SUSTAINING INNOVATION IN COMPASSIONATE FREE-ROAMING CAT MANAGEMENT ACROSS THE GLOBE: A DECADAL REAPPRAISAL OF THE PRACTICE AND PROMISE OF TNVR

EDITED BY: Joan E. Schaffner, Geoffrey Wandesforde-Smith, Peter Joseph Wolf, Julie Levy, Sophie Riley and Mark James Farnworth

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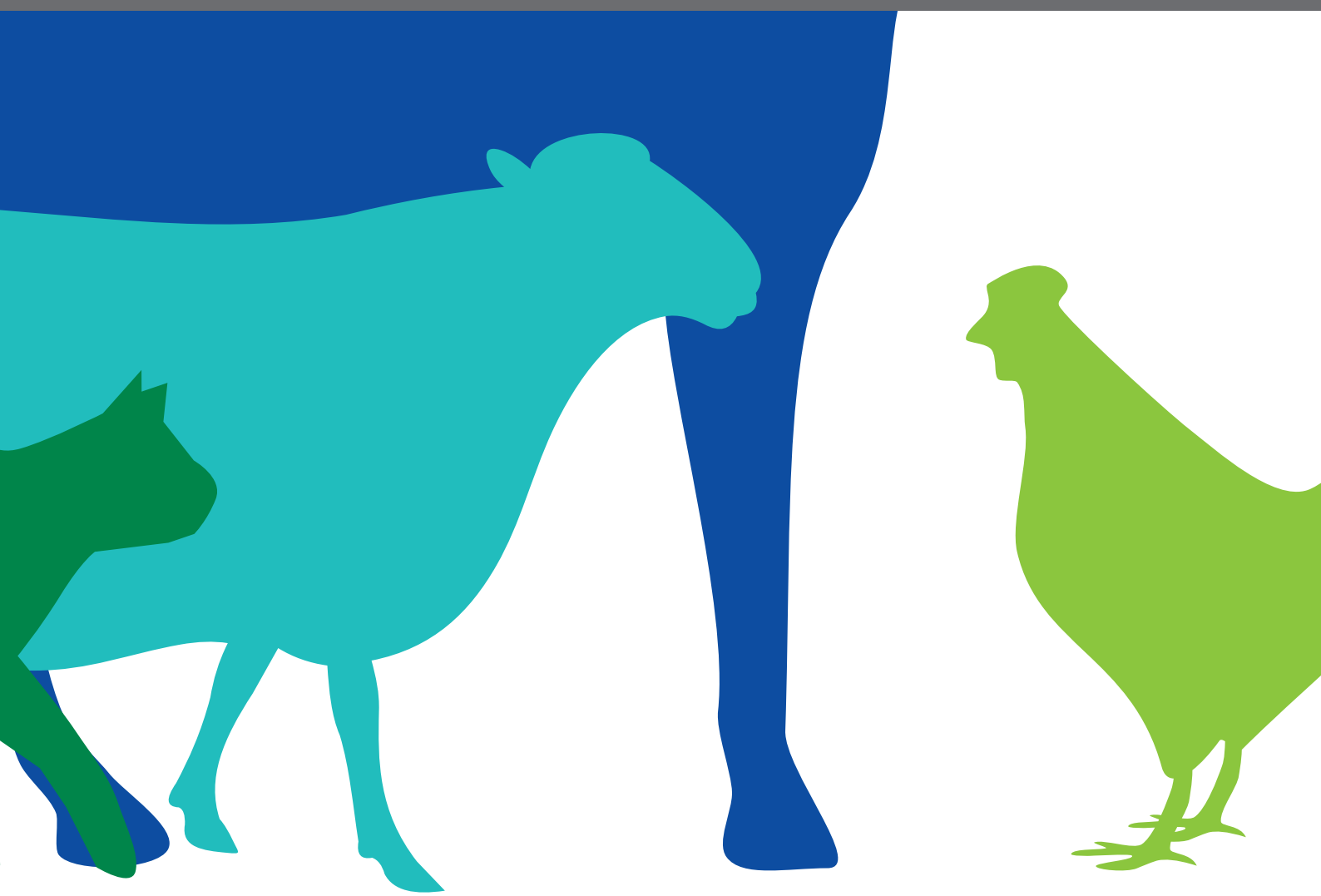

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EDITORIAL
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Editorial: Sustaining Innovation in Compassionate Free-Roaming Cat Management Across the Globe: A Decadal Reappraisal of the Practice and Promise of Trap-Neuter-Vaccinate-Return (TNVR)

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Editorial on the Research Topic

Sustaining Innovation in Compassionate Free-Roaming Cat Management Across the Globe: A Decadal Reappraisal of the Practice and Promise of TNVR

In "A review of feral cat control," published in the *Journal of Feline Medicine and Surgery* in 2008, Sheilah Robertson recognized that there was a clear, evolutionary trend in global thinking and advocacy about free-roaming cat management, moving away from lethal methods toward trap-neuter-vaccinate-return (TNVR). Although in some local circumstances the available data "support the success of TNR in reducing cat populations," argued Robertson, "to have a large impact it will have to be adopted on a far greater scale than it is currently practiced" (1).

In the intervening period, advocacy of TNVR has remained strong particularly, but not exclusively, among local, national, and international animal welfare non-governmental organizations (NGOs), and in developed countries. However, there is some evidence that in countries where free-roaming cats are thought to pose a substantial threat to native species, lethal culling, and perhaps even the complete extermination, of free-roaming cats is being seriously contemplated as a matter of national policy (2, 3). Promoting such a policy appears to ignore the potential for effective TNVR activities and fails to account for public sentiment in favor of a more compassionate approach.

Ten years following the publication of Robertson's review, when this Research Topic was first conceived, we called on contributors representing a broad range of disciplines from across the globe to submit their latest research investigating various aspects of TNVR. Compiling the resulting articles, three distinct (but also, at times, overlapping) themes emerged: (1) human attitudes and beliefs regarding the management of free-roaming cats, (2) the effectiveness of TNVR as a management tool, and (3) the behavior and welfare of free-roaming cats.

HUMAN ATTITUDES AND BELIEFS REGARDING FREE-ROAMING CATS

Employing structural equation models to analyze survey results from their case study from Bulwell, England, McDonald et al. developed a framework "whereby TNVR operations can be embedded within community engagement." And successful engagement requires a deep understanding of a range of underlying factors: "the drivers of behavioral intention go far beyond a lack of awareness alone… attitudes, perceptions and knowledge are all significant drivers." Wolf and Schaffner examine some of these same drivers through the lens of "our evolving ethics." Focusing on an aspect of the issue that Robertson left largely untouched, the authors situate the current trend toward TNVR as a preferred management scheme within the larger sociocultural context, specifically the "profound shift away from an anthropocentric utilitarian ethical framework toward a zoocentric virtue-based ethical framework."

In one of three articles from researchers in Australia, where the government has publicly "declared war" on feral cats (4), Riley provides a historical perspective on the "changing legal status of cats… from friend of the settlers, to enemy of the rabbit, and now a threat to biodiversity and biosecurity risk." Although TNVR is "unlikely to provide a complete solution to the problem of free-roaming cats in Australia," Riley argues for its inclusion in policymaker's "suite of official measures." Also reporting from Australia, Rand et al. present the results of their survey of Brisbane residents. "After being informed about [TNVR] programs for management of urban stray cats," explain the authors, 79% indicated a preference for TNVR while 18% agreed with the city's current practice of lethal control, with the remaining 3% choosing to "leave the cats alone." In a related article, Rand et al. examined the "perceptions of support and opposition from various stakeholders" among individuals involved with TNVR in Australia through an online questionnaire. Their results highlight the potential conflicts faced by practitioners and "authorities, landowners, neighbors, and people living and working in the area," prompting the authors to conclude that there is a "need for legislative change to facilitate best-practice TN[V]R."

THE EFFECTIVENESS OF TNVR AS A MANAGEMENT TOOL

Analyzing 23 years of cat census data and veterinary records for more than 2,500 cats (including 1,691 sterilization surgeries), Kreisler et al. documented a 55% decrease in the population of free-roaming cats in the Key Largo, Florida, community they studied, as well as improved welfare "as measured by increased average age of population and decreased retrovirus prevalence." Natoli et al. provide an update to an often-cited 2006 article (5) with their examination of 30 years of data to investigate the impact of a series of Italian laws designed to protect free-roaming cats, the first of which was implemented in 1991. Since 1988, 1,878 colonies have been registered in Rome alone, 89 (4.7%) of which have been eliminated and another 204 (10.8%) of which are considered stable, as a result of ongoing TNVR efforts. Hamilton details the steps involved as Hillsborough County, Florida, adopted three related programs (spay/neuter vouchers; TNVR; and a shelter-based version of TNVR commonly known as return-to-field, or RTF) for reducing the number of cats entering its shelter system and increasing the number leaving alive. Over 12 years, feline intake decreased by 51% and the municipal shelter's live-release rate reached 81.8% in 2017. Spehar and Wolf document the results of six large-scale U.S. shelter-based programs that integrated return-to-field (for "strays" brought to the shelter) and targeted TNVR, finding median reductions of 32% in feline intake and 83% in feline euthanasia. In addition, the authors report that the 72,970 cats enrolled were generally in good health, with only 0.5% euthanized due to serious health concerns. And, building upon their previous research (6), Boone et al. used stochastic modeling to compare seven scenarios for managing free-roaming cats (e.g., low- and high-intensity removal, episodic culling, and TNVR). Their findings highlight the importance of intensity "not only to reduce populations more quickly, but also to minimize the number of preventable deaths that occur over time."

THE BEHAVIOR AND WELFARE OF FREE-ROAMING CATS

As in Australia, free-roaming cats are an especially contentious issue in New Zealand. Using a newly developed "5-component visual health-related welfare assessment scale," Zito et al. found no statistical differences between the apparent health and welfare of their samples of free-roaming pet cats, managed stray cats, and unmanaged stray cats in Auckland, providing "a starting point for further research that is urgently needed in this area." Bruce et al. used small video cameras and global positioning system (GPS) technology mounted to break-away collars to document the activities of 37 free-roaming cats in Auckland, New Zealand. The authors report predation among 23 of the cats (62%) with 33% of events resulting is successful prey capture (46% invertebrates and 7% skinks; no mammals, birds, or amphibians). A total of 326 risk behaviors was observed among 32 cats, mostly cats "venturing onto the road."

CONCLUSION

Robertson's 2008 review (1) concludes with the observation that "the scientific literature on feral cats is increasing and is essential for modifying and improving current control methods." As the articles compiled for this Research Topic illustrate, this body of literature has expanded considerably over the past decade, demonstrating TNVR's value as a tool for managing free-roaming cat populations.

AUTHOR CONTRIBUTIONS

PW drafted the editorial, which was reviewed and accepted by JS, GW-S, JL, SR, and MF.

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ORIGINAL RESEARCH
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Integrating Trap-Neuter-Return Campaigns Into a Social Framework: Developing Long-Term Positive Behavior Change Toward Unowned Cats in Urban Areas

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Cat management is often discussed in terms of population reduction, with trap-neuter-return (TNR) campaigns commonly organized to manage unowned urban cat populations. However, long-term effectiveness is only possible if positive neutering practices are continued by local residents. Here we discuss how implementing TNR within a wider framework of social engagement has the potential to tackle cat overpopulation and instill long-term positive behavior change toward them. We demonstrate how community engagement pre-TNR can help establish a baseline of the attitudes, knowledge and behavior concerning cats. Using a case study, we explore whether this information can be linked with positive intended behavior based on intentions to arrange for neutering of unowned cats. Structural equation modeling indicated that negative attitudes toward cats and reduced knowledge around neutering reduced the likelihood of positive intended behavior. This result was underpinned by the indirect effects of perceptions of unowned cats and reduced understanding of their needs. Utilizing these results alongside an understanding of the values and motivation of the community allows for tailored and targeted education and intervention. In turn, this addresses the underlying knowledge gaps and perceptions regarding cat welfare. This framework can help address the challenge of cat management because it: (1) takes an integrative approach to identifying the motivations of communities to take responsibility for unowned cats; (2) changes the structure of the social environment, encouraging positive neutering practices for unowned cats. In turn this improves the impact and longevity of TNR campaigns whilst promoting positive welfare change for unowned and owned cats; and (3) appreciates that opinions are likely to vary hugely between areas, therefore providing an adaptable community level approach.

Keywords: Domestic cat, *Felis catus*, urban environment, behavior change, neuter, TNR, stray cat, unowned cat

INTRODUCTION

Human behavior change is fundamental to tackling anthropogenic problems, both globally and locally. The unowned cat overpopulation problem in urban areas is one such issue, largely a function of socio-demographic parameters (1–3), human behavior (4), and attitudes (5, 6). Large numbers of free-roaming unowned cats can be found in areas of high human population density where they are an integral, if sometimes contentious, part of the community. Although no accurate population estimates for unowned cats exist in the United Kingdom (UK) their prevalence in urban areas is often of animal-welfare (7–9), public-health (8, 10), and environmental (9) concern. Human behavior is a key contributor to unowned cat populations, with abandonment of unneutered cats and unwanted litters providing a persistent source of unwanted cats in the environment (4). Additionally, the provision of neutering for unowned cats will largely be influenced by a community's capability, opportunity and motivation to care for unowned cats. Consequently, the long-term impact of any management that aims to control breeding, such as trap-neuter-return (TNR) campaigns, can be undermined by local neutering practices, with TNR treating the symptoms of the overpopulation problem but not necessarily the cause.

The dynamic nature of unowned cat populations, influenced by constant immigration, and emigration (4), necessitates intensive and persistent neutering campaigns of unowned cats to prevent increases in population size (11–13). Such TNR work is both time and resource intensive, yet is at risk of becoming insignificant in the long-term if human behaviors and attitudes within the community are not taken into account (3, 4). The barriers which exist for people to conduct their everyday lives can impact hugely on any other desirable behavior toward cats (3), especially as the unowned cat population is more likely to be a problem in highly deprived areas (1–3). Consequently, barriers and motivators for different behaviors toward cats will vary between people and across communities, being somewhat reflective of cultural, social, or economic differences (3). Therefore, untargeted interventions alone are likely to receive modest and variable success without looking at behaviors in the community.

Assuming the provision of affordable neutering services, the capacity of local people to arrange neutering for their cat and/or for unowned cats in their community, will still be strongly influenced by their perceptions and beliefs. Some studies have shown that the intention to neuter unowned cats is predicted by religious beliefs, attitudes toward neutering and beliefs about personal capacity (6). Additionally, the provision of care for unowned cats is influenced by feelings toward them (14). Understanding these psychological factors will allow community awareness campaigns and interventions to approach the issue of neutering in a way that is consistent with cultural, social and economic circumstances.

Here we propose a modeling framework to identify key factors underpinning positive neutering behavior in a community. We illustrate the potential for TNR campaigns to not only have short-term operational benefit but, through community engagement and behavior change interventions, also the potential to empower a community to ensure the continuation of positive neutering practices for the cat population as a whole. We provide an example of how a modeling approach can unravel the beliefs underpinning a positive intended behavior, and how this could potentially be used for further community engagement.

DEVELOPMENT OF A BEHAVIOR CHANGE FRAMEWORK

Behavioral Conditions

Education often forms the focus of any campaign to bring about behavior change, whether based on health, conservation or animal welfare. A plethora of models exist that set out to provide a deeper understanding of the psychological processes underpinning behavioral change. However, it is increasingly recognized that knowledge alone is insufficient, because many other factors influence behavior change including self-efficacy (15), social norms (16, 17) and habits (18) to name but a few. More recently these wide ranging behavioral conditions have been grouped within a single tool, the behavior change wheel (19). For the purposes of this study we will discuss behavioral concepts using the behavior change wheel, but we recognize that this framework is a synthesis of pre-existing frameworks.

Individual behavior can be driven by three essential components; capability, opportunity and motivation, termed the COM-B model (**Table 1**). Capability is an individual's ability to engage in a behavior including physical and psychological barriers to performance. Opportunity considers external factors that prompt or enable the individual to perform the target behavior. These include social opportunity based on the positive or negative influences of social norms and community values and physical opportunity determined by situational or environmental factors. Motivation includes all internal factors that trigger behavior, including knowledge-based, reflective, and conscious motivation and automatic impulsive and emotionally driven motivation. Effective behavior change therefore requires maximizing capability to regulate one's own behavior, maximizing opportunity to support desired behavior, increasing motivation to engage in desired behavior and reducing motivation to continue with undesired behaviors. Understanding these key principles of behavior change allows development of tailored interventions.

There are nine intervention functions: Education, Persuasion, Incentivisation, Coercion, Training, Enablement, Modeling, Environmental Restructuring, and Restriction [see (19) for a full summary]. A key first step to deciding interventions is to define the problem and understand the barriers to, and facilitators of, positive change.

Applying a Behavioral Change Framework to TNR

Local neutering practices of both owned and unowned cats will be important factors in driving the number of unowned cats in the community. Therefore, desired behaviors include arranging or taking unowned cats to the veterinarians to be neutered and early

TABLE 1 | COM-B factors, interventions and behavior change techniques in relation to the behavior of reporting stray cats for neutering.

COM-B categories	Definition	Relevance of COM-B component	Intervention function(s)	Example behavior change technique
Capability-physical	Capacity to physically engage in the behavior	N/A—People would generally have the physical ability to report stray cats		
Capability- psychological	Capacity to engage in the thought processes that underpin the behavior	Lack of knowledge about who to report to and how	Training	Demonstration of the behavior and instruction on how to perform the behavior
Opportunity-social	The social and/or cultural features that enable a behavior	No support or prominent community role models obviously doing the behavior	Environmental restructuring; Modeling; Enablement	Restructuring of social environment, providing social support and demonstration of behavior
Opportunity-physical	Situational or environmental features that enable the behavior	No resources or opportunities provided	Training; Environmental restructuring; Enablement	Restructuring the social environment by providing routes to report unowned cats
Motivation-reflective	Conscious thought processes	Worries about what to do, how to report pets, lack of knowledge and confusion	Enablement	Restructuring social environment and providing social support e.g. providing tools to enable the intended behavior
Motivation-automatic	Automatic thought processes driven by impulses, emotions and beliefs	Reporting unowned cats not habitual behavior	Training; Environmental restructuring; Enablement	Restructuring social environment, providing social support, and demonstration of the behavior

neutering of owned pets. Barriers to positive neutering practice may be due to limited capability, motivation and/or opportunity (examples in **Table 1**). Consequently, it is essential to engage with communities to understand specific and localized drivers of, and barriers to, desirable behavior toward cats.

Applying a systematic method for selecting behavior change techniques includes, in the first instance, making a behavioral diagnosis and identifying which of the behavioral conditions are important barriers. This is then linked to specific interventions that, in turn, can guide the most relevant behavior change techniques (**Table 1**). By undertaking this action, TNR interventions may be in a much stronger position to have a long-term and perpetuated impact in local communities.

In practice, understanding and modeling such a complex system firstly requires engaging with the community and using a survey-based approach and/or detailed focus groups to understand behaviors of interest and their potential underpinnings. Secondly, it requires an adaptable modeling framework that is capable of integrating a comprehensive set of behavioral concepts. The framework should allow for robust hypothesis testing and development of theories regarding the ways people think about cats.

Engagement and Targeted Campaigns

Once the behaviors of interest have been identified, data concerning those behaviors should be gathered at the start of the campaign. Surveys and/or focus groups can be used as tools to explore the range of different behavioral barriers previously described. Surveys and community engagement prior to TNR has three direct benefits; (1) data can be gathered to explore barriers to positive neutering practices (2) areas of high unowned cat density can be identified in advance via community knowledge, and (3) buy-in and awareness of TNR within the community is increased prior to implementation.

Data gathering methods will be resource and area dependent. Although in-depth discussion of survey implementation is beyond the scope of this article, generally face-to-face surveys are likely to deliver the most representative results, yet are also the most expensive, requiring the use of highly trained interviewers. Telephone or postal surveys may provide a good alternative. Online surveys are often used as a cost-effective means to gather data, however they are seldom representative of the general population, due to biases related to internet use and access. With all approaches, careful consideration of biases will need to take place and weighting should occur if samples are not representative (20). Questions should target the behavior of interest, behavioral categories and demographic information to ensure representative responses. Additionally, engagement within the community provides an opportunity to identify areas where TNR should be focussed by asking about the number and location of unowned cats in the area.

The knowledge from focus groups and/or surveys can be used to improve community understanding around cats. It may also involve them in solutions that are acceptable whilst tailoring culturally appropriate information to empower individuals within communities. Such processes may function to embed positive behavioral changes regarding cats which persist into the future. Interventions such as posters, social media, leaflets, public

events, school visits, and local TV and radio can all be used to ensure the community remains at the heart of the campaign.

How to Analyse Survey Data

With results of large surveys, an exploratory phase is often helpful in order to evaluate the key relationships between variables. Principal component analysis (PCA) distills multiple correlated variables into singular axes and indicates the degree to which survey items load onto those axes. It is a useful tool to reduce the dimensions of the data, condensing large datasets based on the correlations among multiple survey questions. This is often a helpful first step to understand the underlying correlations that account for most of the variation and structure the data.

Utilizing results from exploratory PCA analyses, structural equation modeling (SEM) can provide a more process-led approach, considering survey items as part of a system with inter-dependent relationships, both correlative and causative. It does so by incorporating a network of equations that accounts for composites of variables, which underlie latent social constructs. For example, perceptions of unowned cats may be underpinned by several survey questions, including both negative and positive perceptions. In this scenario, perceptions would be a latent (unobserved) variable. Multiple latent variables, determined by correlated survey variables, can be incorporated in the model. This allows for simultaneous assessment of interrelationships among different social constructs, whilst including several independent and dependent variables e.g. perceptions, attitudes, knowledge, intended behavior and compliance behavior. The first step of SEM therefore focuses on creating the latent constructs that comprise the various elements of the framework. SEM then provides a means to assess how those constructs are related and the directionality of significant relationships, offering a straightforward method of addressing multiple relationships simultaneously. Consequently, this allows for the testing of theoretical psychological frameworks. SEMs are particularly well suited to model multiple associations within a survey. They combine correlated variables and apply multivariate techniques to determine how interacting concepts influences a key question (or latent variable) of interest. SEMs can therefore, be applied to explore drivers of intended or reported positive behaviors toward cats, assessing which social constructs underpin those behaviors.

CASE STUDY

Using a case study, we provide an example of how TNR campaigns can be part of a wider community engagement program to initiate positive behavior change toward cats.

Study Area

Bulwell is an old English market town of ∼8,000 households about 4.5 miles northwest of Nottingham, England. It was chosen as an area where unowned cats were thought to be prevalent from previous charity work in the community. Additionally, Bulwell was in the 10% most deprived wards in the UK (21), therefore perhaps more likely to have cat overpopulation (2) and animal welfare issues.

Engagement

Engagement started in September 2016, before the commencement of the TNR operations, and continued throughout the campaign (**Figure 1**). It consisted of a variety of communication methods including a combination of face-face engagement and one-way communications. The campaign was called "Bulwell Cat Watch," to maintain a sense of community ownership to the project.

Face-to-face engagement included interviews with residents. To build local awareness of, and trust in, the team a drop-in point was also established. This provided a social hub for interested residents to talk to the outreach team, report on unowned cats and find out more about the work within the community. To target a wider audience numerous community events were held such as fun days alongside team attendance at other local community events. Attending and holding events reached out to people who would not otherwise proactively engage, yielding new information and engaging new audiences (**Figure 1**).

Information regarding areas where unowned cats are reported to occur (cat hotspots) were used to target leafletting prior to TNR. Posters and leaflets were also provided in local shops and targeted Facebook adverts were used for online communications.

In addition, a Facebook group was set up for the project that was largely community led. Content and conversations were decided by the participating Bulwell residents, with the community outreach team contributing and responding to posts. This online community shared images or reported sightings of unowned cats, reported lost, or found pet cats and shared advice around looking after local cats. The group engaged cat-lovers, the target audience for taking action, encouraging reporting of and responsibility for unowned cats. The nature of Facebook groups means that their membership and content builds and evolves organically, providing a low-resource way to reach out to and engage with residents.

Offering different channels for people to report cats maximizes participation. A mobile application was developed to provide another means to support residents to report cats easily and accurately. Local news coverage also introduced Cat Watch to residents and provided progress updates.

Survey

Overview

A cross-sectional random-sample survey was carried out with residents. Field researchers from The Campaign Company (TCC) went door to door to conduct face-to-face interviews over 3 weeks in July 2016.

Survey questions were designed to assess the likelihood of individuals taking or arranging for neutering of unowned cats, as a measure of positive intended behavior. Behavioral intention is thought to directly influence behavior (22). To understand what drives such intentions a range of questions were asked around awareness and knowledge of cat welfare and neutering, barriers, and motivators for neutering cats and socio-demographic status. Additional questions were asked about the number of unowned cats in local areas, providing an indication of their locations and therefore, operational value to identify areas where both TNR and engagement may be most beneficial. In total twenty

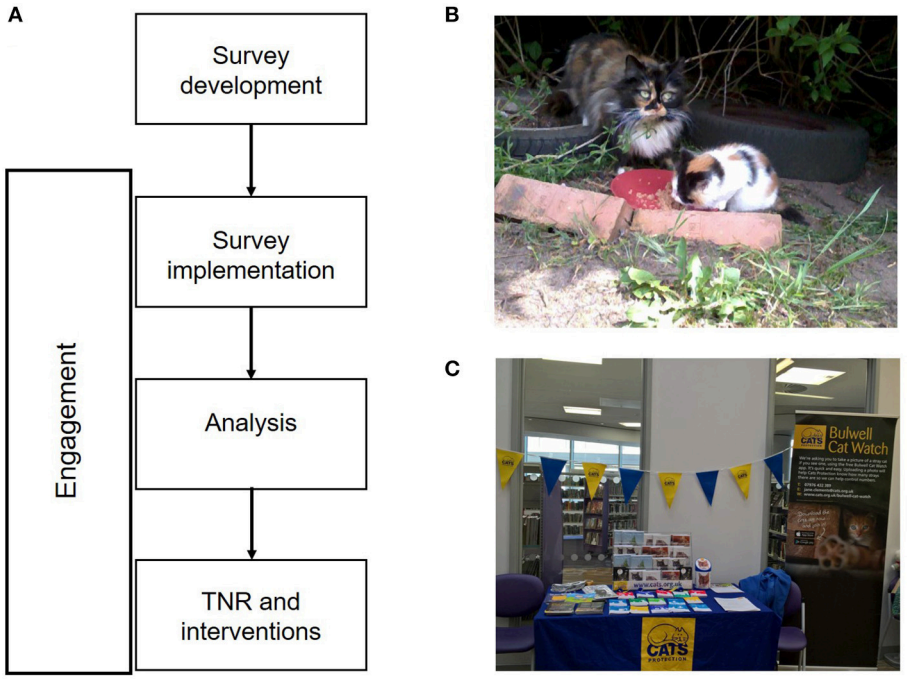

FIGURE 1 | (A) Framework for engagement and TNR activities. **(B)** Stray cats were reported by local residents **(C)** Example of wider community engagement program.

questions were asked around unowned and owned cats in the community (see **Supplementary Table 1**). Additional questions concerning the demographics and profiles of respondents were also included, but are beyond the scope of this study and not discussed further here. The survey took on average 15 min to complete.

Respondents totalled 776 of which, 23% ($n = 178$) owned a cat and 49% ($n = 377$) stated they liked cats either a little or a lot. However, most people (87%) identified negative consequences of unowned cats in the community, with dirtiness and smell the most commonly stated reasons, followed by fighting with pet cats and noise (**Table 2**). Unowned cats breeding with pet cats was identified as a problem by a small minority (14%) of respondents (**Table 2**).

Knowledge of neutering showed substantial variation. Only 37% of people correctly disagreed with the statement that "related cats would not mate with each other," with the remainder either agreeing or unsure. Over two-thirds of respondents agreed that neutering reduces antisocial cat behavior such as wailing and spraying, with the remainder either disagreeing or not sure (**Table 2**).

The majority of respondents thought it was very or quite important to provide neutering and veterinary treatment for unowned cats. However, only 18% of people thought that the community were responsible for looking after unowned cats, with charities considered responsible more often (39%; **Table 2**).

The majority of people (68%) said they were unlikely or very unlikely to arrange or take an unowned cat to be neutered, with only 25% stating they were likely to engage with unowned cat neutering (**Table 2**).

Model Outcomes

To explore the attitudes, knowledge and perceptions that underpin the likelihood that individuals will arrange neutering for unowned cats, an initial exploratory PCA was used to assess the degree to which different survey items were aligned. This approach reduced the dimensions of the data to principal components, which incorporated the variables that had the highest correlations. The first two principal components explained almost 50% of the variation in the data. Intended behavior was correlated with both PC1 and PC2, allowing identification of key variables that were also correlated with the principal components (**Figure 2** and **Table 3**).

PCA is limited in that it is correlative. To incorporate both correlative and causative effects we explored links between interrelated variables using structural equation models (SEMs) using package Lavaan (23) in program R v. 3.4.3 (24). We used a chi-square test, the root mean square error of approximation (RMSEA), and the comparative fit index (CFI) as measures of model fit for the final model, according to the following criteria (25): (1) P-values of chi-square tests > 0.05; (2) lower 90% confidence intervals of RMSEA close to 0; and (3) CFIs ≥ 0.9.

Our starting model explored whether behavioral intent was driven by attitude, perceptions and knowledge of neutering and the needs of unowned cats. Correlations between all drivers were also incorporated in the model. Significance was consequently assessed by examining standard errors and P-values associated with each SEM path.

Our final model indicated that behavioral intent to arrange neutering for an unowned cat was caused by knowledge of neutering and a positive attitude toward cats

TABLE 2 | Percentage distribution alongside sample size of respondents' responses to key survey questions.

	% (*n*)
PERCEPTIONS OF UNOWNED CATS	
Think that there are negative consequences of unowned cats in the community	87 (676)
Cite the following bad points of unowned cats include:	
Dirty	40 (309)
Smell	20 (157)
Fighting with pet cats	18 (137)
Noise	17 (130)
Breeding	14 (112)
Think that there are positive consequences of unowned cats in the community	42 (321)
Good because they control vermin	20 (156)
KNOWLEDGE OF UNOWNED CATS NEEDS	
Think that it is very or quite important that unowned cats are provided with neutering	74 (571)
Think that it is very or quite important that unowned cats are provided with treatment	72 (559)
Think that everyone in the community are responsible for looking after unowned cats	18 (137)
Think that charities are responsible for looking after unowned cats	39 (302)
KNOWLEDGE OF NEUTERING	
Disagree that related cats won't mate with each other	37 (290)
Agree that neutering reduces anti-social cat behavior, like wailing and spraying	67 (519)
Disagree that female cats should be allowed to have kittens before being neutered	47 (364)
BEHAVIORAL INTENT	
Likely to arrange or take an unneutered cat, which you believe to be unowned, to the vet to be neutered	25 (192)

(**Figure 3**). However, there were also numerous indirect effects due to correlations between perceptions and knowledge regarding the needs of unowned cats. This final SEM fit the data well ($\chi 2 = 19.11$, $p = 0.161$; RMSEA = 0; CFI = 0.99).

TNR Campaign and Interventions

In the first instance, interventions focussed on targeting the behavior of reporting stray cats to make this the "norm." The provision of different channels to report cats and a strong community presence both face-to-face and online all helped develop both the capability and opportunity to report unowned cats.

To increase motivations, the findings of the survey indicated that knowledge and attitude toward cats had the strongest influence of behavioral intent. Consequently, this was used to inform umbrella messaging, which highlighted the benefits of having stable, neutered cat populations, and how TNR would be used to achieve this. Additionally, increasing knowledge of neutering within the community, through face-to-face events and online, helped to improve behavioral intent.

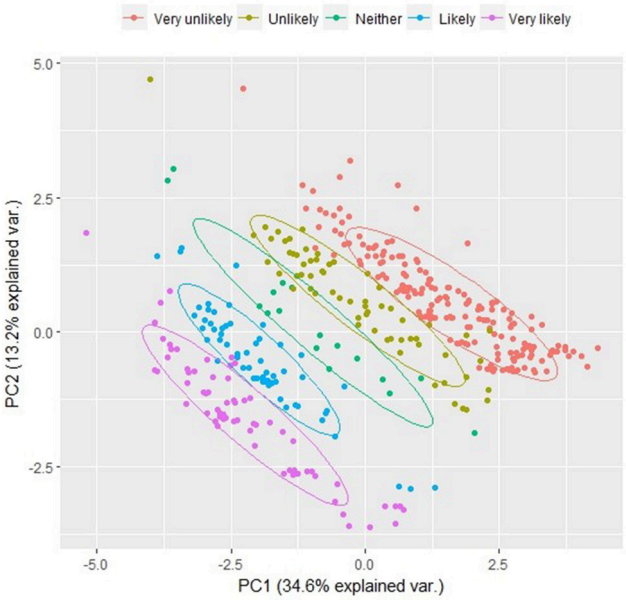

FIGURE 2 | First and second principal components. Colors represent the likelihood of arranging veterinary treatment, which is aligned on both the first and second principal component.

TABLE 3 | The latent variables and underlying survey items, alongside the results from a principal component analysis.

Latent variable/survey item	Loadings (1st PC)	Loadings (2nd PC)
BEHAVIORAL INTENT		
How likely are you to arrange or take an unneutered cat, which you believe to be unowned, to the vet to be neutered?	0.58	0.73
KNOWLEDGE OF UNOWNED CATS NEEDS		
How important do you think it is that unowned cats are provided with neutering?	0.14	
How important do you think it is that unowned cats are provided with treatment?	0.16	
KNOWLEDGE OF NEUTERING		
Disagree that related cats won't mate with each other		0.10
Agree that neutering reduces anti-social cat behavior, like wailing and spraying		0.10
PERCEPTIONS OF UNOWNED CATS		
Total number of bad points respondents stated	0.23	
ATTITUDE TOWARD CATS		
How much do you like or dislike cats?	0.59	0.49
Do you own a cat?	0.13	0.13

The first and second principal components (PC) are aligned with behavior intent. Variables with loadings >0.10 are shown here. The higher the component loading the more important it is and therefore aligns with behavioral intent.

Prior to TNR, 3 months of data on the whereabouts of strays were collected identifying hot spots and targeting TNR to specific streets. Actual TNR started in November 2016, and included simultaneous engagement within hot spot areas

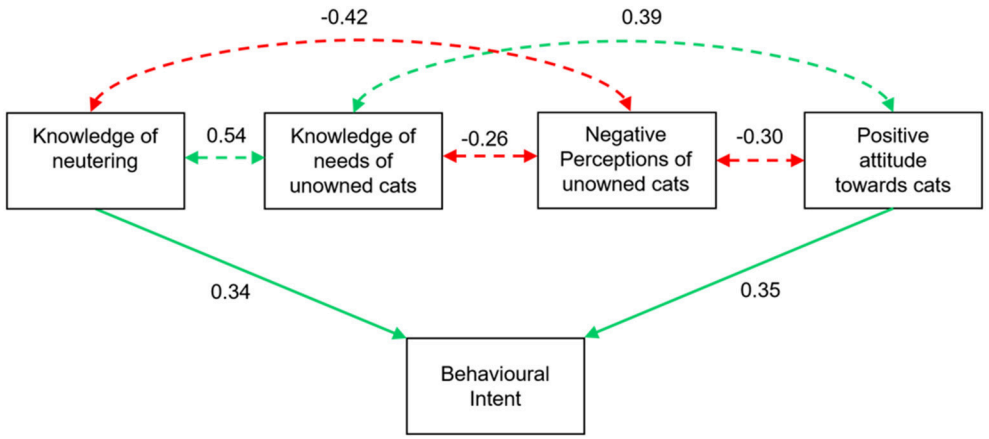

FIGURE 3 | Path diagram used in final structural equation model. See **Table 3** for definition of variables. Solid lines indicate significant direct effects and dashed lines indicate significant correlative effects. Green show positive effects and red negative effects.

through door knocking, leafletting and posters, alongside TNR operations. Advice was provided to 1,200 households across 16 hotspot streets, via direct conversations or the posting of an information leaflet. Consequently, the TNR operation itself provided value as both a process and an intervention. As cats underwent TNR the public were concomitantly provided with information as to correct reporting of cats, appropriate food, water, and shelter provision, and how to help with trapping. Therefore, TNR helped to improve the community's sense of agency. Additionally, seeing the benefits of neutered cats through TNR also had to potential to counteract negative perceptions.

Outcomes

The direct and immediate benefits of community engagement and TNR are the numbers of unowned cats that are taken in for neutering and either returned to the community or rehomed when appropriate. Intelligence regarding unowned cat hotspots was obtained from the 776 household surveys. In addition, a variety of ways to report cats were put in place, including mobile application, face-to-face, and online. This resulted in 124 individual reports of unowned cats within the Bulwell community. This information enabled identification of hotspots and targeted TNR, resulting in 104 unowned cats taken in for neutering, of which 87 were returned and 17 were euthanized on veterinary advice due to poor welfare. In addition, a further 51 unowned cats were fit for rehoming and 7 cats were already microchipped and therefore subsequently reunited with their owners. Further to this, 92 owned cats were neutered as an indirect consequence of the Bulwell Cat Watch campaign specifically.

Long-term benefits of community engagement and TNR will come from behavior change relating to positive neutering practices. Alongside engagement at the permanent hub, between October 2016 and July 2018, the community engagement team attended or ran 29 community events, these included fun days, talks to local community groups including schools and stalls at local community events, with an estimated engagement of over 1,000 individuals. Online engagement via a Facebook group created an active community with ∼600 members, averaging 41 posts in 30 days, reported in July 2018.

In addition, 11 people from the Bulwell community are now actively volunteering to aid community cats in various registered roles such as TNR volunteer, social media volunteer, and community project officer volunteer.

Although, further evaluation of long-term community impacts is needed. Initial evaluation surveys of 54 residents undertaken after TNR had started indicated that the majority of people perceived the Cat Watch to be good or very good for Bulwell cats (96%) and also the community generally (90%). Specifically, Cat Watch was perceived to help the unowned cats, provide support to enable people to help stray cats and raise awareness about stray cat numbers.

> **"Because it is making us aware to look out for and help stray cats. Didn't know there was so many strays."**
> **"Some people don't know what to do about stray cats or how to get them help or find information to help the stray cats."**

Also, responses suggest that Bulwell Cat Watch is changing awareness, attitudes and behavior. With most people agreeing or strongly agreeing that they are more concerned about unowned cats, more aware of cat welfare issues in the community and they will do more to help unowned cats.

> **"They do an excellent job to improve the stray cat population. Neuter and give care when a cat is reported that needs help. Made community more aware of problems and advise [sic]."**
> **"It has given me advice on how to deal with a stray cat."**

DISCUSSION

Without continued neutering within the community, TNR work is at risk of failing to make significant progress in urban areas and its long-term impact jeopardized (3). We highlight a framework,

whereby TNR operations can be embedded within community engagement. Interventions are therefore able to create a legacy of behavior change that is more likely to continue once TNR operations have ceased. We also demonstrate how statistical modeling approaches can identify the direct and indirect basis for desirable behaviors toward cats and aid tailoring of such interventions. Results from our case study affirm the idea that human cognitive biases, emotions, and behavior toward unowned cats are complex and interrelated.

We found that intended behavior toward cats was primarily driven by attitudes toward cats in general. Perceptions about unowned cats also shaped attitudes, suggesting there are higher order cognitions that strongly influence behavioral intentions. This result is not dissimilar from previous studies (5), which found people are more likely to care about cats if they perceive them positively. The most commonly reported problem created by unowned cats was their perceived dirtiness. This may reflect the importance of the community to individuals and their perceived inability to control their own environment. The intervention tools employed, including communications that highlight the benefits of population control and demonstrating how to help unowned cats, may improve perceptions of unowned cats and increase sense of agency in order to improve the community and its cleanliness. Although the extent to which social norms influence attitudes and perceptions was not included in the SEM illustrated in this paper, the perception to be "doing the right thing" is likely to help develop positive feelings toward helping cats. Consequently, interventions that increased visibility of positive behavior toward cats through a strong community presence and Facebook groups, provided another means of modeling behavior by residents. In particular, the Facebook group network that formed as part of this project, and the people within it, have the ability to share information and influence each other. As co-members of the same group people start to build relationships with each other, at a level and scale not possible solely through a TNR team.

