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Review

Research challenges and conservation implications for urban cat management in New Zealand

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Abstract. Over the past 20 years, conservation efforts in New Zealand have moved from being concentrated in rural and isolated island locations, where exotic mammalian predators are often controlled, to begin to bring native fauna back to major cities. However, human–wildlife conflicts arise when conservation occurs in close proximity to cities. These are particularly intense when companion animals are involved either as potential predators or prey of high-value conservation animals. Within New Zealand, this conflict is particularly fraught around domestic cats (*Felis catus*) in the urban environment. Cats in New Zealand are recognised as major introduced predators of native fauna, but they also prey on small introduced predatory mammals. This dynamic causes much conflict between people with different attitudes towards animals; however, as yet, few studies have explored the role(s), either negative or positive, of urban cats in New Zealand. Here, we review current knowledge on domestic cats in urban New Zealand, identify gaps in knowledge and make suggestions for future research, which includes further social science research, citizen science-based research programs, market research, investigation into cat-management legislation, and more in-depth studies of cat diseases and zoonoses. These data are vital for informing the public and improving the management of urban cat populations, including mitigating conservation impacts. Urban ecologists will need to be versatile in the way they design and conduct experiments, exploiting multiple disciplines to both ensure scientific robustness, but also community and government support for uptake of results into management and legislation.

Additional keywords: cat, citizen science, domestic, feral, human–wildlife conflict, invasive species, legislation, owned, stray, unowned, wildlife conservation.

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Introduction

Worldwide, more than half of the human population lives in urban environments (World Health Organization 2016). In New Zealand, over 85% of people live in cities (Statistics New Zealand 2016). Globally, habitat loss is an ongoing threat to biodiversity (Townsend 2008). As such, urban and semi-urban environments are increasingly performing essential environmental roles as wildlife refuges (Aronson *et al.* 2014), contributing to the increase in research on urban ecology, that is, the interdisciplinary study of ecosystems in human-dominated environments (Marzluff *et al.* 2008). However, wildlife in close proximity to cities often leads to human–wildlife conflicts (Conover 2001). These conflicts can be especially fraught where companion animals are predators, or prey, of wildlife of high-conservation value (Baker *et al.* 2008; Gehrt *et al.* 2013). One such conflict is that of domestic cats (*Felis catus*), which are major predators of small mammals, reptiles and invertebrates (Loss *et al.* 2013), as well as birds (Loyd *et al.* 2013) and fish (Woods *et al.* 2003). Whereas direct predation of wildlife by cats is often emphasised in research and popular press (Flux 2007), other documented impacts of cats include competition for resources, alteration of ecological processes, behavioural changes (e.g. induction of stress or changes in breeding behaviour) and disease transmission (Medina *et al.* 2014). In New Zealand, cats pose a particularly complex problem because (1) native species have evolved in the absence of predatory mammals and face current challenges of vastly altered ecosystems (Towns *et al.* 2001), (2) conservation efforts are increasingly focusing on cities (Innes *et al.* 2012), (3) cats are the most common companion animal in New Zealand (National Animal Welfare Advisory

Committee 2007), and are predators of both native and exotic species (Fitzgerald and Karl 1979; King 2005; Tocher 2006), and (4) among New Zealanders, vastly different attitudes towards animals can be found (Farnworth *et al.* 2014). Evidence of predator–prey dynamics of cats in urban locations is in its infancy (but see studies outlined in Table 1), despite cats being known to having been major predators of native species for decades.

Almost 50 years ago, the New Zealand Wildlife Service produced and distributed a pamphlet, Problem Cats, to all New Zealand households, outlining their threat to native wildlife within forested areas (Swarbrick 2013). Since that time, several studies in non-urban areas have added evidence of the threat of cats to native wildlife (e.g. Fitzgerald and Karl 1979; King 2005; Tocher 2006). For example, cats are in part responsible for the extinction of the Stephens Island wren, *Traversia lyalli* (Galbreath and Brown 2004), and the decline of many reptile populations (Daugherty and Towns 1991; Hitchmough *et al.* 2016). Conversely, evidence that cats may have some beneficial effects (e.g. suppressing smaller predatory mammals) has led to disparate views among people with different attitudes towards animals (van Heezik 2010; Loyd and Hernandez 2012; Farnworth *et al.* 2014). Only in the past 13 years have investigations of cats within New Zealand's urban environment, and their potential effects, been published (Table 1). The resurgence in public debate is primarily due to Dr Gareth Morgan's 'Cats to Go' campaign (Morgan Foundation 2013). As a result, public conflict concerning cats in New Zealand has received substantial media coverage, both locally and overseas (Cowlishaw 2013; Shuttleworth 2013; Berwick 2014; Swinnen 2016).

