* (2010) cats n=144	*Silvereyes *Zosterops lateralis* (182) House sparrow *Passer domesticus* (78) Song thrush *Turdus philomelos* (69) Blackbird *Turdus merula* (42) *Fantail *Rhipidura fuliginosa* (32) *Bellbird *Anthornis melanura* (11) European starling *Sturnus vulgaris* Greenfinch *Carduelis chloris* Goldfinch *Carduelis carduelis* Chaffinch *Fringilla coelebs* Redpoll *Carduelis cabaret* Yellowhammer *Emberiza citrinella* (7) Mallard *Anas platyrhynchos* *Kereru *Hemiphaga novaeseelandiae* *Tui *Prosthemadera novaeseelandiae*	House mouse *Mus musculus* (386) Rat *Rattus rattus* (241) Stoat *Mustela erminae*; Rabbit *Oryctolagus cuniculus* (12) Rat *Rattus norvegicus* (2)	Common skink *Oligosoma nigriplantare polychrome* (149) Frog *Litoria* spp. (4)	(**)Invertebrates (362)

(*) Native to New Zealand
(*) May include native species
(**) 22 species of which six were native

4.4 Objective two: Management of the cat population

4.4.1 Management of feral cat populations

Without exception current control and management of feral cats involves lethal means including trapping (Short *et al.* 2002), shooting (Phillips *et al.* 2005), poisoning (Eason and Frampton 1991; Burrows *et al.* 2003; Hetherington *et al.* 2007) introduction of disease (Bester *et al.* 2002), and hunting (Rauzon *et al.* 2008). The goal of any such management is the total eradication of cats from the area and often requires a combination of control measures (e.g. Bester *et al.* 2002). However, total eradication is generally only possible within confined geographical areas such as islands (e.g. Veitch 2001). Within mainland populations control is primarily intended to reduce numbers of feral cats and therefore limit population growth (Gillies *et al.* 2003). Lethal management of feral cats is generally supported by the New Zealand public and is considered more acceptable than lethal control of stray cats (Farnworth *et al.* 2011).

Within the literature there has been some practical (Gorman *et al.* 2002) and theoretical (Courchamp and Cornell 2000) consideration of immunocontraception for remote populations of feral cats. To date immunocontraception remains under investigation. Currently the value of long-acting contraception is also being explored for controlling stray cat populations (Levy 2011) but is not commonly used as it remains under development (Levy *et al.* 2011). The ability of any non-lethal population control method to mitigate cat predation rates and improve welfare requires consideration.

4.4.2 Stray cat management techniques

While much of the information around management focuses on stray cat colonies, the information available for management of the wider stray cat population (i.e. those that are not closely associated with carers) is limited. The number of stray cats able to be supported in any given environment will have upper limits (McCarthy *et al.* 2013). As this is normally resource-driven the presence of anthropogenic food sources indicates that the population carrying capacity of human environments is large. Wilful provision of food in the absence of other population management processes supports significant and growing numbers of stray cats (Tennent and Downs 2008). It is perhaps then self-evident that any strategy to control cat populations requires strong consideration of the human origins of the issue (Lohr *et al.* 2013). Outside New Zealand, a significant body of literature suggests that, overall, public attitudes towards stray cat management favour non-lethal methods (Ash and Adams 2003; Tennent *et al.* 2010; Loyd and Hernandez 2012). In New Zealand, although there is some public support for non-lethal cat control (Farnworth *et al.* 2013a), this is not unequivocal (Farnworth *et al.* 2011) and, as elsewhere (Loyd and Miller 2010b), preferences may be related to perceptions of the value of wildlife.

4.4.2.1 Trap, Neuter, Return (TNR) and Trap-Euthanise (TE)

For the purposes of this review TNR is also considered to encompass other techniques of sterilisation and return including those with additional schedules of vaccination and health care (e.g. trap-test-vaccinate-alter-return-monitor (TTVARM) Hughes and Slater 2002). In general TNR is the process by which individual stray cats, or those living in colonies, are live-trapped, sterilised, potentially vaccinated, and then returned to the location from which they were taken (Robertson 2008). The degree of diagnosis and care provided by individual TNR providers will differ (e.g. Wallace and Levy 2006). It is considered to be a more ethical approach to stray cat population management in that it does not result in the death of otherwise healthy cats. Reportedly it also prevents incursion into areas left vacant by cat removal (Mahlow and Slater 1996), however observations do not support this assertion given that sexually entire cats were in some instances able to exclude and outcompete gonadectomised cats (Gunther *et al.* 2011). Recently an alternative method has been modelled that uses trap-vasectomy-hysterectomy-release (TVHR) (McCarthy *et al.* 2013). Such methods remove a cat's reproductive capability whilst leaving sexual behaviour unaltered (Mendes-de-Almeida *et al.* 2011). This may prevent incursion by other individuals. Compared to other models (see later), TVHR may only require 35% of the population to be captured and treated annually to cause population decline over 11 years, assuming four annual capture efforts with high capture probability. This model indicated that TNR was unable to outperform either TE or TVHR in any simulation. However, this model did not appear to include the potential for population maintenance through abandonment of cats by owners.

TNR and its variants are particularly espoused for semi-owned cats which continue to receive *ad hoc* care on an on-going basis. In general, managed colonies could be considered those which are provided food, water, shelter and veterinary care on an irregular basis. The literature is equivocal concerning decline and extinction of colonies. In one 11-year study a colony was reduced from 68 to 23 individuals. However, of 155 cats removed or lost from the colony over 11 years, 47% of the cats were adopted and 21% either disappeared or migrated away (Levy *et al.* 2003). Another study focused on university campuses with a combined estimate of 186 colony cats across five locations. A TNR rate of 57% did not appear to reduce the colony sizes, although they were stable (Jones and Downs 2011) and a later paper indicated a need for removal of animals to reduce the population (and its impact) before maintenance through TNR (Tennent *et al.* 2009). Where TNR is actively employed, colony extinction may require 5-10 years of on-going management and so is not advised in areas where significant problems require rapid solutions (e.g. colonies in the vicinity to endangered species) (Stoskopf and Nutter 2004). Stoskopf and Nutter (2004) used six colonies of cats where an experimental management protocol, which included TNR, was implemented. This resulted in relatively large colony declines (36%) over short periods of time (2 years), three control colonies concomitantly showed a 47% increase in population size. Early modelling suggested TNR would require 75% of any given population to be consistently sterilised before population stability and decline was achieved. If TE was modelled this percentage dropped to 50% (Andersen *et al.* 2004) suggesting TE was more effective. Other models of TNR and non-surgical contraception suggest that in any given year 51% and 60% of the population would need to be sterile or have a contraceptive implant respectively (Budke and Slater 2009). When TNR and TE procedures were modelled in Hawai'i, TNR was identified as being significantly more expensive, an issue which has previously been cited as an impediment to broad-scale use (Levy 2011). TNR was shown to require 30 years to extirpate any population assuming a 0% abandonment rate. In contrast, TE required 2 years for extirpation (Lohr *et al.* 2013). However 0% influx via abandonment is unrealistic in any open system and in one Italian study this was estimated to be as high as 21% (Natoli *et al.* 2006). As a result, any TE programme would need to be repeated on a regular basis to suppress a growing population whilst TNR failed to significantly reduce the population (Lohr *et al.* 2013) and was described as ‘a waste of time’ (Natoli *et al.* 2006) until cat abandonment by owners was effectively addressed. The suggestion that neither TNR nor TE can effectively manage populations with significant influx from abandonment is supported in other models (Schmidt *et al.* 2009).

Modelling of population interventions is problematic in that models do not incorporate public acceptance which will vary relative to local perception (Robertson 2008). In one study a TE campaign to reduce an unowned free-roaming cat population was routinely disrupted by those opposing it whereas TNR increased compliance (Levy *et al.* 2003) and in another there was strong opposition to eradication of the stray cat population (Tennent *et al.* 2010). Without regular trapping and hysterectomy of females approximately every 6 months (Mendes-de-Almeida *et al.* 2011) the population growth rate of colonies cannot be effectively curbed.

Broadly speaking the literature around TNR tends towards discussion of small groups of cats and small numbers of colonies in localised geographical areas with dedicated carers, often in or around universities (Hughes and Slater 2002; Levy *et al.* 2003; Nutter *et al.* 2004a; Jones and Downs 2011). In examples where large longitudinal samples are explored there appears little evidence of population decline (Foley *et al.* 2005) or only moderate decline (Natoli *et al.* 2006), and where decline is evident it is of questionable validity as it is drawn from surveys which rely on carers’ recollections rather than observation (Centonze and Levy 2002). In the latter study of 103 colonies surveyed only one had become extinct during a 10-year TNR intervention. Likewise, another large study (Hughes *et al.* 2002) was unable to specifically identify a direct cat population reduction as a result of a county-wide TNR effort. Other papers which discuss TNR provide no clear assessment of the size of source populations of cats or the ultimate impacts of the TNR event. Some of these papers discuss small populations (Gibson *et al.* 2002) but others consider TNR on a large scale (n=103,643 Wallace and Levy 2006). Studies on colonies of cats that have undergone TNR suggest that there is no reduction in home-range or in the propensity of cats to enter areas of native forest (Guttilla and Stapp 2010) although this is a single study on a small population. There is some evidence that the provision of localised food sources, often in excessive amounts (Natoli *et al.* 1999), may act as both an attractant for additional stray cats and increase fecundity of any cats which remain unneutered. The tendency of colony carers to have strong emotional attachments to the cat group (Centonze and Levy 2002) may also reduce the likelihood that new cats entering the group will be removed and seems to encourage belief-based rather than evidence-based objectives and systems of care (Peterson *et al.* 2012). Reproductive output is directly attributable, in some cases, to the management style and resources available to the carers (Finkler *et al.* 2011b).

Cat management and predation of wildlife by cats are often addressed in isolation, especially in relation to the direct predation effect of stray cats and cat colonies. No papers were found in this systematic review that directly addressed conservational concerns (e.g. predation rates) alongside active colony management using TNR.

4.4.2.2 Removal and rehoming

One of the most common processes by which stray cats can be permanently removed from environments where they are potentially at risk, and are a potential risk to wildlife, is through removal and adoption (Robertson 2008). Removal and adoption has proved useful in reducing the size of stray cat colonies (Levy *et al.* 2003) but has not always discussed in detail (Natoli *et al.* 2006; Jones and Downs 2011). In other campaigns kittens as young as six weeks were returned to colonies following sterilisation with no clear articulation of an intent to re-home any individuals (Gibson *et al.* 2002). Data on the number of cats arriving at adoption centres and outcomes for those cats are not promising (Rinzin *et al.* 2008; Marston and Bennett 2009; Alberthsen *et al.* 2013). Adoption as a strategy can only generally apply to well socialised adults or kittens (Levy *et al.* 2003).