Respondents knowledge was the second predictor of intentions. More than half of respondents were either unsure or agreed that female cats should be allowed to have a litter prior to being neutered and that related cats would not mate with each other. This result is consistent with previous studies that identified poor owner knowledge of feline reproduction (26). Additionally, knowledge regarding the needs of unowned cats was also indirectly linked to intended behavior toward them. Provision of educational material alongside demonstration of desirable behavior toward cats will also be a valuable intervention to reduce the number of unwanted litters. Preliminary outcomes from such interventions are positive with high neutering rates and positive community feedback, however going forward more in-depth evaluation will be required to explore whether both intentions and actual behavior to help unowned cats has increased.

Early engagement with the community prior to and during TNR operations had the additional operational benefit of identifying perceived areas of high unowned cat density. This is valuable as unowned densities have been found to vary dramatically even across a short distance (27). Additionally, such engagement can build trust and improve communication with cat caretakers, enabling access to previously unidentified colonies. This included those located behind homes and businesses, access to which has been identified as a logistical constraint in previous TNR programs (27). Our case study highlighted the value of different communication channels for reporting unowned cats (e.g., online, phone application, and face-to-face), alongside the initial intelligence from the survey. This intelligence resulted in targeted engagement and high rates of TNR in areas where it was most needed.

As our case study shows, the combination of survey instruments with modeling approaches can inform how best to approach community engagement and interventions. The hierarchical relationships among variables would have been missed if a multiple linear regressions were used. The modeling framework presented here is easily extended to incorporate a range of behavioral concepts and provides the basis to explore different behavioral hypothesizes. The adaptability of this approach is desirable as barriers and motivations will vary across communities and depend on the sociodemographic context (3), therefore there is much to be gained from the insight that community-level empirical data can provide. However, we note the quantitative nature of this modeling approach limits its applicability in situations where qualitative data are collected. For example, focus groups, although not discussed here, are an important source of knowledge to determine intervention approaches.

In highly deprived areas, the barriers to unowned cat management will also encompass broader community problems. Going forward, this community engagement could spark wider collaborations with other stakeholders and human agencies, such as housing authorities and foodbanks. Providing interventions that work together and address community problems will help empower individuals encouraging positive behavior. For example, offering social support has shown to be important for behavior change in other contexts (28–31), but is currently missing from traditional TNR approaches.

CONCLUSION

We have highlighted the importance of accounting for anthropogenic factors when determining appropriate interventions to ensure the long-term benefit of TNR campaigns. Our case study revealed the drivers of behavioral intention go far beyond a lack of awareness alone and that attitudes, perceptions and knowledge are all significant drivers. Studies that fail to account for specific barriers around helping unowned cats within a community may not effectively increase the capacity for people to help unowned cat populations and prevent cat overpopulation more generally. This study adds to the increasing understanding that targeted interventions are necessary for behavior change. We therefore recommend further consideration of the social context within which TNR is often implemented and ultimately application of similar approaches across other urban areas around the world.

ETHICS STATEMENT

All questionnaires were optional, and respondents were advised they did not need to take part and could withdraw involvement at any point. This study was carried out in accordance with the recommendations of University of Bristol's Ethics Policy and Procedure. The protocol was approved by University of Bristol Faculty of Health Science Research Ethics Committee approval number 38661.

AUTHOR CONTRIBUTIONS

JM coded the models, ran the analysis and wrote the paper. JC motivated the research, manages the Cat Watch project and commented on drafts. MF provided constructive input into the development of the project and commented on drafts.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fvets.2018.00258/full#supplementary-material

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The Road to TNR: Examining Trap-Neuter-Return Through the Lens of Our Evolving Ethics

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In the 2008 article "A Review of Feral Cat Control," Robertson explored the trend developing in the management of so-called "feral" cats away from lethal methods toward the non-lethal method of trap-neuter-return (TNR). The review explored various issues raised by the presence of these unowned, free-roaming cats in our neighborhoods (e.g., zoonotic disease and wildlife predation), stakeholder interests, and management options—all based on then-available information. Missing from the review, however, was an exploration of the shifting ethics underlying TNR's increasing popularity. In this essay, we explore the ethical aspects of community cat management in the U.S. as reflected in the momentum of the "no-kill movement" generally and TNR in particular. We argue that these powerful cultural currents reflect two interrelated ethical theories: (1) a zoocentric ethic that recognizes the intrinsic value of non-human animals beyond any instrumental value to humans, and (2) a virtue ethic that recognizes the legitimacy of "emotional" considerations (e.g., compassion) that rightly accompany decisions about how best to manage community cats.

Keywords: cats, feral cats, community cats, trap-neuter-return, TNR, ethics, animal sheltering, public opinion

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INTRODUCTION

In "A Review of Feral Cat Control," Robertson (1) explored the trend developing in the management of unowned, free-roaming ("community") cats, away from lethal methods toward the non-lethal method of trap-neuter-return (TNR). The review explored various issues raised by the presence of community cats (e.g., zoonotic disease and wildlife predation), stakeholder interests, and management options—all based on then-available information. Seven times Robertson alluded to the ethical implications of allowing these cats in our communities, and of the competing management methods. Missing from the review, however, was an exploration of the shifting ethics underlying TNR's increasing popularity.

In the 10 years since the publication of Robertson's review, TNR has become more widely adopted in communities across the U.S. (2), though the practice remains controversial (3). For these reasons alone, it's worth examining "the rise of TNR" through two different (but presumably related) lenses: ethics and public opinion. Among the questions we're most interested in exploring: What are the ethical underpinnings of TNR, and non-lethal management more generally? And how are these ethics reflected in the public's preference for one management scheme over others?

RECOGNIZING THE INTRINSIC VALUE OF NON-HUMAN ANIMALS

As Robertson (1) explained, "the question of ending the life of healthy animals is a far reaching ethical question, as humans do kill healthy animals for food and pest control." Indeed, the management of community cats was, historically, based almost exclusively in an anthropocentric ethical framework—community cats were trapped and killed (4, 5). Anthropocentric theories assign intrinsic value only to humans, with instrumental value assigned to all other entities based only on their use value (or perceived negative impacts) to humans. Increasingly, however, greater consideration is being given to the intrinsic value of animals—a zoocentric ethic—making their interests morally relevant (6, 7).

This shift from an anthropocentric ethic to a zoocentric ethic is, in part, the result of a growing body of research demonstrating cognition, emotion, and sentience in animals once assumed to be "unfeeling" and relegated to the lower rungs of the now-obsolete "evolutionary ladder" (8, 9). Sentience has become "a criterion of moral significance, of being the kind of entity toward which a moral agent can have moral obligations" (10). As a result, although causing harm to a morally relevant animal is not automatically considered "wrong" in an absolute sense, the moral obligations associated with the recognition of an animal's intrinsic worth require that "the burden of proof is on one wishing to harm or exploit. The contrast is as sharp as a justice system where an accused is guilty until proven innocent vs. innocent until proven guilty" (11).

THE CULTURAL SHIFT TOWARD ZOOCENTRIC VIRTUE ETHICS

Accompanying this recognition of animals' intrinsic worth is a virtue ethic based neither on maximizing "the good" (i.e., a utilitarian ethic) nor an obligation to some duty (i.e., a deontological ethic). Instead, "virtue ethics focus on the character traits, or virtues, manifested in proper conduct… includ[ing] respect, humility, generosity, integrity, patience, and, of course, compassion" (12).

Even a cursory review of current events reveals evidence of this zoocentric virtue ethic. As we draft this essay, for example, *The New York Times* is reporting that Tahlequah, a 20-year-old female orca "has been swimming with her daughter's body through choppy seas… on what social media observers and orca researchers call a 'tour of grief' " (13) that continued for at least 17 days (14). It's difficult to imagine the "tour" receiving such attention had it not been for the 2013 documentary *Blackfish*, which prompted SeaWorld, 3 years later, to halt its captive breeding program and agree to phase out orca performances in its parks by 2020 (15, 16).

Additional evidence of the powerful cultural shift toward a zoocentric virtue ethic is seen in the growing legal fight over "personhood" for certain animals (5), with perhaps the most noteworthy cases to date involving primates (17). Our increasing recognition of, and concern for, the intrinsic value of animals is also reflected in our expectations for wildlife management, which has traditionally reflected an ecocentric ethic in which the well-being of the collective (e.g., populations, species and ecosystems), rather than any individual of the collective, is the primary goal (11). In 1992, for example, Schmidt (18) proposed a "new philosophical paradigm in wildlife damage management" focusing "on a professional responsibility to *individual* animals in a population, not just 'abstract' populations or species" (emphasis added). The success of this paradigm shift can also be seen in the compassionate conservation movement's guiding principle of "first do no harm" and "desire to eliminate unnecessary suffering and to prioritize animals as individuals, not just as species" (19).

In 2008, the year Robertson's review was published, a Gallup poll of U.S. adults found that 25% agreed with the statement, "Animals deserve the exact same rights as people to be free from harm and exploitation" (20). This result was unchanged since the previous 2003 poll; in 2015, however, agreement with the statement rose to 32% (20), a 28% increase over the previous result. And a 2011 survey of U.S. pet owners found that 71% of respondents agreed with the statement "Animal shelters should only be allowed to euthanize animals when they are too sick to be treated or too aggressive to be adopted," while only 25% agreed with the statement "Sometimes animal shelters should be allowed to euthanize animals as a necessary way of controlling the population of animals" (21). When the same statements were presented to respondents of a 2017 national survey that included pet owners—and non-pet owners—agreement with the first statement dropped to 57%, most likely because, unlike in the 2011 survey, an explicit "don't know" option was offered, and selected by 17% of respondents. Agreement with the second statement, however, remained largely unchanged (26%) (22).

It's not surprising that our interest in the humane treatment of companion animals extends beyond the 94.2 million cats with whom 47.1 million Americans share their homes (23) to the millions of community cats with whom we share our neighborhoods. After all, "our moral obligations are clearer to close relations than to those who are further away from us… the wild feral cat is not just another feral animal but the close relative of the animal asleep on people's sofas" (24).

Indeed, evidence of such moral obligations is found in the results of a 2007 Harris Interactive poll commissioned by Alley Cat Allies, in which 81% of U.S. respondents indicated that leaving a community cat alone would "be the more humane option for the cat," compared to 14% who would opt to have the cat impounded and "put down." Even when presented with the possibility that the cat "would die in 2 years because it would be hit by a car," 72% expressed support for leaving the cat alone, 21% for lethal impoundment, with the remaining 7% refusing to answer or indicating that they didn't know (25). In 2014, Beall Research included the same two questions in a more extensive national survey. Seventy-three percent of respondents to the first question expressed a preference for leaving the cat alone, while 9% indicated a preference for lethal impoundment, and 18% refusing to answer or indicating that they didn't know; responses to the follow-up question were 54, 17, and 29%, respectively (26). As these surveys demonstrate, killing a healthy animal out of

fear of some *possible* future event, as is sometimes advocated to oppose TNR (27), is out of step with public opinion[1].

This low level of public support for killing animals as a means of population control (in our animal shelters or our communities) is further evidence of a shift toward a zoocentric virtue ethic that recognizes the intrinsic value of animals beyond any instrumental value to humans, and the considerable role that compassion and empathy play in our "animal control" preferences. This last point is worth highlighting since critics of TNR routinely dismiss its support by animal welfare organizations and the general public as an emotional, but ultimately misguided, response (34–37). As Rawles (10) points out, such accusations are ironic given the rational nature of "the arguments that animal welfarists draw on" from the ethics literature, which "explicitly *disavow* any appeal to emotion, utilizing instead a very hard-nosed appeal to consistency and logical reasoning."

> "In my view, this approach is if anything *too* rational, leaving no room for the legitimate role of emotions in ethical deliberation and underpinned by a mistaken view of what emotions are like" (10, emphasis in original).

THE NO-KILL MOVEMENT COMES OF AGE

Historically, the management of companion animals was driven largely by the same anthropocentric utilitarian ethical framework used by wildlife managers. As a result, lethal methods were used almost exclusively. As the animal rights movement of the 1970s and 1980s began to focus attention on the intrinsic value of all animals and their right to be treated with compassion (6, 7), the U.S. animal welfare community began calling for the fundamental reform of animal sheltering: "Euthanasia might be a relatively painless end to this journey of terror," reads one seminal essay, "but each death represents an abject failure—not an act of mercy" (38).

In 2007, a year before Robertson's review was published, Winograd (39) formalized the tenets of "the no-kill movement," arguing that it "has the potential to end, once and for all, the century-old notion that the best we can do for homeless dogs and cats is to adopt out a few, and kill the rest." Since then, U.S. cities and states have adopted no-kill resolutions, making public their commitment to saving the animals entering their shelters (40–43). Accompanying such commitments is the recognition that TNR and a suite of related programs (e.g., "working cat" programs, kitten nurseries) are indispensable for achieving no-kill objectives (41, 44). Indeed, the first of the "mandatory programs and services" included in Winograd's "No-Kill Blueprint for Shelters" is TNR.

> "For feral cats, TNR is the sole alternative to the mass killing perpetrated in U.S. animal shelters… In fact, because of their unsocial disposition, they are not considered adoption candidates. As a result, there is no other animal entering whose prospects are so grim and outcome so certain. Without TNR, all feral cats who enter shelters are killed" (39).

The protections offered by these programs reflect our evolving ethics; the once-dominant anthropocentric utilitarian framework is being challenged by our recognition of the intrinsic value of cats (owned and unowned alike) and the legitimacy of compassion in shaping our moral obligation to them.

SUPPORT FOR TNR

Although TNR is controversial (3, 45, 46), even some of its harshest critics concede, "there is little question that cat advocates are winning the war in the court of public opinion" (3). Indeed, the results of public opinion surveys concerning preferred methods of community cat management show strong support for TNR, and for the non-lethal management of community cats more generally. A national survey commissioned by Best Friends Animal Society and conducted by Luntz Global in 2014 found that 68% of respondents preferred TNR, compared to 24% who chose impoundment "followed by lethal injection for any cats not adopted" and 8% who chose "do nothing" (47). Three years later, another national survey asked a nearly identical question with nearly identical results: 72% of respondents chose TNR, compared to 18% who chose impoundment/lethal injection and 11% who chose "do nothing" (22, 48). Similar levels of support have been observed at the state (49) and local levels (50).

Other surveys on the subject indicate lower levels of support for TNR; however, these apparent discrepancies are easily understood when the survey designs are scrutinized. Ash and Adams (51), for example, found that 55% of Texas A&M University employees preferred TNR to manage cats on campus. However, the "removal" option chosen by 42% of respondents was actually two options: "either humanely put to sleep or adopted out to a home" (52), with no way to parse the results. Similarly, residents of Athens-Clarke County, Georgia, were asked to rate the acceptability of four options (including "educate the public about feral cats and wildlife"), rather than select one preferred management method (or rank multiple options). As a result, the observation that "cat sanctuaries were found to be the most acceptable option to reduce feral cat populations (56%), followed by TNR (49%) and capturing and euthanizing cats (44%)" (53) tells us little about management *preferences*. On the other hand, it's clear once again—from both surveys—that there's little public support for lethal management methods.

A survey of the general public in four Florida counties found that 54% of respondents preferred TNR, compared to 25% who preferred placement in a long-term no-kill shelter and 15% preferring to trap and "euthanize" cats (54). In fact, the "long-term no-kill shelter" option is, like the sanctuary option referred to above, largely a false choice;[2] shelters committed to reducing feline intake and killing rarely house cats long-term and are

[1]This "better-off-dead" philosophy, as it's sometimes called, is not supported by the growing body of evidence demonstrating that the vast majority of community cats are healthy (28–33) and is inconsistent with a zoocentric virtue ethic that recognizes and respects the intrinsic worth of individual animals.

[2]TNR critics Marra and Santella (3) significantly understate the case when they acknowledge that "sanctuaries do not appear to be a model that can be scaled to meet the current need."

instead turning to shelter-based TNR, often called return-to-field programs (30, 54). Regardless, 85% of the "general public" (including the presumed 6% who chose "leave alone") preferred the non-lethal options offered.

Other surveys investigating public support for TNR have reported lethal methods to be more popular than non-lethal methods. Loyd and Miller (55), for example, found that 52% of Illinois homeowners "preferred capture and euthanasia for feral cat management, 27% capture-neuter-return, 18% capture and keep in shelter, and 3% chose 'other.' " However, a review of the original survey upon which these results are based (56), and its subsequent analysis, reveals a survey sample that fails to accurately represent Illinois homeowners. Chicago area residents (37% supported TNR, 38% supported "capture and euthanize," and 20% supported "capture and retain in shelter") were underrepresented by nearly 50% compared to other Illinois residents. And hunters, who were found to be less supportive of TNR (13% TNR, 73% lethal, 12% shelter), were overrepresented by a factor of almost 10. Similar sampling issues undermine the claim by Lohr and Lepczyk (57) that "live capture and lethal injection was the most preferred technique and trap-neuter-release was the least preferred technique for managing feral cats" in Hawaii. In fact, 82.5% of the study's "random residents" sample "lived in a rural area or small town" whereas "only 10% of Hawaii's population live in rural areas with fewer than 50,000 residents" (58). Moreover, 24% of "random residents" indicated that they hunted at least once annually, more than 34 times the expected rate (0.7%) based on hunting licenses purchased in 2009 (58). Thus, these surveys tell us very little about the general public's preference for managing community cats.

Support for TNR extends beyond the general public, too. The American Public Health Association's Veterinary Public Health Special Primary Interest Group, for example, "support[s] well-designed [TNVR[3]] programs as the preferred method of management wherever feasible" (59). And the National Animal Care & Control Association "recognizes that in some circumstances, alternative management programs, including [TNVR] programs may be effective, and recommends that each agency assess the individual need with their community and respond accordingly" (60).

In 2016, the American Veterinary Medical Association (AVMA) shifted its official position on the issue in a direction more favorable to TNR. Although the organization notes that "there is currently not consensus around what an ultimate solution will look like," AVMA now "encourages the use of non-lethal strategies as the initial focus for control of free roaming abandoned and feral cat populations. Public, private, and not-for-profit humane organizations and individuals must make every effort to promote adoption of acceptable unowned cats and implement sterilization programs." AVMA's previous position statement, published in 2012, made no mention of non-lethal methods and "neither endorse[d] nor oppose[d] appropriately managed cat colony programs" (61). And more recently, the American Bar Association approved a resolution "support[ing] the adoption of laws and policies supportive of TNVR programs with the intent of decreasing community cat populations and improving public health and safety…" (62).

Such endorsements reflect the considerable and varied memberships of the individual organizations—and by extension, the public they serve. Again, such clear support for TNR reflects the growing consensus that community cats have intrinsic value and deserve to be treated with compassion.

CONCLUSIONS

The momentum we're witnessing in the no-kill movement generally, and TNR in particular, reflect a profound shift away from an anthropocentric utilitarian ethical framework toward a zoocentric virtue-based ethical framework that recognizes the intrinsic value of animals beyond any instrumental value to humans and our moral obligation to treat them with compassion. Ten years ago, Robertson (1) highlighted the need for additional scientific research to "improv[e] current control methods" and called for both TNR programing and education to reduce community cat numbers. As this volume—and the works cited herein—demonstrate, the TNR literature has greatly expanded over the past 10 years; and programing, education, and outreach efforts continue to expand as TNR is adopted across the U.S., in communities large and small, urban and rural.

TNR's momentum and broad public support suggest almost an arc-of-history inevitability, and brings to mind a quote from Vucetich et al. (11): "Although the principles of social justice were developed with humans in mind, social justice's roots in intrinsic value suggests that it might be expanded and adapted to better understand what constitutes appropriate relationships between humans and the rest of the natural world."

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Both authors contributed equally to the overall development of this essay. PW contributed the majority of content related to public opinion surveys while JS contributed the majority of content related to various ethical philosophies.

[3]APHA, NACA, and ABA use the term *TNVR* to make explicit the vaccination component of TNR. Although vaccination against rabies is common practice for TNR programs located in areas of the U.S. where rabies in cats occurs most frequently—and is considered best practice for *all* TNR programs—it is not yet universal. Nor is the term *TNVR*; we've therefore chosen to use the more common term *TNR* throughout this paper.

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Decrease in Population and Increase in Welfare of Community Cats in a Twenty-Three Year Trap-Neuter-Return Program in Key Largo, FL: The ORCAT Program

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The objective of this study was to evaluate the effect of a long-term (23-year) trap-neuter-return program on the population size of community cats in the Ocean Reef Community and to describe the demographic composition and outcome of enrolled cats. A retrospective study was performed using both cat census data collected between 1999 and 2013 as well as individual medical records for cats whose first visit occurred between 3/31/1995 and 12/31/2017. Medical record entries were reviewed to determine program inputs, cat outcomes, retroviral disease prevalence, and average age of first visit, sterilization, and death through 6/11/2018. Change over time was analyzed via linear regression. The free-roaming population decreased from 455 cats recorded in 1999 to 206 recorded in 2013 (55% decrease, $P < 0.0001$). There were 3,487 visits recorded for 2,529 community cats, with 869 ovariohysterectomies and 822 orchiectomies performed. At last recorded visit, there were 1,111 cats returned back to their original location, and 1,419 cats removed via adoption (510), transfer to the adoption center (201), euthanasia of unhealthy or retrovirus positive cats (441), died in care (58), or outcome of dead on arrival (209). The number of first visits per year decreased 80% from 348 in 1995 to 68 in 2017. The estimated average age of the active cat population increased by 0.003 months each year ($P = 0.031$) from 16.6 months in 1995 to 43.8 months in 2017. The mean age of cats at removal increased 1.9 months per year over time ($P < 0.0001$) from 6.4 months in 1995 to 77.3 months in 2017. The mean age of cats at return to the original location was 20.8 months, which did not change over time. The overall retrovirus prevalence over the entire duration was 6.5%, with FIV identified in 3.3% of cats and FeLV identified in 3.6%. Retrovirus prevalence decreased by 0.32% per year ($P = 0.001$), with FIV decreasing by 0.16% per year ($P = 0.013$) and FeLV decreasing 0.18% per year ($P = 0.033$). In conclusion, a trap-neuter-return program operating for over two decades achieved a decrease in population and an increase in population welfare as measured by increased average age of population and decreased retrovirus prevalence.

Keywords: trap-neuter-return, TNR, free-roaming cats, feral cats, stray cats, community cats, animal welfare, retrovirus

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INTRODUCTION

Trap Neuter Return (TNR) programs exist in large part to reduce population size and growth rate by decreasing reproduction (1–5). Reductions in population size are desirable due to concerns regarding wildlife predation, public health and nuisance factors (6). In addition to reducing population size or growth, TNR is also promoted as a method for improving cat welfare (3, 4, 7–10). TNR of free-roaming cats may decrease predation as compared to populations that are not sterilized or provided anthropogenic food sources (11). TNR allows for the provision of veterinary care, including vaccination against infectious disease, treatment of injuries and illnesses, and humane euthanasia for animals found to be suffering. It is also a method for promoting humane communities by avoiding euthanasia as a means of population control or nuisance abatement.

Multiple studies have shown TNR to be effective in reducing population size or curtailing population growth, but they are complicated by the fact that many colonies are not geographically restricted (2, 4, 12–14). The presence of a long-term TNR program with both population level and detailed individual information was a unique opportunity to study the impacts of sustained TNR on a geographically isolated population of free-roaming cats.

The objective of this study was to evaluate the effect of a long-term (23 year) TNR program on the population size of community cats in the Ocean Reef Community and to describe the demographic composition and outcome of cats enrolled in the TNR program. These findings can be used by shelters and other invested parties to estimate the impact of TNR on cat welfare and provide input parameters for mathematical models used to estimate the impact of TNR programs on community cat populations.

MATERIALS AND METHODS

Study Community

The community of Ocean Reef occupies ∼2,500 acres on the northernmost tip of Key Largo in the Florida Keys. It is a peninsula approximately four miles long and a mile wide, with a single gated road staffed 24 h a day leading into the community. This private club is bordered on three sides by water and on the fourth by protected state and federal conservation land. Ocean Reef contains ∼1,700 homes, although much of the occupation is seasonal and there is a correspondingly large number of seasonal workers.[1]

Five unaltered cats were brought to Ocean Reef by a groundskeeper to perform rat control in the 1960s. While the cats controlled the rat problem successfully, by the 1980s, the number of cats had grown large enough to be themselves considered a nuisance to the increasing number of residents. Over 2,000 cats are stated anecdotally to have been present in the 1980s. Population control measures, which included lethal methods, were instituted to control the cat population. As an alternative to lethal measures, an individual resident began to trap cats and bring them to a local veterinarian for neutering. In 1995, the Ocean Reef Community Association (ORCA) supported the opening of a spay/neuter clinic in Ocean Reef and the formation of the ORCAT program to provide sterilization, care, and feeding to the free-roaming cats (15). In 2006, the Grayvik Animal Care Center opened, which contains a full-service veterinary and grooming clinic for the pets of residents in addition to a cat adoption center and sanctuary. There has been a single individual in the role of director of the ORCAT program since its inception, maintaining feeding stations, creating individual cat medical records and performing episodic surveys of the population. This position reports to the Vice President of Ocean Reef and is accountable for annual goals. Only two veterinarians have been the main provider of services for the population, one from 1995 to 1998, and the other since 1998.

Surveys of the cat population were performed between 1999 and 2013. Documented population surveys were not executed after 2013, although cats continued to be cared for and TNR efforts continued. Surveys were recorded by marking feeding stations on a paper map and recording the total number of cats per feeding station. The number and location of feeding stations was determined by homeowner preference, convenience, and minimization of feeding station colony size. The initial number of feeding stations was large in order to facilitate complete trapping of colonies, which was easier with smaller numbers of cats per colony, and to minimize fighting between cats. All cat counts were performed by the caretaker.

Cats were trapped when un-marked individuals were noted at feeding stations, or when previously sterilized cats required veterinary care. Individual medical records for each cat were maintained in paper files. Each cat's visit (check-in to check-out at the medical center) was documented in the medical record. At their first visit, cats were routinely neutered, marked by ear-tipping, vaccinated with FVRCP, rabies and FeLV vaccines, and dewormed (pyrantel pamoate, praziquantel). They were also tested for FIV antibodies and FeLV antigen;[2] cats that tested positive for either retrovirus were typically euthanized prior to administration of routine preventive care. Cats were determined to be euthanized for retrovirus status if they were euthanized concurrently with a positive test and there was no evidence that the cat was otherwise significantly unhealthy. A date of birth was estimated through the joint effort of the caretaker and veterinarian. Upon re-trapping, cats were provided with vaccine boosters for FVRCP, rabies and FeLV and medical care as required. Microchipping of cats was implemented beginning in mid-2005.

Study Design

A retrospective study was performed using both aggregate cat census data spanning years 1999–2013 as well as review of individual cat medical records for cats whose first visit occurred from 3/31/1995 through 12/31/2017. Feeding stations and their associated populations were geocoded to visualize the change in population over time through Geographic Information System

[1] http://www.oceanreef.com

[2] Idexx. SNAP FIV/FeLV Combo Test. Westbrook, Maine, USA.

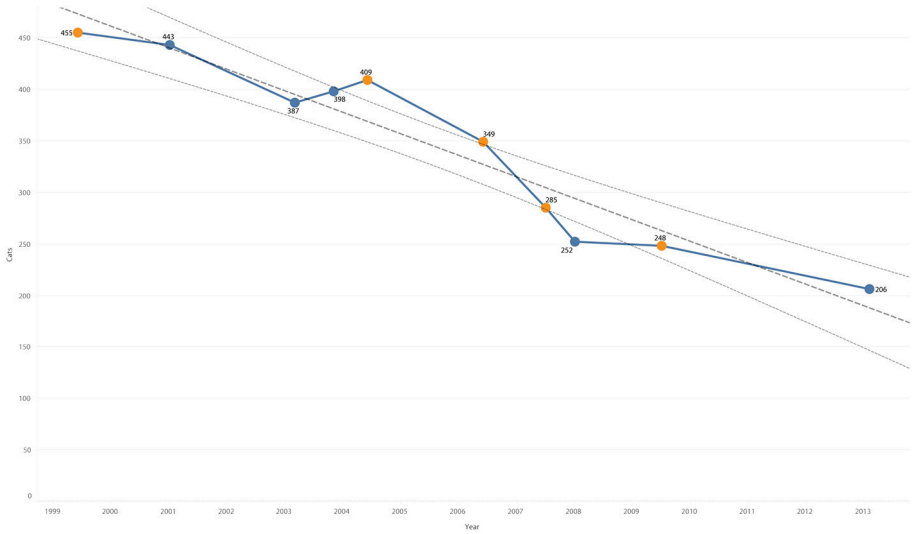

FIGURE 1 | Cat population from census by year overlaid with trend line and 95% confidence interval. Summer months in orange, winter months in blue.

mapping technology.[3] Geographic changes were visualized via hexbin maps in order to protect privacy. The paper-based medical records were coded and entered into a custom database.[4] The associated cat demographics and outcomes were used to generate descriptive statistics and graphs.[5]

For population-level analyses based on individual records (estimated count, average age, and age structure of population) a likely date of death was calculated for each cat with an outcome of returned. The estimated date of death was determined by calculating the mean age for cats at outcome which had an outcome of DOA or euthanasia. This was compared to their age at return, and if younger, the difference was calculated and added to their date of return to determine a likely date of death. If older, an additional 12 months was added to the likely date of death. The data for the population-level analyses was then constructed by creating a scaffold consisting of each day contained within the study period and performing an outer join with the individual records to select cats with a date of birth less than or equal to the scaffold date and a date of death (or estimated death) greater than or equal to the scaffold date. Average age of the cat population per year was determined by calculating the age of each cat per year between birth and removal by death or likely death which included euthanasia, died in care, dead on arrival (DOA) or missing in action (MIA). The status of MIA was assigned to cats that had not been sighted at their usual feeding station for an unusual period of time, as determined by the caretaker. Cats removed from the active population by adoption were not included in the average age analysis. Linear regression was used to analyze change over time.[6] Significance was set at $p < 0.05$ for all quantitative analyses.

[3]Esri. 2018. ArcGIS. Redlands, CA, USA.
[4]Filemaker Inc. 2015. Filemaker Pro 14 Advanced. Santa Clara, CA, USA.
[5]Tableau. 2018. Tableau Desktop 2018.1. Seattle, WA, USA.
[6]StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX, USA.

RESULTS

Population of Cats

Surveys of the cat population occurred in June 1999, January 2001, March 2003, November 2003, June 2004, June 2006, July 2007, January 2008, July 2009, and February 2013. Per the census records, the free-roaming cat population decreased over time from 455 cats recorded in 1999 to 206 recorded in 2013 (55% decrease). The decrease was linear and significant, with a slope of −0.06, $P < 0.0001$ (**Figure 1**). Neither month of the year nor a binary seasonal variable of fall/winter as compared to spring/summer were significant.

The number of feeding stations changed over time, starting with 60 stations in 1999 (**Figure 2**), and increasing to 85 stations in 2001 (**Figure 3**). Stations were maintained at a number between 76 and 82 until 2008, and then decreased to 44 in 2013 (**Figure 4**). The average number of cats per station started at 7.6 in 1999, decreased to 5.2 in 2001, was maintained at between 4.6 and 5.3 from 2001 to 2006, before decreasing to 3.1 in 2008. After 2008, the average number of cats per station increased to 4.7 in 2013 as the number of feeding stations decreased more rapidly than did the number of cats.

Individual Records

There were 3,487 visits to the clinic recorded for 2,571 records of 2,529 community cats. There was a mean of 1.4 visits per cat, with 1,995 (77.6%) cats having only a single visit. Of the 2,571 records, 119 (4.6%) were missing an estimated date of birth, 19 (0.7%) a gender and 42 (1.6%) were suspected to be a duplicate of a prior identification number. The number of clinic visits decreased 75.1% from 353 in 1995 to 88 in 2017 (**Figure 5**). The greatest decrease occurred between 1995 and 2004, with a decrease of 23.3 visits per year ($P = 0.004$). After 2004, the mean number of visits was 116.5 per year, and there was no significant difference in the number of visits between years 2005 and 2017.

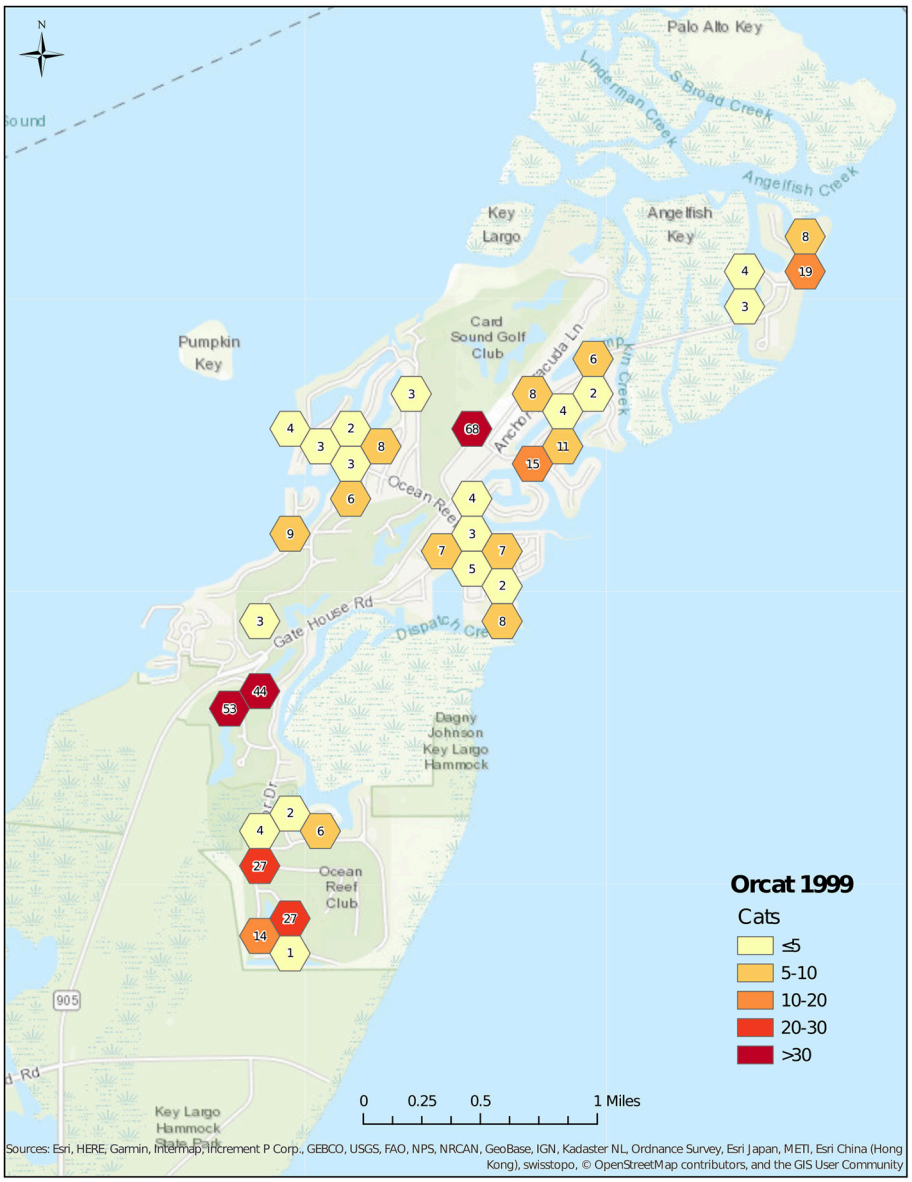

FIGURE 2 | Cat census locations, 1999.

First visits decreased 80.5% (**Figure 6**) from 348 in 1995 to 68 in 2017. The mean number of first visits was 111.5 (range 41–348). First visits fell sharply from 348 in 1995 to 52 in 2004, with a decrease of 25.5 first visits per year ($P = 0.004$). After 2004, there was a mean of 83.6 first visits per year, which did not change significantly between 2005 and 2017.

Program Inputs

A total of 1,691 gonadectomies were performed, including 869 ovariohysterectomies and 822 orchiectomies. Over 18% of cats (479) were found to be already sterilized at their first visit, whether from sterilization prior to the official ORCAT program started in 1995, duplicate cats, trapping efforts by individuals or from lost/abandoned cats. Of the cats found to be already sterilized, 196 (40.9%) were also previously ear tipped; however, 13 of these ear tipped cats were noted to not be ORCAT's. An additional 165 non-sterilization surgeries were performed to treat injuries. A total of 2,327 FeLV, 1,897 rabies, and 2,727 FVRCP vaccines were administered. Over 2,800 fecal examinations were completed, and 2,327 FIV/FeLV tests were performed. Of female cats undergoing ovariohysterectomy, 11.5% were pregnant, with a mean of 4 fetuses (range 1–6).

Retroviral Prevalence

The overall retrovirus seropositivity was 6.5%, with 9 cats positive for both FIV and FeLV. The overall prevalence of FIV was 3.3%,

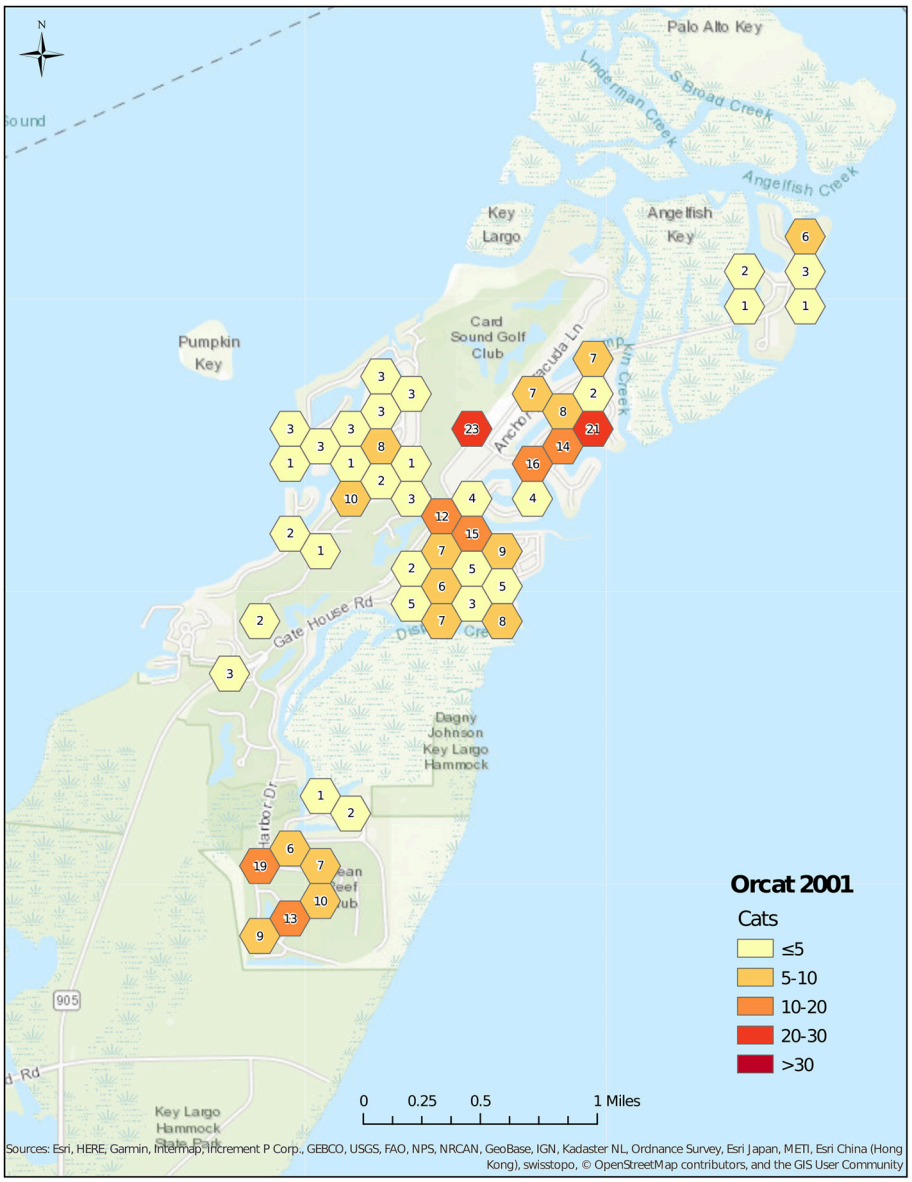

FIGURE 3 | Cat census locations, 2001.

with a range of 0.0–8.5% per year. The overall prevalence of FeLV was 3.6%, with a range of 0.0–11.6% per year. Total retrovirus prevalence decreased by 0.32% per year ($P = 0.001$), **Figure 7**. FIV prevalence decreased by 0.16% per year ($P = 0.013$), **Figure 8**. FeLV prevalence decreased 0.18% per year ($P = 0.033$), **Figure 9**.