In New Zealand, the public perception of cats (in general) ranges from valued household companion animals to introduced pests (K. H. Kikillus, unpubl. data); in part, this perception is likely to be due to the perceived emotional value provided by cats in conjunction with the perceived environmental costs imposed by their presence (Farnworth *et al.* 2011). These underlying social perceptions of cats have driven the development of the following three categories found in the Animal Welfare (Companion Cats) Code of Welfare (NAWAC 2007; hereinafter called 'the code'): companion, stray and feral cats. Likewise, variations in public considerations concerning the control of these three categories of cat are associated with value-based judgements (Farnworth *et al.* 2011). The definitions are primarily driven by anthropocentric principles; companion cats are those fully provided for within an ownership model, stray cats are provided for either directly or indirectly by human populations (e.g. *ad hoc* provision of food and shelter), whereas feral cats receive no human support. These definitions may easily be misconstrued by those who do not have a working knowledge of the code (Farnworth *et al.* 2010*a*, 2010*b*). However, the definitions do indicate that unowned urban cats are stray as opposed to feral. Stray cats, as per the code, are considered within the purview of animal welfare charities, whereas feral cats are 'in a wild state' and, therefore, able to be controlled and managed (Anonymous 1987; National Animal Welfare Advisory Committee 2007). As such, for simplicity, here we refer to cats as 'owned' or 'unowned' to enable their management to be addressed appropriately.

Despite the aforementioned definitions of cats, it is reasonable to suggest that the cat population is, in reality, a single fluid contiguous group where individuals may transition from one group to another, dependent on their location and the human population that it lives within or besides. Unowned urban cats are more prevalent in areas with higher human population density (Aguilar and Farnworth 2012, 2013; Aguilar *et al.* 2015) and live at far higher densities than do unowned cats in rural environs (Langham and Porter 1991). Proximity to human environments and anthropogenic food sources are likely to provide unowned urban cats with the necessary resources to reproduce and survive in significant numbers.

In 2013, the New Zealand Veterinary Association (NZVA) commissioned a systematic literature review of peer-reviewed cat publications from New Zealand and overseas (Farnworth *et al.* 2013). The key findings from the report included that cats in New Zealand are likely to prey on millions of small animals (both native and non-native) annually; trap–neuter–return (TNR) is unlikely to provide a long-term solution to cat population management in New Zealand; formal mechanisms to establish cat ownership should be investigated (e.g. compulsory registration and microchipping); more research is needed on cat population management; and the promotion of responsible pet ownership must be a focus of any strategy for cat management (Farnworth *et al.* 2013). In all cases, more research is needed to better understand the impact of cats on the environment.

Despite much research in New Zealand on the impacts of unowned cats in rural locations, the impact of owned cats on wildlife in urban locations is a matter of vigorous public debate, and one that may be hard to resolve, given that conservationists and those involved with (companion) animal-welfare organisations can have diametrically opposed viewpoints (Farnworth *et al.* 2014). Studies on other impacts of cats, such as disease transmission and the emotional value of pet cats in New Zealand to their owners, are also limited (but see Farnworth *et al.* 2011; Roe *et al.* 2013). There is scope for much more research on cats in New Zealand.

Here, we review the current knowledge of research on urban cats in New Zealand, so as to help identify areas of investigation required to better understand their ecological and social impacts that are needed to inform management and legislation. This includes information on the following five main areas: social studies (i.e. public perceptions and attitudes towards cats and their management); ecology and environment (e.g. population size, home range size, predator–prey dynamics, meso-predator release, behavioural syndromes); business and marketing (e.g. anti-predator devices and catios); current law and governance; and diseases and zoonoses. This information is necessary to enable the public to make informed decisions regarding how they manage their pet cats and for government bodies (local and central) to improve cat management, aid in mitigating conservation impacts within urban environments, and to make informed decisions when passing laws and legislation.