There has been some discussion around cat sanctuaries which would be organised spaces where large numbers of cats can be allowed to live. Within some areas in the USA there appears to be significant support for this idea (Loyd and Hernandez 2012). However, evidence suggests that where these do exist they fill rapidly, are inefficient, and are unable to meet service demand (Levy and Crawford 2004). Dense populations of cats are also likely to require significant health care to prevent outbreaks of infectious diseases such as upper respiratory tract disease (Dinnage *et al.* 2009). This is especially important for individuals not intended to be adopted.

4.5 Companion cat management techniques

Modelling of TNR and TE for stray cat population management suggests that abandonment of companion cats places significant financial and temporal impairment on either strategy (Castillo and Clarke 2003; Natoli *et al.* 2006; Lohr *et al.* 2013) and therefore strategies to improve the cat-owner bond are vital. In Israel persistent negative ownership behaviours such as allowing uncontrolled breeding and wilful abandonment have been shown to contribute to stray cat over-population (Finkler and Terkel 2012).

Preventing companion cats from contributing to the stray cat population requires two main problems to be addressed. First, suitable levels of gonadectomy must be achieved. Current evidence is that, within New Zealand, gonadectomy rates for owned cats are close to 90% (McKay *et al.* 2009; Farnworth *et al.* 2010a) and comparable to those in Australia (Marston and Bennett 2009). Furthermore, early gonadectomy (prior to puberty) appears to be the norm within New Zealand's veterinary practices (Farnworth *et al.* 2013b). However, internationally, poor companion cat care and management has been linked to variations in the socio-economic characteristics of carers and locations (Finkler *et al.* 2011a; Gunther *et al.* 2011). Within Auckland, the prevalence of stray cats in areas with high deprivation scores suggests that similar problems may be present (Aguilar and Farnworth 2012).

Beyond minimising the reproductive potential of the companion cat population there is a need to minimise abandonment. Anthropologically, identifiable colonies of cats may increase the likelihood that additional cats will be abandoned in that locale (Castillo and Clarke 2003; Natoli et al. 2006). Public perception of cats as independent animals may lead to individuals abandoning cats in an attempt to 'give them a chance' rather than relinquishment at a welfare centre where they may be euthanased (Levy and Crawford 2004). Acceptance that cats should be free-roaming also increases the likelihood of semi-ownership (Toukhsati et al. 2007). There is a strong need to minimise abandonment rates by improving the owner-cat bond.

Minimising the predation impact of companion cats would appear to be best served by use of collars with attached bells or sonic devices. In instances where this has been directly assessed it appears to cause a significant reduction in predation (Ruxton *et al.* 2002; Woods *et al.* 2003; Nelson *et al.* 2005; Gordon *et al.* 2010; Calver and Thomas 2011), although this effect has not been observed in all studies (Barratt 1998; Morgan *et al.* 2009b) and some devices can be unreliable (Nelson *et al.* 2006). Alongside prevention of predation, collars also allow ready identification of owned cats and hence the owner. This increases likelihood that companion animals will be reunited with owners (Weiss *et al.* 2011). Current research suggests that cats in New Zealand are unlikely to be provided with a collar and even less so one with an attached bell (Farnworth *et al.* 2010a). A survey in Australia suggests that this may result from a generally unfounded fear of injuries being caused by collars (Calver *et al.* 2013).

Within Australia, confinement of cats or curfews have been implemented to minimise owned cats' opportunities to hunt, a measure which has received support within the State of Victoria (Toukhsati *et al.* 2012). Many espouse keeping cats in at night, something which has been identified as reducing predation rates (Woods *et al.* 2003), or restricting ownership (Lilith *et al.* 2006). However, cat restrictions have not clearly been linked to changes in prey density or type (Lilith *et al.* 2010). In countries such as the USA where cats are themselves prey for larger predators, indoor cats are more common and are less likely to receive injuries from other cats (Clancy *et al.* 2003). Evidence suggests that exclusively indoor cats, if provided for appropriately (e.g. with opportunities to display normal behaviour patterns), are unlikely to experience poor welfare (Jongman 2007). Other strategies that would allow companion cats, and by association stray cats, to be identified include compulsory registration, an intervention which has been proposed in Australia (Calver *et al.* 2011).

5 Discussion

5.1 Literature included

As with any systematic review of the literature inclusion of information is potentially limited by the terms and search engines used. We have, however, gone to considerable effort to engage with the peer-reviewed literature at the broadest possible level. In terms of literature prevalence there is clear evidence that studies of both cat predation and population management have gained significant attention of late with a particular increase in the last 20 years. However, this may be associated with a general increase in peer-reviewed publication and not solely a result of increased concern about cat populations.

Much of the predation literature focuses on feral cats (see section 4.1.2) and companion cats. There is little information concerning predation by stray or colony cats, possibly as a result of an inability to easily sample these groups. The predation literature, in particular, addresses the problem in countries and island chains that fall into categories 1-3, but relatively few papers address predation in countries which fall into categories 4-5. In part this may be due to a more obvious impact upon naïve fauna caused by recent cat introductions and also a stronger drive towards conservation imperatives in countries such as New Zealand (category 1), Australia (category 3) and islands with sea bird colonies and unique fauna (category 2). Likewise, these studies tend to originate from areas of sparse human population where conflict between feral cats and wildlife is most common. In countries such as those in North America (category 4) and Europe (category 5) the historic presence of the domestic cat, high human density and the likely historic extirpation of vulnerable species may reduce the perceived urgency of research to quantify and mitigate predation impact.

In contrast, the literature around the management of cat groups, whilst also focussed on removal of feral cats, has a significant body of research which addresses stray and companion cats. Much of this literature arises directly from category 4 and 5 countries where discussion of cat management likely does not have the same conservational imperative for action. In this regard it also focuses primarily on non-lethal control methods for stray and feral cats. Literature from Australia and New Zealand which addresses population management for stray and companion cats tends to address mechanisms by which ownership and shelter practices can be addressed to minimise impacts.

5.2 Defining cat populations

Wherever possible the literature discussed in this document has been attributed to one of The Cat Code definitions. This was particularly problematic when reviewing the American literature where little clear distinction is made between 'stray' and 'feral' populations. In addition to Farnworth *et al.* (2010b) this research raises further questions about defining cat groups on a primarily anthropocentric basis. For example, some papers indicate that cats feeding at refuse sites (Hutchings 2003) or on the margins of farms (Langham 1990) are 'feral', but within the definitions of The Cat Code these could be argued to be stray in that they, at least in part, derive food from human sources, habitats and activities and may, at some point, have been abandoned. Additionally, an unneutered companion cat in a rural or semi-rural environment, where its home range is larger (Lilith *et al.* 2008), is arguably more likely to encounter, and contribute directly to, the feral cat population than a similar individual in an urban centre. This is despite the supposition within The Cat Code that the companion cat population and feral cat population are largely independent of one another. In fact there is little evidence within the scientific literature that this is, or is not, the case. Future research should consider genetic flow between the three cat groupings as well as the origins of New Zealand's companion cats.

If New Zealand's major cities are similar to Melbourne, Victoria (Australia) it may be that the stray population acts to maintain the companion population (Marston and Bennett 2009). This is especially so as the companion population, within Auckland and Kaitaia at least, seemingly exceeds a sterilisation rate of 87% (McKay *et al.* 2009; Farnworth *et al.* 2010a). A rate around 76-88% has been identified as being able to prevent population increases (Burns *et al.* 2013). These statistics suggest that the unneutered stray and semi-owned populations may be the primary source of companion cats (Toukhsati *et al.* 2007), either through casual acquisition or through adoption at shelters (Marston and Bennett 2009). In essence, the companion and stray cat populations overlap significantly. Likewise, so too do the feral and stray populations, despite The Cat Code stating that stray cats will likely breed with unneutered companion cats (but with no mention of feral cats). The inability to clearly extricate one cat grouping from another presents significant problems in terms of population and welfare management. The definitions within The Cat Code may also lead to misunderstandings and miscommunication between interested parties with different foci (e.g. cat control agencies and cat protection agencies).

5.3 Impact of cats

The estimated numbers of animals killed by cats proposed within the literature reviewed in this document suggest that cats have a substantial impact upon other species. At an individual level, companion cats will likely have a reduced predation impact when compared to stray, feral, or colony cats by virtue of the ready availability of food which is shown to reduce prey take (Silva-Rodriguez and Sieving 2011). However, there are a number of reasons why these rudimentary calculations should be treated with caution. Firstly, beyond companion cat data, little or no evidence could be found for the prey take of stray cats and we would recommend work similar to that of Loyd *et al.* (2013) be undertaken. The lack of evidence meant that the estimated take of stray cats was created using highly conservative values, and stray cats may well kill far more than twice the mean annual number of prey taken by companion cats. Secondly, stray cat number estimates were based upon the lower population estimate of an American study (Mahlow and Slater 1996) and may be inaccurate within the New Zealand context so again further study is recommended to provide a clear estimate of the stray cat population. Thirdly, the three studies used to generate the companion cat estimate were not conducted in comparable areas on comparable populations and some included invertebrates explicitly in the prey take (Gillies and Clout 2003; van Heezik *et al.* 2010) whilst others did not (Flux 2007). Finally these calculations are extrapolated from urban and semi-urban cat populations and cannot take into account local and regional variations in cat territory and prey availability. However, these limitations noted, the total prey take parameters provided are more likely to underestimate impact than overestimate it.

5.3.1 Feral cats

Notwithstanding the information provided in 5.1, the evidence shows that the impact of the feral domestic cat is substantial, despite generally living at low densities (Fitzgerald and Gibb 2001). This is particularly so: 1) in environments where anthropogenic food is neither directly nor indirectly available; 2) where the ecology has evolved in the absence of mammalian predators; and 3) where introduced predator populations can be either sustained or grow unchecked. Therefore, the feral cat within New Zealand is legitimately identified as a pest and has had, and continues to have, significant impacts upon native fauna since its introduction. Some of these impacts, even those of single individuals (Scrimgeour *et al.* 2012), are extremely relevant to the conservation of critically endangered or vulnerable fauna (Clout and Merton 1998). This is despite evidence of a preference for other introduced mammals such as rodents and lagomorphs and assertions that cats may function to reduce the populations of other predators and meso-predators (Fitzgerald and Gibb 2001). Research into the impact of feral cats outside islands and particularly in protected or pristine mainland areas should be encouraged, especially as related to populations of other predators.