Cat Outcomes

Outcomes for visits were classified as either returned or removed, with an average of 50.0% (range 16.7–83.3%) of visits ending in removal per year (**Figure 10**). Removal included adoption, transfer to Grayvik center, died in care, euthanasia, and DOA, while returned included outcomes of released and missing in action (MIA). Of the 1,869 visits ending in release, 318 (17.0%) released the cat to a different location than they had been trapped due to a conflict with the original location. For the final disposition (outcome of the last recorded visit), 1,111 cats were released back to their outdoor location, and 1,419 cats were removed via adoption (510), transfer to the adoption center (201), died in care (58), euthanasia of unhealthy or retrovirus-positive cats (441), or outcome of DOA (209), **Figure 11**. Six of 9 (67%) cats were euthanized for double-positive retrovirus status, 61 of 73 (84%) for FeLV positive status and 45 of 67 (67%) for FIV positive status, with the remainder of the euthanized cats, 329 (75%), euthanized due to health. Cats that were DOA had cause of death split between trauma (43.1%), unknown (43.1%), trapped in fumigation tent (9.1%), and illness (4.8%). Trauma was primarily

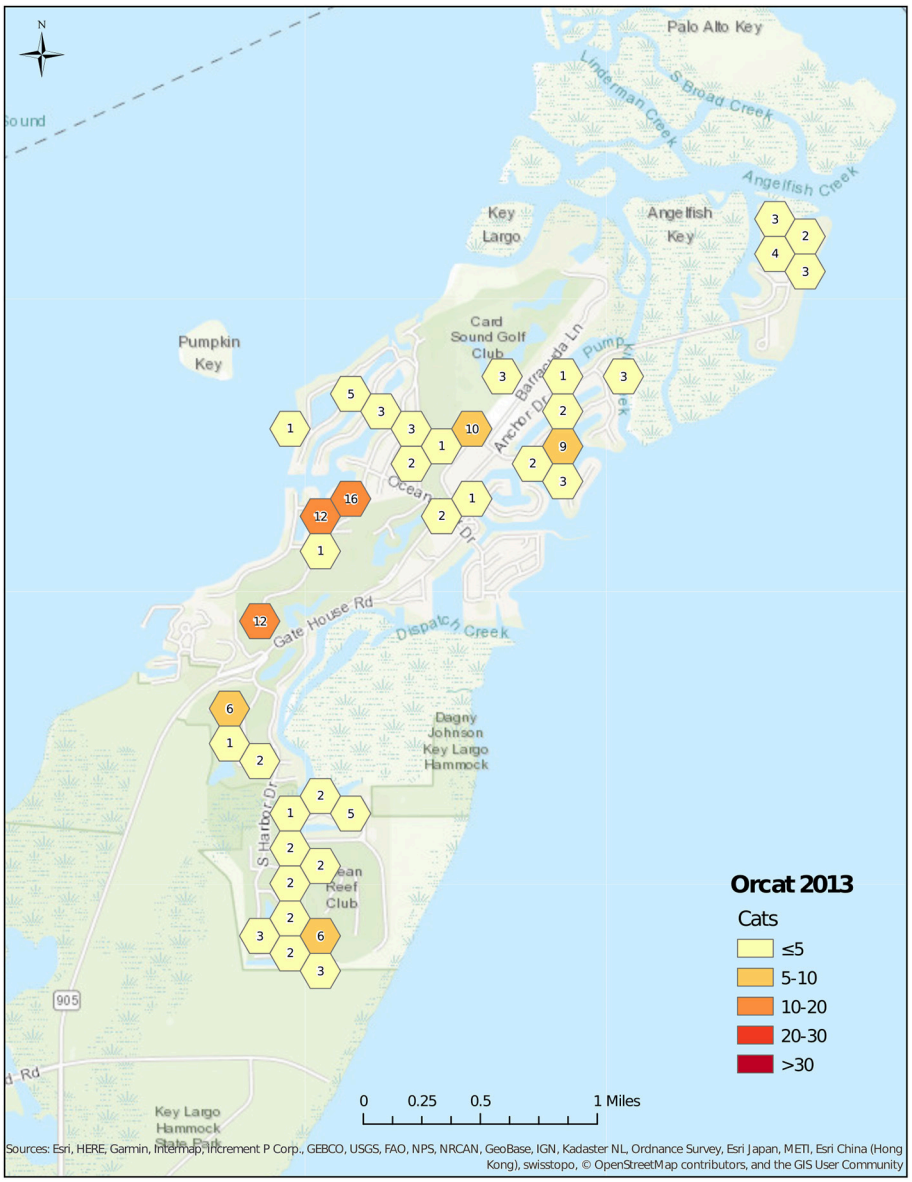

FIGURE 4 | Cat census locations, 2013.

from motor vehicles (81.1%), unknown (10.0%), and predation (8.9%).

Estimated Age Structure and Sex Distribution

The mean estimated age of cats at first visit was 21 months (95%CI 20 to 23), with a range of 0 (newborn) through 275 months. For cats sexually intact at first visit (2,026), the mean age was 11 months (95%CI 10 to 11), with a range of 0 through 204 months. For cats already sterilized and ear-tipped at first visit, the mean age was 70.3 months (95%CI 62.5 to 78.2), with a range of 6.7–204 months. For cats already sterilized, but with no documented ear-tip, the mean age at first visit was similar to previously sterilized cats with an ear-tip at 76.4 months (95%CI 69.1 to 83.6), with a range of 2.0–275 months. For previously sterilized cats, the age at first visit increased by 0.01 months per year ($P = 0.043$). There was no change over time in the age of cats intact at first visit. The estimated average age (calculated age of cats without an outcome of removed) of the active cat population increased by 0.003 months each year ($P = 0.030$; **Figure 12**). The estimated age structure fluctuated over time (**Figure 13**).

Overall, the mean age of cats at removal was 41.3 months (95%CI 38.2 to 44.4), which increased 1.9 months per year ($P < 0.0001$). The mean age at adoption was 11.3 months (95%CI 9.2–13.5), which did not change significantly over time. The mean age at euthanasia was 82.1 months (95%CI 75.3 to 88.8) which increased over time by 4.0 months per year ($P < 0.0001$). The mean age of DOA/MIA cats was 58.7 (95%CI 51.2 to 66.2)

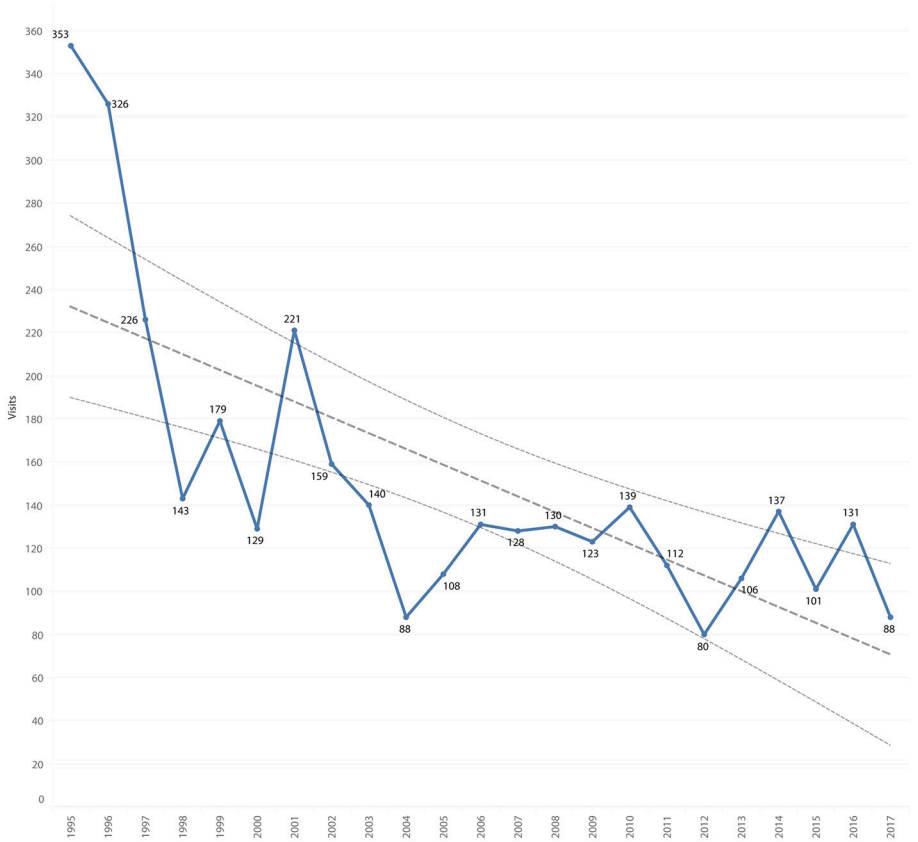

FIGURE 5 | All visits by year, overlaid with trend line and 95% confidence interval.

which increased by 1.4 months per year ($P = 0.028$). The mean age of died in care was 36.2 (95%CI 20.8 to 51.5) which did not change over time. The mean age of cats removed to the Grayvik center was 20.9 months (95%CI 15.4 to 26.5) which increased by 1.3 months per year ($P = 0.004$). The mean age of released cats was 20.4 (95%CI 18.7 to 22.1) which did not change over time. The mean age of cats euthanized for double retrovirus positive status was 3.7 years, while it was 4.1 and 2.3 for FIV and FeLV, respectively. Age at euthanasia for positive retrovirus status did not change over time. Double retrovirus positive cats not euthanized at time of diagnosis survived a mean of 13.3 months (95%CI 0 to 36.2) after diagnosis, with all double positive cats having an ultimate outcome of euthanasia. Cats positive for FIV not euthanized at time of diagnosis and with a final outcome of died, euthanized or DOA survived a mean of 15.4 months (95%CI 2.9 to 27.9) while cats similarly positive for FeLV survived a mean of 7.1 months (95%CI 0 to 19.3).

Females accounted for 52% (95%CI 49.7 to 53.6) of the population at first visit. The mean age of females at first visit was 22.9 (95%CI 20.7 to 25.1), while it was 19.4 (95%CI 17.4 to 21.3) for males. Females that were intact at first visit had a mean age of 11.0 months (95%CI 9.8 to 12.1), while males intact at first visit had a mean age of 9.8 (95%CI 8.7 to 10.9). Females that were previously sterilized were the oldest at first visit with a mean of 79.3 months of age (95%CI 71.5 to 87.2), with males that were previously sterilized having a mean of 67.5 months of age (95%CI 60.1 to 74.9). Females had a mean age of 32.7 months (95%CI 30.0 to 35.5) at last visit, while males had a mean age of 31.0 (95%CI 28.3 to 33.6). Females intact at first visit had an age at last visit of 21.1 months (95%CI 18.9 to 23.4) while males had an age of 21.5 (95%CI 19.2 to 23.9). Females found to be sterilized at first visit had a mean age of 87.5 at last visit (95%CI 79.3 to 95.7) while males had a mean age of 78.6 (95%CI 70.8 to 86.3) at last visit.

Population Estimate Compared to Census

The model of the estimated cat population based on individual records was found to decrease significantly over time ($P < 0.0001$). The decrease was similar to the census values, with comparable slopes (−0.06 for the census, −0.05 for the model). The difference in count per year between the census values and the model for years included in the census ranged from −20 to 30%, with a mean difference of 3.4%. This model estimated the free-roaming population to be 83 in 2017 (**Figure 14**).

DISCUSSION

The findings of this study are congruent with prior intensive TNR sites which show a decrease in population over time (2, 16–18).

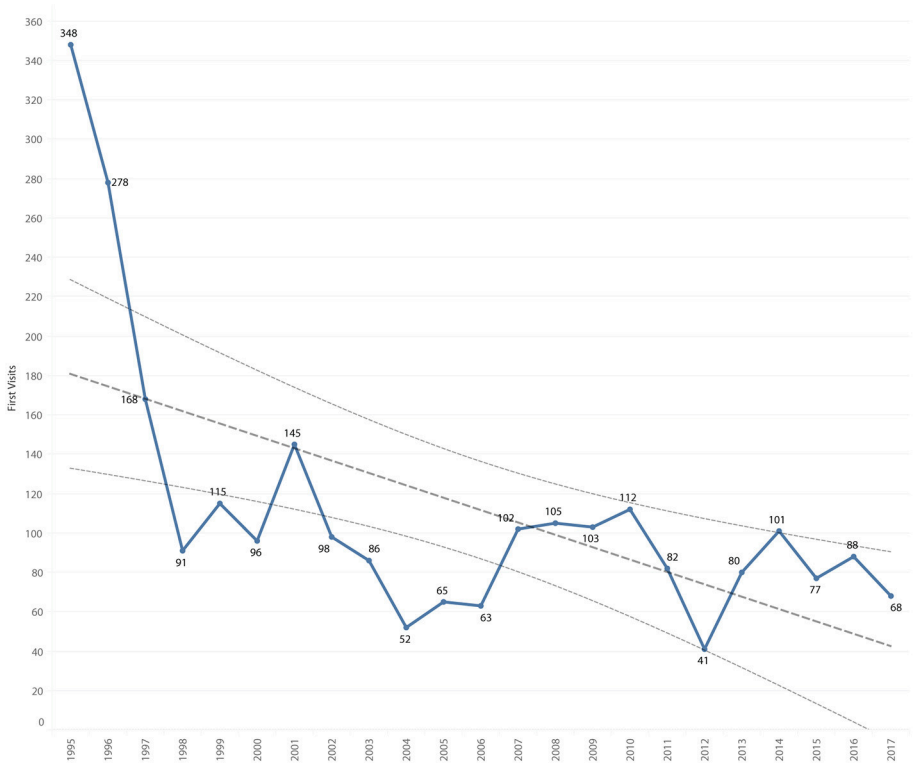

FIGURE 6 | First visits by year, overlaid with trend line and 95% confidence interval.

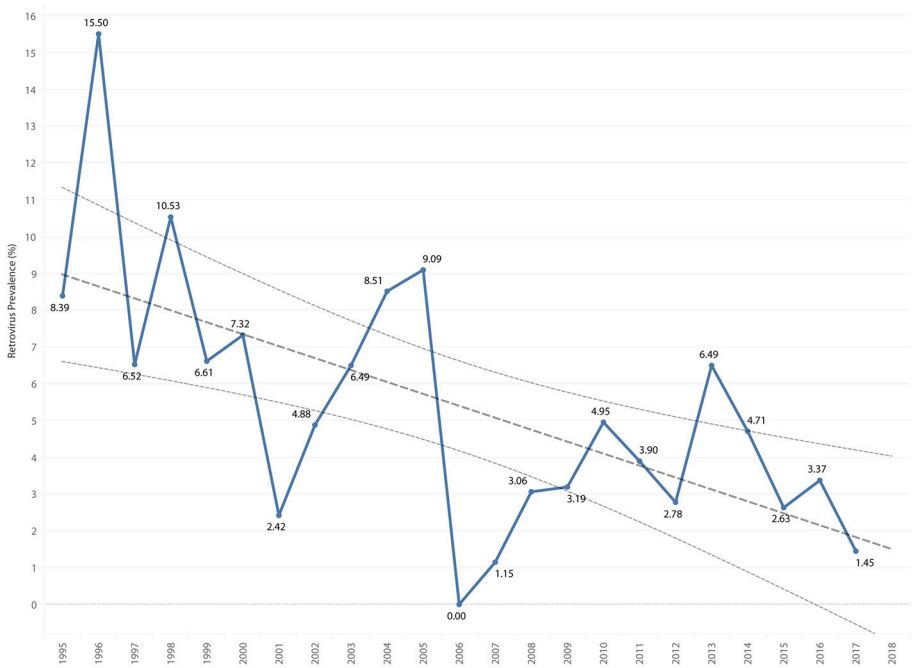

FIGURE 7 | Total retrovirus prevalence by year overlaid with trend line and 95% confidence interval.

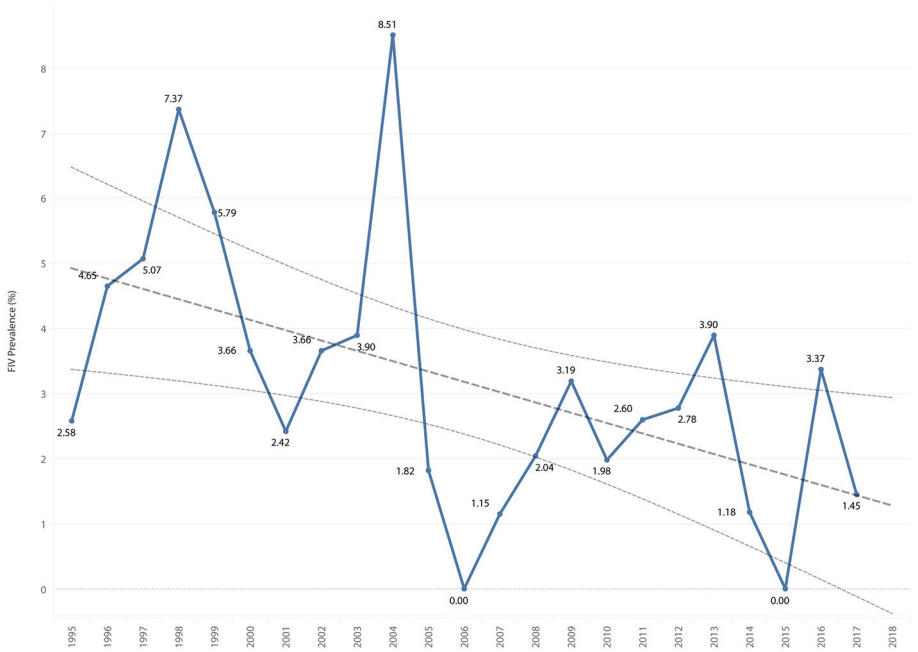

FIGURE 8 | FIV prevalence by year overlaid with trend line and 95% confidence interval.

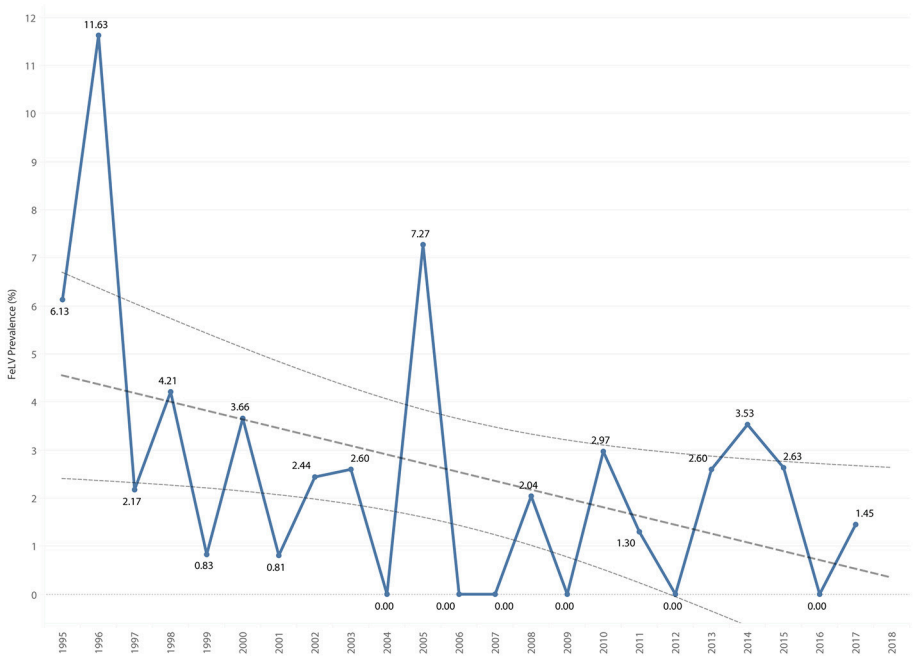

FIGURE 9 | FeLV prevalence by year overlaid with trend line and 95% confidence interval.

The geographic restriction of this location and duration of the program partially address critiques of previous studies regarding the length of observation and unknown effects of immigration and emigration (12, 19).

Both the observed and modeled population decreased over time, with minor fluctuations observed. The effects of hurricane Irene in October of 1999, Wilma in October of 2005, and Irma in September of 2017, if any, were not discernible with the

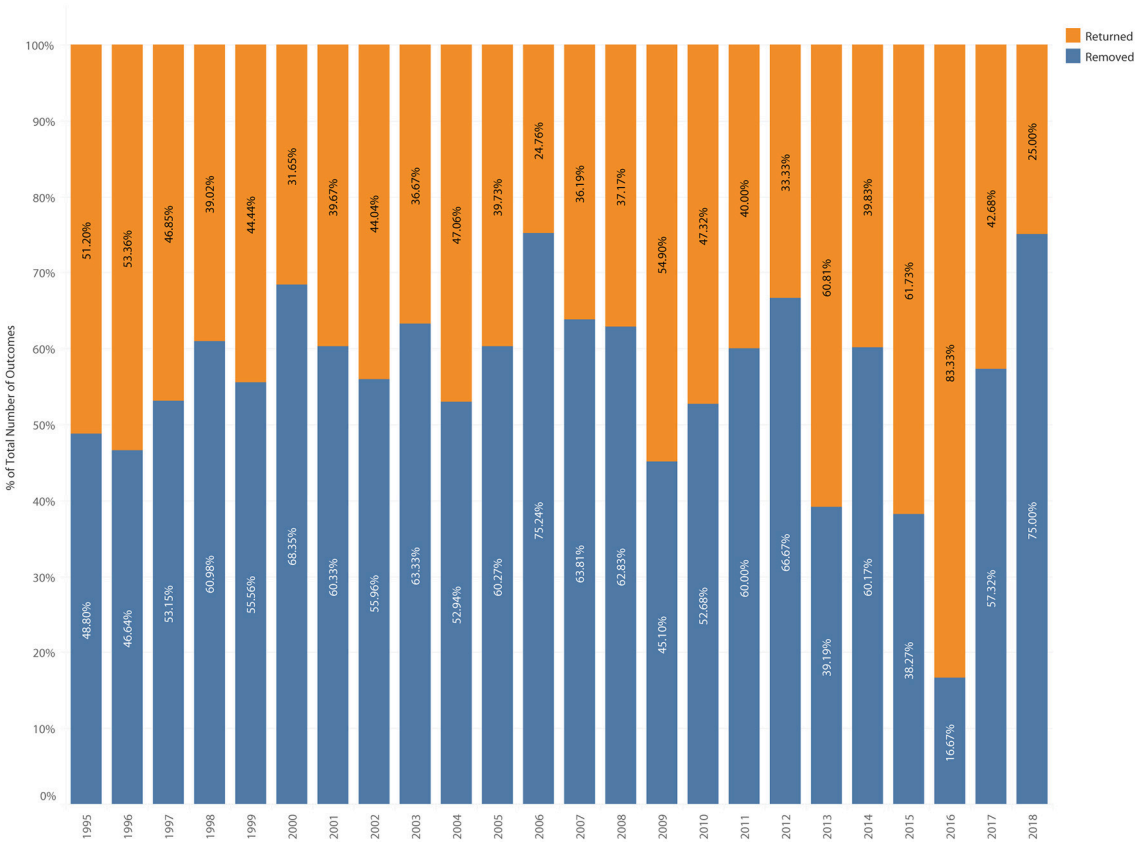

FIGURE 10 | Last visit outcome category of removed or returned as percent of total outcomes.

population data available.[7] Changes noted in the age structure and modeled population in 2007 and 2013 were due to temporary disruption of the program's trapping efforts. In 2006 the program moved in to the new Grayvik Center, and focus was temporarily diverted from trapping. In 2012 and 2013 there was a temporary change in directorship, which resulted in decreased trapping efforts. The changes observed in the population numbers and age structure subsequent to these two disruptions underscores the importance of continuity in trapping efforts.

Despite the geographically restricted location, there was evidence of a significant amount of introgression (sterilized cats that were not ear tipped), possibly cats brought by seasonal community members or workers that were lost or abandoned or cats from outside geographic areas that were deliberately abandoned. Previously sterilized but not ear-tipped cats most likely represent only 10–20% of lost or abandoned animals, given sterilization rates in at-risk populations (20). The high quality and visibility of the program, which provided food and veterinary care, may have encouraged abandonment of cats if owners believed that the cats would be well taken care of after abandonment. Abandonment may also have occurred if owners believed that cats would be better off under the care of the program rather than surrendered to a shelter where they would face the risk of euthanasia. Interestingly, nine cats sterilized and with ear-tips were noted in the record to not have been sterilized or ear tipped through ORCAT, which suggests deliberate abandonment or, less likely, cats taken to alternative clinic for TNR surgery by an individual. Introgression, particularly of intact cats, has been noted to be a barrier to decreasing cat populations over time through TNR efforts (13, 21, 22). It is unclear whether the introgression observed here was higher or lower than other geographic areas. Access to this location is limited and controlled through a 24-h manned gate, decreasing the likelihood of casual abandonment of cats. It is also geographically isolated, decreasing the chance of cats migrating from adjacent locales. However, human occupation is highly seasonal, which may increase the chance of loss or abandonment by part-time residents and staff. Given the strict control and geographic isolation, required microchipping, sterilization, and licensure of cats might decrease introgression of intact cats.

Retroviral prevalence decreased over time as expected given the elimination of significant risk factors (fighting, mating, vertical transmission) for infection via sterilization, removal of positive cats, and vaccination against FeLV. The point-of-care test that was employed to test for FIV and FeLV is reported to have the best performance for detecting FeLV, with a calculated positive predictive value of 100% for FeLV and between 50 and 84% for FIV depending on prevalence (23). The FeLV vaccine

[7]http://www.hurricanecity.com/city/keylargo.htm

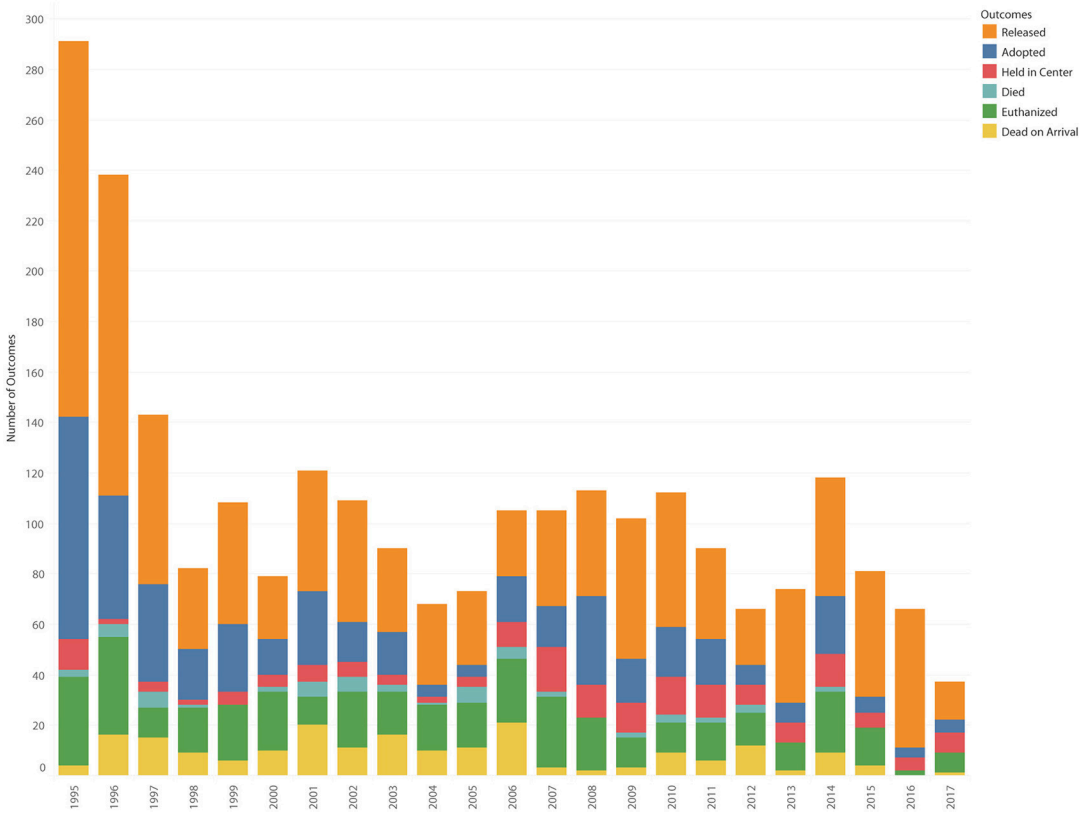

FIGURE 11 | Last visit outcomes by outcome type.

FIGURE 12 | Average age (months) of cat population by quarter overlaid with trend line and 95% confidence interval.

was an adjuvanted killed vaccine that required 2 doses 3–4 weeks apart for efficacy. Because of the inability to safely and humanely house unsocial cats for the duration necessary to booster the vaccine, many cats received only 1 dose. In addition, many cats did not receive recommended re-vaccinations. It is unknown what level of protection may have been afforded from a single

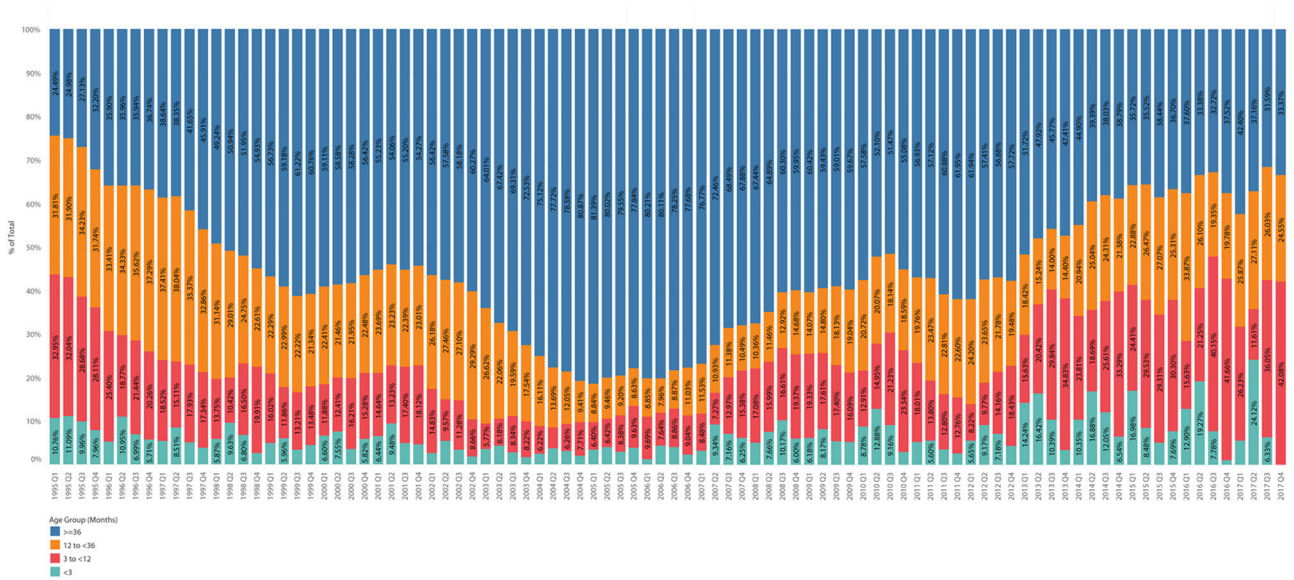

FIGURE 13 | Age structure by age group as percent of total population by quarter.

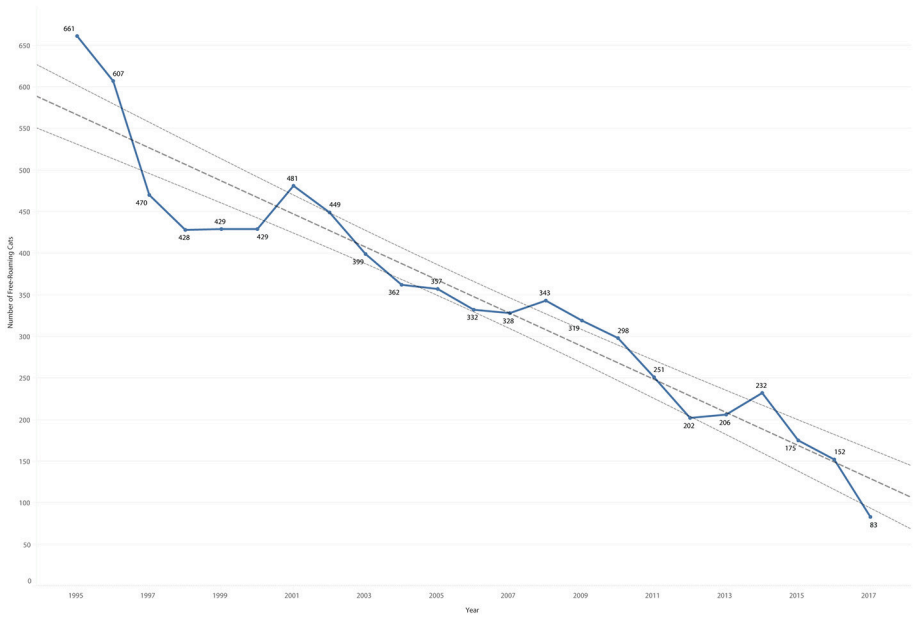

FIGURE 14 | Estimated count of cat population by year based on individual records overlaid by trend line and 95% confidence intervals.

FeLV vaccination, and it should be noted that not even fully vaccinated cats are completely protected from infection. For naturally exposed cats, infection with FeLV is approximately 3 times more likely in those unvaccinated as opposed to fully vaccinated (24).

Limitations

The data are limited as they were collected for programmatic record-keeping rather than epidemiologic analysis. The censuses were not collected at regular intervals, and the years of collection were not regularly spaced. The month of collection was not standard. Cat populations tend to be seasonal, with peak populations observed in the summer and the lowest populations observed in the winter and spring (25). However, neither month nor season were significant in this limited analysis. This may have been due to the preferential removal of juveniles, which make up the vast majority of seasonal variation, or simply a lack of sufficient data points. Classic markers of animal

welfare (such as growth, reproduction, body damage, disease, immunosuppression, adrenal activity, behavior anomalies, and self-narcotization) (26) were either not systematically captured or were not captured in a way that could be compared to animals not enrolled in the TNR program and were limited to the measures of life expectancy and a single class of disease prevalence. These measures of cat welfare do not account for concerns regarding return rather than routine euthanasia of trapped cats that include the potential for increased animal suffering due to non-retroviral disease or trauma (in other words, that free-roaming cats would be better off dead).

Another limitation is that all population estimates were counts by a single caretaker. Multiple population census methods would have been ideal, as caretakers may underestimate the number of cats (1). However, this caretaker was highly knowledgeable of the entire population, which she interacted with on a daily basis, which may minimize concerns regarding accuracy of the count. Twenty cats were added to census estimates by the caretaker to account for potential undercounting. The small size of each colony, particularly in later years, should also have made count estimates more accurate.

Nearly all ages were estimates, which makes analysis of age-related data more challenging. The estimated average age of the free-roaming cat population may be biased toward an older age as cats with undocumented removals may have continued to contribute to the average age of the population. This bias was minimized by intensive efforts on the part of ORCAT to document outcomes such as MIA and requests to the community to bring cats that were found dead to the clinic to be outcomed as DOA. Estimated date of death for cats with an outcome of released was based on the average age of death for DOA and euthanized cats, with cats older than that average age at time of release being estimated to live for only an additional 12 months.

In conclusion, a TNR program operating for over two decades achieved a decrease in population and an increase in population welfare as measured by increased average age of population and decreased prevalence of retroviruses.

AUTHOR CONTRIBUTIONS

RK collected the data, created the database, entered data, analyzed the data, and was the main author of the manuscript. HC entered data, drafted the introduction of the manuscript and edited the entire manuscript. JL contributed to the study design and data analysis, funded data collection, and edited the manuscript.

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CORRECTION
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Corrigendum: Decrease in Population and Increase in Welfare of Community Cats in a Twenty-Three Year Trap-Neuter-Return Program in Key Largo, FL: The ORCAT Program

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Keywords: trap-neuter-return, TNR, free-roaming cats, feral cats, stray cats, community cats, animal welfare, retrovirus

A Corrigendum on

Decrease in Population and Increase in Welfare of Community Cats in a Twenty-Three Year Trap-Neuter-Return Program in Key Largo, FL: the ORCAT Program
by Kreisler, R. E., Cornell, H. N., and Levy, J. K. (2019). Front. Vet. Sci. 6:7. doi: 10.3389/fvets.2019.00007

In the original article, there was an error. The decrease in the free-roaming population was incorrectly stated as "45%" and should be "55%" in both the **Abstract** and **Results**.

A correction has been made to the ***Abstract***:

"The objective of this study was to evaluate the effect of a long-term (23-year) trap-neuter-return program on the population size of community cats in the Ocean Reef Community and to describe the demographic composition and outcome of enrolled cats. A retrospective study was performed using both cat census data collected between 1999 and 2013 as well as individual medical records for cats whose first visit occurred between 3/31/1995 and 12/31/2017. Medical record entries were reviewed to determine program inputs, cat outcomes, retroviral disease prevalence, and average age of first visit, sterilization, and death through 6/11/2018. Change over time was analyzed via linear regression. The free-roaming population decreased from 455 cats recorded in 1999 to 206 recorded in 2013 (55% decrease, $P < 0.0001$). There were 3,487 visits recorded for 2,529 community cats, with 869 ovariohysterectomies and 822 orchiectomies performed. At last recorded visit, there were 1,111 cats returned back to their original location, and 1,419 cats removed via adoption (510), transfer to the adoption center (201), euthanasia of unhealthy or retrovirus positive cats (441), died in care (58), or outcome of dead on arrival (209). The number of first visits per year decreased 80% from 348 in 1995 to 68 in 2017. The estimated average age of the active cat population increased by 0.003 months each year ($P = 0.031$) from 16.6 months in 1995 to 43.8 months in 2017. The mean age of cats at removal increased 1.9 months per year over time ($P < 0.0001$) from 6.4 months in 1995 to 77.3 months in 2017. The mean age of cats at return to the original location was 20.8 months, which did not change over time. The overall retrovirus prevalence over the entire duration was 6.5%, with FIV identified in 3.3% of cats and FeLV identified in 3.6%. Retrovirus prevalence decreased by 0.32% per year ($P = 0.001$), with FIV decreasing by 0.16% per year ($P = 0.013$) and FeLV decreasing 0.18% per year ($P = 0.033$). In conclusion, a trap-neuter-return program operating for over two decades achieved a decrease in population and an increase in population welfare as measured by increased average age of population and decreased retrovirus prevalence."

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As well as the ***Results***, subsection ***Population of Cats***, paragraph one:

"Surveys of the cat population occurred in June 1999, January 2001, March 2003, November 2003, June 2004, June 2006, July 2007, January 2008, July 2009, and February 2013. Per the census records, the free-roaming cat population decreased over time from 455 cats recorded in 1999 to 206 recorded in 2013 (55% decrease). The decrease was linear and significant, with a slope of -0.06, $P < 0.0001$ (Figure 1). Neither month of the year nor a binary seasonal variable of fall/winter as compared to spring/summer were significant."

Additionally, there was an error in the **Discussion**. An extraneous word ("would") was erroneously inserted.

A correction has been made to the ***Discussion***, subsection ***Limitations***, paragraph three:

"Nearly all ages were estimates, which makes analysis of age-related data more challenging. The estimated average age of the free-roaming cat population may be biased toward an older age as cats with undocumented removals may have continued to contribute to the average age of the population. This bias was minimized by intensive efforts on the part of ORCAT to document outcomes such as MIA and requests to the community to bring cats that were found dead to the clinic to be outcomed as DOA. Estimated date of death for cats with an outcome of released was based on the average age of death for DOA and euthanized cats, with cats older than that average age at time of release being estimated to live for only an additional 12 months."

The authors apologize for these errors and state that they do not change the scientific conclusions of the article in any way. The original article has been updated.