Research on cats in urban environments in New Zealand

Social studies

Being such an emotive topic, any research and management of urban cats is going to raise debate among the public. Therefore, social research to help understand the public perception of cats

Table 1. Studies of urban domestic cats (*Felis catus*) conducted in New Zealand

This table was constructed by using the search term 'cat*' in conjunction with other terms such as 'companion', 'urban', 'predation', 'New Zealand', 'perception', 'attitudes' and 'ecology' in the online database 'Web of Science' and 'urban cats New Zealand' in the search engine 'Google Scholar'. References within articles were also sought. MCP, minimum convex polygon

Type of study	Location	*N*	Recorded	Outcome	Citation
Ecology and environment					
Prey type	Auckland City	46 cats	Prey brought in by owned cats over 12 months	73% invertebrates; ~14% birds; ~5% lizards	Gillies and Clout 2003
	Auckland (Urban-rural fringe)	34 cats	Prey brought in by owned cats over 12 months	66% rodents; ~15% birds; 11% lizards	Gillies and Clout 2003
	Christchurch	88 cats	Prey brought in by owned cats over 12 months	38% rodents; 20% birds; 18% lizards; 22% invertebrates; 2% other (frogs, goldfish, mustelids)	Morgan *et al.* 2009
	Dunedin	144 cats	Prey brought in by owned cats over 12 months	37% birds; ~34% rodents; ~20% invertebrates; ~8% lizards; 0.65% other mammals (lagomorphs and mustelids)	van Heezik *et al.* 2010
	Wellington	1 cat	Prey brought in by a single cat over 17 years	~51% rodents; ~40% birds; ~6% rabbits; ~2% lizards	Flux 2007
	Dunedin	45 cats	Prey capture over 6 weeks (control group in belled collar trial)	~57% rodents; ~32% birds; ~5% invertebrates; ~4% lizards, ~2% rabbits	Gordon *et al.* 2010
	Stewart Island	11 cats	Prey capture over 6 months	Only 4 cats brought home prey. 67% rodents; 33% birds	Wood *et al.*2015
Spatial movement	Auckland	Numerous cats	1 year of stray-cat location data (2010–11) analysed via GIS	Aggregated stray-cat density: Manurewa = 50.41 km^{-2}; Papakura = 35.29 km^{-2}; Mangere = 32.64 km^{-2}	Aguilar and Farnworth 2012
	Auckland	Numerous cats	20 years of colony-cat data analysed via GIS	Colonies were located close to urbanised areas and reports of colonies increased over time	Aguilar and Farnworth 2013
	New Zealand	Numerous cats	Data from Aguilar and Farnworth (2012, 2013) analysed via species distribution modelling	Projections to a climate change-based scenario showed a consistent increase in the area and intensity of areas suitable for un-owned cats, especially in the North Island	Aguilar Farnworth and Winder 2015
	Christchurch	21 cats	Tracking owned cats via radio-telemetry over 12 months	Median home range (100% MCP) = 1.8 ha; range = 0.1–10.0 ha	Morgan *et al.* 2009
	Dunedin	32 cats	Tracking owned cats via GPS collars over 6 days	Median home range (100% MCP) = 2.2 ha; range = 0.48 – 21.75 ha	van Heezik *et al.* 2010
	Dunedin	20 cats	Tracking owned cats via differently-weighted GPS collars for 1 week at a time	Cats travelled slightly further while wearing tracking units that were ~1% of their bodyweight, than they did when wearing heavier tracking collars	Coughlin and van Heezik 2014
	Oban, Stewart Island	15 cats	Radio-tracking of pet cats over a 1-month period (minimum of 30 fixes)	Median home range (100% MCP) = 0.05; range = 0.05–16.58 ha	Wood *et al.* 2015
	Canterbury (urban fringe)	11 cats	Tracking owned cats via GPS collars over 10 days	Median home range (95% MCP) = 4 ha	Metsers *et al.* 2010
	Otago (urban fringe)	14 cats	Tracking owned cats via GPS collars over 10 days	Median home range (95% MCP) = 3.5 ha	Metsers *et al.* 2010;