5.3.2 Companion cats

Tables 1 and 2 demonstrate the wide variation found in both the nature of studies concerning companion cats and the impacts of companion cats. With the exception of studies which recruited known hunters (e.g. Calver and Thomas 2011), all studies of companion cats indicate a significant proportion that do not actively hunt or do so only rarely. Precisely why this is the case is difficult to establish but it is likely a result of a range of factors including age (Woods *et al.* 2003), home-range, food intake (Silva-Rodriguez and Sieving 2011), prey availability (Sims *et al.* 2008) and food type. Research comparing specific samples of cats that hunt with those that do not may provide further insight. Despite this, at high densities (e.g. 223/km2: van Heezik *et al.* 2010), even the lowest estimate of the number of hunters (26%: Baker *et al.* 2005) would indicate a density of actively hunting cats far in excess of that found in uninhabited environments (Ferreira *et al.* 2011). As a result, the cumulative impact of companion cats upon prey species is likely to be substantial. Further, the number of prey taken is often significantly underestimated, with prey numbers potentially being more than four times what owner report (Loyd *et al.* 2013). Of interest is that there was no significant difference in the likelihood that any particular group of species (e.g. birds) would be left at the site of the predation event, consumed, or brought home. This suggests that the proportion and diversity at the level of taxa, notwithstanding rare items, is likely accurate. There may, however, be some bias based upon the palatability of individual species (Krauze-Gryz *et al.* 2012). How aspects of prey return rate and palatability relate to New Zealand's native vertebrate and invertebrate species are not currently known.

There is clear evidence that, in general, companion cats kill substantial numbers of other animals (Table 1). Within New Zealand this is predominantly non-native species (e.g. Gillies and Clout 2003) but does include significant numbers of native birds, reptiles and invertebrates (Table 2). Our calculations indicate that this impact may be quite large, but note that this is a rudimentary calculation only, hence it used assumptions that lie at the lower end of any ranges provided in the literature. Which species are killed, and how often, will depend on availability of prey which, in turn, is dependent upon the environment in which the cat is kept. Urban companion cats, for example, are more likely to prey upon small mammals, birds and insects, and likely those species which are introduced and commonly adapted to urban environments (van Heezik *et al.* 2010). In this regard urban studies in New Zealand are similar to those elsewhere (e.g. UK: Woods *et al.* 2003) in that urban biodiversity often comprises a number of ubiquitous species which are well represented in recorded kills (e.g. house sparrows, house mice and rats). New Zealand's urban fauna is already depauperate, lacking in native species diversity. However, cats living close to fragments of native forest, stands of mature trees or open park land may have increased access to a wider diversity of prey species including those that are native (Gillies and Clout 2003). Studies suggest that cats show a preference for nearby edge habitats and areas of cover (Kays and DeWan 2004; Lilith *et al.* 2008) and will enter them regularly (Fandos *et al.* 2012). Although anecdotally, this likelihood declines as distance from the fragment increases (Gillies 2007). This means that in these areas prey species that exploit edge habitats may be particularly vulnerable (Barratt 1998; Marks and Duncan 2009). In one New Zealand study native birds were more likely to be preyed upon, albeit still in low numbers, in less urbanised suburbs (Gillies and Clout 2003) or larger gardens with mature trees (van Heezik *et al.* 2010). The most commonly caught native bird in New Zealand is the silvereye (Gillies and Clout 2003; Flux 2007; van Heezik *et al.* 2010), perhaps reflecting its adaptability to living in urban and semi-urban environments. Of concern may be the indication that these are predominantly adults of breeding age whilst other non-native species are more likely to be preyed on shortly after fledgling (Flux 2007). Cat-free exclusion zones have been proposed to restrict ownership in areas with vulnerable populations of native species, however research suggests that this is an unpopular measure (Grayson et al.

2002). To date implementation of these strategies has not been explored in a New Zealand setting.

Large densities of companion cats should also be considered beyond their immediate and direct predation impacts. The hyper-predation hypothesis (see Courchamp *et al.* 2000) suggests that prey populations at low numbers may be particularly at risk in urban or semi-urban environments. Likewise, a high density of predators potentially acts to suppress normal population growth through sub-lethal (e.g. reduced foraging rates and nest provisioning rates) as well as lethal effects (e.g. direct predation) and, if this is the case, the hunting status of the cat is ostensibly irrelevant. These effects may also reduce the likelihood that vulnerable prey species will either persist or re-establish themselves in areas of high cat density. In a number of papers it is asserted that cats may have a quantifiably positive effect on native species populations (especially birds) by controlling rodent numbers (e.g. Flux 2007). This may be true in areas where no pest control is currently implemented. However, most urban environments do implement targeted rodent control and targeted pest control may be preferable to the use of cats which also prey upon non-pest species.

Little is known about the predation habits of companion cats outside major urban centres in New Zealand. Studies elsewhere suggest that their predation rate may not be increased (Lepczyk *et al.* 2004), however home-ranges do increase (Loyd and Hernandez 2012) as does access to different habitat and vegetation types which support higher biodiversity (Baker *et al.* 2003). Therefore the predation impact of rural companion cats may be substantially different to that of companion cats in urban environments. For example, rural studies indicate a strong preference for lagomorphs

(Liberg 1984; Langham 1990) which are rare or absent in urban studies and, conversely, urban studies indicate a significant increase in the proportion of invertebrate prey (Gillies and Clout 2003; van Heezik *et al.* 2010). Further research is required to explore this issue.

Ultimately, the direct conservation impact of companion cats may be limited by the species available for predation. Unlike other countries in which predation studies have been conducted (Woods *et al.* 2003; Baker *et al.* 2005; Lilith *et al.* 2006), New Zealand has no vulnerable species of ground-dwelling endemic mammals, often favoured by cats, and urban and suburban birds are predominantly introduced European species (van Heezik *et al.* 2010). The question as to how important non-native bird species are for urban cats is one that requires further exploration. Little is known about the impact of cats upon urban populations of native reptiles and arthropods despite evidence that they are also directly affected (Gillies and Clout 2003). A tendency to focus on cats as bird predators may therefore mask other significant issues.

Future research should explore a wider range of companion cat density including a comparison of the impacts of companion cats in New Zealand's rural, semi-rural and urban environments. The persistence of native and non-native species in areas of high companion cat density also requires further consideration. Currently there are few New Zealand studies and all are limited either by the sample size or by the geographic region under consideration. Single cat studies such as that by Flux (2007) may be of limited value as they function at a small scale. As indicated previously, population assessments at the individual garden scale are unable to accurately reflect species abundance (Parsons *et al.* 2006), possibly because gardens act as sinks for birds in adjacent properties. Further research should include overlaying aspects of density, population size and breeding success of prey species with cat density and be similar to the work of van Heezik *et al.* (2010) but on a national scale, including more robust estimates of both avian and non-avian prey populations.

5.3.3 Stray cats

Most stray cats are unlikely to exist in managed colonies and many unmanaged colonies have been identified (Aguilar and Farnworth 2013). However, stray cats, including those in colonies, may have a substantially larger predation rate than companion cats in that, by definition, they are less likely to be fed regularly or to have their nutrient needs met than companion cats. They are therefore more likely to hunt systematically and have larger home ranges (Horn *et al.* 2011). A much smaller population of cats can thus have a disproportionate impact upon local fauna. Stray cats are also more likely to aggregate at sources of food and shelter (Natoli 1985; Denny *et al.* 2002) but as these may be ephemeral there is significant opportunity for migration. Given that they are more likely to survive longer than feral cats and have higher fecundity than either companion or feral cats (Schmidt *et al.* 2007), the stray cat population is likely self-sustaining and it can therefore be proposed they have a marked potential to impact negatively on urban bird, insect and reptile populations.

As for companion cats, the location in which a stray cat is resident will directly affect which species it preys on and any impact it has. To date this has not been effectively quantified. Given the propensity for stray and unowned cats to have larger home-ranges (Horn *et al.* 2011) and be more active, it is probable that they will aggregate either around provided food sources or around suitable hunting habitat. If the latter results in populations which attract the former there is potential for stray cats to become a major concern.

There is a need to further consider the direct impacts of stray cats in New Zealand and specifically to explore the dispersal of stray cats, especially in semi-rural and rural areas where stray and feral cats may be difficult to distinguish as per The Cat Code definitions. It is reasonable to suggest that stray cats may have the greatest predation impact simply by virtue of both numbers and necessity. They also likely bolster both the companion and feral populations, compounding this effect.

5.4 Management techniques

5.4.1 Managing the stray cat population

Managing stray cats is difficult given the understandable emotional attachment that many people have to them. This report demonstrates that there is no simple answer and control of stray cats is likely going to require multiple strategies which can be efficiently and judiciously applied. In line with current recommendations, management techniques should be considered that meet the needs of the cats themselves, minimise suffering, mitigate poor welfare, allow populations to be controlled such that re-incursion opportunities are minimised (Sparkes *et al.* 2013) and to be fully integrated with management strategies for other pests to minimise the potential effects of prey-switching. However, these methods need to take into consideration New Zealand's unique fauna and ecology. Methods such as immunocontraception would, if sufficiently developed, allow non-lethal management of populations but are difficult to apply to free-roaming populations (Jewgenow et al.

2006). This is because such methods are indiscriminate and would affect feral and owned cats. Immunocontraception is likely only of potential in isolated areas and would not prevent on-going issues of direct predation by individual cats.

No strategy will be without its financial costs and research from the UK suggests that the economic burden of managing un-owned cats and dogs may already outstrip the capacity of charitable organisations (Stavisky *et al.* 2012). Serious consideration needs to be given, and research undertaken, to explore cat population management further. Some discourse must also occur around where the fiscal burden lies for any such initiative. All other discussion aside, there appears strong international, inter-disciplinary, and temporal consensus that preventing cats from becoming stray by reducing abandonment and promoting responsible ownership must be the major focus of any management strategy (Feldmann and Carding 1973; Clarke and Pacin 2002; Natoli *et al.* 2006; Finkler *et al.* 2011b; Lohr *et al.* 2013). In terms of mitigation of predation, it appears from the evidence available for this review, that TNR can only have an impact in the longer term if it effectively prevents population growth or initiates population decline. In the short term there is, therefore, no likely reduction in predation impact.