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ORIGINAL RESEARCH
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Public Opinions on Strategies for Managing Stray Cats and Predictors of Opposition to Trap-Neuter and Return in Brisbane, Australia

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A survey of Brisbane residents was undertaken to investigate community attitudes toward urban stray cats and their management. Surveys were distributed to 84 medical and dental practices across Brisbane City, and were completed by 305 patients and staff. Practices were targeted to achieve a sample of respondents from a representative distribution of socioeconomic backgrounds. After being informed about trap, neuter, and return (TNR) programs for management of urban stray cats, most respondents (79%), chose TNR as their preferred management strategy, while a lesser proportion (18%) expressed a preference to continue the current Brisbane City Council lethal control program (catching and culling ∼1,000 cats annually), and 3.4% selected to leave the cats alone. Differences in beliefs and attitudes toward urban stray cats as a function of demographic variables were investigated. Statistical analyses indicated that respondents who were male, older, non-cat owners, those who believed euthanasia of stray cats was humane, and that urban stray cats spread disease to humans were significantly more likely to express a preference for lethal control, as opposed to non-lethal population management. Based on these findings, we recommend that information is disseminated to mitigate these concerns or negative beliefs, where warranted. Ultimately, findings from this study demonstrate that current Queensland legislation does not reflect public views and opinions on stray cat management and should be reviewed. Formal research evaluating the efficacy of TNR programs for urban stray cats in Australia would be in the public interest.

Keywords: trap neuter return, urban stray, cats, sterilize, euthanasia

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INTRODUCTION

Like many countries, in urban areas of Australia, unowned cats result in complaints to local government bodies responsible for animal management, and result in costs associated with mitigating these complaints. Complaints relating to free-living cats stem from nuisances caused by fighting, soiling property, and the perception of threats to human and pet health (1, 2). In addition, there are concerns about the welfare of urban stray cats themselves (3–6), but there are also concerns about the ecological impact of stray cats killing birds, small mammals, and other suburban native wildlife (7–9). As such, effective interventions are needed to manage the

stray cat population, which in turn will reduce costs associated with mitigating such complaints. Australia's urban stray cat population is estimated at ∼1.2–2 million (10). In cities, the number of stray cats is estimated to be 60–100 per 1,000 human residents (11–13), but may be higher or lower depending on the location (14). Approximately 85% of cats admitted to Australian municipal animal facilities and 50–70% admitted to animal welfare shelters are urban strays, and on average 48–56% of all impounded cats across Australia are euthanized (12, 15–17). The resulting large number of euthanized kittens and cats, mostly young and healthy, produce perpetration-induced posttraumatic stress in many workers directly involved with their euthanasia (18). Workers also experience other mental and physical health issues such as depression, substance abuse, high blood pressure, sleeplessness, and increased risk of suicide (18–20).

Over time cat numbers can be reduced by culling, or, by preventing reproduction. In open populations, culling at a rate able to achieve population control requires removing 30–50% of the cat population every 6 months for ∼10 years (21), which is beyond most local government budgets, unlikely to be acceptable in the community, and would certainly lead to an increase in the mental health issues already prevalent in those tasked with euthanizing the cats (19). In a city with a population of 1 million (approximate size of Brisbane), using modeling that specifies a culling rate of 40% for a population of 60,000 stray cats, it is estimated that 40,000 cats would need to be killed in the first year alone to effectively reduce the stray cat population (21). In contrast, the low-level culling of stray cats (2–5% annually) that is typically used by municipalities (10, 17) is ineffective at decreasing the urban stray cat population, and can paradoxically encourage population rebound, or even growth, due to an influx of new stray cats to the area, and increased juvenile survival due to less competition for resources (22–24).

Culling programs may also be highly unfavorable with members of the public. Overseas, it has been found that lethal control methods are strongly opposed, especially by cat owners (25–29). Likewise, it has been strongly opposed by those who have formed an attachment with strays in their neighborhood or who exhibit "semi-ownership" bonds with these animals (30). Lethal control methods without community support have even resulted in sabotage of the program (31). Performing the level of culling required to render lethal programs effective could significantly worsen mental health issues already prevalent in animal management employees (18), and may likely be met with significant community backlash.

An alternative to culling is to trap, neuter, and return (TNR) stray cats to the location in which they were originally found. This method has been shown in both the USA and Australia to effectively reduce cat numbers in targeted urban and periurban areas (10, 14, 17, 31–35), reduce the intake and subsequent euthanasia in shelters, and reduce cat-related complaints (31, 32, 36–39). Thus, it may be a more effective alternative to the current low level culling of urban stray cats, more humane to the animals, and relieve strain and burden from shelter facilities and their workers. Although some earlier studies reported that cat numbers did not decrease with TNR, typically this was because adequate sterilization rates were not achieved and/or immigrant and dumped cats were not quickly managed by sterilization and the adoption of socialized cats (40–42). For either trap and kill or TNR to result in a reduction in cat numbers over time, more than 50% of the population must be culled or sterilized annually (21, 43–45). Although some modeling studies suggest that trap and kill reduces cat numbers faster than TNR (21, 43), the magnitude of the culling is beyond the budgets and tolerance of most communities. Of note, there are no published studies from Western countries reporting successful trap and kill programs for cats in either a zipcode or city, in contrast to a number of effective large-scale TNR programs reported in the literature (14, 38). Based on current international literature, when conducted using best practice, TNR is an efficacious and viable method in which to manage stray cats in urban communities. It reduces strain on shelters by reducing cat intake, and support from the community typically helps to defray government costs. TNR programs that actively place the more sociable stray cats and kittens up for adoption achieve a quicker initial reduction in cat numbers (10). Potential for disease transmission to humans, pets and wildlife is also likely reduced because fighting and roaming behaviors in sterilized cats are less frequent than in entire (i.e., non-sterilized) cats, and there are fewer kittens to shed parasite eggs or oocysts (toxoplasma) compared to trap and kill programs (46–48).

Management of urban stray cats is an emotive issue because of the wide diversity of public perceptions about stray cats and differences in the way people interact with these animals. To date, the majority of TNR research has been conducted internationally, and data are lacking in Australia with regards to how the general public prefers unowned urban cats to be managed. Brisbane is the capital city for the state of Queensland in Australia, and the Brisbane City Council's (BCC)[1] local government area has a population of ∼1.2 million—it is roughly equivalent to the population of Tasmania, ACT, and the Northern Territory combined. As well as this, there is a high diversity of demographic and socioeconomic characteristics (49). This size makes it an ideal Australian city to study a variety of opinions on stray cats.

The BCC has an active cat trapping program targeted to locations of community complaints and stray cat sightings, and the current program has a target of 1,000 cats per year, most of which are killed (50). An additional ∼700 are euthanized annually in the municipal pound and local welfare agency shelter, representing a total cull rate of ∼2.5% of the estimated free-living cat population (unpublished data, author JR). Cat legislation in Queensland is very restrictive and disallows the possibility of using TNR. Under the *Biosecurity Act of 2014*[2], and *Land Protection (Pest and Stock Route Management) Act 2002,*[3] no distinction is made between urban strays and truly feral cats in remote areas which get no support from humans for food or shelter, despite fundamental differences between these groups

[1]Brisbane City Council (BCC). Biodiversity in Brisbane. Available online at: https://www.brisbane.qld.gov.au/environment-waste/natural-environment/biodiversity-brisbane

[2]Queensland Government 2014. Queensland Biosecurity Act 2014. *In*: Government, Q. (ed.). Brisbane.

[3]Queensland Government 2002. Land Protection (Pest and Stock Route Management) Act 2002. *In*: Government, Q. (ed.). Brisbane.

of cats. Under Queensland legislation, both are classed as non-domestic cats, with only owned cats classed as domestic. The acts stipulate that non-domestic cats "must not be moved, fed, given away, sold, or released into the environment without a permit". Due to this legislation, many TNR activities in Queensland and other Australian states are conducted unofficially by rescue organizations and volunteers (10).

Assessing the level of public support for TNR is vital to obtaining supporting evidence for governments interested in making legislative changes. Furthermore, knowledge of public support for non-lethal control methods of urban stray cats would facilitate more formal research into the efficacy of TNR in an Australian context. Overseas studies show that the majority of people surveyed prefer non-lethal cat management programs in comparison to culling (2, 28, 51, 52). However, Brisbane is one of the most biodiverse capital cities in Australia[1], and substantial media has focused on the negative impact of cats on native wildlife (53). Therefore, it is unknown if residents of Brisbane largely support current lethal methods of cat control in the city, or have similar attitudes to residents overseas who prefer non-lethal control.

The aims of this study were to determine the attitudes of Brisbane city residents toward urban stray cats and factors which affect respondents' preferences for stray cat management methods. In doing so, we aim to identify the most salient concerns about urban stray cats held by those in opposition to TNR, and identify the most effective method to mitigate such concerns where warranted. Finally, we aim to provide evidence of the need to facilitate formal research into the efficacy of TNR as an alternative to current stray cat management methods in Australia.

MATERIALS AND METHODS

Study Design Overview

A cross-sectional study was conducted with adult residents of the BCC area recruited from those attending selected medical and dental practices, and participants of a community group between 17th August 2017 and January 30th 2018. The Australian Bureau of Statistics (ABS) index of relative socioeconomic advantage and disadvantage (SEIFA score) values (54) as at 2011 for each of the 71 postcode areas in the BCC area were identified. One quarter of the postcodes were placed in each of four strata based on their SEIFA score. We then randomly selected 5 postcodes from each of the four socioeconomic quartiles with replacement (i.e., the same postcode could be selected more than once) using probability in proportion to size sampling (PPS), where postcodes having higher populations were proportionally weighted to have a higher chance of being selected. Resident populations as at 2011 were used.

We then identified all medical practices within each of the selected postcodes, allocated these with a number and used a random number generator to select one practice from each postcode (except for two postcodes selected twice in which case two practices were selected). Practice managers from each clinic were called to gain permission to leave the survey forms within their clinic's waiting room, and were asked if reception staff could inform patients of the survey's existence, which could be completed while waiting for their appointment. Reception staff were asked if they could encourage a 50/50 male: female ratio of respondents. Practices that declined to be involved were removed from the list and the random number generator was used to select another practice from that postcode. Where all medical practices in selected postcode areas declined to participate, replacement postcodes were randomly selected from the same socioeconomic quartile as described above. All random selections were made using Microsoft Excel's RANDBETWEEN function. Practices that granted permission to conduct the survey were delivered blank copies of the survey. Completed surveys were collected from the practice 2–4 weeks later. To increase the number of completed surveys, dental practices closest to the medical practices were then later included, as was a community group involved with restoration of a waterway (catchment group). Surveys were completed from 30 medical practices, 54 dental practices and the catchment group (15 surveys only).

The survey contained four groups of questions concerning general information on respondents and their pet ownership history, and residents' attitudes and interactions with urban stray cats (assessed by responding to statements with a five-point Likert scale, with 1 denoting *strongly disagree* and 5 denoting *strongly agree*). Preferences for the management of strays before and after being provided with information about TNR were assessed via the selection of one of three discrete options. Attitudes toward a trial of TNR in their community was assessed via responses to a statement using the same Likert scale described, and the selection of discrete answers provided in response to the question. The full survey is available in the Appendix (**Table A1** in Supplementary Material). For demographic questions, age groupings were based on ABS groupings to allow comparison with the Australian population. Education level was classed on a scale between 1 and 4 based on respondents' answers to "what is your highest level of education?" in line with the Australian Qualifications Framework (55).

Questions pertaining to attitudes about urban stray cats were formulated in response to commonly reported complaints and concerns in communities cited in prior literature (1–3, 5, 6, 8). A portion of the questions were adapted from a prior survey [items 4 and 5; (3)]. A small pilot study of 17 participants was performed to gain feedback on the clarity of questions, and those deemed unclear were subsequently reworded and tested again. This was performed prior to printing and distributing the surveys for the main study. Data from the pilot study were not included in the study results.

Statistical Analyses

Statistical analyses of the 305 questionnaires aimed to determine what factors may be associated with negative attitudes toward urban strays, and factors associated with the preference for lethal as opposed to non-lethal urban stray population management. Firstly, a series of chi-square tests were conducted to examine whether there were differences in the pattern of responses for key questionnaire items based on demographic variables.

Independent variables were categorical, and included age (above vs. below the modal age), gender (male vs. female), pet ownership status (owner vs. non-owner), cat ownership status (owner vs. non-owner), and respondents' awareness of strays (i.e., aware vs. unaware of strays). The dependent variable in each test was ordinal in nature and consisted of the level of agreement with the given questionnaire item from 1 (strongly disagree) to 5 (strongly agree). Cross tabulations between demographic variables and agreement level were analyzed (all tables are available in the **Appendix** in Supplementary Material). As per the requirements of a chi-square analysis of association, no table cells had <1 observation, and at least 80% of all cells had more than 5 observations (56).

Secondly, a logistic regression was performed to determine whether certain demographic variables (education level, gender, cat ownership status, age, and SEIFA score) were predictive of respondents' preferences for managing stray cat populations (lethal vs. non-lethal). A separate logistic regression was performed to determine whether responses to certain attitudinal measures (belief that cats spread diseases to humans or pets, the belief that urban strays reduce native birds or small animals, and the belief that euthanasia would be more humane than leaving an urban stray cat in their environment) were predictive of lethal vs. non-lethal preferences for stray cat management strategies. For each statistical test, only respondents who had provided a valid response to all items in the model were included. The sample size of both logistic regressions adhered to the established rule of thumb that regression or cox analyses require a minimum of 10 observations per predictor (57), or in the case of a binary logistic regression, a minimum of 5–9 observations per predictor (58).

RESULTS

Respondent Demographics

Completed surveys were obtained from 305 respondents. On average, only 1.6% of survey items were left unanswered by respondents (range = 0–5.3%, $SD = 1.3\%$), demonstrating a good level of engagement with surveys. Seventy-percent of participants were female, 27% male, and 1% identified as "other" (2% of respondents did not provide a response). Respondents specified which ABS age bracket they belonged to. The median age bracket was 35 to 39 years of age, and the modal age bracket was 18–24 years of age, with 22.2% of respondents coming from this bracket. Most respondents reported being born in Australia (73%), however, 20 other countries of birth were represented. The next most commonly reported places of birth were New Zealand (5%) and the United Kingdom (5%). The majority of respondents held a university degree or graduate diploma (47%), and a large proportion posessed a vocational certificate or secondary school certificate (28%). The majority of respondents owned a pet (76%), with cats being the most common (56%), followed by dogs (52%), birds (10%), reptiles (1%), and fish (1%). Of cat owners, most had a single cat, but 45% had two or more. The majority of cat-owners reported that all cats owned were microchipped (89%) and sterilized (93%). Respondents came from 34 of the 71 postcode areas within the Brisbane metropolitan area, thereby representing 48% of the total postcodes. The average SEIFA score of socioeconomic advantage and disadvantage for respondents was 1,054 ($SD = 83$), which was close to the average for the BCC local government area of 1,052.

TABLE 1 | Locations of reported stray cat sightings and associated proportion of total sightings.

Sighting location	Frequency	Proportion of total sightings (%)
Private residences	44	20.5
Commercial businesses	33	15.3
Alleyways	33	15.3
Suburban parks	27	12.6
Industrial areas	22	10.2
Vacant blocks	19	8.8
Schools	18	8.4
Train stations	12	5.6
Government housing	7	3.3

Respondents' Awareness of Strays and Feeding Behavior

Less than half (43%) the respondents reported that they were aware of stray cats in their area, while 57% were unaware. Stray cats were observed in a wide variety of locations, with the most common being private residences, alleyways, and commercial businesses (i.e., eateries and shops; **Table 1**).

Fifteen percent of respondents reported feeding urban stray cats. Of these respondents, 18% fed strays on a daily basis (3% of all respondents), 11% on a weekly basis, 28% on a monthly basis, and 43% on a yearly basis. Cat feeders were represented in every age bracket, with the median being the 30 to 34 years of age, and the mode being the 18–24 years of age bracket (representing 29.5% of cat feeders). Similar proportions of females (14.4%) and males (13.4%) reported feeding urban stray cats. Many cat feeders did not own a cat (38.6%), but most were cat owners (61.4%); cat feeders accounted for 9.7% of all non-cat owners, and 20.8% of all cat-owners.

Perceptions Regarding Nuisance Behaviors of Urban Stray Cats

More participants agreed (i.e., either selected agree or strongly agree) than disagreed (i.e., selected disagree or strongly disagree) that stray cats caused a nuisance by urinating and defecating in people's gardens (45.3 vs. 28.1%), and are annoying because they fight and make loud noises (46.2 vs. 25.8%; **Table 2**). However, many respondents did not hold an opinion and expressed a neutral attitude toward items (27–44%). Older respondents and those who reported being aware of strays were more inclined to agree with the nuisance behavior items than younger respondents and those that were not aware of strays (**Table 2** and **Table A2** in Supplementary Material). Additionally, cat-owners demonstrated less agreement toward both nuisance behavior items than non-cat owners, and pet-owners demonstrated less agreement with the statement that cats caused a nuisance by defecating and urinating than non-pet owners.

TABLE 2 | Response distributions for survey items pertaining to nuisance behaviors of stray cats, and chi-square tests for differences in response distributions as a function of demographic variables.

Survey item (number of valid responses for item)	Response proportions as % and (frequencies)	Demographic variables tested (number of respondents in model)	Pearson's Chi-Square statistic and degrees of freedom	*p*-values
Cause a nuisance by urinating and defecating in people's gardens (302)	SD = 11.9 (36)	Gender (294)	$\chi^2_{(4)} = 3.57$	$p = 0.468$
	D = 16.2 (49)	**Age (297)**	$\mathbf{\chi^2_{(4)} = 19.87}$	$\mathbf{p = 0.001^{***}}$
	N = 26.5 (80)	**Own-pet (298)**	$\mathbf{\chi^2_{(4)} = 10.79}$	$\mathbf{p = 0.029^{*}}$
	A = 24.8 (75)	**Own-cat (302)**	$\mathbf{\chi^2_{(4)} = 41.81}$	$\mathbf{p < 0.001^{***}}$
	SA = 20.5 (62)	**Aware of Strays (298)**	$\mathbf{\chi^2_{(4)} = 34.18}$	$\mathbf{p < 0.001^{***}}$
Are annoying because they fight and make loud noises (303)	SD = 10.9 (33)	Gender (295)	$\chi^2_{(4)} = 7.09$	$p = 0.131$
	D = 14.9 (45)	**Age (298)**	$\mathbf{\chi^2_{(4)} = 24.21}$	$\mathbf{p < 0.001^{***}}$
	N = 28.1 (85)	Own-pet (299)	$\chi^2_{(4)} = 6.33$	$p = 0.176$
	A = 25.7 (78)	**Own-cat (303)**	$\mathbf{\chi^2_{(4)} = 34.01}$	$\mathbf{p < 0.001^{***}}$
	SA = 20.5 (62)	**Aware of Strays (299)**	$\mathbf{\chi^2_{(4)} = 14.10}$	$\mathbf{p = 0.007^{**}}$
Spread diseases to humans (301)	SD = 16.3 (49)	Gender (293)	$\chi^2_{(4)} = 7.65$	$p = 0.105$
	D = 22.3 (67)	Age (296)	$\chi^2_{(4)} = 4.01$	$p = 0.405$
	N = 43.5 (131)	**Own-pet (297)**	$\mathbf{\chi^2_{(4)} = 16.81}$	$\mathbf{p = 0.002^{**}}$
	A = 8.6 (26)	**Own-cat (301)**	$\mathbf{\chi^2_{(4)} = 56.66}$	$\mathbf{p < 0.001^{***}}$
	SA = 9.3 (28)	**Aware of Strays (297)**	$\mathbf{\chi^2_{(4)} = 15.69}$	$\mathbf{p = 0.003^{**}}$
Spread diseases to owned pets (299)	SD = 8.7 (26)	Gender (291)	$\chi^2_{(4)} = 5.12$	$p = 0.275$
	D = 8.7(26)	Age (294)	$\chi^2_{(4)} = 3.85$	$p = 0.426$
	N = 34.4 (103)	Own-pet (295)	$\chi^2_{(4)} = 6.80$	$p = 0.147$
	A = 31.8 (95)	**Own-cat (299)**	$\mathbf{\chi^2_{(4)} = 18.61}$	$\mathbf{p = 0.001^{***}}$
	SA = 16.4 (49)	**Aware of Strays (295)**	$\mathbf{\chi^2_{(4)} = 15.37}$	$\mathbf{p = 0.004^{**}}$

*SD, strongly disagree; D, disagree; N, neutral; A, agree; SA, strongly agree. *Significant at the < 0.05 level; **Significant at the ≤ 0.01 level; ***Significant at the ≤ 0.001 level. Response distributions associated with significant chi-square results are displayed in plots under the explanation of findings for the given items. For simplicity, descriptive statistics for non-significant results are not reported. Bold indicates variables with significantly different response distributions at P < 0.05.*

Perceptions Regarding Spread of Disease

More respondents disagreed (38.6%) than agreed (17.9%) that stray cats spread diseases to humans. Cat and pet-owners were more inclined to disagree or have a neutral opinion than respondents that owned no pets (**Figure 1**, **Table 2**, and **Table A1** in Supplementary Material). Contrastingly, those who were aware of strays were more inclined to agree that cats spread diseases to humans than those unaware of strays. More respondents agreed (48.2%) than disagreed (17.4%) that stray cats spread diseases to owned pets. Again, cat-owners appeared to express more disagreement than non-cat owners, and those who were aware of strays expressed more agreement than respondents unaware of strays.

Perceptions Concerning Effects on Wildlife

Respondents' views on the impact of urban stray cats on wildlife were varied, but more respondents agreed that urban stray cats decreased the number of native birds in their suburb compared to those that disagreed (31.8 vs. 18.3%; **Table 3**). In addition, more respondents agreed that urban stray cats decreased the numbers of small native animals compared to those who disagreed (32.9 vs. 19.0%). Females and cat owners expressed less agreement with the ecological impact items than males or non-cat owners (**Figure 2** and **Table A2** in Supplementary Material). Those that were aware of strays expressed more agreement with ecological impact items than those who were not aware.

Caring and Humane Attitudes to Urban Stray Cats

Very few respondents were of the view that urban stray cats had a good life (5.4%), with just over half disagreeing (51.5%), and a large proportion neither agreeing nor disagreeing (43.1%). Responses did not differ based on any demographic factors (**Table 4**). Respondents' agreement as to whether seeing a healthy stray cat, or feeding a stray cat would make them feel good varied substantially, and many respondents neither agreed nor disagreed (34.1 and 38.3%) (**Figures 3**, **4**). Cat-owners expressed more agreement with both items, while respondents who reported being aware of strays expressed more disagreement with both items (**Figure 3**). Interestingly, the proportion of responses for the statement "feeding a stray cat would make me feel good" also differed depending on gender and age. Males and older participants appeared to express more disagreement with the item than did females or younger respondents.

More respondents agreed than disagreed that urban stray cats should be managed differently from feral cats in the bush (i.e., forest or wildness areas; 49.3 vs. 22.6%). Cat-owners expressed more agreement than non-cat owners, and those aware of strays expressed more disagreement than those un-aware (**Table 4** and **Figure 5**).

In addition to the stray-welfare items, respondents were asked to decide whether it would be more humane to: (a) euthanize, or (b) leave a stray cat in its environment, if they came across

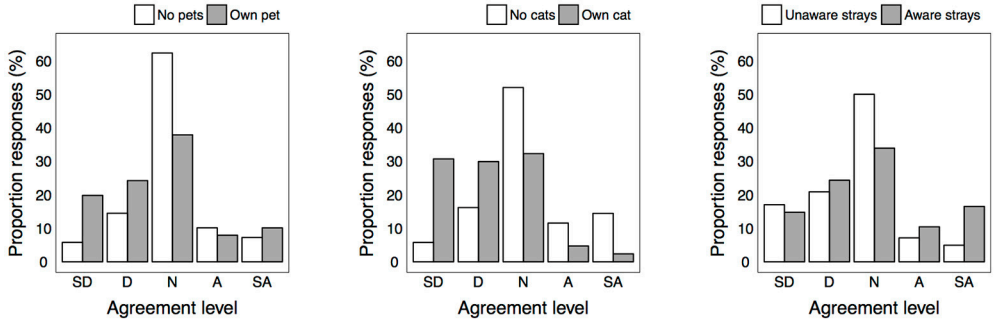

FIGURE 1 | Level of agreement for statement "urban stray cats spread diseases to humans" between significantly different groups. SD, strongly disagree; D, disagree; N, neutral; A, agree; SA, strongly agree.

TABLE 3 | Response distributions for survey items pertaining to stray cats' ecological impact and chi-square tests for differences in response distributions as a function of demographic variables.

Survey Item (number of valid responses for item)	Response proportions as % and (frequencies)	Demographic variables tested (number of respondents in model)	Pearson's Chi-Square statistic and degrees of freedom	*p*-values
Urban stray cats have decreased the number of native birds in my suburb (302)	SD = 7.0 (21)	**Gender (294)**	$\mathbf{\chi^2_{(4)} = 14.59}$	$\mathbf{p = 0.006^{**}}$
	D = 11.3 (34)	Age (297)	$\chi^2_{(4)} = 4.81$	$p = 0.308$
	N = 50.0 (151)	Own-pet (298)	$\chi^2_{(4)} = 7.22$	$p = 0.125$
	A = 16.6 (50)	**Own-cat (302)**	$\mathbf{\chi^2_{(4)} = 16.63}$	$\mathbf{p = 0.002^{**}}$
	SA = 15.2 (46)	**Aware of Strays (298)**	$\mathbf{\chi^2_{(4)} = 37.99}$	$\mathbf{p < 0.001^{***}}$
Urban stray cats have decreased the number of small native animals in my suburb (301)	SD = 6.0 (18)	**Gender (293)**	$\mathbf{\chi^2_{(4)} = 15.86}$	$\mathbf{p = 0.003^{**}}$
	D = 13.0 (39)	Age (296)	$\chi^2_{(4)} = 4.39$	$p = 0.356$
	N = 48.2 (145)	Own-pet (297)	$\chi^2_{(4)} = 4.82$	$p = 0.306$
	A = 17.3 (52)	**Own-cat (301)**	$\mathbf{\chi^2_{(4)} = 19.44}$	$\mathbf{p = 0.001^{***}}$
	SA = 15.6 (47)	**Aware of Strays (297)**	$\mathbf{\chi^2_{(4)} = 38.11}$	$\mathbf{p < 0.001^{***}}$

***Significant at the ≤ 0.01 level; ***Significant at the ≤ 0.001 level. Response distributions associated with significant chi-square results are displayed in plots under the explanation of findings for the given items. Bold indicates variables with significantly different response distributions at P < 0.05.*

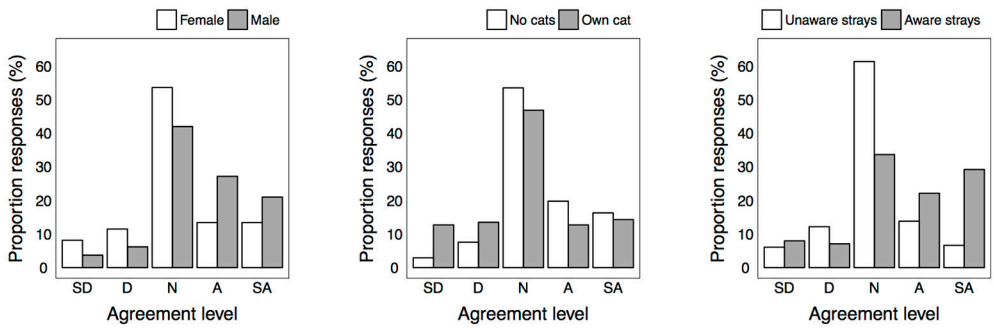

FIGURE 2 | Level of agreement for statement "urban stray cats decrease the number of native birds in my suburb" for each significantly different group.

a healthy stray cat in Brisbane. The majority of participants believed it was more humane to leave the cat (71.5%), while others selected euthanasia (27.9%). Respondents were then asked to choose the more humane option if it were the case that they knew the stray cat would die in 2-years-time because it would be hit by a car. After this information, the proportion of respondents who thought it was more humane to leave the cat decreased to 61.0%, while those that believed it was more humane to have the cat euthanized increased to 37.4%.

For the first scenario, chi-square tests revealed that significantly more males, older adults, non-cat owners, and respondents aware of strays selected the euthanasia option than females: $\chi^2_{(2)} = 22.93$, $p < 0.001$, younger adults: $\chi^2_{(2)} = 13.15$, $p = 0.001$, cat-owners: $\chi^2_{(2)} = 8.41$, $p = 0.016$, and those

TABLE 4 | Response distributions for survey items pertaining to welfare of stray cats and chi-square tests for differences in response distributions as a function of demographic variables.

Survey Item (number of valid responses for item)	Response proportions as % and (frequencies)	Demographic variables tested (number of respondents in model)	Pearson's Chi-Square statistic and degrees of freedom	*p*-values
Urban stray cats have a good life (297)	SD = 21.2 (63)	Gender (289)	$\chi^2_{(4)} = 3.13$	$p = 0.537$
	D = 30.3 (90)	Age (292)	$\chi^2_{(4)} = 1.32$	$p = 0.858$
	N = 43.1 (128)	Own-pet (293)	$\chi^2_{(4)} = 2.40$	$p = 0.663$
	A = 3.4 (10)	Own-cat (297)	$\chi^2_{(4)} = 4.38$	$p = 0.357$
	SA = 2.0 (6)	Aware of Strays (293)	$\chi^2_{(4)} = 6.39$	$p = 0.172$
Seeing a healthy stray cat would make me feel good (300)	SD = 14.7 (44)	Gender (295)	$\chi^2_{(4)} = 3.99$	$p = 0.408$
	D = 18.0 (54)	Age (295)	$\chi^2_{(4)} = 8.05$	$p = 0.090$
	N = 38.3 (115)	Own-pet (297)	$\chi^2_{(4)} = 0.80$	$p = 0.938$
	A = 17.7 (53)	**Own-cat (300)**	$\mathbf{\chi^2_{(4)} = 20.52}$	$\mathbf{p < 0.001}$***
	SA = 11.3 (34)	**Aware of Strays (296)**	$\mathbf{\chi^2_{(4)} = 14.73}$	$\mathbf{p = 0.005}$**
Feeding a stray cat would make me feel good (299)	SD = 19.4 (58)	**Gender (291)**	$\mathbf{\chi^2_{(4)} = 14.76}$	$\mathbf{p = 0.005}$***
	D = 14.4 (43)	**Age (294)**	$\mathbf{\chi^2_{(4)} = 10.59}$	$\mathbf{p = 0.032}$*
	N = 34.1 (102)	Own-pet (296)	$\chi^2_{(4)} = 0.76$	$p = 0.944$
	A = 21.1 (63)	**Own-cat (299)**	$\mathbf{\chi^2_{(4)} = 18.16}$	$\mathbf{p = 0.001}$***
	SA = 11.0 (33)	Aware of Strays (295)	$\mathbf{\chi^2_{(4)} = 10.52}$	$\mathbf{p = 0.033}$*
Urban stray cats should be managed differently from feral cats in the bush (302)	SD = 11.3 (34)	Gender (294)	$\chi^2_{(4)} = 8.48$	$p = 0.075$
	D = 11.3 (34)	Age (297)	$\chi^2_{(4)} = 9.17$	$p = 0.057$
	N = 28.1 (85)	Own-pet (298)	$\chi^2_{(4)} = 5.75$	$p = 0.219$
	A = 31.1 (94)	**Own-cat (302)**	$\mathbf{\chi^2_{(4)} = 12.74}$	$\mathbf{p = 0.013}$*
	SA = 18.2 (55)	**Aware of Strays (298)**	$\mathbf{\chi^2_{(4)} = 18.47}$	$\mathbf{p = 0.001}$***

**Significant at the < 0.05 level; **Significant at the ≤ 0.01 level; ***Significant at the ≤ 0.001 level. Response distributions associated with significant chi-square results are displayed in plots under the explanation of findings for the given items. Bold indicates variables with significantly different response distributions at P < 0.05.*

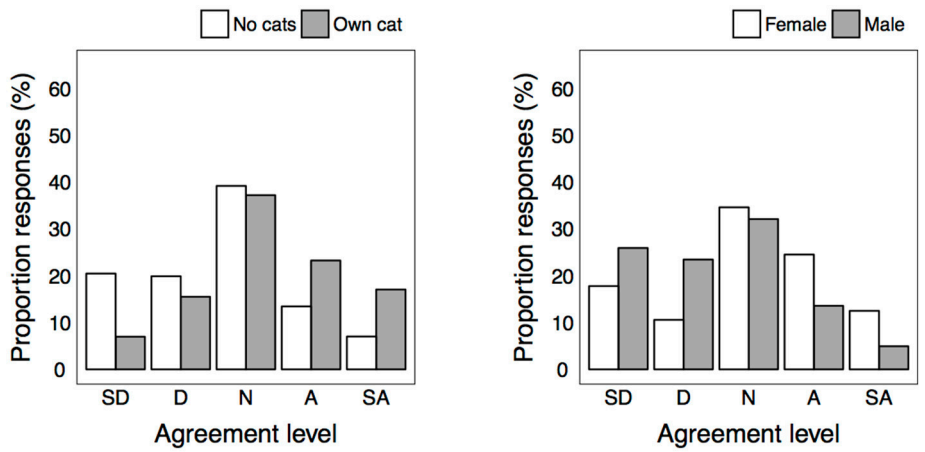

FIGURE 3 | Level of agreement for statement "seeing a healthy stray cat would make me feel good" for each significantly different group.

unaware of strays: $\chi^2_{(2)} = 24.98$, $p < 0.001$. After being told the cat would die, response proportions significantly differed as a function of the same demographic variables described for the first scenario, but the differences were less significant in some cases; gender: $\chi^2_{(2)} = 18.54$, $p < 0.001$, age: $\chi^2_{(2)} = 7.92$, $p = 0.019$, cat-ownership: $\chi^2_{(2)} = 8.75$, $p = 0.008$, awareness of strays: $\chi^2_{(2)} = 29.84$, $p < 0.001$.

Managing Urban Stray Cats

Respondents were asked to choose between three alternative options for managing stray urban cats. The first option was: "urban stray cats should be caught, sterilized, microchipped, and vaccinated. Healthy, friendly cats should be adopted to new homes where possible. Those that cannot be found new homes, but are healthy, should be returned to where they were found. Cats that are too sick to be treated should be

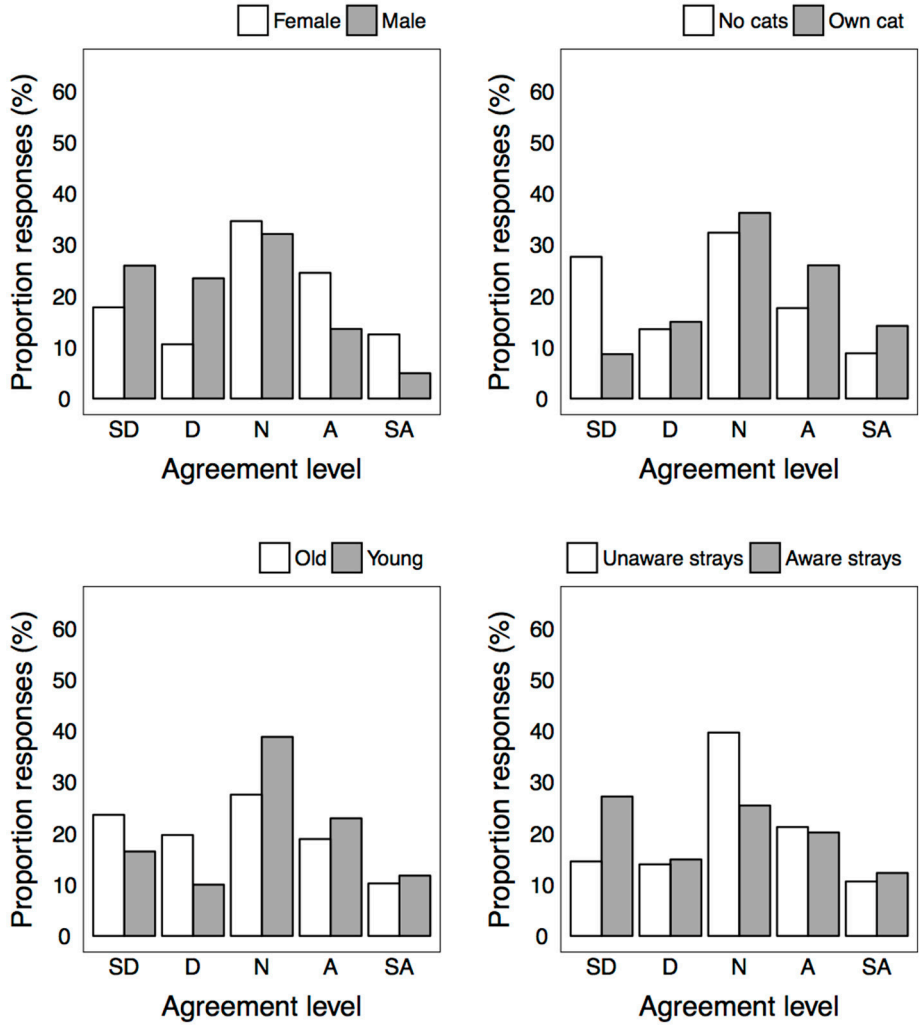

FIGURE 4 | Level of agreement for statement "feeding a healthy stray cat would make me feel good" for each significantly different group.

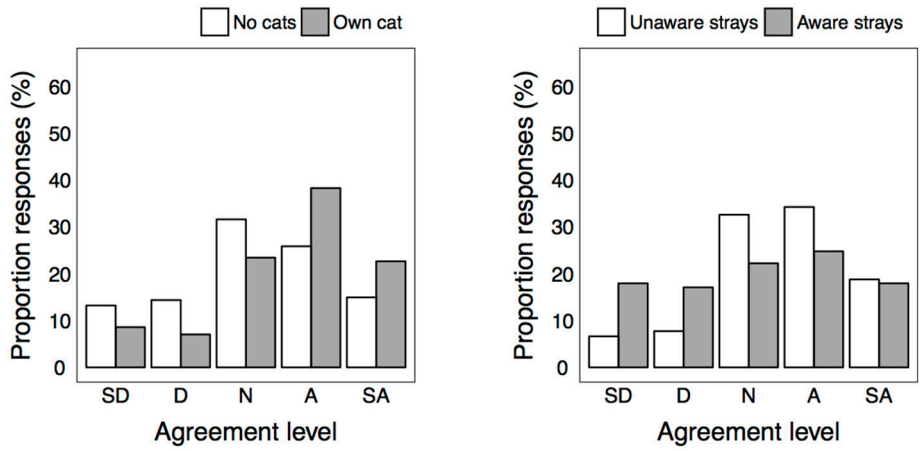

FIGURE 5 | Level of agreement for statement "urban stray cats should be managed differently" for each significantly different group.

euthanized (put to sleep)." The second option was to: "continue the current practice of the Brisbane City Council which is to catch ∼1,000 stray cats annually in suburban areas (not forests) and to euthanize (put to sleep or kill) most of them." The third option was to: "leave urban stray cats where they were." Most respondents (68%) expressed a preference for TNR, while only 28% preferred the current method of managing urban stray cats with culling, and 4% said they should be left alone.

Participants were then provided with information about the efficacy of TNR programs from recent overseas research. Specifically, respondents were informed that: (a) the number of urban stray cats can be reduced by killing them *or* by sterilizing them so that they are unable to have more kittens; (b) to effectively decrease stray cat numbers by killing means that 40% of the population must be killed every 6 months for at least 10 years; (c) in North America and Europe, sterilizing, adopting friendly cats to new homes, and returning the others to where they were found reduces euthanasia of cats and kittens in shelters and pounds, reduces cat-related complaints, and over time, it reduces the number of stray cats in cities at a similar rate as killing cats; (d) that sterilizing and adopting or returning stray cats is often funded by community and welfare agencies, reducing costs to the government compared to killing cats; and lastly, (e) that most urban stray cats are as healthy as owned domestic cats, and less than one in a hundred stray cats (1%) are too unhealthy to be returned to where they were found. After reading this information, respondents were asked again what their preference would be to manage stray cat populations; a greater proportion selected TNR (78%), only 18% selected the current culling method, and 3% elected to leave them alone. The results of a McNemar–Bowker test indicated that the change responses significantly differed to the proportion of responses observed when the same question was answered prior to reading the information supplied, $\chi^2_{(2)} = 24.533$, $p < 0.001$.

A logistic regression was performed to determine which demographic variables (education level, gender, cat-ownership, age, and SEIFA score) were predictive of respondents' choices for lethal (culling) as opposed to non-lethal (TNR or leaving alone) management strategies for stray cat populations. Option 1 and 3 were collapsed together to create the "non-lethal" option to allow for a binomial logistic regression analysis. The logistic regression was based on management choices in the first question (i.e., prior to receiving information) to gain insight into barriers to TNR support before receiving any persuasive arguments. The model was statistically significant, $\chi^2_{(5)} = 33.22$, $p < 0.001$ ($n = 219$). It explained 19.6% of the variance in respondents' preferences (Nagelkerke R square), and correctly classified 72.6% of cases (i.e., respondents' preferences). Cat owners were more than three times as likely to select non-lethal management methods than non-cat owners, $p = 0.001$; females were three times more likely to opt for non-lethal methods than males, $p = 0.001$; and an increase in age was associated with an increased likelihood to select lethal, as opposed to the non-lethal management strategies (1.02 times more likely for each increase in age bracket, $p = 0.019$). Education level and SEIFA score were not significant predictors of management preference (ps = 0.872 and 0.619, respectively).