(*Continued*)

Table 1. (Continued)

Type of study	Location	*N*	Recorded	Outcome	Citation
Behaviour	Wellington	10 cats	~80 h of video footage captured using collar-mounted video cameras	Cats spent the majority of their time 'investigating' (~40%) or indoors (~32%)	KH Kikillus and MJ Gaby (unpubl. data)
Anti-predation device	Dunedin	45 cats	Prey capture over 6 weeks for cats wearing a collar with a bell attached	Bells on cat collars reduced hunting by half, but did not affect prey-species composition in comparison to control group (see above under prey type)	Gordon *et al.* 2010
Social science					
Public attitudes and perceptions	New Zealand	511 people (393 cat owners)	Survey of cat owners and non-cat owners about the use and perception of cat collars	Cat owners preferred microchips over collars for identification; cat owners felt stronger than non-cat owners that cats were beneficial for pest control; more non-cat owners than owners felt that cats should be contained at night and disagreed with the statement that well fed cats do not hunt birds	Harrod *et al.* 2016
	New Zealand	354 people	Survey to ascertain levels of awareness of legislation governing the welfare of cats	Fewer than half of respondents were aware of the animal-welfare legislation within New Zealand	Farnworth *et al.* 2010*a*
	New Zealand	354 people	Survey of perceptions of stray and feral-cat welfare and control	Respondents felt that lethal control was more appropriate for feral cats than stray cats	Farnworth *et al.* 2011
	New Zealand	263 people	Survey of attitudes towards pests and control measures	Rats, possums and stoats were ranked as the worst pests. The preference for lethal vs non-lethal control measures was associated with the species in question. The general public preferred non-lethal control methods for feral cats	Farnworth *et al.* 2014
	Wellington	108 people (64 cat owners)	Survey of attitudes to predict intentions of cat owners containing cats at night	Respondents who brought their cat in at night were more motivated to do so for their cat's welfare, not for the benefit of native wildlife	MacDonald *et al.* 2015
	New Zealand	347 people (175 cat owners)	Survey of attitudes regarding predation by pet cats on wildlife	Majority of respondents agreed that cats in reserves are harmful for wildlife. Cat owners were less likely to support cat-management legislation than were non-owners	Hall *et al.* 2016

in New Zealand is vital. Some research has begun (see Table 1), including investigating the use and perception of cat collars (cat owners preferred to use microchips for identification purposes; Harrod *et al.* 2016), to the acceptability of unowned-cat control (respondents who owned cats perceived non-lethal control of unowned cats to be more acceptable than lethal control methods, when compared with non-owners; Farnworth *et al.* 2011). A survey designed to better understand the attitudes of Western Australians towards cat-control legislation (Grayson *et al.* 2002) has been adapted for use in other countries, including New Zealand. Results have indicated that most of New Zealand respondents agreed that pet cats in nature reserves are harmful to wildlife. Despite this, responses suggested that New Zealanders that did not own cats were much more likely to support the idea of cat legislation than those who did own cats (Hall *et al.* 2016). In the UK, cat owners are often unwilling to admit that their pets may be a threat to wildlife (McDonald *et al.* 2015). Recent research has suggested that advocacy campaigns for cat containment that focus on the benefits to cat welfare, rather than wildlife conservation, may be more successful (MacDonald *et al.* 2015; Hall *et al.* 2016) and that a better understanding by cat owners of the risks encountered by free-ranging cats may result in behaviour change (Gramza *et al.* 2016). Integrating social science with ecological studies is particularly useful, and can be achieved well by using citizen-science methodologies.