Few actual studies have been done on the wider implications of broad scale TNR campaigns. One major issue is a general lack of accurate assessments of the stray cat population size and hence an inability to draw a full understanding of the financial, conservational, and social implications of any such strategy. It is precisely this absence of information which causes wide divisions around TNR and a demand for greater evidence within conservation and animal welfare sciences (Longcore et al. 2009; Lepczyk et al. 2010; Calver et al. 2011).

If utilised, techniques such as TNR and TVHR are likely only of significant value in specific circumstances. The population of cats would require regular human care, including routine capture, vaccination and treatment to prevent transmission of both feline specific and zoonotic diseases (Nutter *et al.* 2004a). A named person should be required to act as a *de facto* owner of the cats. It would also likely be preferable that the group of cats be limited in number with no new cats being added (an immigration rate of zero). Given that TNR can in no way mitigate the predation impacts of individuals, cats should, perhaps, not be returned within the proximity of areas of ecological value, fragments of bush or even areas with mature trees. It would be valuable to conduct more research around New Zealanders' attitudes towards, and interactions with, stray cats including the intentions of colony carers and semi-owners during such provision.

On a wider scale TNR is unlikely to be a viable broad scale response to a large stray cat population and, as a sole strategy, TNR is unlikely to result in the extinction of colonies where cat immigration and abandonment continues without removal. Much of the current research comes from countries where the ecology of the cat is substantially different. Extrapolation from these studies is therefore problematic. For example, modelling in Australia indicates that cat populations may be partially suppressed, and their impacts reduced, by the presence of other larger native and non-native carnivores (Hanna and Cardillo 2013). In New Zealand there is no such dynamic. Similarly, feline diseases may be more or less prevalent in New Zealand as compared to other countries. Hence specific research is needed regarding the size, health and reproductive viability of New Zealand's stray cat population. Given estimates from Australia that indicate between 92% (Alberthsen *et al.* 2013) and 96% (Marston and Bennett 2009) of stray cats entering shelters are not de-sexed the ability to have a meaningful impact upon the stray population through TNR primarily is questionable, especially if decline requires 71-81% (Budke and Slater 2009) or 75% (Andersen *et al.* 2004) of the population to be sterilised. In countries where stray cats are a common feature of the urban landscape cat density is high and no clear population decline, or stabilisation, can be discerned outside small sub-population samples (i.e. known colonies). In studies where TNR resulted in significant and rapid declines it was implemented alongside other rigid protocols and selection criteria for inclusion of colonies in the study (Stoskopf and Nutter 2004). This means TNR is only likely to be wholly effective in small isolated areas where intensive management is long-term and on-going and where the goal of any such management is extirpation of the colony. TNR is also unable, on a broad scale, to mitigate the potential for reduced welfare in the stray population. Stray cats are likely to continue to have poorer condition, higher parasite and disease burdens (Spada *et al.* 2012; Spada *et al.* 2013) and increased rates of injury compared with companion cats. In addition stray cats are also more likely to have shorter lives than companion cats, and in some models urban 'feral' lifespan is estimated at just 3 years (Budke and Slater 2009). Likewise, in the USA colony born kittens generally experience very low survival rates with 75% dying before 6 months of age (Nutter *et al.* 2004b). Kitten survival in New Zealand requires further exploration as survival pressure is likely to differ from that reported in other countries..

From the perspective of the welfare of the cats TNR can only be considered to be positive if it improves outcomes for the cats themselves. How this is measured is not clear but should consider the health of the animal, longevity, condition and injury status, many of which are suboptimal (Jessup 2004). All of these aspects will also be impacted upon by the nature of any ad hoc care given to the cat or colony. Understanding how exactly carers provide for stray cats and cat colonies requires future research. There is some evidence that under intense management protocols such as TTVARM colonies of cats may have a comparable disease status to companion cats (Nutter et al. 2004c), but this level of care is likely rare. TNR may also improve kitten and adult survival rates (Gunther et al. 2011) by reducing sexual aggression and resource competition. Body-condition score has also been noted to improve following TNR (Scott et al. 2002) although this was ascertained using only 14 of 105 individual cats assessed one year after sterilisation. Other authors suggest that colonies maintained by TNR represent significant populations of cats that act as a reservoir for zoonotic infections such as *Toxoplasma gondii* (Gerhold and Jessup 2013) and that, in general, cat colonies experience significant levels of disease (Borji et al. 2011; Spada et al. 2013). Higher rates of disease transmission (Mendes-de-Almeida et al. 2011) and shorter lifespans may be associated with TVHR, as compared to TNR (McCarthy et al. 2013), due to continued aggression and copulation (Mendes-de-Almeida et al. 2007b). It is likely therefore that the collateral costs in terms of cat welfare are potentially too great.

The value of current research into TNR is unclear given that it often focuses on well managed colonies outside New Zealand where cats are socialised to human presence and regularly trapped. This socialisation means they are potentially easier to catch and manage on a routine basis (Nutter *et al.* 2004a). Little information exists as to how TNR would apply to a wider scale management process in environments where cats are not well socialised and are avoidant of people or traps. More exploration of TNR as a management tool and its economic costs and benefits in a New Zealand setting is required.

Most of the literature addresses groups of cats in urban centres or industrial areas and there is little information concerning semi-rural or rural application of TNR. Broader application of TNR must consider the impacts of cats in different geographical locations especially as it relates to variable predation impacts (see section 4.2.2). TE has also been demonstrated to be unable to be effectively applied to reduce stray cat populations in environments where abandonment of cats continues (Andersen *et al.* 2004; Schmidt *et al.* 2009) and whether or not it is economically preferable is unclear. However, given the on-going commitment required to manage populations of stray cats it is probable that short-term costs of TE are lower (Lohr *et al.* 2013). Beyond the practical implications of TNR it already receives significant public support globally. Public education and research around alternatives is important (Clarke and Pacin 2002) if indeed TNR is considered inappropriate for New Zealand.

Removal and adoption is, currently, the major strategy utilised within New Zealand. However, wit is likely that the number of homes willing to adopt cats may be declining given the numbers of potential stray cats and kittens that are available as compared to the estimated 48% household ownership of cats in New Zealand (MacKay 2011). Literature from New Zealand (Rinzin *et al.* 2008) and Australia (Marston and Bennett 2009; Alberthsen *et al.* 2013) suggest that a substantial proportion of cats and kittens held in shelters and welfare centres are euthanased. Given the number of cats available it is possible that this may lead to a perception that they represent 'disposable' commodities which, in turn, increases re-abandonment. Thus removal and re-homing can only be considered as an addendum to any wider management strategy to curb source populations.

Given that cat ownership in New Zealand at a household level is high and ownership significantly affects attitudes towards cats (Farnworth *et al.* 2011), public perception is likely of significance here as elsewhere (Finkler *et al.* 2011a). Ownership also impacts upon beliefs around predation impact. Cat-owners were more likely to agree or be unsure when compared to bird-watchers, when presented with the statement "free-roaming cats do not harm wildlife" (Loyd and Hernandez 2012). Awareness of feral cat issues and support of TNR (Loyd and Miller 2010a) may also vary between rural and urban populations. Community approaches to issues around stray overpopulation will require a wider community engagement of stakeholders than simply those considered to be 'pro-cat' or 'anti-cat' (Hamilton 2010); a distinction which is, in and of itself, divisive.

It may be reasonable to say that any predation effect that an individual cat has is unlikely to be mitigated by sterilisation unless a concomitant change occurs in the cat's immediate opportunity or need to be a predator. To date this is only likely to be achieved by removal and adoption, a strategy which is often utilised alongside TNR (Levy *et al.* 2003). Few observations exist concerning predation by colonies following TNR and these are, at best, anecdotal (Levy and Crawford 2004).

5.4.2 Managing companion cats

In terms of predation it is likely that companion cats present the least pressing concern compared with feral and stray cats and their impact on native species could be substantially reduced through promotion of collars with bells attached. Of greater concern is the current lack of ownership models for companion cats. In order to minimise increases in stray cat populations and predation by companion cats it appears that significant steps need to be taken to alter the public perception about cats within New Zealand. This should start with identifying what 'responsible ownership' is construed to be; this call for research not new (Selby *et al.* 1979).

Currently in New Zealand there is no legal requirement for companion cats to be identified either through micro-chipping or the use of collars. There is also no formal process of registration for cats. As a result, distinguishing between stray cats and free-roaming owned cats is problematic. Discussion of responsible ownership of cats should therefore consider several aspects, some of which are progressing well in New Zealand while, for others, dialogue is yet to occur. A major focus should be on education of the wider public about appropriate care of cats. Evidence suggests that New Zealand's companion cat population is already reproductively curtailed, although broader studies of sterilisation rates should be conducted nationwide. The goal to increase sterilisation rates may benefit from more campaigns and funding focussed in areas of low socio-economic status (Aguilar and Farnworth 2012) similar to those which already function to provide cut-price or free desexing services. Identification of cats is also paramount to ensure that effective strategies for control of un-owned cats, whatever they may be, can progress. These strategies could include simple promotion of collars or other visible tagging devices through to registration and compulsory micro-chipping in a similar manner to dog ownership. The addition of a bell to a collar has been shown to be an effective method by which predation impact can also be reduced (e.g. Gordon *et al.* 2010). Strategies should also consider promotion of indoor lifestyles for cats, including dismissing misconceptions around their unsuitability. From a welfare and health perspective strategies that curtail free-roaming may also reduce the opportunities for cats to acquire diseases, fight, or be injured.

If it is accepted that companion cats often originate as strays which are subsequently either informally or formally adopted. Measures should thus also be taken to promote a transition away from semi-ownership towards full-ownership. This can take a number of forms but may require a promotion of full-ownership models through community and governmental action whilst semi-ownership practices which perpetuate stray cat populations (e.g. *ad hoc* food provision without additional care) could be discouraged.

6 Future research

There are a number of areas where information concerning cats, cat management and attitudes towards cats in New Zealand is absent. Research to provide potential answers would be judicious and could include exploration of the following:

- The ecology of the cat across New Zealand, especially rural and urban ecologies of companion and stray cats and their predation impacts. This should include impacts upon desirable (e.g. bird) and undesirable (e.g. rodent) groups.

- The gene flow between the three cat groupings in New Zealand, especially stray cats and their contribution to the wider population.
- Predation rates of un-owned and stray urban cats in New Zealand.
- Public attitudes towards cat population management techniques including the potential for consensus amongst interested parties.
- Cost-benefit analyses of cat population management strategies.
- Understanding the companion cat population, its size, its origins (i.e. where and how people acquire their cats) and end-points (i.e. what happens to cats).
- Public perceptions of responsible ownership practices and barriers to the adoption of such practices.
- Current use of TNR within New Zealand and cat colony management practices.