A second logistic regression was performed to determine whether respondents' level of agreement to items regarding stray cats' ecological impact (decrease native birds and small animals), risk of disease transmission (spread diseases to humans and pets), and choice of whether leaving or euthanizing a stray cat would be more humane were predictive of stray cat management preferences (lethal vs. non-lethal methods). The model was statistically significant, $\chi^2_{(5)} = 118.86$, $p < 0.001$ ($n = 290$). It accounted for 48.9% of the variance in management preferences (Nagelkerke R square) and correctly classified 83.8% of cases (i.e., people's preferences). Results indicated that the belief that stray cats spread diseases to humans significantly increased the likelihood of selecting lethal management of stray cat populations. Those that agreed with the statement were significantly more likely to select the culling management option than were those that disagreed (1.60 times more likely for each increase in agreement level, $p = 0.023$). In addition, those that believed it would be more humane to euthanize a stray cat than to leave it in their environment were 14 times more likely to prefer lethal as opposed to non-lethal management than those who thought it would be more humane to leave the cat alone, $p < 0.001$. Opinions as to whether stray cats transmitted diseases to pets, decreased native birds, or decreased native animals did not predict preferences for managing urban stray cat populations (ps = 0.587, 0.616, and 0.693, respectively).

When asked whether they would support a trial of TNR in their suburb, in which healthy cats were subsequently adopted or returned to their original location, 71.4% of respondents were in agreement with the suggestion, while 15.6% would not support a trial, and 13.0% were uncertain.

Knowledge and Opinions About QLD Cat Legislation

Respondents were largely unaware that under Queensland Government law and BCC by-laws there are only two classifications relating to ownership of cats, these being domestic cats (owned by a person) or non-domestic cats (unowned and feral cats). Non-domestic cats are considered "restricted matter" and must not be moved, fed, given away, or sold. Therefore, to feed or adopt urban stray cats or kittens without a permit is not allowed under the Queensland Biosecurity Act 2014[4] and Land Protection Act 2002 and could result in a fine. Only 11.1% of respondents were aware of these laws.

The majority of respondents (54.8%) disagreed that urban stray cats should be classed as "non-domestic" (feral), while only 28.1% agreed that they should. The remainder (17.1%) did not agree or disagree. Likewise, when asked whether they agreed that urban stray cats must not be moved for adoption, or given away for adoption without a permit, 58.5% disagreed with this, and only 30.5% agreed with the current law. The remainder (11.0%) did not agree or disagree. Finally, 61.4% of respondents disagreed

[4]Queensland Biosecurity Act 2014. (2014).

that urban stray cats and kittens should not be fed without a permit, and only 25.9% agreed with the current law. A minority of responders (12.6%) did not agree or disagree.

DISCUSSION

This study was one of the first to investigate opinions of residents of an Australian city about the problem of urban stray cats. The aim of this study was to explore respondents' experiences and beliefs about urban stray cats and factors associated with negative views toward them. Additionally, this study aimed to investigate preferences for the management of urban stray cats, and factors associated with preferences for lethal as opposed to non-lethal management methods. In doing so, we aimed to identify barriers that need to be addressed to achieve public support for a TNR program to control urban stray cats.

Sightings, Locations, and Feeding Behaviors of Urban Stray Cats

In the current study, 43% of respondents reported being aware of urban stray cats in their area. There is little information about public awareness of strays in Australian cities, as surveys have tended to focus on relationships between residents and stray cats, and thus specifically aim to sample residents who are aware of strays (6, 10, 30). In an Australian survey of respondents engaged in TNR activities, locations of stray cats most commonly reported were private residences, industrial areas or factory complexes, and streets and alleyways (10). This was similar to the pattern of stray cat sightings in our study, although there was a greater representation of locations such as schools, suburban parks, and commercial businesses. Differences in respondent characteristics and reasons for participating, however, make it difficult to compare between frequencies in these studies.

The proportion of respondents who fed urban strays in the current study (15%) was within the range reported in previous literature. In Australia, 9% of respondents from an internet survey (30), and 22% of Victorian residents in a phone-based survey (59) reported feeding a cat they did not own. In US-based studies, feeding rates of 9% (60), 12% (61), and 26% (26) have been reported. Only 3% of respondents in our study daily fed an unowned cat compared to 9% from an Australian internet survey (30). Findings from published studies suggest that feeders are typically middle-aged and female (26, 30). In the current study, however, similar proportions of males and females fed urban stray cats. More females tend to participate in surveys based on animal welfare than males, which may have resulted in an over-representation of female feeding behaviors in previous studies (30, 62). The current study was distributed to attract an equal proportion of males and females, and although only partially successful, the higher proportion of males than in some studies may account for the differences in feeding demographics than previously observed.

The majority of respondents neither agreed nor disagreed that seeing or feeding a healthy stray cat would make them feel good. Cat-owners however, expressed greater agreement with the statements than non-cat owners, and those aware of strays expressed greater disagreement with the statements than those unaware of strays. For the item, "feeding a stray cat would make me feel good," it was also found that males and older respondents expressed more disagreement than females and younger respondents. In an Australian study of cat semi-owners (i.e., people who fed cats and provided other care but did not perceive themselves as owners), 87% said feeding a stray cat made them feel good, 76% said "people who are important to me would approve of me feeding a stray cat," and 58% said "feeding a stray cat is the right thing to do" (6), suggesting that semi-owners derive more satisfaction from caring for a stray cat than is typical for the average population, but similar to cat owners.

Attitudes and Beliefs Toward Urban Stray Cats

Beliefs About Nuisance Behaviors

Respondents' views varied substantially across nuisance behavior items. Interestingly, a large proportion of respondents expressed no opinion toward the items at all. Previous studies have found such behaviors to be a large contributor to the public dislike of strays. In a postal survey study based in Japan, more than a third of respondents reported feces and urine from stray cat colonies being a major nuisance in their community (2). In the United States, loud noises made by cats fighting and the deposition of excrement in communities are common complaints made about urban stray cats (63).

Cat-owners expressed less agreement with the nuisance statements. This is not surprising, as individuals who have a cat or pet are more likely to be understanding and accepting of such behaviors. A California-based study that investigated attitudes toward the fecal deposition of stray cats found that individuals who owned cats themselves were less likely to make complaints about unowned cats, or express concern about health risks related to fecal matter (63). Alternatively, it is also plausible that urban stray cats are less likely to be present around properties of those who own cats, if the domestic cats spend time outdoors around the property and defend their territory. In Australia in 2016, 62% of households owned a pet, and 29% owned a cat (64). The comparatively larger proportion of pet (76%) and cat owners (56%) in our study may have contributed to the lower level of negativity toward urban stray cats for these behaviors than reported in prior literature.

Older respondents and those that were aware of strays expressed more negative views toward urban stray cat nuisance behaviors than younger respondents and those unaware of strays. In gaining public support for a community-based TNR program, arguments that are likely to be persuasive to these individuals should emphasize the efficacy and viability of TNR for reducing stray cat populations, which in turn would result in a reduction in the prevalence of such nuisance behaviors.

Beliefs About Disease Spread

Only 18% of respondents agreed that urban stray cats spread disease to humans, while 39% disagreed. This relatively low level of concern might reflect the large proportion of cat-owners in our study. Cat-owners were less concerned about the risk of disease transmission than non-cat owners in our study,

which aligns with previous findings (63). Respondents who were aware of strays perceived a higher risk of disease transmission than those unaware, however, these respondents had a more negative impression of stray cats in general, with consistently more negative views about stray cats across every survey item tested.

A review of feral cat management strategies has listed the risk of zoonotic diseases as a major cause of public concern regarding stray cats in the United States (1). Articles about TNR programs commonly cite public concern about disease spread as a significant contributor to the opposition of TNR programs (36, 51). Several diseases are of concern, including toxoplasmosis, ringworm, bartonella, and rabies (65). Most are spread by direct contact or fleas, except toxoplasmosis, and rabies does not occur in Australia. Contrary to concern expressed by respondents in our and other studies, there is a low risk of disease transmission from cats to humans (66), and for most diseases, the risk of transmission is even lower from stray cats due to the lack of direct contact. Diseases transmitted from cats are much more likely to come from pet cats who are more frequently in contact with the general public.

Concerns are often raised about toxoplasmosis, which for most healthy humans results in no clinical signs. However, in humans with weakened immune systems or pregnant women, toxoplasmosis can cause serious disease (65). Although infection can occur from accidentally ingesting cat feces with oocysts (eggs) from contaminated hands, especially in children, most infections are caused by the handling or ingestion of poorly cooked/uncooked meat; toxoplasmosis can infect sheep, cattle, pigs and wildlife (65). There is no association between cat ownership and the presence of toxoplasmosis antibodies indicating human exposure (67, 68). Furthermore, environmental contamination with toxoplasmosis oocysts is likely reduced in TNR programs compared to trap and kill programs. This is because the average age of cats in TNR programs is higher than in trap and kill programs; older cats are more likely to be immunized from previous exposure and usually they do not become infected or shed oocysts in feces after the initial infection (46, 48). In contrast, in trap and kill programs, young immunologically naïve kittens are continuously being born, get infected, and shed oocysts in feces. Immunologically naïve cats older than 1 year, if infected, shed fewer oocysts than cats younger than 1 year (47). Educating the public about the actual level of disease transmission risk, and that it is further reduced with TNR, may help to improve impressions of urban stray cats in communities, and lead to more public support of a community TNR program.

More respondents agreed that stray cats spread diseases to pet cats (48%) than to humans (18%), and indeed cellulitis and abscessation resulting from cat scratches or fights is a common occurrence in pet cats with outdoor access (69). However, for potentially fatal infectious diseases, stray cats have similar or lower prevalence rates of infections than those published for pet cats in the United States (36, 70) and the prevalence of feline leukemia virus (FeLV) and feline immunodeficiency virus (FIV) were lower in shelter cats than owned cats with outdoor access in Australia (71). Disease transmission is reduced once cats are sterilized for diseases such as FIV which are spread by fighting.

Beliefs About Ecological Impact

Respondents' views concerning the impact of stray cats on local wildlife widely varied. A higher proportion of respondents agreed (32%) that stray cats negatively affected wildlife than those that disagreed (18%). Concern over wildlife predation and the impact of cats on sensitive ecosystems has traditionally been one of the major problems leading to negative perceptions of cats in Australia (8, 28, 51). In a recent study that investigated attitudes toward wildlife predation by pet cats across different countries, Australians expressed the most extreme attitudes toward pet cats' impact on native wildlife in comparison to other countries. Surveys were distributed to two cities in each of the 6 countries included. Results demonstrated that 95% of Australian non-cat owners and 65% of cat owners agreed that pet cats posed a serious threat to animals and the environment (8).

The same recurring trend in responses emerged for this item whereby cat-owners expressed less negative views about the ecological impact of stray cats than non-cat owners, and those aware of strays in their area expressed more negative views than those unaware of strays. Interestingly however, females were seen to express more disagreement with the ecological impact items than males. It is unclear why differences in ecological impact beliefs may arise as a function of gender. Previous literature indicates that females are more compassionate than males toward animals (72). Perhaps as a result of this they are less forthcoming in placing blame on urban stray cats.

Previous literature has shown that concern about the ecological impact of stray cats differs depending on the location of respondents (urban vs. rural). A study conducted in Japan found that stray cats were perceived more positively in urban areas compared to stray cats that inhabited forests or wilderness areas home to endangered species (29). Additionally, a trend in the international ecological impact survey was evident whereby the strongest attitudes were observed in countries with the greatest endemic biodiversity (8). This aligns with findings from a study conducted in the United States, that found that the popularity of lethal stray cat population management increased as town/city size decreased (28). It is possible that the high proportion of neutral responses to environmental impact questions in the current study could be reflective of respondents coming from relatively low biodiversity suburban areas.

Beliefs About Welfare

Overall, findings demonstrated that very few Brisbane City residents (5.4%) thought stray cats lead a good life, and a substantial proportion (27.4–37.0%) believed that euthanizing an urban stray cat would be more humane than leaving it in its environment. This is higher than a previous study in the United States where 14 and 21% of respondents elected euthanasia in response to the same question (3). Results suggested that females and younger respondents may place more value on the lives of urban stray cats than males and

older respondents, in that they less frequently selected the euthanasia option.

Contrary to respondent's views, urban stray cats are documented to have health and welfare scores comparable to that of owned pet cats (36, 70). Several studies have found that <1% of cats coming into TNR programs had health problems significant enough to warrant euthanasia (37, 73–75). In addition, the welfare of urban stray cats in colonies managed by TNR was not different from pet cats (75). Misconceptions of stray cat welfare have been proposed to contribute to less favorable opinions of TNR programs (36). As found in our study, preferences amongst US respondents for lethal population control were strongly associated with the perception that euthanasia would be more humane (51). However, it is possible that some respondents' choices were motivated by a preference for culling rather than perceptions of comparative humaneness, as it is likely that some respondents did not have any regard for stray cat welfare. Public education programs intended to foster community support for TNR should focus on dispelling negative beliefs about stray cats' welfare that are not backed up by evidence, and emphasize the efficacy of TNR to reduce issues linked to cat-related complaints.

Preferences for Managing Urban Stray Cats

Most respondents recognized that urban stray cats are not the same as feral cats, and accordingly they should be managed differently to feral cats in the bush (only 22.6% disagreed with the statement). Those that were aware of strays in their area, however, showed greater disagreement with this statement, which may indicate that they are more likely to equate urban stray cats to feral cats in the bush. Few respondents (11%) were aware that Queensland legislation classified urban stray cats as "restricted matter" which must not be moved, fed, given away, or sold. However, it should be noted that items pertaining to knowledge of Queensland legislation, and whether respondents agreed with this legislation, were responded to in a yes/no format. This limits the interpretation, because it is unknown whether respondents may have known some aspects of the law. Therefore, it is difficult to make strong inferences about these results. That said, survey respondents did have the opportunity to share any additional information or views in a written format at the end of the survey.

The majority of respondents supported a TNR community program as their preferred method for managing urban stray cats (78%). A smaller but substantial portion selected culling (18.1%), and a very small portion chose to leave the cats alone (3.4%). Information about the effectiveness and welfare of cats in TNR community programs lead to a modest but significant increase in support for TNR (from 68 to 78%). Although it was evident that the majority of respondents were in favor of TNR as an effective means of stray cat population management, it is important to explore reasons why other respondents did not support a TNR community program.

Predictive Demographic Variables

Respondents were more likely to select lethal means of stray cat management if they were male, of an older age, and if they were non-cat owners. The association between gender and management preference aligns with findings from an Ohio-based study that also reported male gender being associated with a greater preference for culling rather than a TNR program (26). Prior literature demonstrates that women show greater concern and compassion toward the welfare of animals than men, and are more emotionally disturbed by mistreatment such as unnecessary killing (28, 76). Generational differences may underpin the association between older adults and lethal management preferences; one study has argued that younger individuals are more likely to show pro-animal welfare attitudes (76). In a more recent study, however, little association between age and attitudes toward animals was found (77). Furthermore, previous literature on TNR attitudes has demonstrated that non-cat owners are not as supportive about TNR programs as cat owners (2, 51).

Overall, what has been observed in survey responses suggests that older adults, males, and non-cat owners have less concern about the welfare of stray cats in general, and as a result, it is not likely that these groups would be persuaded by arguments that highlight the humanitarian merit of TNR as an alternative to culling. Instead, appealing to the practicality of TNR over culling is likely to be more persuasive for these groups. Hence, information should more heavily focus on the comparison of implementation costs and viability between a TNR program and a large-scale culling program, the decrease in stray cat populations and stray cat-related complaints, as well as, the reduced risk of disease transmission from stray cats to humans, wildlife or pets after implementing a TNR program. Information should also generate awareness of the mental health damage to shelter workers euthanizing kittens and cats, and that fewer numbers are required to be euthanized in TNR programs.

The information provided to participants in our survey did not explicitly compare the efficacy of culling compared to a TNR program, but reported that culling *or* TNR can be effective at reducing stray cat populations. It was also stated that the TNR programs trialed have been able to reduce stray cat populations as effectively as culling. It was not made clear, however, that the TNR efficacy was being compared to a calculated, large-scale culling practice instead of the current Brisbane City Council culling practices that are not effective in decreasing overall cat numbers in the medium to long-term, or evidence-based. Hence, the persuasive information could have been presented more clearly to outline the practical benefits of a TNR program. Other benefits that were clearly stated included that friendly stray cats and kittens would be able to be adopted and re-homed, and euthanasia in shelters and pounds would decrease as a result of TNR. While it is an extremely important and positive consequence of TNR, the argument is not likely to have been effective for these groups given their views on urban stray cats. Based on observed attitudes and the content of the persuasive information provide to participants, it is unsurprising that a more substantial increase was not achieved in the proportion of respondents that selected TNR.

Predictive Beliefs

Respondents were more likely to select lethal means of stray cat management if they believed that stray cats spread diseases to humans. Although there were only a small proportion

of respondents that expressed this belief, it is evident that it had a strong impact on the selection of preferred stray cat management strategies. Furthermore, lethal management methods were significantly more likely to be preferred by respondents who believed euthanizing a stray cat would be more humane than leaving it in their environment.

Residents that believe stray cats pose a serious health risk to humans are unlikely to support a program that releases stray cats back into the environment, or stipulates that sociable cats be adopted. In the passage of information provided to respondents outlining the merits of TNR, there was no mention of disease transmission risk, or the welfare of urban stray cats. It was stated that urban stray cats have health comparable to that of owned-pets, and that they are rarely too unhealthy to be returned to where they were found. If the information had included a section that addressed concerns relating directly to disease transmission risks and cat welfare, a more substantial increase in the proportion of respondents selecting TNR as the preferred cat-management strategy may have been observed. It is important that information outlining the benefits of TNR over lethal population management strategies firmly and directly addresses risk of disease transmission, and highlights the good welfare of most urban stray cats to dispel the notion that euthanasia would be humane.

Limitations

Some limitations should be acknowledged when interpreting findings from this study. Firstly, although the sampling method was specifically designed to target a representative sample of respondents, the sample was predominantly female (70%), and therefore the data is more reflective of a female perspective. Education level and cat-ownership status also deviated from that of the general population, with our sample being comparatively more educated [48% had a bachelor degree vs. 31% in Australian population; (78)], and consisting of more cat-owners [49 vs. 29%; (64)]. Cat-owners have been observed to hold more positive views toward stray cats, though prior studies suggest that TNR preferences are not influenced by education level (28). The higher proportion of females and cat-owners should be considered when generalizing these findings to the wider Australian population. As noted, some survey questions did not allow for a detailed response (i.e., invoked yes/no answers), and therefore inferences that can be made are limited. Lastly, the information covering stray cat management strategies could have been presented more clearly, which may have led to a more compelling response.

Implications for Policy and Further Research

Results from this study demonstrated that current Queensland legislation does not align with the beliefs or preferences of Brisbane City residents. Only a small minority of respondents agreed that urban stray cats should be classed as "feral" and must not be adopted or fed. Most Brisbane City residents indicated that TNR was their preferred method for managing urban stray cats rather than the current Brisbane City Council method of culling, and an overwhelming proportion supported a trial of TNR for urban stray cats in their suburb. Conducting trials of TNR in urban areas of Australia where stray cats are a source of complaints, or overrepresented in shelter intake, are needed to provide evidence for the efficacy and viability of TNR over current practices.

CONCLUSION

Results of this study have shown that for most Brisbane City residents, when awareness is raised about the problem of urban stray cats and management strategies, the majority are supportive of a TNR community program with little or no persuasion required. Results have illuminated that certain groups—males, older adults, non-cat owners, and those aware of strays—are less easily persuaded about the merits of TNR. Findings from this study indicate that appealing to the practicality of TNR is likely the optimal strategy in disseminating information that will appeal to all demographic groups. Specific concerns or negative beliefs about stray cats can be targeted by emphasizing the efficacy in steadily reducing populations of urban stray cats, and in turn, the nuisances associated with them. In addition, this study brought to light harmful and erroneous beliefs that information promoting TNR should dispel in order to achieve public support. Beliefs about disease transmission and the humanness of euthanasia were significant predictors of lethal management preferences, and negative beliefs about urban stray cats' welfare were widespread. Information disseminated about TNR needs to address the health and wellbeing of urban stray cats, and the low risk of disease transmission. In conclusion, this study pinpointed the beliefs and demographic variables associated with negative views about stray cats and TNR, and has provided clear recommendations for the type of information to be disseminated to combat such barriers.

ETHICS STATEMENT

This study adheres to the Guidelines of the ethical review process of The University of Queensland and the National Statement on Ethical Conduct in Human Research. All subjects were provided with an information sheet about the survey prior to participation in the study. Participants indicated their consent by checking a box that read I understand that this survey is about managing stray cats and I agree to participate (please tick).

AUTHOR CONTRIBUTIONS

JR conceived the experiment. JR, KL, and AH designed the experiments. GF analyzed the data. KL wrote a draft of the pilot data which was extensively reworked by GF and JR with input from AH.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fvets.2018.00290/full#supplementary-material

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The Changing Legal Status of Cats in Australia: From Friend of the Settlers, to Enemy of the Rabbit, and Now a Threat to Biodiversity and Biosecurity Risk

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In NSW, free-roaming cats are regarded as one the biggest threats to biodiversity. Yet, at one stage they were classified as "the enemy of the rabbit" and were protected and released in their thousands. The purpose of this article is to examine the changing status of cats in Australia, demonstrating that regulation frequently depends on a narrow set of values based on the usefulness of cats at a given point in time. By the late twentieth century, the status of free-roaming cats had changed from enemy of the rabbit, to threat to biodiversity and then in the twenty-first century, to a risk to biosecurity. Once the status of cats changed from enemy of the rabbit, management practices followed historically-driven pathways that rely on lethal methods, which do not necessarily prioritize efficacy, animal wellbeing, or changing community outlooks. This is reflected in current practice, which gives scant regard to non-lethal processes, such as Trap-Neuter-Release, and in some cases makes the feeding and release of free-roaming cats, illegal. This article argues that regulatory preferences for employing lethal methods, now occur in a society which increasingly questions the efficacy of these measures, as well as the very need to kill. While TNR is unlikely to provide a complete solution to the problem of free-roaming cats in Australia, given the success of TNR among community groups, accompanied by changing societal perspectives, the time has come for regulators to engage with alternative control methods and include them in their suite of official measures.

Keywords: free-roaming cats, TNR, enemy of the rabbit, lethal measures, biosecurity

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INTRODUCTION

It is estimated that Australian families house ~3.3 million pet cats, [*Felis catus* (Linnaeus, 1758)] frequently treasured as family members and otherwise protected by a range of laws and policies that proscribe animal cruelty and impose obligations of care[1]. At the same time, Australia also contains large populations of free-roaming cats, with estimates varying from "between 12 and 19 million"

[1]RSPCA (1); Prevention of Cruelty to Animals Act 1979 (NSW), ss 5, 6 and 9 (proscription of cruelty); Animal Welfare Act 1985 (SA) s 13 (proscription of ill-treatment); Animal Welfare Act 1992 (ACT) s 6B (duty).

(2) to between "2.1 and 6.3 million[2]." These cats are categorized as "wild" or "feral," and according to the Australian Department of the Environment, threaten the survival of some 139 native species, resulting in "severe to catastrophic" impacts on Australian biodiversity[3]. While it is not disputed that free-roaming cats predate on native fauna and can also spread toxoplasmosis, the extent of these impacts remains unsettled[4]. Nevertheless, such threats have been used to justify lethal measures, including poisoning, trapping and shooting, leading to contentious debates between environmentalists and animal welfare advocates[5]. One element of the debate questions whether non-lethal processes, such as trap-neuter-release (TNR) have a place in regulatory regimes[6].

Although free-roaming cats are now targeted for eradication and control, this was not always the case. In the early days of the colony of New South Wales (NSW) cats were valued as a companion animal, as well as for their ability to catch rats and mice (6). By the end of the nineteenth century, cats had also been acclaimed as "the enemy of the rabbit" and released by the thousands in the hope they would control the spread of rabbits[7]. Yet, barely 100 years later, predation by free-roaming cats was officially listed as a threating process to native biodiversity and some jurisdictions currently regard the presence of free-roaming cats as a biosecurity risk[8].

The purpose of this article is to examine the changing status of cats in Australia and to evaluate how this links to management practices, particularly those that rely on killing. Historical influences are especially significant, keeping in mind the stark comparison between nineteenth-century regulators who attempted to use free-roaming cats to counterbalance damage caused by rabbits, and the regulatory turn-about in the later part of the twentieth century. At present, in common with other unwanted species, the status of free-roaming cats is underpinned by legal classifications, such as, invasive, pest or feral, which provide the triggers and parameters for regulation (7). These classifications invariably lead to reliance on lethal control, normalizing killing, and shutting down discussion on alternative control methods (8).

In one sense, this turnabout is consistent with regulatory patterns emerging from the later part of the twentieth century, that saw introduced species targeted for eradication and control, by listing their impacts as a threatening process, or otherwise making the species subject to eradication and control[9]. However, unlike other introduced species, the cat was also legally protected and deliberately released, with the expectation that it would control rabbits. The protected status achieved by cats has thus far not been replicated by any other introduced animal now classified as a threat or pest, making the study of cats an important topic.

The discussion adopts a qualitative methodology, analyzing and synthesizing historical and contemporary instruments, to identify and evaluate patterns of behavior. Instruments from the nineteenth and early twentieth century largely comprise legislation, proclamations and newspaper reports, while material from the late twentieth century comprises legislation, policy instruments, codes of conduct, strategies, and plans[10]. This analysis is intended to provide a snapshot of standards and principles relating to regimes and to question assumptions that support those regimes. Two themes predominate: first, that regulation frequently depends on a narrow set of values based on the usefulness of cats at a given point in time; and second, that these values promote killing on the supposition that this is an appropriate and effective response in all situations.

The discussion commences by examining how, during the nineteenth century, cats became elevated from friend of the settler to enemy of the rabbit, a classification which fostered the protection and release of cats across Australia. As identified by Dunlap, these perspectives stemmed from a "natural history" approach, where Anglo-settlers understood, and attempted to modify, their environment through observation of cause and effect, hoping that cats would restore balance to nature by ridding the land of rabbits (9). Cats, however, were not effective in this task, yet remained virtually unmanaged until the end of twentieth century.

By this time, understanding the land had evolved from natural history toward ecology, a movement which incrementally integrated scientific discoveries and advances (9). Although this led to better understanding of relationships and dependencies among species, killing individual species continued to form the backbone of regulation (9–11). Parts two and three evaluate these developments in a socio-legal context, not only exposing limitations on settlers' abilities to remodel the land, but also drawing parallels with current practices. The material from the later part of the twentieth century contains more detailed discussion on management practices. This stems from the fact

[2]RSPCA (1), 6.

[3]Department of the Environment, *Threat Abatement Plan for Predation by Feral Cats*, Commonwealth of Australia, 2015, 5-7 indicates threats to 74 species of mammals, 40 birds, 21 reptiles, and 4 amphibians. Available online at: http://www.environment.gov.au/system/files/resources/78f3dea5-c278-4273-8923-fa0de27aacfb/files/tap-predation-feral-cats-2015.pdf

[4]Discussion in Part 4.1 of this article.

[5]Low (3); Predation by cats is listed as a threatening process pursuant to the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) s18. The current list of key threatening processes is maintained by Department of the Department of Environment and Energy. Available online at: http://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl; Department of the Environment, *Threat Abatement Plan for Predation by Feral Cats*, above n[3], 8; Predation by free-roaming cats is also listed as a threatening process pursuant to the *Biodiversity Conservation Act 2016* (NSW) Schedule 4, "Predation by the Feral Cat Felis catus (Linnaeus, 1758);" (4).

[6]Trigger and Mulcock (5); TNR involves capturing free-roaming cats "sterilising them and returning them to the place where they were found", Paterson (2), 170.

[7]Discussion in part 2.1 of this article.

[8]Discussion in part 3 of this article.

[9]For example, *Game Protection Act* 1866 (NSW), sections 5–7, First and Second Schedules, protected introduced species, such as, pheasants, partridges and deer by having closed hunting seasons. In New South Wales, deer are now listed as key threatening process, pursuant to Schedule 4 of the Biodiversity Conservation act 2016, as are rabbits, goats, foxes, and cats; The Australian Government, has developed a strategy for reducing camel numbers—Department of Sustainability, Environment, Water, Population, and Communities, *National Feral Camel Action Plan: A National Strategy for the Management of Feral Camels in Australia*, (2010) available from http://www.environment.gov.au/system/files/resources/2060c7a8-088f-415d-94c8-5d0d657614e8/files/feral-camel-action-plan.pdf

[10]Historical newspapers were sourced through the "Trove" site of the Australian National Library. The website may be accessed from https://trove.nla.gov.au/

that the impacts of free-roaming cats had attracted attention and were, therefore, subject to more detailed regulation.

Part four of the article evaluates TNR, both in an official capacity, where TNR is largely dismissed, and at the community level, where TNR has achieved localized success. It is argued that official responses to TNR evince a failure to progress beyond entrenched killing patterns, which have scarcely changed from a nineteenth-century emphasis on destroying pest animals[11]. The official stance also persists in the face of debate on transformed social and cultural values that question the need to kill in every situation. The article concludes that while TNR is unlikely to provide a complete solution to the problem of free-roaming cats in Australia, regulators cannot continue to ignore societal calls for more humane treatment of these animals. At the very least, it behooves regulators to engage with alternative control methods and include them in the suite of official measures.

Before commencing the discussion, it is helpful to clarify key terms, such as, wild/feral/free-roaming, stray, and domesticated that are used in the literature. For the purposes of this article, words, and phrases have the following meanings, which have been adapted from the *Threat Abatement Plan for Predation by Feral Cats*, adopted by the Commonwealth Government of Australia: wild/feral/free-roaming cats are cats who "live and reproduce in the wild… and survive by hunting or scavenging [with] none of their need…[being]satisfied intentionally by humans;" stray cats are those found in urban or rural areas and who "may depend on some resources provided by humans but are not owned;" and, domesticated cats are those who are owned and whose "needs are supplied by their owners[12]." These categories demonstrate an understanding of the breadth of the human-cat relationship and are useful in contextualizing law and policy. However, as discussed in part three of this article, law and policy does not always reflect these subtleties. In addition, cats may move among these categories, further complicating regulation[13].

FRIEND OF THE SETTLER AND ENEMY OF THE RABBIT: OBSERVATIONS FROM NATURAL HISTORY

The fortunes of the cat in Australia were closely connected with the introduction of the rabbit, an event which occurred during the nineteenth century and which coincided with land management practices that fostered the introduction and removal of species with impunity.

Friend of the Settler and Enemy of the Rabbit

Although debate surrounds the manner and timing of the introduction of cats, records indicate that they arrived in 1788, at the time of European occupation[14]. In the early days of NSW, cats were valued for their skill in controlling rats and mice and also as a companion animal, a role that increased throughout the nineteenth century as Australia adopted the European practice of breeding show cats[15]. Both the aesthetic and practical appeal of cats secured their position, so that by the late nineteenth century, cats had spread throughout 90% of the continent[16]. They had become a feature of colonial life, yet for much of the nineteenth century they were not at the forefront of settlers' lives. Cats, for example, were not considered especially advantageous or overly detrimental. Accordingly, they escaped the type of treatment meted out to free-roaming dogs, dingoes, kangaroos, quolls, and wallabies, who were earmarked for destruction because of their perceived danger to humans and/or threat to primary production[17]. As the nineteenth century drew to a close, however, the status of the cat was about to change, its fortunes being dramatically linked with the fortunes of another introduced animal, the rabbit.

As with the introduction of cats, domesticated rabbits were brought to Australia in 1788 (16). However, it was not until 1859 when Thomas Austin released wild rabbits into the state of Victoria that rabbits established themselves and proliferated (16). Their impact on the Australian economy was devastating, prompting inquiries, a Royal Commission, and legislation that imposed obligations on landholders to poison rabbits and build exclusion fencing[18]. Yet, rabbits continued to thrive. Not every landholder had the financial resources to comply with legal obligations, which in any event often proved futile because the crown was not under similar responsibilities, allowing rabbits to move easily from crown land to private landholdings[19]. Economically-based measures, such as bounties were also ineffective because rabbit trappers ensured that a few rabbits always remained, in order to provide themselves with continuous work (17). As these policies collapsed, the damage attributable to rabbits became so great that farmers started leaving their land[20].

[11] Discussion in part 4.1 of this article.

[12] Department of the Environment, *Threat Abatement Plan for Predation by Feral Cats*, Commonwealth of Australia, 2015, above n[3], 6.

[13] Ibid, 22.

[14] Abbott has extensively researched the manner of introduction and spread of the cat, including theories that cats were introduced prior to European settlement in 1788; (12) Abbott (6), 4; (13).

[15] Smith (14); Abbott (6), 1; (15).

[16] Abbott (6), 4.

[17] *Dog Nuisance Act*, II GEO IV No 8 (1830)—An Act for abating the Nuisance occasioned by the great number of Dogs which are loose in the Streets of the Towns of Sydney, Parramatta, Liverpool and Windsor in the Colony of New South Wales, s 1; *Native Dogs Destruction Act* 1852 (NSW), sections 1 and 3; *Pastures and Stock Protection Act 1880* (NSW), recital and section 1; *Native Dogs Destruction and Poisoned Baits Act 1901* (NSW), sections 3 and 14; *Pastures Protection Act 1902* (NSW) sections 4 and 58; *Pastures Protection Act 1912* (NSW) section 4; *Birds and Animals Protection Act 1918*, section 3, sections 5-7, First and Second Schedule; Smith (14), 294.

[18] For example, *Pastures and Stock Protection Act 1880* (NSW), ss 8, 14 and 24; *Rabbit Nuisance Act 1883* (NSW) 22 7-12; *Rabbit Act 1902* (WA), s 27-34; *Rabbit Act 1913* (Qld), s 9; *Rabbits Destruction Act 1935* (Tas), ss22-26; *Royal Commission of Inquiry into Schemes for Extermination or Rabbits in Australasia* (Progress Report, Minutes of Proceedings) Government Printer (1890).

[19] Dunlap (9), 82; for example, the *Rabbit Nuisance Act*, An Act to provide for the Abatement of the Rabbit Nuisance 1883 (NSW), provided in sections 4 and 5 that inspectors had power to enter onto crown land to destroy rabbits but did not oblige inspectors or the crown to destroy rabbits.

[20] Stodart and Parer (16).

Authorities were impelled to consider alternative measures and they turned to finding the rabbit's natural enemies, who could reduce rabbit numbers to a "natural level," restoring nature's equilibrium[21]. Accordingly, legislation from 1883 provided that the governor could declare an animal the natural enemy of the rabbit[22]. Once this occurred, the animal became legally protected against killing, capturing or disposal[23]. Numerous declarations were made, evincing strong belief in the restorative power of domesticated and free-roaming cats, "iguanas" (goannas), and "native cats" (quolls) as enemies of the rabbit[24].

The strength of belief was reinforced by opinion pieces and letters to the editor, as well as by enthusiastic explanations accompanying reports of declarations[25]. One commentary dating from 1892, unequivocally declared "[e]xperience has proved that no damage is done by the cats which confine their attention solely to the rabbits[26]." While another dating from 1896 noted that although rabbits were increasing in the Dubbo region, "the natural enemies of the rabbit will prove too much for it[27]." This atmosphere of optimism encouraged the release of cats from NSW in the east to Western Australia in west, leading to the demand for cats quickly exceeding supply[28]. Events at Warrialpha station in South Australia were typical, where the landholder called for the release of additional cats, despite the fact that the station already contained some 5,000 of these animals[29]. Indeed, the notion of cats as an effective bulwark against rabbits persisted into the twentieth century, with one government stock inspector of 18 years' experience declaring that he knew: "…of no more formidable enemy of the rabbit than the domestic cat in a wild state[30]." Yet, farmers had already observed that notwithstanding how many rabbits were killed, their numbers quickly recovered[31]. In particular, by the early twentieth century commentators observed that decades of killing and poisoning had failed to reduce numbers in the long-term[32].

Rabbits had learned to avoid poisoned baits, leaving them to be taken up by useful animals such as horses, cattle and sheep, as well as native kangaroos, emus and brush turkeys[33]. In addition, poison destroyed other animals which were enemies of the rabbit, such as goannas, quolls, and cats. This upset the balance of nature by killing the very animals who would otherwise have kept rabbit populations in check[34]. Moreover, notwithstanding the many positive statements regarding the ability of cats to dispatch rabbits, one account from 1891 stated that cats "fraternize" with rabbits and that rabbits often take "no notice of the cats whatsoever[35]." The writer concluded that cats probably kill a few young rabbits, but "it is evident that the old ones have no fear of them[36]." This led to a level of dissatisfaction with the failure of official policies, with landholders conceding that rabbit killing was a chronic problem, which would provide regulators with "a permanent job[37]."

Discontent with official policies was also exacerbated by the fact that, in similarity with poison, cats were destroying animals other than rabbits[38]. In 1863, the famed ornithologist, John Gould observed that cats were attacking and killing a range of native birds and animals[39]. This was consistent with reports elsewhere that cats had killed introduced game birds such as pheasants and partridges[40], domesticated chickens[41], small animals and lizards[42]. Cats were also regarded as being especially destructive to sea bird populations on Lord Howe and Macquarie Islands[43]. Moreover, some settlers underscored their concerns by pointing to the fact that cats had no natural enemies, allowing them to multiply "at a great rate[44]." The role of dingoes or foxes in suppressing cat numbers was mentioned occasionally, but was not seriously discussed, as these were also considered to be agricultural pests[45].

By the twentieth century, Le Souef, a prominent biologist and zoologist, had expressed misgivings at official policy. He not only drew attention to the impact of free-roaming cats on

[21] Dunlap (9), King (18).

[22] *Rabbit Nuisance Act 1883* (NSW), ss 31, 32; *Rabbits Destruction Act 1889* (Tas), s24; *Pastures Protection Act 1902* (NSW), ss 24, 46; *Rabbit Act 1901* (NSW), s46; *Rabbit Act 1902* (WA), s 32; *Pastures Protection Act 1912* (NSW), s 69.

[23] Ibid.

[24] For example, Proclamation by His Excellency, the Right Honorable Lord Augustus William Frederick Spencer Loftus, declared cats as the enemy of the rabbit for a number of Electoral Districts, including, Albury, the Hume, Murrumbidgee, the Murray and Bourke, *New South Wales Government Gazette*, Tuesday July 31, 1883, page 4130; Proclamation by His Excellency, the Right Honorable Henry Robert Brand, Viscount Hampden, that the Iguana was natural enemy of the rabbit within the land district of Boorowa, *New South Wales Government Gazette*, Wednesday, 16 December, 1896, page 9063; Proclamation by His Excellency, Knight Commander of the Bath, Harry H. Rawson, that the iguana, native cat, tiger cat, ferret, mongoose, and stoat were natural enemies of the rabbit within the state of New South Wales, *New South Wales Government Gazette*, Saturday, 29 November, 1902, page 692 (supplement).

[25] "Protection of Cats", *Albury Banner and Wodonga Express (NSW)*, Friday 18 November 1904 p 29, with respect to the Gundagai region.

[26] "News Notes", *Macleay Argus (Kempsey, NSW)*, Wednesday 14 September 1892, p 5.

[27] "Rabbits Increasing", *Bathurst Free Press and Mining Journal*, Tuesday 11 August, 1896, p 2.

[28] For example, 400 cats were transported to Bourke in 1886 to be distributed throughout the region, Denny and Dickman (15), 4–5; 300 cats were released at one location, in Eyre, Stodart and Parer (16), 15.

[29] "News Notes", above n[26], 5.

[30] "The Useful Cat", *Bundarra and Tingha Advocate (NSW)*, Saturday 25 November 1905 p. 2. This statement is attributed to E W Proctor, an Inspector of Stock.

[31] "Agricultural Notes", *The Leader (Melbourne, Vic)*, Saturday 20 March 1886 p. 9.