Citizen science

In much of traditional ecology, experiments involving control and treatment groups are used (Karban and Huntzinger 2006). However, in the case of urban cats and the public, it is difficult to obtain such a broad-scale level of cooperation (e.g. by comparing one neighbourhood with free-roaming owned cats to a similar neighbourhood where residents have agreed to keep their cats indoors for a specified period of time). Therefore, other research options are needed in place of traditional ecological methods, including citizen science, where scientists partner with the public to answer scientific questions. Citizen science provides scientists with increased potential for data collection and analyses, and the public with important science education; not only do they gain a better understanding of science, but also an increased engagement in environmental issues (Roetman and Daniels 2011). Studies involving citizen science are becoming more popular in New Zealand (e.g. Great Kereru Count, Garden Bird Survey), and by using this methodology, extensive research on urban cats will be possible. Large-scale citizen science projects involving cats may include investigating cat movements, behaviour (especially via collar-mounted cameras, as per Loyd *et al.* 2013), owner's attitudes towards cat management, and building a large database of prey brought home by owned cats.

Ecology and environment

How many cats are there?

According to the New Zealand Companion Animal Council, New Zealand has the highest recorded rate of cat ownership in the developed world (Mackay 2011). However, because no registration regulations exist for cats in New Zealand (as they do with dogs), no reliable population census of cat numbers exists. Two studies focused on the South Island cities of Dunedin and Christchurch estimated the percentages of households owning cats as 35% and 33% respectively (Morgan *et al.* 2009; van Heezik *et al.* 2010). It is unknown whether the cat-ownership estimates in these cities are representative of all of New Zealand urban areas, especially small urban centres, and cities in the North Island, where infill housing and legislative restrictions mean fewer areas for larger companion animals (such as dogs), which may mean people are more likely to keep cats as pets.

Because of the maintenance provided by humans, high densities of cats can exist in urban spaces (Lepczyk *et al.* 2004; Sims *et al.* 2008; Aguilar and Farnworth 2013). Knowing the percentage of households owning one or more cats is vital for local government agencies considering implementing legislation changes, and, hence, how many rate payers may be affected by these changes (M. Emeny, Team Leader, Urban Ecology, Wellington City Council, pers. comm.). Similarly, the proportion of cats that are owned (companion) versus unowned (stray), and how these interact with free-living (feral) cats, is unclear. Within Auckland, unowned stray and owned pet cats are geographically indistinguishable, and the cat population density is positively correlated with human population density (Aguilar and Farnworth 2012, 2013).

Where does kitty wander?

A home range is defined as the area an animal uses to find food and resources, whereas a territory is a portion of the home range that is defended (Spotte 2014). Several studies of cat home ranges overseas (encompassing both owned and unowned cats) show that cats can vary dramatically in this regard, namely, from less than 1 ha for urban strays in Japan (Yamane *et al.* 1994) to over 2000 ha for rural feral cats in Australia's Northern Territory (Edwards *et al.* 2001). In general, bigger cats have larger home-range sizes (Molsher *et al.* 2005; Spotte 2014). In New Zealand, pet cats living near natural areas (such as, for example, wetlands and reserves) or in rural areas have larger home ranges than do cats residing in strictly urban areas (Morgan *et al.* 2009; Metsers *et al.* 2010; Table 1). Additional studies will help clarify patterns that may predict home-range sizes for urban cats, or whether home range is related to habitat-specific traits of a city (for example, do urban cats venture further in areas with more open space, such as reserves, or in areas where they may be constrained by buildings and motorways?). Use of GPS techniques, along a with stringent effort to reduce location error from devices (Coughlin and Van Heezik 2014), will help identify how often owned cats are entering areas of high conservation value, and, thus, whether more management is required, and/or whether cat 'buffer zones' may be possible, both in the practicality of having enough space and in the public support for them (Metsers *et al.* 2010).

What does the cat drag in?

The type of environment in which cats are located will affect the type(s) of prey captured. For example, in one study in Auckland, prey captured by cats in more 'natural' forested neighbourhoods consisted mostly of rodents, and was dramatically different from prey caught in purely urban areas (primarily invertebrates; Gillies and Clout 2003; Table 1). Therefore, within urban

environments, ecologists must take into account the differences among various available habitats.