7 Conclusions

Exactly how cats impact upon New Zealand depends upon the environment in which they live as well as human attitudes towards their well-being and management. Overall there is a substantial need for a greater understanding of cat ecologies within New Zealand. That aside, there is strong evidence that, although feral cats provide the greatest risk to native species, the domestic cat has a significant and potentially harmful impact upon New Zealand's wildlife. It is likely, however, that the negative impacts of domestic cats can, in the large part, be mitigated through effective and responsible ownership policies for companion cats and effective population management for stray cats. Taking a precautionary approach to reducing predation effect such as that proposed by Calver *et al.* (2011), while maximising the welfare of free-roaming cats, would suggest that active management to reduce the numbers of free-roaming cats, and especially un-owned cats, is required in the short to medium-term. Delays in implementing effective strategies will likely have a quantifiable impact on both cat welfare and wildlife persistence. Given our limited understanding of cat ecologies in New Zealand and elsewhere any management processes should be responsive to new information as it arises to ensure best practice. Furthermore, there is a need for the stray cat (including colonies) and companion cat populations to be more clearly delineated, for example through a formal identification of owned cats and active promotion of change in how cats are perceived and owned in New Zealand. This would allow more effective management to occur.

In general the stray cat population is likely to grow without clear management and it is already likely a self-sustained population which, rather than being supported by the companion cat population, is the primary source of companion cats. Methods of control such as TNR, whilst possibly effective for small isolated groups of cats which are consistently managed, are not likely to reduce the impact of cats on wildlife, nor can they mitigate welfare issues experienced by un-owned and unmanaged cats. They are also likely to be prohibitively expensive when extrapolated to the wider stray population. In this regard TNR, although potentially useful in very specific circumstances, is unlikely to present a viable option for long-term cat population management at a regional or national level. In instances where colonies are extant their impact can be minimised by ensuring they are not adjacent to areas of ecological value and that they are routinely de-sexed every 6 months (Mendes-de-Almeida *et al.* 2011). Cats in colonies should also be vaccinated and health-checked annually by a veterinary professional and have a person who is legally responsible for their welfare and care. To prevent growth and promote gradual disestablishment of colonies all new adults and kittens should be routinely removed and re-homed. Where re-homing is not possible and would compromise the welfare of the individual euthanasia may be the preferable option. Returning cats to areas where they are un-managed is not in the interests of cat welfare.

Formation of a national working party, which includes welfare, governmental, academic and conservation stakeholders would be of benefit. Such a group could collaboratively address how a framework of legislation, education and research may allow more effective management of cats, especially stray cats, to occur within New Zealand.

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9 References

Aguilar GD, Farnworth MJ. Stray cats in Auckland, New Zealand: Discovering geographic information for exploratory spatial analysis. *Applied Geography* 34, 230-8, 2012

Aguilar GD, Farnworth MJ. Distribution characteristics of unmanaged cat colonies over a 20 year period in Auckland, New Zealand. *Applied Geography* 37, 160-7, 2013

Alberthsen C, Rand JS, Bennett PC, Paterson M, Lawrie M, Morton JM. Cat admissions to RSPCA shelters in Queensland, Australia: Description of cats and risk factors for euthanasia after entry. *Australian Veterinary Journal* 91, 35-42, 2013

Alterio N, Moller H. Diet of feral house cats *Felis catus*, ferrets *Mustela furo* and stoats *M. erminea* in grassland surrounding yellow-eyed penguin Megadyptes antipodes breeding areas, South Island, New Zealand. *Journal of Zoology* 243, 869-77, 1997

Ancillotto L, Serangeli MT, Russo D. Curiosity killed the bat: Domestic cats as bat predators. *Mammalian Biology*, 2013

Andersen MC, Martin BJ, Roemer GW. Use of matrix population models to estimate the efficacy of euthanasia versus trap-neuter-return for management of free-roaming cats. *Javma-Journal of the American Veterinary Medical Association* 225, 1871-6, 2004

Anonymous. National Animal Welfare Advisory Committee. Animal welfare (companion cats) code of welfare 2007. Wellington, New Zealand: Ministry of Agriculture and Forestry. 2007

Anonymous. International Companion Animal Management Coalition Humane Dog Population Management Guidance pp 5, www.icam-coalition.org, undated

Arnaud G, Rodriguez A, Ortega-Rubio A, Alvarez-Cardenas S. Predation by cats on the unique endemic lizard of Socorro Island (*Urosaurus auriculatus*), Revillagigedo, Mexico. *Ohio Journal of Science* 93, 101-4, 1993

Ash SJ, Adams CE. Public preferences for free-ranging domestic cat (*Felis catus*) management options. *Wildlife Society Bulletin* 31, 334-9, 2003

Baker PJ, Bentley AJ, Ansell RJ, Harris S. Impact of predation by domestic cats *Felis catus* in an urban area. *Mammal Review* 35, 302-12, 2005

Baker PJ, Ansell RJ, Dodds PAA, Webber CE, Harris S. Factors affecting the distribution of small mammals in an urban area. *Mammal Review* 33, 95-100, 2003

Baker PJ, Molony SE, Stone E, Cuthill IC, Harris S. Cats about town: is predation by free-ranging pet cats *Felis catus* likely to affect urban bird populations? *Ibis* 150, 86-99, 2008

Barratt DG. Predation by house cats, *Felis catus* (L.), in Canberra, Australia. I. Prey composition and preference. *Wildlife Research* 24, 263-77, 1997

Barratt DG. Predation by house cats, *Felis catus* (L.), in Canberra, Australia. II. Factors affecting the amount of prey caught and estimates of the impact on wildlife. *Wildlife Research* 25, 475-87, 1998

Beckerman AP, Boots M, Gaston KJ. Urban bird declines and the fear of cats. *Animal Conservation* 10, 320-5, 2007

Bengsen A, Butler J, Masters P. Estimating and indexing feral cat population abundances using camera traps. *Wildlife Research* 38, 732-9, 2011

Bergstrom DM, Lucieer A, Kiefer K, Wasley J, Belbin L, Pedersen TK, Chown SL. Indirect effects of invasive species removal devastate World Heritage Island. *Journal of Applied Ecology* 46, 73-81, 2009

Bester MN, Bloomer JP, van Aarde RJ, Erasmus BH, van Rensburg PJJ, Skinner JD, Howell PG, Naude TW. A review of the successful eradication of feral cats from sub-Antarctic Marion Island, Southern Indian Ocean. *South African Journal of Wildlife Research* 32, 65-73, 2002

Bonnaud E, Medina FM, Vidal E, Nogales M, Tershy B, Zavaleta E, Donlan CJ, Keitt B, Le Corre M, Horwath SV. The diet of feral cats on islands: a review and a call for more studies. *Biological Invasions* 13, 581-603, 2011

Bonnington C, Gaston KJ, Evans KL. Fearing the feline: domestic cats reduce avian fecundity through trait-mediated indirect effects that increase nest predation by other species. *Journal of Applied Ecology* 50, 15-24, 2013

Borkenhagen P. Von Hauskatzen (Felis sylvestris f. catus L., 1758) eingetragene Beute. *Zeitschrift für Jagdwissenschaft* 24, 27-33, 1979

Brickner-Braun I, Geffen E, Yom-Tov Y. The domestic cat as a predator of Israeli wildlife. *Israel Journal of Ecology & Evolution* 53, 129-42, 2007

Budke CM, Slater MR. Utilization of matrix population models to assess a 3-year single treatment nonsurgical contraception program versus surgical sterilization in feral cat populations. *Journal of applied animal welfare science : JAAWS* 12, 277-92, 2009

Burns F, McCulloch N, Székely T, Bolton M. The impact of introduced predators on an island endemic, the St Helena Plover, *Charadrius sanctaehelenae*. *Bird Conservation International* 23, 125-35, 2013

Burrows ND, Algar D, Robinson AD, Sinagra J, Ward B, Liddelow G. Controlling introduced predators in the Gibson Desert of Western Australia. *Journal of Arid Environments* 55, 691-713, 2003

Calver MC, Thomas SR. Effectiveness of the Liberator™ in reducing predation on wildlife by domestic cats. *Pacific Conservation Biology* 16, 244-50, 2011

Calver MC, Grayson J, Lilith M, Dickman CR. Applying the precautionary principle to the issue of impacts by pet cats on urban wildlife. *Biological Conservation* 144, 1895-901, 2011

Calver MC, Adams G, Clark W, Pollock KH. Assessing the safety of collars used to attach predation deterrent devices and ID tags to pet cats. *Animal Welfare* 22, 95-105, 2013

Campos CB, Esteves CF, Ferraz K, Crawshaw PG, Verdade LM. Diet of free-ranging cats and dogs in a suburban and rural environment, south-eastern Brazil. *Journal of Zoology* 273, 14-20, 2007

Castillo D, Clarke AL. Trap/neuter/release methods ineffective in controlling domestic cat "colonies" on public lands. *Natural Areas Journal* 23, 247-53, 2003

Catling PC. Similarities and contrasts in the diets of foxes, *Vulpes vulpes*, and cats, *Felis catus*, relative to fluctuating prey populations and drought. *Australian Wildlife Research* 15, 307-17, 1988

Catry P, Silva MC, MacKay S, Campos A, Masello J, Quillfeldt P, Strange IJ. Can thin-billed prions *Pachyptila belcheri* breed successfully on an island with introduced rats, mice and cats? The case of New Island, Falkland Islands. *Polar Biology* 30, 391-4, 2007

Centonze LA, Levy JK. Characteristics of free-roaming cats and their caretakers. *Journal of the American Veterinary Medical Association* 220, 1627-33, 2002

Clancy EA, Moore AS, Bertone ER. Evaluation of cat and owner characteristics and their relationships to outdoor access of owned cats. *Journal of the American Veterinary Medical Association* 222, 1541-5, 2003

Clarke AL, Pacin T. Domestic cat "colonies" in natural areas: A growing exotic species threat. *Natural Areas Journal* 22, 154-9, 2002

Clout MN, Merton DV. Saving the kakapo: the conservation of the world's most peculiar parrot. *Bird Conservation International* 8, 281-96, 1998

Courchamp F, Cornell SJ. Virus-vectored immunocontraception to control feral cats on islands: a mathematical model. *Journal of Applied Ecology* 37, 903-13, 2000

Courchamp F, Langlais M, Sugihara G. Cats protecting birds: modelling the mesopredator release effect. *Journal of Animal Ecology* 68, 282-92, 1999