[32] "Rabbits and Remedies, the Balance of Nature", by "Gossip", *The Sydney Stock and Station Journal (NSW)*, Friday 11 May 1917 p. 3.

[33] "When you are Kept Awake", *The Armidale Chronicle (NSW)*, Saturday 30 March 1907 p 8.

[34] "Rabbits and Remedies, the Balance of Nature", by "Gossip", above n[32], 3; "When you are Kept Awake", *The Armidale Chronicle (NSW)*, above n[33], 8.

[35] Untitled, *The Hay Standard and Advertiser for Balranald, Wentworth, Maude (Hay, NSW)*, Saturday 16 May 1891 p. 2.

[36] Ibid.

[37] "Agricultural Notes", above n[31], 9.

[38] "Notes and News", *Australian Town and Country Journal (Sydney)*, Saturday 16 October 1886, p. 28; "Wild Cat Legislation", *The Newsletter: an Australian Paper for Australian People (Sydney, NSW)*, Saturday 4 November 1905, p. 15; "Nature is too Slow", *The Sydney Stock and Station Journal (NSW)*, Friday 13 July 1917, p. 4.

[39] Denny and Dickman (15), 5.

[40] "Notes and News", above n[38], 28.

[41] "Wild Cat Legislation", above n[38], 15; "Nature is too Slow", above n[38], 4.

[42] For example, "A New Cat that eats Lambs", *The Newsletter: an Australian Paper for Australian People (Sydney)*, Saturday 27 December 1913, p. 5; "Nature is too Slow", above n[38], 4.

[43] "A new Cat that eats Lambs", above n[42], 5.

[44] For example, ""A new Cat that eats Lambs", above n[42], 5; ""Nature is too Slow", above n[38], 4.

[45] Discussion in part 2.2 of this article.

sea-birds and native animals[46], but he also questioned the cat's usefulness as the enemy of the rabbit. He pointedly noted that "[the cats'] influence on the rabbit question remains to be seen and it is to be hoped that in this direction they will be of some use to the country and justify their existence[47]." Almost two decades before these observations, other commentators had voiced comparable concerns, critiquing accepted wisdom that every pest had a natural enemy and noting that "the natural enemies of the rabbits have themselves become pests[48]." Yet, the notion of managing nature by using natural enemies was hard to shake off and the official position stood firm. In 1913, W E Abbott, an advisor to the NSW government, used mathematical calculations to demonstrate how growing numbers of cats would, in a short time, eradicate any residual rabbits, allowing "the balance of nature… [to] be restored[49]."

THE BALANCE OF NATURE

The balance of nature was an important concept in settler societies. It was intricately connected with ideals of creating "a new England," to be achieved by dispossessing Indigenous populations and overhauling the land to make it suitable for game hunting, agriculture and pastoral activities[50]. King describes the concept of balance in nature

> as a stable state of nature, steadily maintained by the interactions between natural communities and their environment… [allowing] disturbances to this mutual harmony… [to be] corrected by increased attention from their natural enemies… [51]

The ideal balance could be discerned by "observation and common sense," which would identify predators and prey, encouraging predators to reduce unwanted animals[52]. Cats attacked rabbits, therefore they were the enemy of the rabbit, signifying that more cats meant fewer rabbits. It was a simplistic view that involved limited observation of species' interactions. It did not, for example, deal with broader connections, such as, the impact *of* free-roaming cats on native biodiversity, or the impact *on* rabbits or free-roaming cats of predators, such as dingoes and foxes.

By the twentieth century commentators were making these connections, but they were also aware of the scant regard paid by regulators, which was invariably limited to improving primary production. In 1935, for example, an anonymous letter to the editor of *The West Australian (Perth)*, drew analogies between game management in England and the rabbit problem in Australia[53]. The writer explained that typical management practices involved destroying foxes, cats, and hawks, which were the enemies of game animals, allowing the latter to proliferate. In the writer's opinion, an analogous situation had occurred in Australia. Foxes and raptors were earmarked for destruction because of conflicts with livestock production, yet this ignored the fact that these animals were also the enemy of the rabbit[54]. Accordingly, by killing predators, landholders had upset the balance of nature, allowing rabbits to proliferate[55]. The author, therefore, favored protecting foxes[56]. This was not a novel idea with another commentator having noted in 1923 that although foxes might cause damage during the lambing season, at other times they are "a powerful enemy of the rabbit[57]." In a similar way, Christopher Lynch who was a rural inspector, had concluded that the presence of foxes meant low rabbit numbers and mooted the idea of protecting foxes (19). The difficulty, however, was that the fox was also an agricultural pest and the thought of it being protected would have been incomprehensible.

In any event, although discussion in the media identified relationships between rabbits, cats, foxes, and native biodiversity, the connections did not filter through to official regulation. In particular, protection of species and subsequently, biodiversity at large, only started gaining momentum from the mid-twentieth century onwards (20). Yet, even at this time, free roaming cats eluded official scrutiny. They did not pose a threat to primary production, nor were they considered harmful to native fauna, thus they escaped regulatory attention.

THREAT TO BIODIVERSITY AND BIOSECURITY RISK

Australian jurisdictions have long regulated nuisance/pest/feral animals[58]. However, up to the later part of the twentieth century this was traditionally undertaken to protect the agricultural and pastoral product sectors[59]. The notion of protecting native biodiversity from introduced species started gaining traction after this time. The *Territory Parks and Wildlife Conservation Act 1977* (NT), for example, authorized the Minister to declare species a "feral animal," triggering obligations on the part of

[46] "The Cat Problem in Australia", *Sunday Times (Perth)*, Sunday 22 December 1912 p. 8; "The Cat Problem", *The Kadina and Wallaroo Times (SA)*, Wednesday 29 January 1913 p. 4.
[47] "The Cat Problem", above n[46], 4.
[48] "The Natural Enemy", *Daily Telegraph (Launceston, Tasmania)*, Saturday 17 March 1894 p. 7.
[49] Abbott WE. *The Rabbit Pest and the Balance of Nature,* cited in Smith (14), 295.
[50] Dunlap (9), 2, 141.
[51] King (18), 54.
[52] Dunlap (9), 87.
[53] "Rabbit Menace" letter to the editor by "one who has suffered", *The West Australian (Perth)*, Thursday 2 May 1935, p. 10.
[54] Ibid.
[55] Ibid; "Foxy Ways", *Smith's Weekly (Sydney, NSW)*, Saturday 24 March 1923 p. 23.
[56] "Rabbit Menace", letter to the editor by "one who has suffered", above n[53], 10; "Foxy Ways", above n[55], 23.
[57] "Foxy Ways" above n[55], 23.
[58] *Dog Nuisance Act 1830* No 9a (NSW) (An Act for abating the Nuisance occasioned by the great number of Dogs which are loose in the Streets of the Towns of Sydney Parramatta, Liverpool and Windsor in the Colony of New South Wales); from Tasmania, the *Rabbits Destruction Act 1882* (46 Vic, No. 35); the *Rabbit Boards Act 1896* (Qld); the *Pastures and Stock Protection (Rabbit) Act 1900* (NSW); the *Vermin Act* 1918 (WA); the *Stock Routes Improvement and Animal and Vegetable Pests Destruction Act 1936* (Qld); and the *Pastoral Land Act 2011* (NT); *Local Land Services Act 2013* (NSW), ss 130 and 142 [now repealed and subsumed into the *Biosecurity Act 2015*(NSW)]; *Land Protection (Pest and Stock Route Management) Act 2002* (Qld), sections 36–38.
[59] Ibid.

landholders to eradicate declared animals[60]. Several species were categorized as feral, including rabbits, donkeys, pigs, camels, and cats[61].

It was not until the 1990s, however, with the advent of international interest in the protection of biodiversity that the impact of introduced species, including free-roaming cats, started receiving broad attention. In 1992 Australia became a signatory to the Convention on Biological Diversity, which amongst other things, requires the contracting parties to "prevent the introduction of, control or eradicate" alien species that threaten biodiversity[62]. In accordance with this obligation the Commonwealth Government passed the *Environment Protection and Biodiversity Conservation Act 1999* (CTH) which provides for the listing of threatening and key threatening processes[63]. Predation by free-roaming cats is currently listed as a key threatening process pursuant to this act[64]. Similarly in NSW, Predation by the Feral Cat *Felis catus* (Linnaeus, 1758) was listed as a threatening process in Schedule 3 of the *Threatened Species Conservation Act 1995* (NSW). This has now been carried over to schedule 4 of the *Biodiversity Conservation Act 2016* (NSW). In response to these listings, the state of NSW adopted a range of regional pest management strategies to deal with multiple pests, including cats[65]. At the Commonwealth level, the Australian government has directly targeted free-roaming cats, adopting three threat abatement plans (TAPs): The Threat Abatement Plan for Predation by Feral Cats, 1999 (1999 TAP); The Threat Abatement Plan for Predation by Feral Cats, 2008 (2008 TAP); and, the latest TAP, the Threat Abatement Plan for Predation by Feral Cats, 2015 (2015 TAP)[66].

In addition to these TAPs and management plans, cats are also managed by an array of legislative and policy instruments that declare them a pest or feral, triggering further eradication and control provisions. In NSW, for example, the *Game and Feral Animal Control Act 2002* (NSW), allows shooting of non-indigenous game animals, defined to include free-roaming cats, as long as shooters have the appropriate license[67]. In the Australian Capital Territory, the *Pest Plants and Animals Act 2005* (ACT) allows the Minister to declare an animal a "pest animal," which among other things leads to prohibitions on keeping and supplying the animal[68]. At the time of writing, no animal had formally been declared a pest, although authorities have adopted the *ACT Pest Animal Management Strategy, 2012–2022*, a policy instrument that deals with pest animals, including free-roaming cats (22).

The strategy emphasizes the negative impacts of free-roaming cats and proffers a variety of traditional management options based on trapping, shooting and baiting (22). At the same time, the strategy also qualifies the use of lethal methods by noting that cats may not readily accept poison baits and also points out that trapping and shooting are expensive and labor-intensive[69]. Importantly, the strategy stipulates that more research on free-roaming cats is needed and that, apart from trapping and shooting at ecologically important sites, the cat's "[e]cological role as a predator/competitor needs to be determined if a broad-acre control program is contemplated[70]." These qualifications hint at underlying problems with broadscale lethal control, which in other jurisdictions continues to be rolled out, notwithstanding a lack of adequate data on species interactions and the place of free-roaming cats in Australia[71]. The latest iteration of laws proscribing free-roaming cats derives from biosecurity regulation that encompasses economic concerns, risks posed by cats to human health, as well as threats to biodiversity[72].

In Queensland free-roaming cats were a declared pest under the *Stock Route Management Act 2002* (QLD)[73], but are now are regulated under the *Biosecurity Act 2014* (QLD). Amongst other things, the latter contains seven categories of "restricted matter," which are set out in schedule 2. The categories relate to noxious fish, pest and invasive animals, insects, and weeds and are supplemented by a series of obligations and offenses, that vary according to the category[74]. Typical obligations prohibit the release or distribution of restricted matter, as well as prohibitions on moving or feeding them[75]. Species may be listed in more than one category

[60] *Territory Parks and Wildlife Conservation Act 1977* (NT), ss 47–51.

[61] Regulations under the Territory Parks and Wildlife Conservation Ordinance (1978), clause 5, Schedule 3.

[62] *Convention on Biological Diversity 1992*, Article 8(h). The Convention was adopted 5 June 1992, [1993] ATS no 32 (entered into force 29 December 1993). The convention had 196 Parties as of November 2018.

[63] *Environment Protection and Biodiversity Conservation Act 1999* (Cth), ss 183, 188, 528.

[64] *Environment Protection and Biodiversity Conservation Act 1999* (Cth), s183, the list is maintained by Department of the Department of Environment and Energy. Available online at: http://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl

[65] For example, the Blue Mountains regional strategy deals with plant and animal pests, including lantana, foxes, wild dogs, and cats. Office of the Environment and Heritage, Regional Pest Management Strategy 2012–2017: Blue Mountains Region, (2013) 45–46. Available online at: http://www.environment.nsw.gov.au/research-and-publications/publications-search/regional-pest-management-strategy-2012-2017-blue-mountains-region

[66] Department of the Environment, *Threat Abatement Plan for Predation by Feral Cats*, Commonwealth of Australia, 2015, above n[3]. Two prior plans had been made in 1999 and 2008: Environment Australia, Biodiversity Group, *Threat Abatement Plan for Predation by Feral Cats*, (1999); (21).

[67] *Game and Feral Animal Control Act 2002* (NSW), ss 5, 16, Schedule 3.

[68] *Pest Plants and Animals Act 2005* (ACT), ss 16, 19–20.

[69] ACT Government, Environment and Sustainable Development, *ACT Pest Animal Management Strategy, 2012-2022*, (22), 70.

[70] Ibid.

[71] Discussion in part 4.1 of this article.

[72] *Biosecurity Act* 2015 (NSW) s 13, definition of biosecurity risk; *Biosecurity Act 2015* (Cth) contains numerous provisions, where the concept can vary, however Chapter 3 deals with biosecurity risks deriving from imported goods and Chapter 4 manages biosecurity risks with respect to conveyances and vehicles entering Australia.

[73] Denny and Dickman (15), 10.

[74] *Biosecurity Act 2014* (QLD), ss 42–45.

[75] *Biosecurity Act 2014* (QLD), s 43 (1) prohibits the release or distribution of category 3 restricted matter, which in accordance with 43(3) includes giving it to another person or releasing it into the environment; s 44 obliges the holders of category 7 restricted matter to kill or destroy it; s 45 (1) (a) prohibits moving a category 5 restricted matter, while s 45 (1) (c) prohibits feeding a category 6 restricted matter.

resulting in overlapping obligations and prohibitions. Free-roaming cats, for example, are listed in categories 3, 4, and 6, leading to prohibitions on feeding or giving them to another person as well as releasing them into the environment. This legislation only differentiates between two categories of cats, domestic cats, and other cats. It does not acknowledge stray cats as a separate category, which has implications, discussed in section Facilitating TNR, with respect to the legality of TNR.

In a comparable manner, Schedule 3 of the *Biosecurity Act 2015* (NSW), lists a number of "prohibited dealings," which include moving, releasing, feeding or treating domestic cats who have genetic material from *Leptailurus serval*[76]. This prohibition is consistent with a ban on importing savannah cats (a cross between a wild serval cat and a domestic cat) made by the then Minister for the environment, Peter Garrett in 2008 (23). Given the controversy surrounding management of free-roaming cats and the potential for savannah cats to form free-roaming populations, the decision was sound from an environmental perspective, but it proved contentious, as evinced by threats from proposed importers to sue the government[77].

The restrictions, prohibitions, and control of free-roaming cats discussed thus far, represent views of nature and humanity's relationship to nature, which are based on human ideas of what needs to be protected and how to protect it. Accordingly, in the early days of NSW, cats were defended for their role in destroying rabbits; yet, without a backward glance, the same animal is now targeted for eradication and control. However, some sections of the community are voicing concern about lethal control, raising difficult issues concerning the management of unwanted and problem species[78]. Although advances in science and the scientific method have progressed from natural history to ecology, scientific developments neither dictate how advances in knowledge should be used, nor do they necessarily identify the most appropriate choice of measures[79]. The discussion now leads to the remaining question, concerning community views on lethal control, the effectiveness of TNR and the role of TNR in regulatory regimes.

TRAP NEUTER RELEASE

TNR involves catching free-roaming cats, "sterilizing them and returning them to the place where they were found[80]." It offers regulators a management choice that differs from current practices which rely on wholesale killing in all circumstances. TNR, itself, has led to a lively debate in the literature concerning its practicability, effectiveness and welfare outcomes[81]. In some cases, TNR has reduced population numbers and has had good welfare outcomes, yet in other cases TNR has operated less effectively (25). Australian commentators are ambivalent about TNR, concluding that it "is unsuccessful in open populations and not practical over large areas[82]," or that it "could work in specific well-defined areas but in general is not a solution to the problem in Australia[83]." These conclusions, do not give whole-hearted support for TNR; yet they also do not dismiss it out of hand, something that Australian regulation comes close to doing. The background statement to the 2015 TAP states

> Capturing, sterilising and releasing (otherwise known as trap, neuter, release/return, or TNR) programs are seen as an effective approach to managing colonies of stray cats in urban areas elsewhere in the world and are promoted in Australia. This approach should be considered unacceptable in Australia as there are no benefits to wildlife and it does not improve the welfare of the individual animals concerned (26)

The 2015 TAP itself, similarly rejects TNR, although it grudgingly concedes that it could be useful in very limited circumstances

> The concept of trapping, neutering, and releasing stray cats as a method of population control should also be discouraged on animal welfare grounds and because it is not effective, except where populations are truly isolated and all females are neutered[84]

Notwithstanding the lukewarm appraisal of TNR, two arguments can be made in favor of supporting it, one deriving from management goals and the other based on ethical considerations.

TNR and Management Goals

Management goals should be a means of aligning activities with aims and objectives. The overarching goal of the 2015 TAP is to minimize the impact of free-roaming cats on native biodiversity[85]. Hence, control and eradication measures should demonstrate improvements in biodiversity protection. In addition, the *Threatened Species Strategy* (TSS) operates in conjunction with the 2015 TAP by detailing policies for species' recovery (27) Both the TSS and the 2015 TAP proceed on the assumption that killing free-roaming cats is the most effective management option[86]. The TSS, in particular, aims at killing 2 million free-roaming cats by 2020, as well assisting in the recovery of 40 threatened mammal and bird species[87]. Yet, neither instrument explains how killing this number of free-roaming cats will improve biodiversity outcomes or aid in species'

[76] *Biosecurity Act 2015* (NSW), ss s 12, 151.

[77] Unattributed author, news story, "Couple to Sue over Savannah Cat Ban," Sydney Morning Herald, 4 August, 2008. Available online at: https://www.smh.com.au/national/couple-to-sue-over-savannah-cat-ban-20080804-3pi0.html

[78] Mellor and Littin (24); generally, Thiriet D. Flying Fox Conservation Laws, Policies and Practices in Australia - A Case Study in Conserving Unpopular Species, (8), 161.

[79] Dunlap (9), 273.

[80] Paterson (2), 170.

[81] For example, Trigger and Mulcock (5); Paterson (2), 170.

[82] Denny and Dickman (15), 1-2.

[83] Paterson (2), 170.

[84] Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats*. Commonwealth of Australia (2015) above n[3], 3.

[85] Ibid, 10.

[86] Australian Government (27); Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats*. Commonwealth of Australia (2015). above n[3], 8–9.

[87] Australian Government. *Threatened Species Strategy*, above n[86], 11, details 20 mammal species and 20 bird species.

recovery[88]. By way of contrast, some activities proposed by the TSS, such as reporting and monitoring in the Kosciusko National Park NSW, facilitate gathering and analyzing data, which will identify the effectiveness, or otherwise, of culling[89]. However, the overall focus of the TSS still deems killing *per se* as an effective performance indicator[90]. This outlook is reinforced by a progress report that classifies killing one million cats within 2 years as an important environmental milestone[91]. The literature, however, challenges this comfortable reliance on wholesale killing.

To start with, culling does not always succeed in reducing population numbers in the long-term, unless the number of cats killed "exceed[s] the replacement rate through breeding and immigration" (28). Accordingly, reductions in cat numbers following culling operations are often short-lived, as cats move from adjoining areas to depleted colonies (28). In addition, population numbers are at best, "guesstimates" and where regulators incorrectly gauge the required level of culling it can lead to increased populations[92]. Generally speaking, culling is also unlikely to eradicate free-roaming cats on mainland Australia, a point conceded by the 1999 TAP and confirmed by the 2015 TAP[93]. Managing free-roaming cats is thus likely to remain a lingering environmental problem, creating many regulatory challenges, which to date have not been resolved by continual killing.

Second, the problem also extends to the choice of methods, such as the use of poisons, which kill indiscriminately. "Predation events" are attributable to male cats weighing 3.5 kg or more, signifying that to improve environmental outcomes, poisoning needs to target these animals (30). Yet, free-roaming cats frequently avoid taking poison baits and even when they do, there is no guarantee that individuals responsible for predation will be the ones to do so[94]. In addition, poison destroys other, susceptible animals, including native species that baiting programs are presumed to protect[95]. Regulators are in the process of creating cat-specific poisons, but this also raises ethical issues that are dealt with in the next part of this article.

Third, alternative methods, such as trapping and shooting are more targeted, but they are expensive and not suitable for large areas, although they could be feasible for more restricted areas, such as islands[96]. Yet, even here, the 2015 TAP notes that "[t]his is generally not cost-effective in the long-term" as it still requires continued monitoring and "a sustained control program[97]." It is therefore a matter of some irony, that cost and ineffectiveness are frequently cited as reasons for dismissing TNR[98].

Fourth, a related issue stems from species' interactions and the impact of cat eradication programs on populations of rabbits and rodents, which are prey species for free-roaming cats[99]. Research indicates that reducing densities of free-roaming cats would likely lead to increased numbers of rabbits and rodents, which would be an unwelcome side-effect of cat eradication programs[100]. Similarly, the role of free-roaming cats as prey for foxes and wild dogs requires greater consideration[101]. Where populations of free-roaming cats are reduced, the impact on other predators is unclear, particularly whether these predators will turn to native animals. As already discussed, these types of issues were highlighted in the *ACT Pest Animal Management Strategy*, 2012–2022 and are also acknowledged by the 2015 TAP[102]. The latter concedes that while regulators need to be aware of species' interactions, it is a very difficult task, bearing in mind the vastness and variety of ecosystems across Australia and the inconsistency of interactions within these ecosystems[103]. One benefit of TNR is that it does not immediately remove large numbers of free-roaming cats from an environment. Instead, it provides an opportunity to monitor and evaluate changes in the ecosystem as neutered cats die out. From a practical perspective, this fact alone should have signaled that TNR deserves, at least, to be tested properly.

In reality, the reliance on lethal methods is an almost a perverse turnabout of logic, reverting to the natural history approaches of the nineteenth and early twentieth centuries. As discussed, these approaches promoted the removal of unwanted species *per se*, in an attempt to restore balance to nature and also provided the justification for releasing cats to control rabbits. The dissent created by those policies finds parallels with modern-day controversies where environmentalists see culling as the most effective management option, while animal welfarists argue against this. Certainly, arguments made today against wholesale culling of cats, are strikingly similar to those made in the nineteenth and early twentieth centuries against the use of cats to control rabbits: killing does not pay sufficient attention to relationships among species[104]; the ineffectiveness of poison[105]; and, the fact that populations of animals recover as migrations occur from adjoining areas[106]. In as much as the fundamental arguments have not changed, but apply to different aspects of society's relationship with cats, this should cause regulators to

[88] Ibid, 11, 47, 48, 49–50.
[89] Ibid, 48.
[90] Ibid, 11.
[91] Australian Government. *Progress Report to the Minister for the Environment and Energy*, July 2016–December 2017, 19. Available online at: http://www.environment.gov.au/system/files/resources/12d8cf25-0169-46d6-8c72-dfe204ccf44c/files/threatened-species-strategy-progress-report.pdf
[92] Lynn (4); (29).
[93] Environment Australia, Biodiversity Group. *Threat Abatement Plan for Predation by Feral Cats* (1999), above n[66], 6, 19; Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats*. Commonwealth of Australia (2015), above n[3], 9; Doherty et al. (13), 92.
[94] Denny and Dickman (15), 2.
[95] Ibid.
[96] Paterson (2), 170.
[97] Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats*. Commonwealth of Australia, 2015, above n[3], 20.
[98] Ibid, 23.
[99] Denny and Dickman (15), 2.
[100] Ibid.
[101] Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats.* Commonwealth of Australia (2015), above n[3], 15.
[102] Australian Government, Department of the Environment (26), 5.
[103] Ibid.
[104] "Rabbit Menace," letter to the editor by "one who has suffered," above n[53], 10; "Foxy Ways," above n[55], 23; Denny and Dickman (15), 2.
[105] "When you are Kept Awake," above n[33], 8; "Rabbits and Remedies, the Balance of Nature," by "Gossip," above n[32], 3; Denny and Dickman (15), 2.
[106] "Agricultural Notes," above n[31], 9; Swarbrick and Rand (28), 3–4.

question why policy failures of the past are repeated in present-day regimes and why non-lethal methods and ethical concerns have been side-lined.

TNR, Societal, and Ethical Values

Incorporating ethical concerns, as well as social and cultural values, is essential to managing free-roaming cats. Killing animals polarizes public opinion and without community engagement, regimes may be seen to lack legitimacy. For some, "the only good cat is a dead one[107]." Yet for others, cats have assumed a high degree of symbolism, being unfairly targeted as scapegoats for loss of biodiversity[108]. Yet again, others with a more pragmatic outlook, agree that regulators need to protect native birds and animals from cat predation, but without relying on wholesale culling[109]. Consequently, cats have social and cultural values that, arguably, should be captured by regimes[110].

Yet, current policy statements tend to gloss over the importance of societal and ethical values, instead relying on utilitarian ideals to justify culling and the use of poison on the basis that these methods are "net-humane":

> When considering the use of [poison]…, it's important to think about whether it will be effective, and whether the action is justified, including the impact of not taking those actions on the nightly slaughter and maiming of threatened species caused by feral cats. Acting on feral cats is net -humane because it saves millions of native animal lives...It is not realistic or feasible to trap neuter and release millions of feral cats across the more than seven million square kilometres of the Australian continent…[it] would not be humane, effective, or justifiable.… highly stressful for millions of feral cats, transported as wild animals in cages in remote and hot conditions across thousands of kilometres to be neutered and then returned to the wild[111].

These statements proffer a typical utilitarian analysis that accepts culling as necessary because it is seen as the only way to improve biodiversity outcomes, as well as save native species and deal with the ethical limitations of TNR. The clear message is that TNR raises welfare and conservation issues, which somewhat paradoxically, can only be addressed by dismissing TNR in every situation. In an analogous context, dealing with gray squirrels in the United Kingdom, Crowley et al. conclude that these perspectives make introduced species "killable"

> The message is that grey squirrels are not appropriate subjects of care or concern (indeed, some implied that encounters with them shouldn't be encouraged or enjoyed), that their appropriate classification is as vermin or invasives, and that they should be treated (killed) accordingly (32).

The substance of this argument, is consistent with processes that occur in Australia, where national codes of conduct and local management plans turn to killing as a first point response, normalizing it and entrenching it into regulation[112]. Such conclusions are based on underlying assumptions regarding the damage attributable to free-roaming cats, the effectiveness and relative humaneness of culling and the futility of TNR—assumptions which are contested[113].

To start with, it is important to acknowledge that free-roaming cats can cause environmental harm. A recent study on the damage attributable to free-roaming cats concludes that they impact on native species "through predation, disease transmission, and resource competition…[as well as being] the principal cause of extinction of at least one Australian bird subspecies (Macquarie Island red-fronted parakeet)[114]." Free-roaming cats have also been implicated in the transmission of diseases such as toxoplasmosis, although the effects on native species are not well-understood[115]. However, free-roaming cats also help control some introduced species, such as rodents and rabbits[116] and, in addition the scope and extent of threats presented by free-roaming cats remains unsettled[117]. These differing considerations create many challenges for regulators, who must navigate incomplete knowledge structures and community expectations, when deciding on appropriate measures to protect native biodiversity. The latter is without question an important environmental objective, yet the contentious nature of killing makes alternative methods a more palatable solution in the eyes of the public[118]. The intricacies of this point become clearer on further examination of the relationship between killing and the impact of free-roaming cats on biodiversity.

Such impacts vary according to location. In urban and peri-urban areas, for example, cats kill birds, but so too do other predators, such as snakes, goannas, and raptors[119]. This does not necessarily lead to loss of biodiversity, unless more birds are taken than survive to adulthood[120]. Additionally, species taken by cats are invariably the ones who survive urbanization and are often among the most abundant due to increased availability of food and habitat provided by human-generated changes[121]. Perhaps of more concern in urban areas

[107] Trigger and Mulcock (5), 1307.
[108] Smith (14), 301.
[109] Trigger and Mulcock (5), 1307; Swarbrick and Rand (28), 2.
[110] Trigger et al. (31); Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats*. Commonwealth of Australia (2015), above n[3], 15.
[111] Australian Government, Department of the Environment and Energy. *Frequently Asked Questions, Tackling Feral Cats and Their Impacts*, Office of the Threatened Species Commission, 5, 7. Available online at: https://www.environment.gov.au/system/files/resources/bb591b82-1699-4660-8e75-6f5612b21d5f/files/factsheet-tackling-feral-cats-and-their-impacts-faqs.pdf; also Australian Government, Department of the Environment (26), 6; Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats*. Commonwealth of Australia (2015), above n[3], 23.
[112] Riley (8), 280.
[113] Lynn (4).
[114] Doherty et al. (13), 84.
[115] Dickman (33); Institute of Wildlife Research University of Sydney (1996). Available online at: https://www.pestsmart.org.au/wp-content/uploads/2010/03/impacts-feral-cats.pdf; Doherty et al. (13), 87-88.
[116] Doherty et al. (13), 94.
[117] Lynn (4).
[118] Crowley et al. (32), 129.
[119] Low T. *Feral Future*, above n[5], 190–194.
[120] Ibid, 191.
[121] Ibid, 190–194.

is the way urbanization and land clearing are altering the mix of species, leading to decline in populations of small birds (34–37).

Elsewhere, research reveals that cats usually prey on animals such as rabbits and house mice, while in plague seasons, mice comprise the entire diet of free-roaming cats with rabbits comprising up to "89% by weight[122]." However, where there are insufficient mammals, free-roaming cats turn their attention to small animals, reptiles, and birds, so that threatened species such as the bilby and marsupial mole may be at risk[123].

However, it is questionable whether the fact that free-roaming cats threaten native species in some circumstances, justifies the use of lethal measures as the default position on the basis that it is "net humane." Lethal measures should always require a high degree of justification, and at the very least should be underpinned by sound research that allows them to be deployed where they will be most effective[124]. Moreover, lethal measures need to be monitored, not only to establish whether populations of free-roaming cats have reduced in the long-term, but also to demonstrate how this leads to improved biodiversity outcomes. The 2015 TAP does in fact incorporate provisions regarding research on species interactions and devising ways to improve survival rates of threatened species[125]. However, this needs to be read in conjunction with the TSS that, as already discussed, focusses on killing 2 million cats without providing detail as to how regulators will determine whether culling is linked to successful biodiversity protection[126].

These matters signal that law and policy rely on a superficial form of utilitarianism that balances killing cats against the assumed ineffectiveness of TNR, as well as unverified biodiversity outcomes. Law and policy do not consider either the pain and suffering of animals who are subjected to lethal measures, or the social and cultural dimensions of free-roaming cats. Although the three TAPs make brief references to ethical, social and cultural concerns, it is doubtful whether these matters are adequately addressed. The 1999 TAP, for example, agreed that regard to "differing cultural values attached to domestic and feral cats [was important to] any control program[127]." However, this did not lead to cultural values being incorporated into management plans. In a similar way, the 1999 TAP also refers to animal welfare, a concept which has clear ethical implications. Yet, this was seen in terms of a form of "humaneness," which condoned lethal methods, as long as they were environmentally safe and did not affect domesticated cats[128]. In restricting the notion of humaneness in this way, the TAP deftly side-stepped problematic welfare concerns. The 2008 TAP also contained references to humaneness, but this was equated with the need to develop a toxin-bait that was specific to cats[129]. Likewise, the 2015 TAP acknowledges that ethical and social issues need to be examined, but considers that these issues can be addressed by adhering to the Model Code of Practice for the Humane Control of Feral Cats[130]. However, this code, in common with other model codes, has been critiqued for its focus on lethal measures and lack of ethical awareness[131].

Consequently, while the TAPs refer to animal welfare, humane methods of control and cultural issues, engagement with these matters is not meaningful. Non-lethal methods, such as using Maremma dogs to protect native species, developing immunocontraceptive vaccines and habitat management, are not given credence[132]. The focus firmly remains on finding a poison that is quick-working, that cats will accept and that is unattractive to non-target animals. This line of thought is so entrenched, that it has extended to investigating whether gene editing can alter cat DNA, to make cats susceptible to particular poisons[133]. It seems incongruous that such a process is being considered, without even a perfunctory review of its ethical basis. From a more pragmatic perspective, these developments also continue to focus on killing, which as already discussed, is not a long-term solution[134]. At best, it is a stop-gap measure that necessitates constant eradication and control efforts[135]. The benefit of TNR is that provides an alternative method that can achieve results and can also re-set the debate by addressing ethical concerns that current regulation side-steps.

Although society might not be conversant with, or even interested in ethical theory, community abhorrence, at mistreating animals has a very practical consequence that manifests in reluctance to endorse killing as the usual response. This much was clear as early as 1913, when in the course of critiquing the effectiveness of cats as the enemy of the rabbit, Le Souef noted that people simply do not enjoy killing cats[136]. In his view, this partially explained why cats continued to be released, rather than being controlled or eradicated, given their ineffectiveness in controlling rabbits[137]. Indeed, disregard of ethical and social values can undermine the best-planned regimes, a point demonstrated by the recent reversal of a planned brumby cull in NSW (39).

In an analogous manner, individuals as well as community groups and animal welfare organizations, in Australian and

[122] Dickman C. Overview of the impacts of feral cats on Australian Native Fauna, (33), parags 3.4, 4.2.
[123] Paltridge (38); Paterson (2), 172.
[124] Mellor and Littin (24), 44.
[125] Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats*, Commonwealth of Australia, 2015, above n[3], objective 1, action 1.3 and 1.4, p 15-16, objective 2, action 2.3, p 19, objective 3, action 3.4, p. 22.
[126] Australian Government. *Threatened Species Strategy*, above n[86], 41, 63.
[127] Environment Australia, Biodiversity Group. *Threat Abatement Plan for Predation by Feral Cats* (1999), above n[66], 17.
[128] Ibid.
[129] Department of the Environment, Water, Heritage and the Arts. *The Threat Abatement Plan for Predation by Feral Cats* (2008), (21), objective 4, p 8.
[130] Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats*. Commonwealth of Australia (2015), above n[3], 20.
[131] Generally, Riley (8).
[132] Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats*. Commonwealth of Australia (2015), above n[3], 15-17.
[133] Australian Government, Department of the Environment (26), 16.
[134] Doherty et al. (13), 90.
[135] Ibid.
[136] "The Cat Problem", above n[46], 4.
[137] Ibid.

overseas jurisdictions have undertaken several TNR programs[138]. They have achieved success and have generated important information[139]. At the same time, the programmes in Australia have usually been conducted independently of official strategies, which has meant that the community has had to tread a fine line, to avoid potential breaches of the law as they treat, feed and/or release free-roaming cats.

Facilitating TNR

The use of TNR among the community is gaining ground. In this context, the notion of "community" is not a term with a settled meaning. It includes programs run by: Non-Government Organizations, such as the Australian Pet Welfare Foundation, which is lobbying for legalized TNR[140]; actions by *ad hoc* rescue groups, such as University of NSW, the Campus Cat Coalition[141]; and, individuals who feed cats, neuter them and return them to the wild (42). In Australia, TNR is commonly carried out by individuals, rather than organizations and occurs in urban areas, such as capital cities (42).

The acceptance and popularity of TNR among the community represents an opportunity for regulators to engage with the public in addressing the issue of free-roaming cats. Indeed, community engagement, is itself an objective of the 2015 TAP[142]. Yet the TAP has interpreted this aim as a call to convince the public that TNR is not viable, warning them against assisting or feeding free-roaming cats[143]. The TAP also advocates managing refuse responsibly, to discourage rats and mice, which are prey for cats[144]. While managing refuse has health and safety benefits, the admonishment against feeding cats raises the prospect of illegality in implementing TNR, both in feeding stray cats and also in treating and releasing free-roaming cats.

The *Prevention of Cruelty to Animals Act 1979* (NSW), for example, simply says that "a person shall not abandon an animal[145]." This provision, which applies to all animals, potentially makes the release of cats, as part of TNR, an offense under animal cruelty regulation[146]. In Victoria, similar legislation applies to domestic animals or animals "usually kept in a state of confinement for a domestic purpose[147]." Given that cats can shift between categories, from domestic to stray to free-roaming and back again, these types of provisions create legal uncertainty. Moreover, as already discussed, particularly with respect to Queensland, biosecurity legislation creates offenses for capturing, treating and feeding cats[148].

Although regulation pertaining to cats may be difficult to police, is susceptible to ambiguities and, as far as the writer is aware, has not yet resulted in any prosecutions, it is nevertheless a formidable barrier to trialing TNR. The threat of illegality and the potential for lawsuits have been identified in other situations as having "chilling" effects, causing stakeholders to waiver in undertaking activities (43, 44). This potentially discourages trials of TNR, a constraint that in a research context is reinforced by the fact that Animal Ethics Committees are highly unlikely to approve research that does not comply with the law[149]. In Australian higher educational institutions, for example, Animal Ethics Committees, are governed by stringent research and integrity policies that specifically call for compliance with rules and regulations[150].

A novel attempt at dealing with these matters occurred in 2014, when Alex Greenwich, the independent member for the Sydney electorate, introduced a private members bill into the Legislative Assembly of the NSW Parliament. The bill, titled the Animal Welfare (Population Control Programs) Bill 2014 (the Bill), aimed at removing liability for groups and individuals undertaking TNR[151]. In accordance with the Bill, TNR activities would have been licensed and provided they were undertaken under the auspices of a "sponsoring agency," the activities would not have been illegal[152]. Sponsoring agencies were nominated in clause 3 of the Bill, to include animal welfare organizations such as the Royal Society for the Prevention of Cruelty to Animals, NSW, the Animal Welfare League NSW as well as local government councils. Although the Bill lapsed in February 2015 it nevertheless is instructive.

In a narrow sense, the tabling of the Bill demonstrates that it is possible to draft TNR legislation that conforms with both biosecurity and animal welfare law. In a more general sense, the Bill reflects community concern at the way free-roaming cats are managed. The Bill placed TNR on the official agenda, leading to a parliamentary report on the efficacy of TNR[153]. Although the report dismissed the general practicability of TNR, it did

[138] Generally, Spehar and Wolf (40); Swarbrick and Rand (28), 2; Andersen et al. (41).

[139] Generally, Spehar and Wolf (40), 1-2.

[140] Australian Pet Welfare Foundation, runs a Community Cat Program https://www.petwelfare.org.au/community-cat-programs/

[141] Campus Cat Coalition, information available from http://www.campuscats.org.au/

[142] Department of the Environment. *Threat Abatement Plan for Predation by Feral Cats.* Commonwealth of Australia, 2015, above n[3], 10.

[143] Ibid, 23.

[144] Ibid.

[145] *Prevention of Cruelty to Animals Act 1979* (NSW), s 11.

[146] *Prevention of Cruelty to Animals Act 1979* (NSW), s 4.

[147] *Domestic Animals Act 1994* (Vic), s 33; *Prevention of Cruelty to Animals Act 1986* (Vic), s 9 (1)(h).

[148] Discussion in part 3 of this paper.

[149] Animal Ethics committees are established pursuant to the National Health and Medical Research Council. (45); Examples of specific implementation at the state level include Animal Research Act 1985 (NSW), ss 13-16 and the Prevention of Cruelty to Animals Act 1986 (Vic) s 86.

[150] By way of illustration, *Research and Integrity Policy at the University of Technology Sydney,* section 3.2, available from http://www.gsu.uts.edu.au/policies/research-ethics-integrity-policy.html#principles; *Macquarie University Code for the Responsible Conduct of Research,* section 17.1, available from https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policies/responsible-conduct-of-research/media/The-Macquarie-University-Code-for-the-Responsible-Conduct-of-Research_June2017.pdf

[151] Animal Welfare (Population Control Programs) Bill 2014, text of bill available from https://www.parliament.nsw.gov.au/bill/files/2821/First%20Print.pdf; explanatory notes available from https://www.parliament.nsw.gov.au/bill/files/2821/XN%20Animal%20Welfare.pdf; second reading speech available from, https://www.parliament.nsw.gov.au/bill/files/2821/2R%20Animal%20Welfare.pdf

[152] Ibid.

[153] Gotsis (25), 10, 14.

note that in some cases TNR reduced population numbers[154]. The report however, also emphasized that more research was needed to resolve unclear issues, including: whether TNR was suitable only for urban areas; to determine sterilization rates; and, to decide whether community groups should be funded to undertake TNR, with or without, adoption and re-homing programs[155]. These matters, however, are difficult to undertake in the face of uncertainties regarding the legality of TNR. The lapsing of the Bill is also unlikely to stop individuals and community groups proceeding with TNR, although, they need to be creative.