Cats have no natural predators in New Zealand; yet, they prey on a wide variety of smaller animals (King 2005) and may have impacts on native fauna. Yet cats may indirectly help native wildlife by keeping other introduced pests in check (Wood *et al.* 2015). Further research into the impacts of owned cats on prey populations (both introduced mammals and native wildlife) is warranted and a large database of prey captured by cats could be easily conducted via a citizen science smartphone app. Meso-predator release (when a top predator is removed and another predator, for example, rodents, fills the void) can occur in some situations when an apex predator is eradicated (Oppel *et al.* 2014). Research into meso-predator release scenarios in areas where cats are removed is needed within the urban environment in New Zealand (ideally, via field comparisons between similar areas where cats, but no other predators, have and have not been eradicated, but also possibly through modelling scenarios). It has been suggested that the potential of meso-predator release involving the eradication of cats should be considered on a case-by-case basis in areas in New Zealand (Jones 2008).

Consistent differences in behavioural syndromes have been well documented in numerous species of animals (Sih *et al.* 2004) and, among cats, not all cats are avid predators (van Heezik *et al.* 2010; Loyd *et al.* 2013). Investigation of factors influencing predatory behaviour and prey specialisation by cats (e.g. some target certain prey species, such as birds or rodents) could investigate factors such as the prey available in a given environment or genetic components of behavioural syndromes. For example, urban cats in the USA avoided larger-sized rats and focussed their hunting efforts on smaller (under 300 g) specimens – these may have been easier to catch than larger rats, but the predation had no real impact on the rat population size as larger, sexually-mature rats were not controlled by cats (Glass *et al.* 2009). In Australia, cats often specialise in a particular type of prey and may continue to hunt their preferred prey, even if numbers are low, contributing another challenge to the conservation of rare native species (Dickman and Newsome 2015). For New Zealand cats, it appears that not all owned cats bring prey home, and, those that do, capture mainly rodents, followed by birds (Table 1). For owners wanting to reduce capture of prey, while still leaving their cat free-to-roam, the purchase and use of anti-predation devices can be a desirable action.

Business and marketing

Overseas, the business of cats is a lucrative one, from containment/indoor cat-keeping needs to cat anti-predator devices. Containment is a common practice overseas, preventing predation of wildlife, but also for the welfare of the cats themselves (which may have their own predators; American Bird Conservancy 2013). In Tasmania, Australia, a survey of cat owners found that the most commonly reported barrier to containing pet cats was the belief that 'it is natural behaviour for cats to wander so they should be allowed to do so' (McLeod *et al.* 2015). How does this compare with the beliefs of New Zealand cat owners? A survey of 151 cat owners in New Zealand indicated that 95% of companion cats had free access to the outdoors (Farnworth *et al.* 2010*a*), whereas a recent survey found that New Zealand cat owners had low support for 24-h containment of cats (18.6% of respondents; Hall *et al.* 2016). Further research to identify the drivers and barriers of pet-cat containment is warranted.

A Google search of the term 'catio' (a combination of the words 'cat' and 'patio', which is an enclosed outdoor area in which to contain cats) turns up multiple websites and businesses providing cat-containment equipment. However, if search results are filtered to only pages from New Zealand, the results are limited, with only one distributor selling cat-containment equipment in the country, and offering installation of the equipment only in the city of Auckland (Oscillot 2016). Why do cat-containment systems appear to be unpopular in New Zealand when compared with other countries? What factors are preventing their widespread use and acceptance here? Are there business opportunities for overseas companies to provide cat-containment solutions to the New Zealand public? Market research may help provide answers to these questions.

Cats are likely to remain as a fixture in the urban environment of New Zealand. For example, the release of the Predator Free Wellington initiative in September 2016 does not include a mention of predatory companion animals (Thomas 2016). Therefore, research on effective anti-predation methods is vital. In Dunedin, New Zealand, bells attached to domestic-cat collars reduced prey catch by half (Gordon *et al.* 2010). Overseas, trials of various anti-predation products, such as the CatBib (CatGoods, Portland, OR, USA), sonic devices, and the Birdsbesafe collar cover (Birdsbesafe, Duxbury, VT, USA) have successfully reduced prey catch by owned cats when compared with control groups (Nelson *et al.* 2005; Calver *et al.* 2007; Hall *et al.* 2015; Willson *et al.* 2015). Similar trials are urgently needed in New Zealand to test the effectiveness of these products and to investigate whether they are more effective than bells on collars. Of special interest are Birdsbesafe collar covers, which have overseas been shown to decrease bird and herpetofauna predation by over 50%, without significantly reducing the predation of small mammals (Hall *et al.* 2015). This is of great relevance to New Zealand, where native birds and herpetofauna are vulnerable to free-roaming cats, but where most small mammals in urban environments are introduced pests. However, although anti-predation devices may assist in mitigating the impacts of cats on native wildlife, they are not an ultimate solution because they do not address other issues, such as wandering cats (which may spread diseases and cause a nuisance to neighbours).