Courchamp F, Langlais M, Sugihara G. Rabbits killing birds: modelling the hyperpredation process. *Journal of Animal Ecology* 69, 154-64, 2000

Dabritz HA, Conrad PA. Cats and toxoplasma: Implications for public health. *Zoonoses and Public Health* 57, 34-52, 2010

Denny E, Yakovlevich P, Eldridge MDB, Dickman C. Social and genetic analysis of a population of free-living cats (*Felis catus* L.) exploiting a resource-rich habitat. *Wildlife Research* 29, 405-13, 2002

Dinnage JD, Scarlett JM, Richards JR. Descriptive epidemiology of feline upper respiratory tract disease in an animal shelter. *Journal of Feline Medicine and Surgery* 11, 816-25, 2009

Dowding JE, Murphy EC. Decline of the Stewart Island population of the New Zealand dotterel. *Notornis* 40, 1-13, 1993

Dowding JE, Murphy EC. The impact of predation by introduced mammals on endemic shorebirds in New Zealand: a conservation perspective. *Biological Conservation* 99, 47-64, 2001

Eason CT, Frampton CM. Acute toxicity of sodium monofluoroacetate (1080) baits to feral cats. *Wildlife Research* 18, 445-9, 1991

Fandos G, Fernandez-Lopez J, Telleria JL. Incursion of domestic carnivores around urban areas: a test in central Spain. *Mammalia* 76, 223-5, 2012

Farnworth MJ, Campbell J, Adams NJ. Public awareness in New Zealand of animal welfare legislation relating to cats. *New Zealand Veterinary Journal* 58, 213-7, 2010a

Farnworth MJ, Dye NG, Keown N. The legal status of cats in New Zealand: A perspective on the welfare of companion, stray, and feral domestic cats (*Felis catus*). *Journal of Applied Animal Welfare Science* 13, 180-8, 2010b

Farnworth MJ, Campbell J, Adams NJ. What's in a name? Perceptions of stray and feral cat welfare and control in Aotearoa, New Zealand. *Journal of Applied Animal Welfare Science* 14, 59-74, 2011

Farnworth MJ, Watson H, Adams NJ. Understanding Attitudes Toward the Control of Nonnative Wild and Feral Mammals: Similarities and Differences in the Opinions of the General Public, Animal Protectionists, and Conservationists in New Zealand (Aotearoa). *Journal of Applied Animal Welfare Science*, 2013a

Farnworth MJ, Adams NJ, Seksel K, Waran NK, Beausoleil NJ, Stafford KJ. Veterinary attitudes towards pre-pubertal gonadectomy of cats: A comparison of samples from New Zealand, Australia and the United Kingdom. *New Zealand Veterinary Journal* 61, 226-33, 2013b

Feldmann BM, Carding TH. Free roaming urban pets. *Health Services Reports* 88, 956-62, 1973

Ferreira JP, Leitão I, Santos-Reis M, Revilla E. Human-related factors regulate the spatial ecology of domestic cats in sensitive areas for conservation. *PLoS ONE* 6, 2011

Finkler H, Terkel J. The contribution of cat owners' attitudes and behaviours to the free-roaming cat overpopulation in Tel Aviv, Israel. *Preventive Veterinary Medicine* 104, 125-35, 2012

Finkler H, Hatna E, Terkel J. The influence of neighbourhood socio-demographic factors on densities of free-roaming cat populations in an urban ecosystem in Israel. *Wildlife Research* 38, 235-43, 2011a

Finkler H, Hatna E, Terkel J. The impact of anthropogenic factors on the behavior, reproduction, management and welfare of urban, free-roaming cat populations. *Anthrozoos* 24, 31-49, 2011b

Fitzgerald BM, Karl BJ. Home range of feral house cats (*Felis catus* L.) in forest of the Orongorongo Valley, Wellington, New Zealand. *New Zealand Journal of Ecology* 9, 71-81, 1986

Fitzgerald BM, Gibb JA. Introduced mammals in a New Zealand forest: long-term research in the Orongorongo Valley. *Biological Conservation* 99, 97-108, 2001

Fitzgerald BM, Karl BJ, Veitch CR. The diet of feral cats (*Felis catus*) on Raoul Island, Kermadec Group. *New Zealand Journal of Ecology* 15, 123-9, 1991

Flux JEC. Seventeen years of predation by one suburban cat in New Zealand. *New Zealand Journal of Zoology* 34, 289-96, 2007

Foley P, Foley JE, Levy JK, Paik T. Analysis of the impact of trap-neuter-return programs on populations of feral cats. *Journal of the American Veterinary Medical Association* 227, 1775-81, 2005

Galbreath R, Brown D. The tale of the lighthouse-keeper's cat: Discovery and extinction of the Stephens Island wren (*Traversia lyalli*). *Notornis* 51, 193-200, 2004

Gibson KL, Keizer K, Golding C. A trap, neuter, and release program for feral cats on Prince Edward Island. *Programme de capture, de stérilisation et de remise en liberté des chats errants (harets) de l'Île-du-Prince-Édouard* 43, 695-8, 2002

Gillies C, Clout M. The prey of domestic cats (*Felis catus*) in two suburbs of Auckland City, New Zealand. *Journal of Zoology* 259, 309-15, 2003

Gillies CA. Notes on New Zealand mammals 5. How far did a neighbour's pet cat venture into Trounson Kauri Park? *New Zealand Journal of Zoology* 34, 335-6, 2007

Gillies CA, Leach MR, Coad NB, Theobald SW, Campbell J, Herbert T, Graham PJ, Pierce RJ. Six years of intensive pest mammal control at Trounson Kauri Park, a Department of Conservation "mainland island", June 1996-July 2002. *New Zealand Journal of Zoology* 30, 399-420, 2003

Gordon JK, Matthaei C, Van Heezik Y. Belled collars reduce catch of domestic cats in New Zealand by half. *Wildlife Research* 37, 372-8, 2010

Gorman SP, Levy JK, Hampton AL, Collante WR, Harris AL, Brown RG. Evaluation of a porcine zona pellucida vaccine for the immunocontraception of domestic kittens (*Felis catus*). *Theriogenology* 58, 135-49, 2002

Gunther I, Finkler H, Terkel J. Demographic differences between urban feeding groups of neutered and sexually intact free-roaming cats following a trap-neuter-return procedure. *Javma-Journal of the American Veterinary Medical Association* 238, 1134-40, 2011

Guttilla DA, Stapp P. Effects of sterilization on movements of feral cats at a wildlandurban interface. *Journal of Mammalogy* 91, 482-9, 2010

Hamilton FE. Leading and organizing social change for companion animals. *Anthrozoos* 23, 277-92, 2010

Hanna E, Cardillo M. Island mammal extinctions are determined by interactive effects of life history, island biogeography and mesopredator suppression. *Global Ecology and Biogeography*, 2013

Harlow PS, Fisher M, Tuiwawa M, Biciloa PN, Palmeirim JM, Mersai C, Naidu S, Naikatini A, Thaman B, Niukula J, *et al.* The decline of the endemic Fijian crested iguana *Brachylophus vitiensis* in the Yasawa and Mamanuca archipelagos, western Fiji. *ORYX* 41, 44-50, 2007

Harper GA. Numerical and functional response of feral cats (*Felis catus*) to variations in abundance of primary prey on Stewart Island (Rakiura), New Zealand. *Wildlife Research* 32, 597-604, 2005

Harper GA. Diet of feral cats on subantarctic Auckland Island. *New Zealand Journal of Ecology* 34, 259-61, 2010

Hawkins CC, Grant WE, Longnecker MT. *Effect of subsidized house cats on California birds and rodents*. 1999

Hetherington CA, Algar D, Mills H, Bencini R. Increasing the target-specificity of ERADICAT (R) for feral cat (*Felis catus*) control by encapsulating a toxicant. *Wildlife Research* 34, 467-71, 2007

Horn JA, Mateus-Pinilla N, Warner RE, Heske EJ. Home range, habitat use, and activity patterns of free-roaming domestic cats. *Journal of Wildlife Management* 75, 1177-85, 2011

Hughes BJ, Martin GR, Reynolds SJ. Cats and seabirds: Effects of feral Domestic Cat *Felis silvestris catus* eradication on the population of Sooty Terns *Onychoprion fuscata* on Ascension Island, South Atlantic. *Ibis* 150, 122-31, 2008

Hughes KL, Slater MR. Implementation of a feral cat management program on a university campus. *Journal of Applied Animal Welfare Science* 5, 15-28, 2002

Hughes KL, Slater MR, Haller L. The effects of implementing a feral cat spay/neuter program in a Florida county animal control service. *Journal of Applied Animal Welfare Science* 5, 285-98, 2002

Hutchings S. The diet of feral house cats (*Felis catus*) at a regional rubbish tip, Victoria. *Wildlife Research* 30, 103-10, 2003

Jokimäki J, Kaisanlahti-Jokimäki ML, Sorace A, Fernández-Juricic E, Rodriguez-Prieto I, Jimenez MD. Evaluation of the "safe nesting zone" hypothesis across an urban gradient: A multi-scale study. *Ecography* 28, 59-70, 2005

Jones AL, Downs CT. Managing feral cats on a university's campuses: How many are there and is sterilization having an effect? *Journal of Applied Animal Welfare Science* 14, 304-20, 2011

Jongman EC. Adaptation of domestic cats to confinement. *Journal of Veterinary Behavior: Clinical Applications and Research* 2, 193-6, 2007

Kays RW, DeWan AA. Ecological impact of inside/outside house cats around a suburban nature preserve. *Animal Conservation* 7, 273-83, 2004

Khan QJA, Al-Lawatia MA. Birds, rabbits and cats interaction model with switching strategy of opportunistic cats. Pp 172-7, 2008

Krauze-Gryz D, Gryz J, Goszczynski J. Predation by domestic cats in rural areas of central Poland: an assessment based on two methods. *Journal of Zoology* 288, 260-6, 2012

Kutt AS. The diet of the feral cat (*Felis catus*) in north-eastern Australia. *Acta Theriologica* 56, 157-69, 2011

Kutt AS. Feral cat (*Felis catus*) prey size and selectivity in north-eastern Australia: Implications for mammal conservation. *Journal of Zoology* 287, 292-300, 2012

Langham NPE. The diet of feral cats (*Felis catus* L.) on Hawke's Bay farmland, New Zealand. *New Zealand Journal of Zoology* 17, 243-55, 1990

Larsen CT, Henshaw RE. Predation of the sand lizard *Lacerta agilis* by the domestic cat *Felis catus* on the Sefton Coast. *Costal Dune Management* 2001