At the University of NSW, the Campus Cat Coalition, manages a colony of cats and kittens who live on property owned by the university. The program, which has run since 2009, is based on spaying/neutering cats, feeding them, vaccinating them, rehoming them where possible, or otherwise releasing them on campus. The Coalition has overcome legal restrictions by claiming ownership of the cats. Research on the project demonstrates that the program has reduced cat numbers, but this is deemed a qualified success, because cat numbers have declined "through adoption of socialized cats and kittens, natural death, or euthanasia of sick animals, and disappearance or emigration of cats[156]." At the same time, free-roaming cats can emigrate from surrounding areas to the colony, meaning that the effectiveness of the program calls for consistent management and intervention[157]. Notwithstanding these qualifications, the program has succeeded in demonstrating that TNR deserves a role in cat management programs which needs to be further evaluated for effectiveness and community acceptance.

This is not to say that TNR is without challenge. The difficulties just discussed, with respect to cats migrating to managed colonies has also been observed in studies conducted in the United States of America. One survey revealed that population reductions in managed colonies are offset over time by "illegal dumping" of cats and migrations to the colony (46). Other limitations include mixed success rates and the fact that TNR is not suitable for large areas, although it would be feasible for more restricted locations[158]. In addition, TNR generates welfare issues, including the ability of neutered cats to survive in the wild[159]. For this reason, some TNR schemes provide for feeding of cat colonies and also for the removal of individual cats for adoption, or to allow them to be raised in cat sanctuaries (47). Other, practical limitations, stem from challenges in financial and personnel resourcing to feed, house and neuter cats[160]. Nevertheless, TNR still proffers a range of advantages which warrant further discussion.

TNR is arguably more compassionate than lethal methods, such as those that use 1,080, which despite official claims of being net-humane, involves the use of a poison with questionable welfare credentials[161]. Another vital consideration derives from the fact that community TNR projects generate a great deal of information[162]. This material is potentially useful for evaluating the effectiveness of different types of TNR projects and comparing them to regimes based on culling[163]. However, given official antipathy toward TNR, this data can be difficult to collect and verify scientifically[164]. This not only leads to gaps in the information base, but also misses an opportunity to analyse and understand why TNR is effective in some situations and not others. Recent Australian research, for example, concludes that TNR can have positive impacts on population reductions in areas where cats are "over-represented by cat intake into shelters and municipal pounds, and by cat-related complaints[165]." This observation provides a starting point as to where TNR could be initially trialed. Similarly, studies in the United States of America, have demonstrated that notwithstanding emigration, in the long-term, TNR reduces the size of some cat colonies[166]. Again, this conclusion provides yet another issue suitable for more detailed research. Inasmuch as the literature has identified successful TNR projects, the time has come for large-scale trials of TNR, supported by government funding and regulation that facilitates licensing or exemptions to the law. This would enable the collection and analysis of data to determine whether, and in what way, TNR can be most effective[167]. Accordingly, rather than trying to thwart TNR, government should be resolving legal uncertainties, to facilitate evaluation and consideration of community views conducive to including TNR in its suite of existing measures.

Another, especially important point derives from the fact that as killing wildlife for conservation becomes increasingly common, it also becomes increasingly prone to public scrutiny[168]. As this occurs, the public demands high thresholds of justification for lethal measures[169]. Regimes which ignore or subvert TNR, thus risk alienating the public and undermining the legitimacy of regimes. Increasing scrutiny is particularly pronounced in settler jurisdictions where landscapes have been perceptibly altered by the introduction of species, which are now targeted for eradication and control[170]. On one level, this may be seen as an environmental issue, where lethal measures are necessarily undertaken to protect native biodiversity. Yet, on another level it presents as an ethical dilemma pertinent to how humans ascribe value to animals (49). In this instance, discourse from the field of critical animal studies questions the fact that introduced animals bear the brunt of environmental management, while simultaneously ignoring the significant

[154] Ibid.
[155] Ibid, 14.
[156] Swarbrick and Rand (28), 3-4.
[157] Ibid.
[158] Andersen et al. (41), 1875; Paterson (2), 170.
[159] Paterson (2), 172.
[160] Tan et al. (42), 15.
[161] Sherley (48); 1080 is the main poison used to kill foxes, for the government's position see NSW Government, Local Land Services, Foxes Factsheet, http://www.lls.nsw.gov.au/biosecurity/pest-control/foxes
[162] Spehar and Wolf (40), 1–2.
[163] Ibid.
[164] Ibid.
[165] Tan et al. (42), 19.
[166] Schaffner JE. *Community Cats: Changing the Legal Paradigm for The Management of So-Called "Pests"*. 67 *Syracuse Law Review* (2017) 71, 90.
[167] Andersen et al. (41), 1871, 15.
[168] Crowley et al. (32), 122.
[169] Ibid.
[170] Ibid, 136.

ethical dimension that those very regimes engender[171]. These points signal that regulators need to find more ethical and workable alternatives to wholesale killing.

CONCLUSION

This article was not intended to afford definitive solutions to how to deal with free-roaming cats, but to question assumptions upon which the current regime is based and to argue in favor of creating regulatory space for TNR.

The current focus on killing free-roaming cats evolved from two events in Australia's history: the damage to pastoralism caused by rabbits and the biodiversity crisis of the later part of the twentieth century. In just over 100 years, from the end of the nineteenth century to the beginning of the twenty-first century, cats in Australia have been categorized and re-classified from friend of the settler, to enemy of the rabbit and finally, a threat to native biodiversity and biosecurity. These changes primarily derive from society's relationship to its environment, finding expression in law and policy that has either advanced or opposed the presence of cats in tandem with their perceived usefulness or threat. Up to approximately the middle of the twentieth century, such decisions were made within a natural history framework, identified by Dunlap as a way of understanding the land through direct observation. It was an approach based on simplistic views of cause and effect, which validated the introduction and removal of animals at will. Accordingly, cats were released by the thousands, in the hope that they would keep rabbit populations under control and restore balance to nature. Cats proliferated and although they did not live up to their human-imposed expectations, they remained unregulated for decades.

In the interim, scientific discoveries and advances in ecology provided regulators with detailed understanding of species interactions. As a result, the concept of balance in nature fell into disfavor as regulation aimed for holistic environmental protection, involving habitats, ecosystems, and biodiversity at large. Notwithstanding such advances, free-roaming cats are managed in the shadow of natural history approaches. Cats are earmarked for eradication and control, without adequate regard for species' interactions, or consideration whether culling will lead to improved environmental outcomes. The Australian example is instructive, where strategies and plans aim at culling two million free-roaming cats by 2020, yet lack detail as to how this will improve biodiversity objectives. As with the days of natural history, killing is the mainstay, an approach which has persisted, notwithstanding its long-term ineffectiveness and notwithstanding society's increasing unease at regimes that lack an ethical mainstay.

Although official regulation warns against it, TNR has been gaining traction among the community. However, unlike culling, which is officially sanctioned, the legal status of TNR is precarious. It is discouraged both by government policy and legislation. Indeed, the latter creates offenses for feeding, treating and releasing cats, activities traditionally associated with TNR[172]. Yet, the community continues to find ways to implement TNR projects.

From a regulatory perspective, the official aversion to TNR means that regulators are missing opportunities to evaluate its effectiveness and to test the data it generates. Moreover, sidelining TNR has done little to settle community concern regarding the management of free-roaming cats. Ultimately, neither culling, nor TNR on their own, are likely to provide an effective solution to the problem of free-roaming cats in Australia. However, management plans will be more successful if they employ a variety of control and eradication methods, as well as engage meaningfully with the ethical, social and cultural dimensions of unwanted species[173]. In the case of TNR, this calls for government facilitating a method that has already demonstrated success at the community level, but which, in an official capacity, has been rebuffed.

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The author confirms being the sole contributor of this work and has approved it for publication.

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Evaluation of Unowned Domestic Cat Management in the Urban Environment of Rome After 30 Years of Implementation of the No-Kill Policy (National and Regional Laws)

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Law no. 281, enacted by the Italian Parliament in 1991, was the first that aimed at managing urban free-roaming cats living in colonies, without killing and/or moving them from their site. It had been anticipated by the Lazio Regional Law no. 63/1988 and subsequently refined by the Lazio Regional Law no. 34/1997. These laws introduced: (i) the cats' right to live free and safe; (ii) the compulsory neutering of cats by the Veterinary Services of the Local Health Unit; (iii) the institutionalization of cat caretakers. Within this context, this paper intends to evaluate the effects of the application of the Italian laws on management of urban free-roaming cats for the years 1988 to 2018. To this end, some indicators have been built and applied to our activity data: number of censused colonies and number of cats; number of stable colonies due to neutering; number of hygiene and sanitary notifications; number of notifications to check cat welfare; number of bites by unowned free-roaming cats; number of notifications of cat poisoning. The number of citizens' requests for institutional interventions by public veterinary services in cat colonies management and, accordingly, the detection of cat colonies yet unknown, seem to confirm the interest of people to control the cat colonies in Rome in a humanitarian way, as evidenced in our data. This fact/phenomenon should be analyzed in its multiple dimensions, also including the many changes and social unrests which have affected the human-cat relationship in the last 30 years.

Keywords: unowned domestic cats, free-roaming domestic cats, control strategies, management, no-kill policy, Italy

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INTRODUCTION

With regard to the evolutionary trend in global thinking and advocacy about unowned urban cat management, as Italian stakeholders, we were born on the right side of the world: in fact, it was back in 1991 that the Italian Parliament passed the first law (no. 281 /1991) that aimed at managing urban free-roaming cats living in colonies, without killing and/or moving them from their site. It had been anticipated by the Lazio Regional Law no. 63/1988 and subsequently refined by the Lazio Regional Law no. 34/1997. Thus, when Sheilah Robertson published her review (1), our 20 years of experience with TNR programs were an invaluable resource. The Italian National and Regional Laws introduced a revolutionary perspective which can be summed up in the following points: (i) the cats' right to live free and safe; (ii) the compulsory neutering of cats

by the Veterinary Services of the Local Health Unit; (iii) the institutionalization of cat caretakers. The latter, gathered in Associations for Animal Protection or in Associations of Animalist Volunteers can, and should, be registered in a regional roll. Once registered, in agreement with the Public Veterinary Service and the Office for the Animal Welfare of the territory, they are officially assigned the management of a cat colony, but the mayor remains the responsible "owner" of the cats.

To verify the impact of the Italian TNR programs in reducing free-roaming cat populations in Rome, a survey was carried out in 2000 on 103 out of 965 cat colonies, where the cats had been previously neutered during the 1991–2000 sterilization campaign (2). The TNR programs resulted in a conspicuous decrease (16 to 32%) in total cat number, though not as great as expected. Furthermore, the effects were not felt until at least 3 years since neutering had passed, on account of the percentage of cat immigration due to abandonment and spontaneous arrival (ca. 16%). Thus, our results support Robertson (1) point of view stating that "….to have a large impact TNR will have to be adopted on a far greater scale than it is currently practiced" and, we would like to add, "it has to be matched with an effective educational campaign directed to citizens (that leads to responsible pet ownership) to reduce the high risk of owned-cat abandonment" (2). In Italy, sanitary education is enforced by law (National Law no. 833/1978) and is promoted in schools, during clinical activity in family counseling units and as part of the rabies prophylaxis after a bite from an animal. Furthermore, concerning all the activities for which we are responsible, the sanitary education is done by means of printed leaflets and informative material.

The intent of this paper is to evaluate, after 30 years, the effects of the application of the Italian laws on the management of urban free-roaming cats. Our hypothesis is that, in Italy, there has been an evolution in the human-cat relationship and, accordingly, we have built some indicators concerning not only cat demography control but also the emotional sensitivity to cat welfare.

DEFINITION OF FERAL DOMESTIC CATS

Defining feral cats is still a complicated issue. It is assumed that all feral cats, no matter how they are defined, are not confined and roam freely, but there are still too many definitions based on different criteria: (i) origin (abandoned by humans, offspring of a feral female cat, lost by an owner); (ii) dependence on/independence from food supplied by human beings; (iii) socialization status to human beings (1, 3). To avoid further confusion, the term employed in this paper is "unowned" since, whatever the origin and the socialization level of cats (urban colony cats are a mixture of these categories), they do not have a single owner; according to the Italian laws the only owner responsible for urban feral cats is the mayor of the municipality.

MATERIALS AND METHODS

In order to evaluate the effects of 30 years of protectionist legislation, 7 indicators of our Local Health Unit activity have been constructed (**Table 1**). Activity data were collected by veterinarians working in our Unit, as the Italian law prescribes and, accordingly, they originate from our Unit database; every 3 months, data are to be transmitted to the Directorate-General of the Local Health Unit Rome 3 which, in turn, will forward them to the Regional Authority.

The evaluation period ranges from 10 to 30 years (see **Table 1**); furthermore, depending on municipal ordinances, some indicators are applied to the whole territory of Rome whereas others are applied only to the area which is directly under the jurisdiction of our Local Health Unit (**Figure 1**).

Since 2008, the Ministerial Ordinance, and subsequent additions and modifications, has focused on animal poisoning. In the 10 years from 2008 to 2018, a database has been created on the various causes of death, with special attention to cases of poisoning. In fact, public and private veterinarians, police and private citizens can bring the dead bodies of animals and/or the suspected poisoned baits found in our territory (see **Figure 1**) for our Unit to make a diagnosis. All categories mentioned, i.e., public and private veterinarians, police and cat care takers that are private citizens, know the current laws; the latter are trained by the competent veterinary public service for the territory. Thus, most dead animals suspected of poisoning are brought to the dog shelter, also because citizens know that it is the collection center for dogs and cats found and collected dead on the street in the whole Rome.

Laboratory diagnoses were made by the Experimental Zoo-Prophylactic Institute of Latium and Tuscany Regions, in Rome, at the Chartered Institute which represents the National Reference Center for forensic veterinary medicine. The Institute routinely performs gross necropsy, histopathology, chemical testing and toxicology screening. The toxin tested is established based on the lesions found during autopsy. The following toxins are included: anticoagulants, pesticides, metaldehyde, strychnine, and zinc phosphide**.**

RESULTS

The total number of censused colonies composed of unowned cats (from 1988) was 1,878 in 2017, 89 of which have gone extinct. Since 2001, the number of new registered colonies of cats has increased, to reach a peak in 2011 (**Figures 2**, **3**); after that year, the trend has started decreasing again. The total number of cats was 15,713, i.e., 8.37 cats per colony on average. Since the neutering campaign has begun, out of 1,878 cat colonies, 204 are stable thanks to the neutering.

Our Unit receives hygiene and sanitary notifications related to all animals in the urban environment, limited to the jurisdiction of Local Health Unit Rome 3 (see **Figure 1**). The notifications are mostly complaints about animal nuisance or about the control of their welfare. In the last 10 years, the total number of notifications was 1,002 (for dogs, pigeons, bats, parrots, owned cats, swallows, aquatic turtles), 84 of which concerned 84 different colony cats. Out of these 84 notifications received from citizens, 47 complained about hygienic and sanitary problems of the environment due to unowned cats, whereas 37 notifications requested control of cat welfare. The trend remained stable over the years.

TABLE 1 | Indicators utilized to evaluate unowned domestic cat management in the urban environment of Rome.

	Indicator	No. of years	Site (see Figure 1)
1	No. of censused colonies	30	Whole Rome/Local Health Unit Rome 3*
2	No. of cats	30	Whole Rome/Local Health Unit Rome 3*
3	No. of stable colonies due to neutering	30	Whole Rome/Local Health Unit Rome 3*
4	No. of hygiene and sanitary notifications	10	Local Health Unit Rome 3
5	No. of notifications to check cat welfare	10	Local Health Unit Rome 3
6	No. of bites by unowned cats	10	Whole Rome
7	No. of notifications of cat poisoning	10	Local Health Unit Rome 3

**1988–2000 data collected from the whole city.*

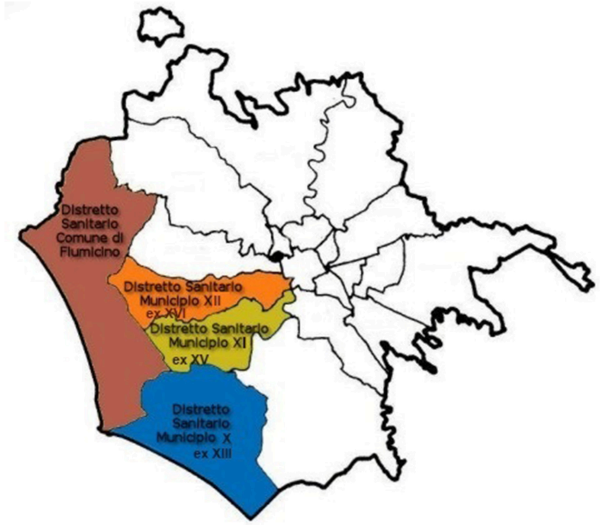

FIGURE 1 | Map of Rome. Colored areas show the jurisdiction of Local Health Unit Rome 3.

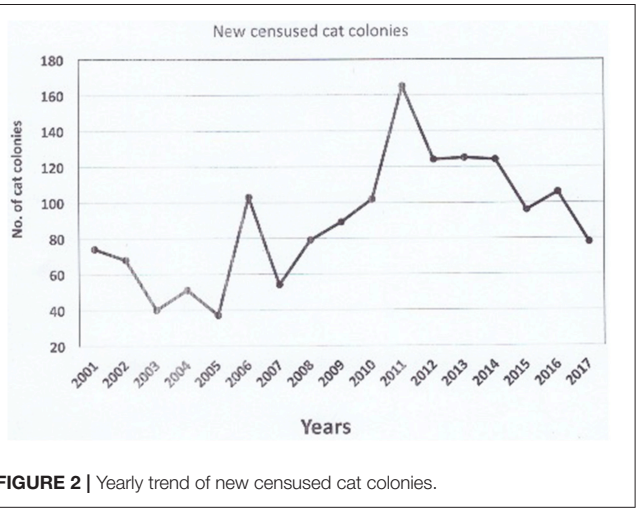

FIGURE 2 | Yearly trend of new censused cat colonies.

Our Local Health Unit is also notified of any animal bite reports or claims filed for the whole city of Rome. In 10 years, out of 4,600, 143 were filed over domestic cat bites and only 6 over unowned cat bites.

Finally, in 10 years (2008–2017), we received 74 notifications of suspected cat poisoning, 21 of which were positive (proven by gross necropsy, histopathology, chemical tests and toxicology screening). The substances most commonly used were rodenticides (anticoagulants) (no. = 9), molluscicide (neurotoxic) (no. = 8) and a mixture of them (no. = 4). Since the above substances were found in edible baits near the dead body of the cats and in the dead cats' stomachs, it is highly probable that it was deliberate poisoning. In fact, the Italian laws forbid using these substances in public places; thus, if a poisoned meat ball is found in a public park, it is evident that it was deliberately put there to eliminate some animals.

The other causes of death were traffic accidents, predation by dogs and/or wild animals, infectious diseases and chronic silent diseases.

DISCUSSION

The first result reported here is the fact that in Rome the dynamic of cat populations has been monitored for 30 years, fulfilling the obligations of law, unlike many countries where unowned free-roaming urban cats are rarely quantified (4). Therefore, with the implementation of laws, the management of non-owned urban cats has become part of the profession of veterinarians, biologists, ethologists and operators of the National Health Service. This has lowered the share of emotionality that influences professional decisions. A positive consequence is that the debate on animal management is less emotional (both in the pro-cat and anti-cat sense) because the guidelines are established by law. Furthermore, management is financed entirely with public money.

The 2006 survey on 103 colonies of free-roaming unowned cats in Rome, based on the data gathered up to 2000 (2), yielded a 16–32% decrease in total cat number due to neutering, the positive effect of which was weakened by the percentage of cat abandonment and spontaneous arrival (around 16%). In the years 2000–2018, the TNR approach has been adopted on a greater scale (the whole city) and our Unit has never stopped matching it with an educational campaign for responsible pet ownership addressed to citizens (2). Have these actions yielded some changes? The results presented here suggest a positive trend with regards to the management of quantitative aspects. First of all, the yearly trend of new censused cat colonies, not only those identified by the Public Veterinary Service but, in most cases, those reported by citizens who submit a request for their authorized management, indicates that

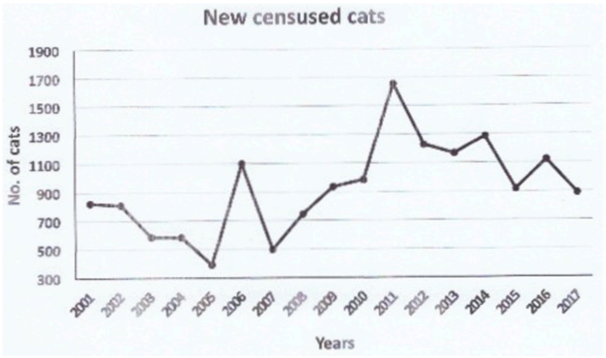

FIGURE 3 | Yearly trend of new censused cats.

people in Rome are willing to look after unowned cats in a responsible way.

This latter issue is also confirmed by the peak of requests registered in 2011. A municipal project that started in 2010 took charge of the free neutering of owned cats. A by-result of this project was the increased promotion of the neutering of cat colonies: neutering has always been free, but not everyone was aware of this. As a consequence, in 2011 the number of requests for taking responsibility of cat colony management exploded, and only subsequently did the phenomenon normalize. No change in colony size was nonetheless registered.

Still, further evidence seems to support this general trend of interest in cat colony management. Despite the lack of precise data on abandonment (data are gathered and reported by volunteer cat caretakers, who are not professional operators), the undeniable fact is that 204 cat colonies are entirely composed of neutered cats and this makes them stable. Since some abandonment rate, although low, should be presumed along the years, the data seem to confirm the positive effect of the institutionalized management of cats by registered cat caretakers. In fact, few immigrated cats have replaced the dead or adopted cats. The demographic control put into action by TNR is the first step to a responsible management of unowned cat colonies. When a member of our research group (E.N.) started studying unowned free-roaming cat behavior in 1978, before the Italian laws on neutering were passed and no unowned cats were neutered yet, a slight constant increase in the number of cats was recorded throughout the years. The problem, however, was not only the increase in the number of cats, but rather the reason as to why such an increase was not as massive as expected: as a matter of fact, there was mass infant mortality [(5); p. 303]. About 90% of kittens living in the most "famous" and largest colonies in Rome died from various diseases, most often from rhinotracheitis (feline Herpes virus, Calicivirus). Kittens died with tangible and visible suffering. Thus, in terms of welfare, the TNR approach yields more benefits than costs.

Furthermore, if we consider the number of notifications from citizens asking for the control of unowned cats' welfare in the last 10 years (notifications were practically non-existent before 2008), there is evidence that Roman citizens are increasingly concerned for cat welfare. One of the concurrent causes of this trend could be the educational campaign on urban animals addressed to citizens.

Interestingly, in Rome, Toxoplasmosis sero-prevalence greatly decreased between 1991 and 2013. In fact, in 1990–1991 the sero-prevalence was 50.4% (IC 95% range 41–60%) (6), whereas in 2012–2013 it was 28% (IC 95% range 28–34%) (7).

The different rate of Toxoplasmosis sero-prevalence registered after about 2 decades is mainly attributable to the common practice of feeding cats (unowned and/or pets) with industrial food rather than with home leftovers and/or meat remnants from butchers. But data are still scarce, and more extensive studies will have to be carried out before formulating any conclusion.

The number of cat bite reports also deserves some comment: in 10 years, only 6 out of 4,600 reports were registered regarding non owned free-roaming cats. These numbers suggest why cats, unlike dogs, are not feared for their bites and aggressiveness. In fact, even when non owned, cats are not aggressive (with few exceptions) and people do not fear them. As the data discussed here have shown, the reports notified to our Unit from citizens complaining about hygienic and sanitary problems of the environment due to non owned cats, although still rare (on average 4.7 hygienic and sanitary notifications per year), were much more frequent than non owned cats bite reports (on average 0.6 bites per year).

Finally, although poisoning is not so frequent, it requires monitoring. Since 2008, thanks to the specific Ministerial ordinance enactment, and to other national laws against animal abuse, the attention of public bodies and private citizens has increased. This has resulted in a parallel increase in the number of reports filed. Of course, abuse and poisoning occurred also before 2008, but they were not notified. This is further evidence that institutionalized cat caretakers have become more sensitive and keener to know the causes of sudden cat deaths, mainly in order to prevent them and thus protect unowned free-roaming cats.

In conclusion, notwithstanding the fact that evidence from other parts of Italy point to still growing concerns for unowned free-roaming cat diffusion in terms of human health, animal welfare and social costs (4), in our opinion their management has greatly improved since 1988, and not only in Rome. Other big cities like Milan, Genoa and Florence have also attained valuable results [Genoa (9 cats/colony) and Florence (12 cats/colony) (8)], thanks to the efficient control activity put into action by the Public Veterinary Services. It would nonetheless be naïve to analyze the phenomenon without also accounting for the many other changes which have deeply affected human society in the last 30 years in Westernized Countries, including Italy. The constant registration of new cat colonies notified to our Unit does not necessarily imply a general increase in cat colonies. Often, in fact, people report or notify colonies which have long existed in the territory. Rather, this phenomenon probably testifies the increasing desire of people to manage them properly. Accordingly, more and more people ask for institutionalized support in cat colony management. This behavior could be determined by a variety of factors including, for instance, (i) the improvement, in the last 30 years, of the economic level and, accordingly, of the human welfare (thus making easy animal care); (ii) the increase of human sensitivity to the animal issue;

(iii) the improvement of cat food quality (indirectly proven also by the decreased seroprevalence of toxoplasmosis); (iv) the wish of having more contact with nature and of relieving loneliness in a metropolis; (v) the increase of knowledge of the animal kingdom.

The results of this survey suggest that an evolution in the relationship between humans and cats has taken place in Italy, prompting the shift from demographic control to the adoption of a more sensitive attitude toward cat welfare.

Laws

Lazio Regional Law no. 34 issued on 21/10/1997. Tutela degli animali di affezione e prevenzione del randagismo. Suppl. ord. no. 3, Bollettino ufficiale della Regione Lazio no. 30, 30 ottobre 1997.

Lazio Regional Law no. 63, issued on 09/09/1988. Istituzione anagrafe canina e protezione degli animali. GU 3ª Serie Speciale - Regioni n.36 del 09/09/1989.

Ministerial Ordinance 18th December 2008, and subsequent additions and modifications. Norme sul divieto di utilizzo e di detenzione di esche o di bocconi avvelenati. GU Serie Generale no.13 17/01/2009.

National Law no. 833, issued on 23/12/1978. Istituzione del Servizio Sanitario Nazionale. GU Serie Generale n. 360 del 28-12-1978–Suppl. Ordinario.

National Law no. 281, issued on 14/08/1991. Legge quadro in materia di animali di affezione e prevenzione del randagismo. Gazzetta Ufficiale no. 203, 30 August 1991.

National Law no. 189, come out 20/07/2004. Disposizioni concernenti il divieto di maltrattamento degli animali nonché di impiego degli stessi in combattimenti clandestini o competizioni non autorizzate. G.U. no. 178 of 31/07/2004.

ETHICS STATEMENT

We did not need an institutional or governmental permission to carry on the study since it was an observational study and the neutering falls in good veterinary practice allowed by the National and International Laws.

Neither euthanasia, or any kind of animal sacrifice, was part of the study.

AUTHOR CONTRIBUTIONS

EN, LiM, and AF contributed conception and design of the study. LiM, LaM, SV, RP, LL, FP and AF organized the database. EN wrote the first draft of the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

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ORIGINAL RESEARCH
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A Preliminary Description of Companion Cat, Managed Stray Cat, and Unmanaged Stray Cat Welfare in Auckland, New Zealand Using a 5-Component Assessment Scale

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Free-roaming cats are a polarizing issue in New Zealand and there is strong need for a comprehensive evaluation of their welfare to better inform population management decisions. In this study, a 5-component visual health-related welfare assessment scale was developed and piloted on a convenience sample of 213 free-roaming companion cats (CC), 210 managed stray cats (MS), and 253 unmanaged stray cats (UMS) from various locations in Auckland, New Zealand. The welfare assessment was performed through distance observation and consisted of body condition score (BCS); coat condition score; nose and eye discharge score; ear crusting score; and injury score. The majority of cats in all groups appeared generally healthy with no nose or eye discharge, ear crusting, or injuries. Although there were no appreciable differences in the apparent welfare of CC and MS cats, future studies with more robust sampling designs are needed to draw accurate inferences. The scale also requires further validation by comparing the visual observations against more detailed physical examination and biochemical data. Nonetheless, the results from this study provide preliminary information about assessing the health and welfare of stray cats as well as considerations for developing and implementing robust assessment scales.

Keywords: cat management, unwanted cats, shelter medicine, stray cats, semi-owned cats, animal welfare, colony cats, cat welfare

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INTRODUCTION

In New Zealand, the Code of Welfare: Companion Cats (1) defines cats as belonging to one of three categories:

- Companion cats live with humans as "companions" and are dependent on humans for their welfare.
- Stray cats are companion cats who are lost or abandoned and who are living individually or in a group (colony). Stray cats have many of their needs indirectly supplied by humans, and live around centers of human habitation. Stray cats are likely to interbreed with the unneutered companion cat population.

- Feral cats are not stray cats and have none of their needs provided by humans. Generally, feral cats do not live around centers 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.

New Zealand has one of the highest rates of cat ownership in the world with almost half of all households (44%) having at least one cat. There is an estimated total companion cat population of 1,134,000 in New Zealand and the majority of owned cats are at least partly free-roaming (2). There are also considerable numbers of stray cats in New Zealand; estimates indicate that there are approximately 196,000 stray cats in New Zealand, although the stray cat population is not able to be accurately quantified (3). Recently it has been suggested that the stray cat category should be further defined into managed and unmanaged stray cat categories. Managed stray cats have a human carer(s) who provides some care to the cat (feeding and sometimes other care such as veterinary care); unmanaged stray cats do not have a human carer(s) (4). The managed stray cat category includes, but is not limited to, cats referred to as colony cats (these are managed stray cats living within a specific cat colony) and semi-owned cats (these managed stray cats are of varying sociability, many are socialized to humans, they interact with people regularly and are directly and indirectly dependent on specific humans but are not part of a cat colony) (4, 5).

Concerns have been raised about the welfare state of stray cats, particularly when compared with companion cats (6–9). It has also been suggested that stray cats without carers suffer poorer welfare than cats in managed colonies who receive ongoing care from humans (10). Common welfare concerns include exposure of the cats to infectious diseases, the potential for cats to be injured or treated cruelly, and lack of adequate food and water resources (4, 7, 9, 11–15).

Concerns about cat welfare influence ethical cat management decisions and it is important that the choice of cat management strategy has no or minimal negative impact on cat welfare. The benefits to themselves reported by cat carers and their desire to continue to care for cats are sometimes used as justification for maintaining cat colonies (5, 16–18). However, the welfare of the cats should always be considered and given appropriate weighting vs. the needs and desires of cat carers.

In order to inform ethical cat management decisions, information about the welfare states of stray cats is vital in assessing whether the use of non-lethal return to field methods of cat management such as trap-neuter-return (TNR; where cats are sterilized and returned to live in their previous location), is appropriate in terms of cat welfare. If stray cats are known to generally suffer from poor welfare, then return to field cat management methods may not be ethically appropriate. However, if stray cat welfare is generally good then return to field cat management options should not be dismissed on cat welfare grounds.

To the authors' knowledge, a systematic welfare assessment of stray cats (managed stray cats with human carers and unmanaged stray cats without human carers) and companion cats has not been undertaken. The aim of this research was to collect empirical data on the welfare states of companion, managed stray, and unmanaged stray cats, piloting a new 5-compononent visual health-related welfare assessment as a tool to help inform ethical cat management decision making.

MATERIALS AND METHODS

Development and Validation of Welfare Assessment Protocol

A 5-component visual health-related welfare assessment tool was developed in consultation with two veterinarians, one veterinary nurse, and two animal behaviorists. The assessment consisted of body condition score (BCS: emaciated, thin, ideal, overweight, over-condition or unknown/not recorded), which gives some information about the cats' nutritional and health status; coat condition score (poor, fair, good, excellent or unknown/not recorded), which gives some indication of the cats' general health status; nose and eye discharge score (none, mild, moderate, severe or unknown/not recorded), which can give some indications about whether the cats' are suffering from infectious disease such as feline upper respiratory tract infection; ear crusting score (none, mild, moderate, severe or unknown/not recorded), which can give some indications about whether the cats' are suffering from health problems such as ear mites or sun damage; and injury score (none, mild, moderate, severe or unknown/not recorded), which can give information about whether the cats have suffered an accident or injury. Only observable indicators of welfare were included as no direct contact with the cats could occur due to the welfare compromise that would have been inherent in handling the unmanaged stray cats.

The assessment was initially tested on a colony of approximately 100 cats and refined to maximize consistency between raters. No formal statistical testing of inter-and intra-rater reliability was conducted at the time the assessment was developed. However, an informal intra-observer reliability calibration was performed during the testing on the colony of cats used to test the assessment tool. This was done by discussing each cat with all researchers till agreement was reached. This was not repeated but two researchers assessed all cats except the companion cats and for consistency there was a calibration photo sheet (**Figure 1**) for all researchers to refer to for the different assessment items.

Identification and Enrollment of Subjects

Cats were divided into companion, managed stray and unmanaged stray cats based on the definitions in the New Zealand Code of Welfare: Companion Cats (1). Companion cats (CC) were recruited for the study through friends, neighbors, veterinary clinics, and family of students who were involved in data collection. Advertisements were also placed in school newsletters and the local paper. Managed stray cats (MS) and unmanaged stray cats (UMS) were recruited via cat welfare organizations that work with managed and unmanaged stray cats in Auckland.

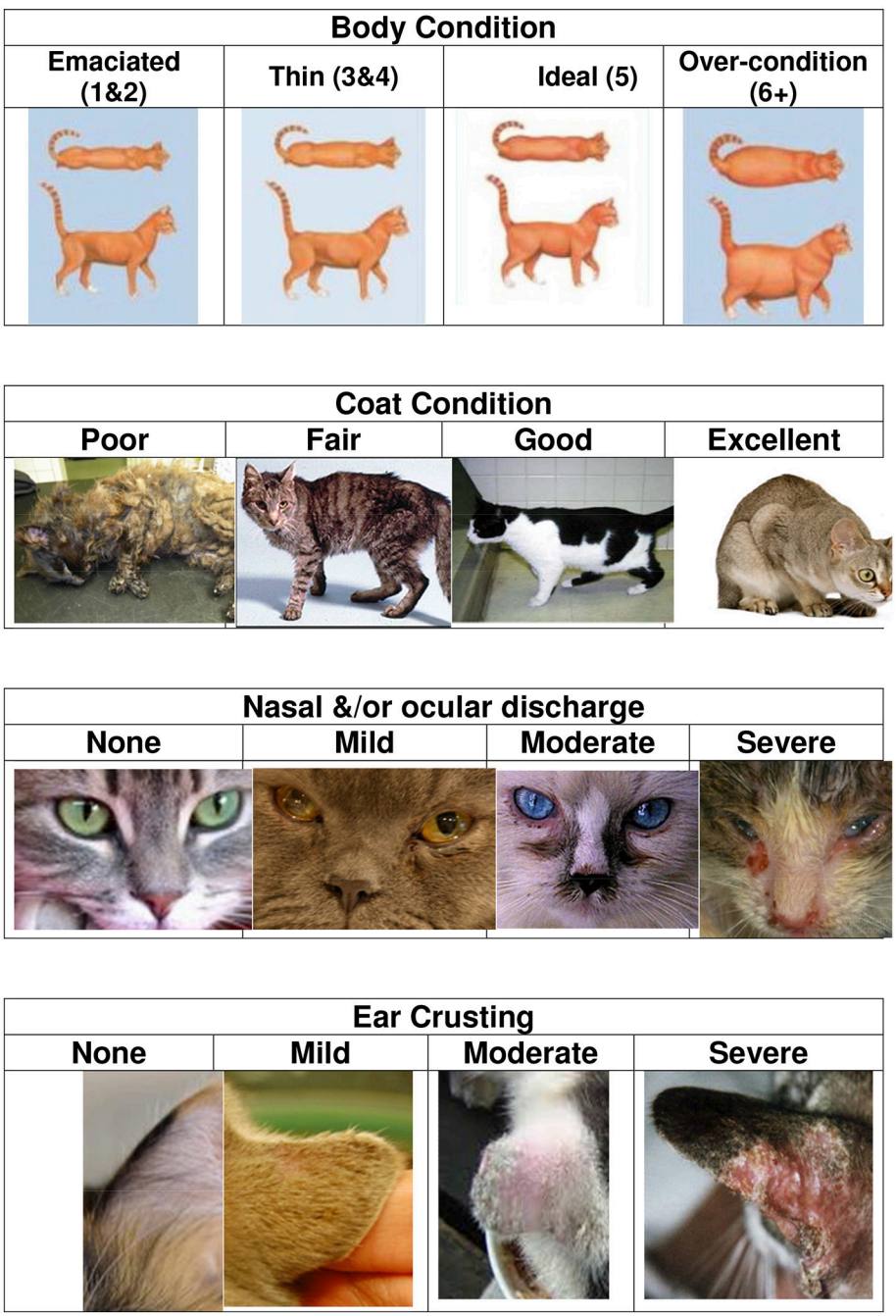

FIGURE 1 | Cat welfare assessment criteria reference photographs.

Assessment of Cats

The welfare assessments were conducted by a team of 10 researchers over a 12-month period from November 2013 to November 2014 on a convenience sample of 676 cats from various unspecified locations in Auckland, New Zealand. The assessments for CC took place at the cats' homes with the owner present, while the assessments for MS cats were conducted when the animals were being fed by their carers; this allowed the researchers to be within a few meters of the cats to be able to observe them and carry out the welfare scoring. The assessments

for UMS cats were conducted when the animals were trapped by the cat welfare organizations for other reasons; researchers were able to visually observe and welfare score the cats in the traps, or when the cats were removed from the traps at a shelter or veterinary clinic. The distance from which the cats were observed ranged from 1 to 5 m. In the case of colony cats, if the cats could clearly be seen they were scored, researchers were instructed that if it was not possible to see the whole cat or the cat was more than 5 m away the cat was not to be scored. However, it was possible to get within 5 m of all of the cats, including the unmanaged strays as these cats were all in traps and so were easily able to be assessed.

Cat demographic variables including color, coat length (categorized into short hair, medium hair, long hair, or unknown/not recorded), approximate age (categorized into juvenile, adult, or unknown), sex (categorized into male, female, or unknown/not recorded), and whether the cat was ear tipped (yes, no, or unknown/not recorded) were also recorded through visual observations. Companion cats' ages were recorded in years as indicated by the owners; this age was then used to categorize the cats into juveniles (<12 months of age) or adult (12 months of age or more). The carers of the managed stray cats provided an estimate of the age of the cat, based on whether the cat had joined the colony as a kitten or adult and how long the cat had been in the colony. The same age categorization as for companion cats was then applied. The unmanaged stray cats' age categorization was based on the information collected by the staff of the welfare organization, shelter or veterinary clinic when the cats were trapped as described previously. Categorization of the sex of the cats was based on information from the owners for companion cats, the cat carers and visual assessment for managed stray cats (whether the cats were ear-tipped), and visual assessment and information from the staff of the welfare organization, shelter or veterinary clinics for the unmanaged stray cats. Where sex could not be determined visually, the cat was recorded as being of unknown sex. It is common for free roaming stray cats to be ear-tipped when they are sterilized (19–24); this identifies the cat as a managed stray cat and should prevent a repeat surgery in error if the cat is re-trapped. Therefore, ear-tipping and information from the cats' carers were used to crudely estimate the percentage of MS and UMS who were sterilized since it was not possible to accurately assess the sterilization status through visual observation. Owners of CC were directly asked if their cat(s) had previously been sterilized.

Cats were visually assessed for the welfare assessment using a scoring sheet and the following health-based welfare assessments scored: body condition score (BCS; on a 9 point scale with 1–2 indicating emaciated, 3–4 thin, 5 ideal, and 6 or more over-condition), coat condition score (on a 4 point scale of poor, fair, good, and excellent), nose and eye discharge score (on a 4 point scale of none, mild, moderate, and severe), ear crusting score (on a 4 point scale of none, mild, moderate, and severe), and injury score (on a 4 point scale of none, mild, moderate, and severe; some specific injuries were recorded under comments). There was a calibration photo sheet for all researchers to refer to for the different assessment items (**Figure 1**). Animal ethics approval was not required as this was a purely observational study. Approval from the Unitec Human Ethics Committee was obtained for gaining informed consent from owners to participate in collecting data about their cats.