Law, legislation and governance for cat management

Jurisdictions in several overseas countries have implemented legislation regarding the management of pet cats, specifically restricting the number of cats permitted at a residential premises, mandatory identification and registration, or requiring cats to be confined to their owners' property (Anonymous 2016*a*, 2016*b*).

No national body for the management of owned cats currently exists in New Zealand. However, in November 2014, several organisations came together to form the 'National Cat Management Strategy Group' (NCMSG). Member organisations include the New Zealand Veterinary Association (NZVA), the

Table 2. Existing owned cat legislation by 15 of 78 Councils in New Zealand (as of August 2016)

Documents are available on request from the corresponding author. This table was constructed by searching local-government websites for information regarding regulations of owned cats in each local authority. If no information was available, then Councils were contacted individually for clarification

Location and authority	Maximum number of pet cats permitted	Document	Relevant section number
North Island			
Far North District Council	5	Keeping of Animals, Poultry and Bees 2007	1306
Kaipara District Council	5	General Bylaws 2008	807
South Waikato District Council	5	South Waikato District Keeping of Animals, Poultry and Bees Bylaw 2011	7.2.2
New Plymouth District Council	5	New Plymouth District Council Bylaw 2008: Animals	7.1
Hastings District Council	4	Bylaws Part 03: Animals	9
Rangitikei District Council	3	Animal Control Bylaw 2013	7
Manawatu District Council	3	Manawatu District Bylaw 2008	5.4.2
Palmerston North City Council	3	Palmerston North Animals and Bees Bylaw 2011 (incorporating amendments as at 9 September 2013)	8
Ruapehu District Council	4	Animal Control Bylaw 2012	10
Masterton District Council	3	The Masterton and South Wairarapa District Councils' Consolidated Bylaw 2012	5
South Wairarapa District Council	3	The Masterton and South Wairarapa District Councils' Consolidated Bylaw 2012	5
Wellington City Council[A]	–	Wellington Consolidated Bylaw 2008: Animals	4
South Island			
Marlborough District Council	4	Marlborough District Council Bylaw 2010: Keeping of Animals, Poultry and Bees	705
Buller District Council	3	Amendment to the Buller District Council general bylaw NZS 9201 Part 13 The Keeping of Animals	1306
Invercargill City Council	3	Bylaw 2013/2 – Keeping of Animals, Poultry and Bees	3

[A]All domestic cats over the age of 12 weeks must be microchipped by early 2018 and the cat's microchip registered with New Zealand Companion Animal Register.

New Zealand Companion Animal Council, the Royal New Zealand Society for the Prevention of Cruelty to Animals, the Morgan Foundation, and Local Government New Zealand. Technical advisors to the group include the Department of Conservation and the Ministry for Primary Industries. This group's primary objective is to promote responsible cat ownership, environmental protection and humane cat management (Smallman 2016).

At present, regulations and bylaws pertaining to the management of owned cats in New Zealand are piecemeal among individual councils (Table 2). The local government sectors in New Zealand are comprised of 11 Regional Councils, 61 territorial authorities (50 District Councils and 11 City Councils), and six Unitary Councils (territorial authorities with regional council responsibilities; LGNZ 2016). Although cats are not specifically mentioned in the bylaws of many councils, it is possible for management issues regarding pet cats to be addressed under a council's Nuisance Laws or within the *Health Act*; however, these are limited in their ability to reduce impacts on wildlife. Only 14 of the 78 councils in New Zealand limit the maximum number of pet cats allowed (Table 2), and these range from five (four councils) to three (seven councils). Of note, in August 2016, the Wellington City Council reviewed its Animal bylaw and voted that all cats over 12 weeks of age must be microchipped and registered with the New Zealand Companion Animal Register by early 2018. This is the first such cat management legislation of any council in New Zealand.