Lepczyk CA, Mertig AG, Liu JG. Landowners and cat predation across rural-to-urban landscapes. *Biological Conservation* 115, 191-201, 2004

Levy JK. Contraceptive Vaccines for the Humane Control of Community Cat Populations. *American Journal of Reproductive Immunology* 66, 63-70, 2011

Levy JK, Crawford PC. Humane strategies for controlling feral cat populations. *Journal of the American Veterinary Medical Association* 225, 1354-60, 2004

Levy JK, Gale DW, Gale LA. Evaluation of the effect of a long-term trap-neuter-return and adoption program on a free-roaming cat population. *Journal of the American Veterinary Medical Association* 222, 42-6, 2003

Levy JK, Friary JA, Miller LA, Tucker SJ, Fagerstone KA. Long-term fertility control in female cats with GonaCon ™, a GnRH immunocontraceptive. *Theriogenology* 76, 1517-25, 2011

Liberg O. Food habits and prey impact by feral and house-based domestic cats in a rural area in southern Sweden. *Journal of Mammalogy* 65, 424-32, 1984

Lilith M, Calver M, Garkaklis M. Roaming habits of pet cats on the suburban fringe in Perth,Western Australia: what size buffer zone is needed to protect wildlife in reserves? *Too Close for Comfort : Contentious Issues in Human-Wildlife Encounters*, 2008

Lilith M, Calver M, Garkaklis M. Do cat restrictions lead to increased species diversity or abundance of small and mediumsized mammals in remnant urban bushland? *Pacific Conservation Biology* 16, 162-72, 2010

Lilith M, Calver M, Styles I, Garkaklis M. Protecting wildlife from predation by owned domestic cats: Application of a precautionary approach to the acceptability of proposed cat regulations. *Austral Ecology* 31, 176-89, 2006

Lohr CA, Cox LJ, Lepczyk CA. Costs and Benefits of Trap-Neuter-Release and Euthanasia for Removal of Urban Cats in Oahu, Hawaii. *Conservation Biology* 27, 64-73, 2013

Loss SR, Will T, Marra PP. The impact of free-ranging domestic cats on wildlife of the United States. *Nature Communications* 4, 2013

Loyd KA, Miller CA. Factors related to preferences for trap-neuter-release management of feral cats among illinois homeowners. *Journal of Wildlife Management* 74, 160-5, 2010a

Loyd KAT, Miller CA. Influence of demographics, experience and value orientations on preferences for lethal management of feral cats. *Human Dimensions of Wildlife* 15, 262-73, 2010b

Loyd KAT, Hernandez SM. Public perceptions of domestic cats and preferences for feral cat management in the southeastern United States. *Anthrozoos* 25, 337-51, 2012

Loyd KAT, Hernandez SM, Carroll JP, Abernathy KJ, Marshall GJ. Quantifying free-roaming domestic cat predation using animal-borne video cameras. *Biological Conservation* 160, 183-9, 2013

MacKay J. *Companion animals in New Zealand.*, New Zealand Companion Animal Council, Auckland, New Zealand,, 2011

Maclean MM, Carslake DJ, Evans MR, Townley S, Hodgson DJ. The usefulness of sensitivity analysis for predicting the effects of cat predation on the population dynamics of their avian prey. *Ibis* 150, 100-13, 2008

Mahlow JC, Slater MR. Current issues in the control of stray and feral cats. *Journal of the American Veterinary Medical Association* 209, 2016-20, 1996

Marks BK, Duncan RS. Use of forest edges by free-ranging cats and dogs in an urban forest fragment. *Southeastern Naturalist* 8, 427-36, 2009

Marston LC, Bennett PC. Admissions of cats to animal welfare shelters in Melbourne, Australia. *Journal of Applied Animal Welfare Science* 12, 189-213, 2009

Matias R, Catry P. The diet of feral cats at New Island, Falkland Islands, and impact on breeding seabirds. *Polar Biology* 31, 609-16, 2008

McCarthy RJ, Levine SH, Michael Reed J. Estimation of effectiveness of three methods of feral cat population control by use of a simulation model. *Journal of the American Veterinary Medical Association* 243, 502-11, 2013

McKay SA, Farnworth MJ, Waran NK. Current attitudes toward, and incidence of, sterilization of cats and dogs by caregivers (owners) in Auckland, New Zealand. *Journal of applied animal welfare science : JAAWS* 12, 331-44, 2009

Medina FM, Nogales M. A review on the impacts of feral cats (*Felis silvestris catus*) in the Canary Islands: Implications for the conservation of its endangered fauna. *Biodiversity and Conservation* 18, 829-46, 2009

Medina FM, Garcia R, Nogales M. Feeding ecology of feral cats on a heterogeneous subtropical oceanic island (La Palma, Canarian Archipelago). *Acta Theriologica* 51, 75-83, 2006

Medina FM, Bonnaud E, Vidal E, Tershy BR, Zavaleta ES, Donlan CJ, Keitt BS, Le Corre M, Horwath SV, Nogales M. A global review of the impacts of invasive cats on island endangered vertebrates. *Global Change Biology* 17, 3503-10, 2011

Medway DG. The land bird fauna of Stephens Island, New Zealand in the early 1890s, and the cause of its demise. *Notornis* 51, 201-11, 2004

Meek PD. Food items brought home by domestic cats *Felis catus* (L) living in Booderee National Park, Jervis bay. *Proceedings of the Linnean Society of New South Wales* 1998, 43-7, 1998

Mendes-de-Almeida F, Remy GL, Gershony LC, Rodrigues DP, Chame M, Labarthe NV. Reduction of feral cat (*Felis catus* Linnaeus 1758) colony size following hysterectomy of adult female cats. *Journal of Feline Medicine and Surgery* 13, 436-40, 2011

Mendes-de-Almeida F, Labarthe N, Guerrero J, Landau-Remy G, Rodrigues DP, Borja GEM, Pereira MJS. Cochliomyia hominivorax myiasis in a colony of stray cats (*Felis catus* Linnaeus, 1758) in Rio de Janeiro, RJ. *Veterinary Parasitology* 146, 376-8, 2007a

Mendes-De-Almeida F, Faria MCF, Branco AS, Serrão ML, Souza AM, Almosny N, Chame M, Labarthe N. Sanitary conditions of a colony of urban feral cats (*Felis catus* Linnaeus, 1758) in a zoological garden of Rio de Janeiro, Brazil. *Revista do Instituto de Medicina Tropical de Sao Paulo* 46, 269-74, 2004

Mendes-de-Almeida F, Labarthe N, Guerrero J, Faria MCF, Branco AS, Pereira CD, Barreira JD, Pereira MJS. Follow-up of the health conditions of an urban colony of free-roaming cats (*Felis catus* Linnaeus, 1758) in the city of Rio de Janeiro, Brazil. *Veterinary Parasitology* 147, 9-15, 2007b

Mifsud G, Woolley PA. Predation of the Julia Creek dunnart (*Sminthopsis douglasi*) and other native fauna by cats and foxes on Mitchell grass downs in Queensland. *Australian Mammalogy* 34, 188-95, 2012

Millán J. Feeding habits offeral cats felis silvestris catus in the countryside of Majorca Island, Spain. *Wildlife Biology in Practice* 6, 32-8, 2010

Mirmovitch V. Spatial organisation of urban feral cats (*Felis catus*) in Jerusalem. *Wildlife Research* 22, 299-310, 1995

Molsher R, Newsome A, Dickman C. Feeding ecology and population dynamics of the fetal cat (*Felis catus*) in relation to the availability of prey in central-eastern New South Wales. *Wildlife Research* 26, 593-607, 1999

Morgan DKJ, Waas JR, Innes J. An inventory of mammalian pests in a New Zealand city. *New Zealand Journal of Zoology* 36, 23-33, 2009a

Morgan DKJ, Waas JR, Innes J, Fitzgerald N. Identification of nest predators using continuous time-lapse recording in a New Zealand city. *New Zealand Journal of Zoology* 38, 343-7, 2011

Morgan SA, Hansen CM, Ross JG, Hickling GJ, Ogilvie SC, Paterson AM. Urban cat (*Felis catus*) movement and predation activity associated with a wetland reserve in New Zealand. *Wildlife Research* 36, 574-80, 2009b

Moseby KE, Hill BM, Read JL. Arid Recovery - A comparison of reptile and small mammal populations inside and outside a large rabbit, cat and fox-proof exclosure in arid South Australia. *Austral Ecology* 34, 156-69, 2009

Murphy EC, Keedwell RJ, Brown KP, Westbrooke I. Diet of mammalian predators in braided river beds in the central South Island, New Zealand. *Wildlife Research* 31, 631-8, 2004

Natoli E. Spacing pattern in a colony of urban stray cats (*Felis catus* L.) in the historic centre of Rome. *Applied Animal Behaviour Science* 14, 289-304, 1985

Natoli E, Ferrari M, Bolletti E, Pontier D. Relationships between cat lovers and feral cats in Rome. *Anthrozoos* 12, 16-23, 1999

Natoli E, Maragliano L, Cariola G, Faini A, Bonanni R, Cafazzo S, Fantini C. Management of feral domestic cats in the urban environment of Rome (Italy). *Preventive Veterinary Medicine* 77, 180-5, 2006

Nelson SH, Evans AD, Bradbury RB. The efficacy of collar-mounted devices in reducing the rate of predation of wildlife by domestic cats. *Applied Animal Behaviour Science* 94, 273-85, 2005

Nelson SH, Evans AD, Bradbury RB. The efficacy of an ultrasonic cat deterrent. *Applied Animal Behaviour Science* 96, 83-91, 2006

Nogales M, Martín A, Tershy BR, Donlan CJ, Veitch D, Puerta N, Wood B, Alonso J. A review of feral cat eradication on islands. *Conservation Biology* 18, 310-9, 2004

Nutter FB, Stoskopf MK, Levine JF. Time and financial costs of programs for live trapping feral cats. *Journal of the American Veterinary Medical Association* 225, 1403-5, 2004a

Nutter FB, Levine JF, Stoskopf MK. Reproductive capacity of free-roaming domestic cats and kitten survival rate. *Journal of the American Veterinary Medical Association* 225, 1399-402, 2004b

Oppel S, Raine AF, Borg JJ, Raine H, Bonnaud E, Bourgeois K, Breton AR. Is the Yelkouan shearwater *Puffinus yelkouan* threatened by low adult survival probabilities? *Biological Conservation* 144, 2255-63, 2011

Paltridge R. The diets of cats, foxes and dingoes in relation to prey availability in the Tanami Desert, Northern Territory. *Wildlife Research* 29, 389-403, 2002