In September 2016, the NCMSG launched a draft cat management strategy implementation document and requested feedback on the proposal (New Zealand Veterinary Association 2016). The consultation period runs through October 2016 and the NCMSG plans to submit the proposal to the central government by the end of 2016. Consistent national legislation regarding cat management will be a huge step forward, making it easier for local councils to establish bylaws that will both benefit cat welfare and help protect vulnerable native wildlife.

Studies investigating laws and legislations, namely, in regard to which ones work, where they are (or are not) successful and implications for companion animals and society, would help guide decisions of the NCMSG, as well as local and central government.

Cats and zoonoses

Cats can carry a wide variety of diseases, some of which can be transferred to humans (Lepczyk *et al.* 2015). For example, cats are the definitive host for *Toxoplasma gondii*, a protozoan parasite that causes toxoplasmosis (Centers for Disease Control and Prevention 2014). In humans, toxoplasmosis is associated with schizophrenia, memory impairment and birth defects (Wong *et al.* 2013; Gajewski *et al.* 2014). Toxoplasmosis is also a concern for wildlife (Hollings *et al.* 2013) and has been found in New Zealand within native birds (Stewart 2014) and is also linked to local marine-mammal deaths (Roe *et al.* 2013). Investigation of the prevalence rates of *T. gondii* in urban cats in

relation to the prevalence detected in their owners and wider community would aid better understanding of this parasite, its means of transmission, and effects on both humans and wildlife. Free-roaming pet cats are also more susceptible to contracting viruses such as feline leukaemia virus and feline immunodeficiency virus (FIV) from other cats encountered on their wanderings (Lee *et al.* 2002). Other infections reported in cats in New Zealand include numerous bacterial infections, including *Mycobacterium* spp. and *Salmonella* spp., rickettsial diseases, and fungal and ectoparasite diseases (Thompson 2009). The extent to which these and other diseases may be transmitted to other companion animals, humans or wildlife, and their effects, are unknown.

Conclusions

In order to explore the need for, and the subsequent effective management of urban cats in New Zealand, we need a clear understanding of their ecology, behaviour and impact on the local environment. Many of the ideas suggested in the present paper cannot be achieved without the full cooperation of cat owners themselves; therefore, many of these research projects have the ability to become large-scale citizen science programs, with links to social, medical and ecological sciences. Cats are an important part of many human families and scientists need to refrain from accusing cat owners of being irresponsible and contributing to the decline of wildlife, instead providing evidence and facts that can be easily understood by citizens. Co-operative research programs are likely to succeed by gathering data of benefit to researchers and cat owners, and of use by local and central government. Finding ways to increase public awareness about cat-management options and their ability to improve cat welfare and help mitigate cat impacts in New Zealand is also warranted.

Currently, we are unable to effectively establish the number of cats, their ownership status, and the extent of their impact on wildlife. It has been suggested that a 'precautionary principle' be implemented in New Zealand, which 'provides a rationale for immediate intervention to protect wildlife from pet cats while we await definitive studies' (Jones 2008; Calver *et al.* 2011). In New Zealand, this principle has often been taken to mean imposing a complete ban or at least a moratorium until the subject has been proved beyond, not just reasonable, but any, doubt to be 100% safe. In wider practice, the concept more generally urges caution, but captures a balance between costs and benefits, i.e. in the sense that precautions should remain in place until advantages outweigh disadvantages, both real and imagined (Cameron 2006). In this case, we should continue to encourage responsible pet ownership and cat containment among New Zealanders, until the value of pet cats as companions and pest-removers outweighs the combined loss of individuals from native species and risk of owned cats becoming stray or feral (unowned). Urban ecologists will need to be versatile in the way that they design and conduct their experiments and data gathering, using a multidisciplinary and collaborative approach that brings the public along on the journey.

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