Paltridge R, Gibson D, Edwards G. Diet of the feral cat (*Felis catus*) in Central Australia. *Wildlife Research* 24, 67-76, 1997

Parsons H, Major RE, French K. Species interactions and habitat associations of birds inhabiting urban areas of Sydney, Australia. *Austral Ecology* 31, 217-27, 2006

Peterson MN, Hartis B, Rodriguez S, Green M, Lepczyk CA. Opinions from the Front Lines of Cat Colony Management Conflict. *PLoS ONE* 7, 2012

Phillips RB, Cooke BD, Campbell K, Carrion V, Marquez C, Snell HL. Eradicating Feral Cats to protect Galapagos Land Iguanas: Methods and strategies. *Pacific Conservation Biology* 11, 257-67, 2005

Powlesland RG, Roberts A, Lloyd BD, Merton DV. Number, fate and distribution of kakapo (*Strgops habroptilus*) found on Stewart Island, New Zealand, 1979-92. *New Zealand Journal of Zoology* 22, 239-48, 1995

Purvis A, Gittleman JL, Cowlishaw G, Mace GM. Predicting extinction risk in declining species. *Proceedings of the Royal Society B: Biological Sciences* 267, 1947-52, 2000

Radeloff VC, Hammer RB, Stewart SI, Fried JS, Holcomb SS, McKeefry JF. The wildland-urban interface in the United States. *Ecological Applications* 15, 799-805, 2005

Ratcliffe N, Bell M, Pelembe T, Boyle D, Benjamin R, White R, Godley B, Stevenson J, Sanders S. The eradication of feral cats from Ascension Island and its subsequent recolonization by seabirds. *ORYX* 44, 20-9, 2010

Ratz H, Moller H, Fletcher D. Predator identification from bite marks on penguin and albatross chicks. *Marine Ornithology* 27, 149-56, 1999

Rauzon MJ, Everett WT, Boyle D, Bell L, Gilardi J. Eradication of feral Cats at wake atoll. *Atoll Research Bulletin*, 1-21, 2008

Rinzin K, Stevenson MA, Probert DW, Bird RG, Jackson R, French NP, Weir JA. Free-roaming and surrendered dogs and cats submitted to a humane shelter in Wellington, New Zealand, 1999-2006. *New Zealand Veterinary Journal* 56, 297-303, 2008

Robertson HA, McLennan JA, Colbourne RM, McCann AJ. Population status of great spotted kiwi (*Apteryx haastii*) near Saxon Hut, Heaphy Track, New Zealand. *Notornis* 52, 27-33, 2005

Robertson ID. Survey of predation by domestic cats. *Australian Veterinary Journal* 76, 551-4, 1998

Robertson SA. A review of feral cat control. *Journal of Feline Medicine and Surgery* 10, 366-75, 2008

Rödl T, Berger S, Romero LM, Wikelski M. Tameness and stress physiology in a predator-naive island species confronted with novel predation threat. *Proceedings. Biological sciences / The Royal Society* 274, 577-82, 2007

Rowe L. Breeding of variable oystercatchers (*Haematopus unicolor*) at Kaikoura Peninsula, South Island, New Zealand. *Notornis* 55, 146-54, 2008

Ruxton GD, Thomas S, Wright JW. Bells reduce predation of wildlife by domestic cats (*Felis catus*). *Journal of Zoology* 256, 81-3, 2002

Schmidt PM, Lopez RR, Collier BA. Survival, fecundity, and movements of free-roaming cats. *Journal of Wildlife Management* 71, 915-9, 2007

Schmidt PM, Swannack TM, Lopez RR, Slater MR. Evaluation of euthanasia and trap-neuter-return (TNR) programs in managing free-roaming cat populations. *Wildlife Research* 36, 117-25, 2009

Scrimgeour J, Beath A, Swanney M. Cat predation of short-tailed bats (*mystacina tuberculata rhyocobia*) in rangataua forest, mount ruapehu, central North Island, New Zealand. *New Zealand Journal of Zoology* 39, 257-60, 2012

Selby LA, Rhoades JD, Hewett JE, Irvin JA. A survey of attitudes toward responsible pet ownership. *Public Health Reports* 94, 380-6, 1979

Shochat E. Credit or debit? Resource input changes population dynamics of city-slicker birds. *Oikos* 106, 622-6, 2004

Short J, Turner B, Risbey D. Control of feral cats for nature conservation. III. Trapping. *Wildlife Research* 29, 475-87, 2002

Silva-Rodriguez EA, Sieving KE. Influence of Care of Domestic Carnivores on Their Predation on Vertebrates. *Conservation Biology* 25, 808-15, 2011

Sims V, Evans KL, Newson SE, Tratalos JA, Gaston KJ. Avian assemblage structure and domestic cat densities in urban environments. *Diversity and Distributions* 14, 387-99, 2008

Smith AP, Quin DG. Patterns and causes of extinction and decline in Australian conilurine rodents. *Biological Conservation* 77, 243-67, 1996

Spada E, Proverbio D, Della Pepa A, Domenichini G, Bagnagatti De Giorgi G, Traldi G, Ferro E. Prevalence of faecal-borne parasites in colony stray cats in northern Italy. *Journal of Feline Medicine and Surgery* 15, 672-7, 2013

Spada E, Proverbio D, della Pepa A, Perego R, Baggiani L, DeGiorgi GB, Domenichini G, Ferro E, Cremonesi F. Seroprevalence of feline immunodeficiency virus, feline leukaemia virus and *Toxoplasma gondii* in stray cat colonies in northern Italy and correlation with clinical and laboratory data. *Journal of Feline Medicine and Surgery* 14, 369-77, 2012

Sparkes AH, Bessant C, Cope K, Ellis SL, Finka L, Halls V, Hiestand K, Horsford K, Laurence C, MacFarlaine I. ISFM guidelines on population management and welfare of unowned domestic cats (*Felis catus*). *Journal of Feline Medicine and Surgery* 15, 811-7, 2013

Stavisky J, Brennan ML, Downes M, Dean R. Demographics and economic burden of un-owned cats and dogs in the UK: results of a 2010 census. *BMC Veterinary Research* 8, 2012

Stoskopf MK, Nutter FB. Analyzing approaches to feral cat management-one size does not fit all. *Journal of the American Veterinary Medical Association* 225, 1361-4, 2004

Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, Moher D, Becker BJ, Sipe TA, Thacker SB. Meta-analysis of observational studies in epidemiology: A proposal for reporting. *Journal of the American Medical Association* 283, 2008-12, 2000

Tennent J, Downs CT. Abundance and home ranges of feral cats in an urban conservancy where there is supplemental feeding: A case study from South Africa. *African Zoology* 43, 218-29, 2008

Tennent J, Downs CT, Bodasing M. Management recommendations for feral cat (*Felis catus*) populations within an urban conservancy in kwaZulu-natal, South Africa. *South African Journal of Wildlife Research* 39, 137-42, 2009

Tennent JK, Downs CT, Wald DM, Watson HK. Public perceptions of feral cats within an urban conservancy on a campus of the University of KwaZulu-Natal. *South African Journal of Wildlife Research* 40, 16-26, 2010

Thomas RL, Fellowes MDE, Baker PJ. Spatio-Temporal Variation in Predation by Urban Domestic Cats (*Felis catus*) and the Acceptability of Possible Management Actions in the UK. *PLoS ONE* 7, 2012

Tocher M. Survival of Grand and Otago skinks following predator control. *Journal of Wildlife Management* 70, 31-42, 2006

Toukhsati SR, Bennett PC, Coleman GJ. Behaviors and attitudes towards semi-owned cats. *Anthrozoos* 20, 131-42, 2007

Toukhsati SR, Young E, Bennett PC, Coleman GJ. Wandering Cats: Attitudes and Behaviors towards Cat Containment in Australia. *Anthrozoos* 25, 61-74, 2012

Trotz-Williams LA, Trees AJ. Systematic review of the distribution of the major vector-borne parasitic infections in dogs and cats in Europe. *Veterinary Record* 152, 97-105, 2003

Tschanz B, Hegglin D, Gloor S, Bontadina F. Hunters and non-hunters: Skewed predation rate by domestic cats in a rural village. *European Journal of Wildlife Research* 57, 597-602, 2011

Valcarcel A, Fernandez-Juricic E. Antipredator strategies of house finches: are urban habitats safe spots from predators even when humans are around? *Behavioral Ecology and Sociobiology* 63, 673-85, 2009

van Heezik Y, Smyth A, Adams A, Gordon J. Do domestic cats impose an unsustainable harvest on urban bird populations? *Biological Conservation* 143, 121-30, 2010

Veitch CR. The eradication of feral cats (*Felis catus*) from little Barrier Island, New Zealand. *New Zealand Journal of Zoology* 28, 1-12, 2001

Wallace JL, Levy JK. Population characteristics of feral cats admitted to seven trap-neuter-return programs in the United States. *Journal of Feline Medicine and Surgery* 8, 279-84, 2006

Wanless RM, Cunningham J, Hockey PAR, Wanless J, White RW, Wiseman R. The success of a soft-release reintroduction of the flightless Aldabra rail (*Dryolimnas* [c*uvier*i] *aldabranus*) on Aldabra Atoll, Seychelles. *Biological Conservation* 107, 203-10, 2002

Weggler M, Leu B. A source population of black redstarts (Phoenicurus ochruros) in villages with a high density of feral cats (*Felis catus*). *Eine überschuss produzierende population des hausrotschwanzes (Phoenicurus ochruros) in ortschaften mit hoher hauskatzendichte (Felis catus)* 142, 273-83, 2001

Weiss E, Slater MR, Lord LK. Retention of provided identification for dogs and cats seen in veterinary clinics and adopted from shelters in Oklahoma City, OK, USA. *Preventive Veterinary Medicine* 101, 265-9, 2011

Wodziki KA. *Introduced mammals of New Zealand: an ecological and economic survey*. Department of Scientific and Industrial Research, 98, Wellington, New Zealand, 1950

Woods M, McDonald RA, Harris S. Predation of wildlife by domestic cats *Felis catus* in Great Britain. *Mammal Review* 33, 174-88, 2003

Young LC, VanderWerf EA, Lohr MT, Miller CJ, Titmus AJ, Peters D, Wilson L. Multi-species predator eradication within a predator-proof fence at Ka'ena Point, Hawai'i. *Biological Invasions*, 1-12, 2013

Zasloff RL, Kidd AH. Loneliness and pet ownership among single women. *Psychological Reports* 75, 747-52, 1994