Statistical Analysis

All data were imported into the R statistical software package for analysis (25). Descriptive statistics on the body condition score, coat condition score, nose and eye discharge score, ear crusting score, and injury score were provided for each of the different cat groups (CC, MS, and UMS cats). A statistical comparison between groups was not performed because of the known biases in the sampling methods and the inability to account for the random effects when multiple cats from the same colony or household were sampled.

RESULTS

The cats included in the study were 213 CC, 210 MS cats, and 253 UMS cats. Descriptive statistics on the demographic characteristics of the cats are reported in **Table 1**. Most cats were short haired ($n = 535$; 79%) and adults ($n = 557$; 82%). The majority of CC were reported by their owners as being sterilized ($n = 195$; 92%). Only 71 MS cats (34%) were ear-tipped and none of the UMS stray were ear-tipped.

The 5-component visual health-related welfare assessment was found by the researchers to be easy to use. If the researcher had a clear view of the cat, the assessment was able to be performed in approximately 1–3 min per cat; some assessments took longer if the researcher had to wait for the cat to move (to assess lameness etc.). One of the challenges that the researchers faced was getting near enough to the stray cats to do an accurate assessment. In addition, often carers fed the cats at dusk or in the evening and the assessments could not be carried out under these conditions.

The majority of cats regardless of origin were in ideal body condition, good or excellent coat condition, and had no nose and eye discharge, ear crusting, or injuries (**Table 2**). No injuries were observed in 94.4% of CC ($n = 201$), 91.0% of MS ($n = 191$), and 92.5% of UMS ($n = 234$). The injuries that were observed and recorded were: missing eye (old injury), jaw injuries, lameness, scabs/lesions on nose, paralyzed tail, and wounds.

DISCUSSION

This study was a preliminary investigation piloting a five-component objective visual health-related welfare assessment to assess the status of companion, managed stray, and unmanaged stray cats in Auckland, New Zealand. For all five indicators of welfare, the results suggest that the majority of companion, managed stray, and unmanaged stray cats in the study sample had reasonable welfare with ideal body condition score, good to excellent coat condition, no nose or eye discharge, no ear crusting, and no injuries. However, given the limitations with the sampling methods we cannot make accurate inferences about whether this represents the true welfare status of these cat populations in Auckland, New Zealand.

TABLE 1 | Demographic characteristics of 213 companion cats, 210 managed stray cats, and 253 unmanaged stray cats from Auckland, New Zealand.

		Companion Cats ($n = 213$)	Managed Stray Cats ($n = 210$)	Unmanaged Stray Cats ($n = 253$)
Sex	Female	110 (51.6%)	59 (28.1%)	183 (72.3%)
	Male	103 (48.5%)	64 (30.5%)	63 (24.9%)
	Unknown	0 (0%)	87 (41.4%)	7 (2.8%)
Coat length	Short	154 (72.3%)	172 (81.9%)	209 (82.6%)
	Medium	36 (16.9%)	25 (11.9%)	38 (15.0%)
	Long	23 (10.8%)	12 (5.7%)	4 (1.6%)
	Unknown	0 (0%)	1 (0.5%)	2 (0.8%)
Ear Tipped	Yes	N/A*	71 (33.8%)	0 (0%)
	No	N/A	121 (57.6%)	253 (100%)
	Unknown	N/A	18 (8.6%)	0 (0%)
Age	Juvenile	26 (12.2%)	17 (8.1%)	19 (7.5%)
	Adult	187 (87.8%)	193 (91.9%)	233 (2.19%)
	Unknown	0 (0%)	0 (0%)	1 (0.4%)

Note that owned cats aren't routinely ear tipped when being sterilized therefore, these are not reported as numbers.

TABLE 2 | Descriptive statistics on the 5-component visual health-related welfare assessment findings from 213 companion cats, 210 managed stray cats, and 253 unmanaged stray cats from Auckland, New Zealand.

		Companion Cats ($n = 213$)	Managed Stray Cats ($n = 210$)	Unmanaged Stray Cats ($n = 253$)
Body Condition	Emaciated	4 (1.9%)	1 (0.5%)	10 (4.0%)
	Thin	21 (9.9%)	34 (16.2%)	63 (24.9%)
	Ideal	161 (75.6%)	134 (63.8%)	163 (64.4%)
	Overweight	27 (12.7%)	35 (16.7%)	12 (4.7%)
	Over-condition	0 (0%)	0 (0%)	0 (0%)
	Unknown	0 (0%)	6 (2.9%)	5 (2.0%)
Coat Condition	Poor	2 (0.9%)	0 (0%)	21 (8.3%)
	Fair	11 (5.2%)	27 (12.9%)	70 (27.7%)
	Good	79 (37.1%)	140 (66.7%)	155 (61.3%)
	Excellent	120 (56.3%)	29 (13.8%)	5 (2.0%)
	Unknown	1 (0.5%)	14 (6.7%)	2 (0.8%)
Nose and Eye Discharge	None	203 (95.35)	179 (85.2%)	206 (81.4%)
	Mild	10 (4.7%)	16 (7.6%)	30 (11.9%)
	Moderate	0 (0%)	4 (1.9%)	14 (5.5%)
	Severe	0 (0%)	0 (0%)	3 (1.2%)
	Unknown	0 (0%)	11 (5.2%)	0 (0%)
Ear Crusting Score	None	213 (100%)	187 (89.0%)	223 (88.1%)
	Mild	0 (0%)	9 (4.3%)	23 (9.1%)
	Moderate	0 (0%)	1 (0.5%)	5 (2.0%)
	Severe	0 (0%)	0 (0%)	5 (2.0%)
	Unknown	0 (0%)	13 (6.2%)	0 (0%)
Injury Score	None	201 (94.4%)	191 (91.0%)	234 (92.5%)
	Mild	9 (4.2%)	9 (4.3%)	10 (4.0%)
	Moderate	3 (1.4%)	3 (1.4%)	6 (2.4%)
	Severe	0 (0%)	3 (1.4%)	1 (0.4%)
	Unknown	0 (0%)	4 (1.9%)	2 (0.8%)

Although there is also evidence from other studies reporting good general health of stray or free-roaming cats (22, 23, 26–28), risk of infectious disease is a concern for the welfare of stray cats. However, the welfare assessments in this study generally found a relatively low incidence of visually obvious clinical signs that might be associated with infectious diseases. This is consistent with other studies which have found the baseline health status and prevalence of various infectious diseases in stray cats to be similar to that for companion cats. Nevertheless, the reported incidence of some infections varies (particularly Feline Immunodeficiency Virus and Feline Leukemia Virus) and may also be associated with the health status of the cat (13, 14, 20, 29–33). In future research, it would be ideal to collect more information about the disease prevalence in managed and unmanaged stray cat colonies. This would allow the exploration of the variation in disease prevalence between managed and unmanaged stray cat colonies and risk factors that may contribute to higher prevalence of disease in some colonies compared to others. This would also assist in developing evidence based best practice cat colony standards by helping to determine target values of disease prevalence and welfare indicators that managed colonies should be achieving to indicate that they are well-managed and that the cats have good welfare. Collection of blood from cats would allow the assessment of physiological parameters including routine biochemistry, disease prevalence, and indicators of stress such as cortisol. It would only be possible to do this without compromising cat welfare with cats who were sufficiently socialized to be handled for blood to be taken; some managed stray cats would likely fit this criterion but unmanaged stray cats would likely only be able to be sampled without welfare concerns if they were being trapped and sedated/anesthetized for other reasons, which would allow the collection of blood at the same time. For those cats who were not able to be handled for blood collection due to welfare concerns, non-invasive methods such as the quantification of fecal cortisol metabolites (FCMs) could possibly be used to perform some limited evaluation, particularly for unmanaged stray cats. Quantification of FCMs from fecal extracts using enzyme immunoassays has been validated and used in some wild felid species such as Bengal (Panthera tigris tigris) and Sumatran tigers (Panthera tigris sumatrae) (34–36). This has been recommended as a non-invasive method for evaluating the stress physiology of these wild cats and as an indicator of the health and welfare of these wild felids (34) and could be a useful and practical way to do the same for stray cats; this would be a valuable area for future research.

Welfare was assessed in this study through the assessment of relatively simplistic health-related indicators: the cats' body condition, coat condition, nose and eye discharge, ear crusting, and injuries. Although BCS is a relatively crude measure, previous studies have shown a link between body condition and overall animal health, behavior, and welfare (37–46). BCS is a

relatively objective measurement, although it may be difficult to accurately assess through visual observation alone, particularly in long-haired cats. BCS can provide useful information associated with the health-related welfare of a cat because stress is often associated with a decrease in appetite and food intake in cats (47, 48). In addition, weight loss despite adequate food resources being available, is likely to be due to low food intake associated with stress and illness, and has been associated with the development of health problems such as upper respiratory tract infection in shelter cats (47). The relationship between stress, loss of weight, and resultant lower body condition score has implications for cat welfare that make BCS, which is a relatively easily assessed measure, a useful inclusion in welfare evaluations for cats. Nose and eye discharge score gives some indications about whether the cats are suffering from infectious disease that can affect their health and welfare; for example, feline upper respiratory tract infection (47, 49, 50). Ear crusting score can be an indicator of health problems that can negatively affect welfare, such as ear mite infection (*Otodectes cynotis*) or sun damage-related disease (for example, feline solar dermatosis or neoplasia such as squamous cell carcinoma) (51–53). Injury score can help to assess if the cats have suffered an accident or been involved in a physical altercation (54, 55).

A holistic assessment (including physical examination and health parameters, visual health-related welfare indicators, qualitative behavior assessment, and quality of life assessment) would be a valuable tool in determining the welfare of stray cats and informing cat management decisions. QoL relates to an individual's mental state, experiences, and the causes of their experiences (56–58). Recommendations for QoL assessment in veterinary practice and in veterinary research have been made (59); owners' perceptions of their cat's QoL have been reported (60) and owner reported care and behavior, and physical examination have been used to derive a QoL score for cats (61). Nevertheless, to the authors' knowledge, there have been no appropriate, objective, and validated QoL assessments developed specifically for cats, particularly stray cats. QoL scoring should, ideally, take into account the expressive quality of animal behavior and emotions by incorporating elements of qualitative behavior assessment (QBA). QBA relies on the assessor observing details of an animal's behavior and seeking to infer the animal's experience through the expressive nature of his/her demeanor (62–64). It would be important to involve animal behaviorists in the development of an assessment tool that included QBA and QoL scoring. In order for animal management to provide "acceptable" welfare, it is increasingly becoming recognized that positive welfare states must be promoted, as well as negative welfare states minimized (58, 65–69). It is important to consider what this means for stray cat management and, consequently, create a tool for assessing stray cat welfare that includes assessment of emotional as well as physical welfare measures.

There are certain welfare risks associated with the environment of free roaming cats (not just stray cats but also free roaming companion cats) that need to be considered but that are not likely to be adequately evaluated by individual animal welfare assessments. Disappearance or death, most often due to motor vehicle trauma, have been reported as common outcomes for stray cats (14, 23, 28). Accidental death is also generally the most common cause of mortality reported for companion cats with outdoor access, particularly younger cats (70–72). Cats who suffer significant injury or death, may simply disappear and so, cat welfare assessments are not necessarily a good way of evaluating environmental risks to welfare, particularly for stray cats (as their whereabouts may be less likely to be closely monitored compared to companion cats). Certain cat colony locations and situations are likely to be associated with a higher anthropogenic risk to cats (e.g., motor vehicle trauma and human cruelty), for example colonies that are situated in very built up areas and near busy roads (9, 15). These factors could affect the morbidity, mortality, and quality of life of the cats in a colony (9, 15). This highlights the need to assess the environmental risks to cat welfare at a specific site when selecting management options for a particular cat colony, as well as the well-being of the colony and its individual cats. Developing a tool for assessing environmental risk to cat welfare would assist in ethical cat management decision making.

Caution should be exercised when interpreting the results of this study due to the limitations and the preliminary nature of the 5-component visual health-related welfare assessment that needs validation through future research. A significant limitation to the study was that the cat observers were not blinded to the group from which the cats came. This introduces the potential for significant bias in the observations as the observers may unconsciously assign better welfare states to managed stray and companion cats. In future research intended to build on this preliminary study, observers collecting data about the cats should be blinded to the cats' group. While this would be difficult to achieve if the observers were physically present to see the cats (and hence able to infer from the environment and cats' behavior whether the cat was a companion, managed stray or unmanaged stray cat), this limitation could be overcome if photographs and videos were taken of cats and a secondary blind observer could rescore the cats' welfare measures. This could then be compared to the original scores from the non-blinded observer and would also allow formal evaluation of intra- and inter-rater variability, which was not performed when the current 5-component assessment system was developed. Another limitation of this study was the inability to account for the random effects when multiple cats from the same colony or household were sampled. It is suggested that researchers in the future use multistage random sampling to get a more accurate representation of colonies and cats.

Another limitation of this study that should be considered when planning any future research is that information on the date of sampling and the location of sampling was not recorded in the study database, which prevented robust analysis of the prevalence and risk factors for welfare. However, this was not the primary objective of this study. In addition, the data collection over the course of a full calendar year may have resulted in some seasonal variation. However, given the temperate Auckland

climate, seasonal variation is likely to be minimal and most of the cats were fed directly or indirectly by humans, so the food source will have remained relatively constant.

Limitations related to the assessment tool itself included problems associated with assessing the cat demographics and health-related welfare measures visually and the lack of detailed descriptors for the different assessment measure categories. Coat condition is difficult to assess visually, and the perception of apparent differences may be influenced by types of coat and their coloring. Coat condition scoring should take these factors into account and also include tactile and close visual assessment of the coat condition. The ability to only visually assess cats made accurate identification of the sex of stray cats difficult. In the current study, only a small number of stray cats were ear-tipped, including some male cats without visible testicles and who were not ear-tipped. This made it impossible to conclusively determine visually if stray cats were sterilized. While it is possible that some sterilized male stray cats who were not ear-tipped were previously or currently owned (and therefore were not ear-tipped when they were sterilized), this finding could also suggest that there is a need to inform cat carers and veterinarians of the importance ear-tipping at the time of sterilization to ensure that stray cats are not unnecessarily trapped and sedated/anesthetized in order to carry out the same procedure. Regardless, it is still likely that the majority of stray cats were not sterilized. Previous research has suggested that sterilization is likely to reduce stress and improve welfare of stray cats (73–75). This is likely to be related, at least partly, to lower social and reproductive pressure and, consequently, less stress on the sterilized cats; as suggested by the reduced cortisol levels and aggression reported in sterilized stray female cats compared to entire stray female cats (73). In addition, roaming, fighting, and aggressive behaviors can be associated with higher risk of injury and infectious disease (72, 76, 77) and, as a result, poor welfare. Aggression, fighting, and roaming tend to decrease after sterilization (78, 79); this may contribute to the seemingly better welfare of sterilized stray cats compared to entire stray cats. It is suggested that future studies should develop a more detailed assessment tool that includes provision of specific descriptors for the different visual health-related welfare assessment categories, to ensure more consistency and accuracy, and that formal statistical testing of inter-and intra-rater reliability is conducted.

For future research, it is suggested that ethics approval be sought to permit physical examination of the cats where possible; this would allow for more accurate assessment of both demographic variables and health/welfare indicators. However, this would need to be balanced with the need to maintain acceptable welfare for cats who are unused to being handled. Unmanaged stray cats are unlikely to be able to be sufficiently socialized to allow this, and so it would only be possible to perform physical examination of these cats if they were being trapped and sedated/anesthetized for other reasons which would allow for examination at the same time. The unmanaged stray cats in this study were all in traps when they were assessed but full physical examination was not performed due to the more limited scope of the study and ethics approval.

The negative welfare of stray cats has been raised as an objection to the use of TNR programmes to manage their populations (7, 11). However, the results from this preliminary study suggest that the welfare of the stray cats studied in Auckland was reasonable, particularly the managed stray cats. There is also evidence from other studies suggesting that generally human care provided to stray cats has positive effects on the cats' health and welfare (14, 15, 23, 73, 75, 80, 81). More evidence of the benefits of human assistance to stray cat health and welfare are reported in the Newburyport, Massachusetts trap-neuter-return case study (22). In the Newburyport programme, which also included the feeding of and monitoring/caring for cats, all of the stray cats in the targeted area were sterilized over the years of the programme and, over time, the general health of the cats improved (22). The development of best practice guidelines for the management of stray cat colonies and TNR programs could be one way to encourage care that would provide good welfare for stray cats. In addition, a stray cat colony register and a requirement for stray cat carers to register and abide by the best practice guidelines (4) could further improve the welfare and health of stray cats. The evidence seems to suggest that, where stray cats are allowed to continue to reside in an area, it would be of benefit to encourage management of the colony (so that the cats are sterilized and consistently fed, monitored, and cared for).

CONCLUSION

Even though there were considerable limitations with the sampling methods and assessment tool for this study, the findings suggest that stray cats–particularly managed stray cats–can have reasonable welfare that is potentially comparable to companion cats. Therefore, maintaining stray cats in managed colonies where cats are sterilized and consistently fed, monitored, and cared for may be a way to promote good welfare and a positive quality of life for stray cats where non-lethal management is possible and appropriate. However, such a system would need to be carefully managed and colonies judiciously selected.

Information on stray cat welfare is largely unreported but the welfare of stray cats in the field has very important implications for policy development. The ability to generalize the findings from this study is limited by the small sample size and the limitations of the assessment tool and data collected. Nonetheless, despite this research being very preliminary in nature, it provides a starting point for further research that is urgently needed in this area. It would be of benefit if future studies could develop a validated welfare assessment for cats including both visual health-related welfare indicators and QoL assessment; this would likely necessitate comparing visual health-related welfare indicators and QoL assessment scores with physical welfare measurements. The discussion of the limitations and suggestions for prospective research should assist researchers to improve the design of future investigations in this field, including collecting more variables about the managed and unmanaged colonies to help accurately assess the policy implications of the welfare of stray cats and how best to manage them.

ETHICS STATEMENT

Although animals were the subject of this study, animal ethics approval was not required as this was a purely observational study. In NZ, animal ethics approval is only required for animals that are being manipulated for the purpose of research, testing, and teaching, which was not the case with the cats in this study. Approval from the Unitec Human Ethics Committee was obtained for gaining informed consent from owners to participate in collecting data about their cats.

AUTHOR CONTRIBUTIONS

AD and JW oversaw the design and implementation of the study and assisted with data collection. SZ and MG analyzed the data. SZ, JW, MG, and AD wrote the paper and reviewed the manuscript.

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Cat Colony Caretakers' Perceptions of Support and Opposition to TNR

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Trap, neuter and return (TNR) is a non-lethal approach to urban cat management used effectively internationally to decrease urban cat numbers, but deemed illegal in Australia. We investigated perceived support and opposition to TNR experienced by respondents involved in TNR activities, as individuals or through organizations. TNR was initiated to reduce cat numbers, as a humane way to manage community cats, and to improve cat welfare. Many respondents sought permission from local authorities, and all received verbal permission. Perceived attitudes of stakeholders, for example authorities and neighbors, were polarized, with some supporting it and others antagonistic and threatening legal action. Respondents generally managed the colony themselves or with assistance from friends or family, and half obtained aid from a cat welfare agency. Some respondents received cash or food from stakeholders, subsidies for desexing and education on trapping. Complaints were most common from neighbors, and less from those working and living nearby the colony. Resolution was attempted with varying success, by face-to-meetings with complainants, educational flyers, cat deterrents, or relocating cats. Supportive stakeholders had similar motives to the respondents for supporting TNR, namely to reduce cat populations and improve cat welfare. These findings are important because they demonstrate the difficulty faced by individuals and organizations undertaking TNR in Australia. Given the reported effectiveness of well-managed TNR programs, and the lack of other acceptable methods for managing urban stray cats at a city level, it is recommended that TNR be legalized in Australia in urban and periurban areas to facilitate its implementation.

Keywords: trap, neuter, return, community, cats, management, support, opposition

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INTRODUCTION

The majority of Australia's population live in urban areas where the stray cat population is estimated to range from 60 to 100 cats per 1,000 residents, which equates to between 1.2 and 2 million urban stray cats (1, 2). Urban stray cats account for ∼50–70% of Australian RSPCA shelter intake of cats (3–5) and 80–90% of intake into local government animal facilities (council pounds) (2). Based on current data for Australia, it is estimated that ∼3–5% of the urban stray cat population is killed in shelters and council pounds annually (2). This low level *ad hoc* culling is unlikely to reduce cat numbers in the medium to long-term, because of the prolific reproductive capacity of cats, and because culling results in increased juvenile survival and immigration of other cats into the'area (6, 7).

Australian legislation divides cat populations as either domestic (owned) or non-domestic (feral). Depending on the state, urban stray cats with no defined owner are either classified as "non-domestic" and subject to legislation relating to feral cats, or if classified as "domestic," are subject to animal welfare legislation relating to animal abandonment (8). Feral cats are generally located in rural or forested areas and do not depend on humans for shelter or food (9), whereas urban stray cats commonly live in close proximity to humans, and are provided with food and shelter by humans, either intentionally or unintentionally (2).

Trap, neuter and return (TNR) of urban stray cats involves their humane capture, desexing and return to location (10, 11). Typically, it also involves removing kittens and friendly adults for rehoming. Colonies managed with TNR decrease in size over time, when a high proportion are desexed and immigrant cats are rapidly removed or desexed (12–16). Effective population reduction programs have been reported in various international sites and in Australia (2, 8, 17–22). In TNR programs, cat colonies are usually provided with food, veterinary care as needed, and frequently shelter (23). Despite acknowledgment of the problems arising from urban stray cat populations, including nuisance behaviors such as fighting and soiling, concern about disease transmission to humans, pets and wildlife, and predation of native wildlife (10, 11), there is no current consensus of how the community and governments should manage urban stray cats in Australia. Cats in shelters and pounds which are in excess of those that can be rehomed, or are too poorly socialized to be rehomed, are euthanized. However, this lethal control is not wholly supported by the community, and has been demonstrated to impair the mental health of those tasked to kill them (21, 24–28).

Management of urban stray cats varies in Australia depending on state legislation, local government bylaws and landholders (8). Legally, returning unowned cats after neutering to where they were found is generally considered an offense in Australia under either domestic animal welfare legislation relating to abandonment of cats, or biosecurity and land management legislation relating to cats as pest species. An attempt to legalize TNR in NSW was made through the Animal Welfare (Population Control Programs) Bill, but it did not progress past the first reading and has since lapsed (29). To the authors' knowledge, there has been no prosecutions for participating in TNR activities to date, however, prosecutions for feeding urban strays have occurred (30). Queensland has the most restrictive legislation and only owned cats are considered domestic, and it is illegal to feed, remove (for adoption) or release "non-domestic" cats which includes urban strays, because they are considered "restricted matter" (31, 32). In most states and territories of Australia, the RSPCA is the authority legally responsible for investigating animal cruelty, for example, abandonment of pets.

In Australia, TNR is often undertaken covertly because of the threat of prosecution, and the absence of widespread support or advocacy from traditional animal welfare stakeholders. The two largest animal welfare advocacy groups are the Royal Society for the Prevention of Cruelty to Animals (RSPCA), the major not for profit organization in Australia dedicated to prevention of cruelty in animals, and the Australian Veterinary Association (AVA). At the time of writing, the AVA's official policy is "trap, neuter and return strategies have not been shown to be effective under Australian conditions as the cats often do not have a good level of welfare once released, continue to hunt and predate, and can be a significant public nuisance" (33). These findings are based on literature published between 2009 and 2011, and differ from more recent evidence of the positive effect of TNR programs, including improved health of cats, decreased stray cat numbers, and reduced cat-related complaints (2, 13–16, 21, 34). The RSPCA in their 2018 report Identifying Best Practice Domestic Animal Management in Australia suggests that poor implementation is likely to have contributed to poor outcomes in TNR programs and further research is recommended into trap-desex-adopt-or return and support programs under Australian conditions (35).

Welfare of the cats and wildlife predation are often raised as impediments to supporting TNR (36). These concerns are not supported by current research as evidenced by improved body condition of cats in TNR programs, and reduced cat numbers, therefore reducing opportunities for wildlife predation (2, 13–15, 21, 34). Despite the illegality of TNR in many jurisdictions in Australia, TNR is being practiced by citizens concerned for the welfare of stray cats. We recently published a survey of 53 respondents managing cat colonies through TNR (2). Respondents were located in all major capital cities in Australia. We documented in an Australian context the success of TNR in reducing cat numbers. For example, median colony size decreased by 31% over a median of 2 years from 12 to 7 cats, and the total number of cats decreased from 515 to 344 over 2.4 years (2).

The aims of this current study were to identify colony carers' perceptions of support and opposition to TNR from various stakeholders. Perceived challenges, at commencement and currently, faced by respondents who were involved in TNR as individuals or part of an organizations are reported. This information is important to inform whether there is a need for legislative change to facilitate TNR activities in urban and periurban areas of Australia. We second aim was to determine the reasons TNR was initiated for that colony and the perceived reasons it was supported by stakeholders.

MATERIALS AND METHODS

Survey Design

We designed a questionnaire for individuals involved with TNR to determine their perceived experience using TNR, and specifically, their perceptions of support and opposition from various stakeholders. Because there were no published and validated survey tools incorporating the specific areas of interest for this study, the survey was developed and peer reviewed by Australian and international experts in TNR and in survey design (see Acknowledgments). We also piloted the draft questionnaire amongst some individuals involved in TNR, and the questionnaire was modified based on suggestions for change. These responses were not included in the data set.

A retrospective cross-sectional study of adult respondents involved in TNR in Australia was conducted using a convenience sample, including snowball sampling. Snowball sampling enables hard-to-reach populations to be contacted via social networks, by linking participants through a referral chain. Although snowball sampling does have limitations, including potential for bias, it manages to engage participants who are hidden and difficult to contact (37, 38). It was selected for this study as it ensures the anonymity of participants who did not wish to have their potentially illegal activities exposed. The study was approved by Bellberry Human Ethics Committee EC00450.

The survey was created using online survey software (SurveyMonkey®) and an identical downloadable Microsoft Word version was provided for anonymous postal responses for respondents concerned about traceability of IP addresses. We have previously reported data on information of TNR sites and colonies, demographics of respondents, motivations for involvement, TNR operations including feeding, trapping and desexing, identification, provision of healthcare and rehoming, funding and costs (2). In the current study, we report responses from 30 respondents who answered one or more questions on stakeholder support. These respondents represented a subset of the original cohort of 53 respondents and an additional four respondents to the questionnaire.

Data Collection

A link to the questionnaire were hosted on a website for a not for profit, companion animal, re-homing organization (Maggie's Rescue). A downloadable version of the questionnaire was also available on the website for respondents to send back by mail if preferred. Emails advertising the survey were sent to the contact list for Maggie's Rescue (100 contacts). Respondents were requested to complete the survey if they were involved with TNR, and to forward it on to others they knew who were involved in TNR, utilizing a "snowballing" effect. To maximize response rate, a modified form of Dillman's Tailored Method (39) was utilized with 2 email reminders sent at ∼1 week intervals. No inducements were offered to participants for participation in the survey.

Respondents were advised that that TNR could be considered an offense in some jurisdictions and were permitted to withdraw from the survey, or alternatively to complete the survey as a Word document and submit anonymously by post to Maggie's Rescue. The study focused on TNR in urban areas involving stray cats. Respondents were instructed to only complete the questionnaire if TNR was conducted in urban areas, and not in bushland, National or State parks or reserves. A total of 57 responses were received between September and January 2017, with ∼50% of respondents completing the entire survey, which took ∼1 h.

In this current study, 30 of the 57 respondents engaged in TNR in Australia who completed the questionnaire on their activities, answered one or more questions regarding stakeholder support. Respondents were asked about their experiences with colonies they or their organization was using TNR to manage in urban areas of Australia. They were instructed that the questionnaire related to community cats managed by TNR, and not to colonies where desexing did not occur. Respondents were involved with TNR as individuals or as part of an organization. Specifically respondents were asked questions relating to perceived support or opposition to TNR from a variety of stakeholders. Stakeholders were defined as a person, group or organization that had an active interest in the TNR activity. Potential stakeholders included authorities responsible for compliance with legislation related to pest species (state government, local government) and animal welfare (RSPCA in most states), and police. Stakeholders also included landholders, business owners, neighbors, workers and residents where the colony was located, administrators of schools, hospitals, universities, and public or private housing, veterinarians and welfare agencies.

Numbers of respondents to each question are indicated where relevant. Descriptive statistics are only reported because of the small sample size. Although the study was not designed as mixed methods research, comments from participants were included to enrich data from the limited response rate.

TABLE 1 | Location of 52 colonies where respondents ($n = 28$) were conducting TNR.

Location for the colony/ies where 28 respondents were conducting TNR	Number and proportion of colonies at each location ($n = 52$)
Private residential home	15 (29%)
Alleyway or street	7 (13%)
Industrial area or factory complex	7 (13%)
Other: beside railway line, shopping center, derelict hospital, derelict hoarders house, community facility	5 (10%)
Car park (around shops, fast food outlets, or municipal car park)	4 (8%)
University	4 (8%)
Government housing complex e.g., public housing.	3 (6%)
Urban park or reserve	3 (6%)
Vacant block or vacant building	2 (4%)
Hospital	1 (2%)
Private housing complex e.g., residential development; gated community	1 (2%)

RESULTS

Of the 30 respondents who were engaged in TNR activities in Australia and answered one or more questions on attitudes of stakeholders, 28 (93%) were female and most (39%) were aged 46–55 (median age group bracket = 46–55). Respondents were involved with managing colonies located in NSW (15/28), Victoria (6/28,) Queensland (5/28), Western Australia (4/28), and (ACT (1/28) (one respondent managed colonies in NSW and ACT). Most colonies were at private residential homes (29%) and alleyways (13%) or industrial areas (13%) (**Table 1**). More (71%, 20/28) respondents conducted TNR as an individual than as part of an organization (34%, 10/28).

TABLE 2A | Reasons respondents began TNR at that colony. Respondents could select more than one reason.

Reasons TNR commenced at colony	Number and % of respondents selecting option (n = 21)
Effective strategy to reduce the community cat population over time	18 (86%)
Because this is a humane approach to managing community cats	17 (81%)
To improve the welfare of cats/kittens	16 (76%)
To improve the health of cats/kittens	13 (62%)
The organization I belong to is committed to TNR	6 (29%)
Because of complaints to municipal authorities	2 (10%)
The organization I belong to is funded to do a TNR program	1 (5%)
Other reason/s	7 (33%)

TABLE 2B | Free-form comments on reasons respondents began TNR at that colony.

HUMANE STRAY CAT CONTROL
"Because it is the most effective, ethical and non-abusive way to manage animal populations"
"A resident was feeding cats but not desexing, and this was causing a population explosion"
"We just happened to find some kittens 1 day and it started from there—in the beginning there were 28!"
"To control cats at a hoarder's property and for an elderly person with dementia"
PROTECT STRAY CATS
"The council was starting to trap and kill part of the colony. We started laying traps to save them"

Reasons Why TNR Was Begun for That Colony

Respondents were asked why TNR was commenced at the colony, and the two most common reasons provided by the 21 respondents were that TNR was an effective way to reduce the community cat population over time (86% of respondents), and it was a humane approach to cat management (81%) (**Table 2A**). Other reasons were to improve the health and welfare of the cats and kittens. Nearly one third indicated that the organization they belonged to was committed to TNR.

In free form comments, some respondents cited the reason they began TNR was for humane population control and because of an inability to get assistance from cat welfare or other agencies. For others it was to manage the cats for individuals unable to care for the cats on their property, for example, elderly with dementia or hoarders (**Table 2B**).

Perceived Awareness of TNR by Authorities at Commencement and Permissions Sought

Respondents were asked whether authorities were aware that TNR had commenced for this colony. Possible authorities were described as state or local government (council—equivalent to counties in USA), RSPCA, property or business owner, owner or manager of the business, or administration of school, hospital, university, government housing complex, privately owned housing complex. In most situations, permission from more than one authority was likely required, for example, state and local government. Only a minority believed authorities were aware that TNR had commenced (17%; 4/23), while most did not know if authorities were aware (43%; 10/23) or believed that the authorities were not aware (39%; 9/23).

More than half (57%; 10/18) of the respondents sought permission from one or multiple authorities, with permission sought most commonly sought from the property owners ($n = 6$). Less frequently permission was sought from the local government agency (council), ($n = 1$), university administration ($n = 1$), management of government housing ($n = 1$) or from the owner or manager of the business ($n = 1$). None sought approval from the relevant state government office associated with biosecurity or land management, or from the RSPCA (the agency in most states legally responsible for investigating animal cruelty, including abandonment).

Of those who sought permission from agencies or authorities, all (10/10) received permission, which was nearly always verbal (90%, $n = 9$). One respondent indicated that additional paperwork was required for cat registration with the municipality, and another required campus approval for a trial period. Only one of the respondents received an email or hard-copy letter stating approval was granted.

At the Commencement of TNR, Perceptions of Various Stakeholders

Perceived Awareness and Attitudes of Landowners or Authorities Responsible for the Land That the Colony Was Occupying

At the commencement of TNR at the colony, 35% respondents ($n = 20$) believed that the landowners or authorities responsible for the land the colony was occupying were not aware it was occurring, while others (20%) believed they were aware but did not acknowledge TNR (**Table 3**). Only a minority (15%) indicated landowners supported TNR, although only one provided assistance which was in the form of funds for desexing (university management). Of those that reported negative attitudes, one respondent indicated that landowners were antagonistic, although they did not prevent TNR, another described the behavior as tense, and one respondent was threatened with legal action.

Free-form comments tended to elaborate on the more unsupportive behaviors of landowners or authorities responsible for the land the colony was occupying. For example, "my work place advised that if I wanted to do it, it was at my cost, otherwise they would call the RSPCA to have the cats removed and destroyed," and "they have no interest in it, I believe they would think it unnecessary."

Influential Stakeholders Who Facilitated TNR Initially at the Colony

For respondents to the questionnaire, we defined an influential stakeholder as "a person, group or organization that takes an active interest in the activity, and in this case influences. These

TABLE 3 | At commencement of TNR, perceived awareness and attitudes of landowners or authorities responsible for land the colony was occupying.

Reasons	Landholder attitudes toward the colony at commencement of TNR (% of respondents), ($n = 20$)
Threatened to take legal action	1 (5%)
Very antagonistic but took no direct action to prevent occurrence	1 (5%)
Tension only	1 (5%)
I do not think they were aware of it occurring	7 (35%)
The authority/authorities were aware of it but did not acknowledge they were aware of it occurring	4 (20%)
The authority/authorities supported it but did not provide assistance with resources (in-kind or cash)	2 (10%)
The authority/authorities supported it and provided assistance with access to resources (e.g., human resources, desexing vouchers or assistance with desexing, traps, other assistance or cash)	1 (5%)
Don't know/ Not applicable	3 (15%)

could be people in positions of authority in the animal welfare sector, such as municipal employees, councilors, shelters, also landowners, and members of the community who may have taken a leadership role." When asked to provide free-form descriptions about who were the most influential stakeholders who initially helped the TNR work on this colony, 50% (8/16) said that involvement by a community cat welfare agency was in various ways the most helpful. Other respondents indicated friends, their partner or neighbors helped with the TNR work at the colony (44%; 7/16). One respondent was reluctant to disclose influential stakeholders, because TNR was illegal in their state. Some respondents positively commented on stakeholders' influence facilitating the continuation of TNR, with two commenting positively on support from police (**Table 4**).

When asked to provide free-form comments on how these stakeholders influenced the commencement of TNR at this colony, many respondents were given verbal and material support. Some were educated on trapping, some stakeholders fundraised to subsidize the medical costs, and rescue groups offered subsidized desexing. Some stakeholders assisted with socialization of cats before adoption and some gave access to locations where stray cats could be trapped. One respondent commented that her over-riding strategy if someone showed interest, was to recruit them to assist or take over. "It is amazing how motivated people can become when they know they can make a difference!"

At Commencement, Complaints or Issues With Neighbors, People Working or Living Where the TNR Colony Was Located

Complaints were most frequently reported from neighbors, with two thirds of respondents reporting complaints or issues at

TABLE 4 | Free-form comments on positive actions toward respondents from stakeholders.

SUPPORT RECEIVED FROM POLICE
"We have police and security aware, and who help us, and check-in with us at night (that we are OK)."
"I was aware that it is not strictly supported by 'the authorities'. However, many times I met up with police, who I suppose thought is strange to see a woman in corporate suit and high heels lurking about in odd places after dark. As I became known, and I had several discussions, and thankfully was never 'moved along'."
"Several police actually left cat food for me with notes a few times, as did locals."
"I spoke to anyone who wished to understand my actions, and for the most part I would get full or tacit approval."
"The police would happily wave and nod my way if ever they saw me."
SUPPORT RECEIVED FROM HOUSING MANAGER
"The housing representative rang us and asked for help. Later the same person called council to intervene (because) we were making progress—we had desexed seven cats, removed seven kittens, four were very sick, then retrieved two adults taken to the pound for rehoming."
SUPPORT FROM LOCAL RESIDENTS
"In two locations, locals took over the feeding and reporting duties, and also adopted a couple of cats."
SUPPORT FROM COMMUNITY CAT WELFARE GROUPS
"I started my own TNR, not even knowing that this is what it was, after being given assistance from a community cat welfare agency on-line and over the phone."

TABLE 5 | When TNR commenced, were there complaints or issues with neighbors, people working or living adjacent to this colony?

Were there complaints or issues?	Neighbors ($n = 22$)	People working adjacent ($n = 21$)	People living ($n = 22$)
Yes	15 (68%)	7 (33%)	10 (45%)
No	7 (32%)	14 (67%)	12 (55%)

commencement of TNR (**Table 5**), and less frequently (45%) these issues occurred with people living where the colony was located, and least frequently complaints were from people working adjacent to where the colony was located. One respondent reported a hostile resident re-trapped one cat who had been neutered and returned to the colony, then sent the cat to the council pound.

Although a few respondents made no attempt to resolve complaints or issues with neighbors and people working or living adjacent to where the colony was located, most did (**Table 6A**). The most common method utilized was to meet one-on-one to explain the program and educate complainants. For example, regarding issues with neighbors, 73% met one-on-one to explain the program. Others dropped educational flyers into letterboxes or provided cat deterrents, while a few removed the cats to foster care for protection. One respondent said they held a community meeting for neighbors, and other respondent held one for people working adjacent to the colony.

In free-form comments, respondents said to resolve issues or conflict, one strategy they used was to educate the community using information flyers distributed within the community and personalized notices on community noticeboards, with text

TABLE 6A | When TNR commenced, what did you or your organization do to resolve the complaints or issues?

	Neighbors respondents ($n = 15$)	People working adjacent ($n = 6$)	People living ($n = 16$)
No attempts were made to resolve	1 (7%)	0 (0%)	2 (13%)
Met one-to-one to explain the program and educate	11 (73%)	2 (33%)	10 (63%)
Spoke one-to-one by phone to explain, program, and educate	1 (7%)	0 (0%)	1 (6%)
Brought cats into foster care to protect them	3 (20%)	1 (17%)	3 (19%)
Dropped flyers in letterboxes to explain the program and educate	2 (13%)	0 (0%)	1 (6%)
Held a community meeting	1 (7%)	1 (17%)	0 (0%)
Provided cat deterrents for their use	2 (13%)	0 (0%)	1 (6%)
Other free-form comments	6 (40%)	2 (33%)	4 (25%)

TABLE 6B | When TNR commenced, what did you or your organization do to resolve the complaints or issues?

COMMUNITY EDUCATION ABOUT TNR
"I placed information on a community noticeboard in the building hallway, with a picture of the cats and their individual story in English, Korean, Chinese and Spanish."
"We advised that desexing the colony was a first step to stabilize numbers while removing kittens. Next was to remove friendly cats for rehoming. Third was to chip and support remaining cats which could not be adopted due to being unfriendly."
"Sometimes I was laughed at, or told off when people were not aware. I would take my time, explain what I could and turn around their attitudes, where possible to be supportive, or at worst, uninterested in my activities."
RELOCATION OF FEEDING SITE FOR COLONY
"I have helped out with other colonies where people were abused and threatened, and I showed the volunteers how to relocate a feeding station, by short distances over time, to a more supportive, less abusive location."
"If you scout out an area, you can usually find somewhere the cats will happily go to receive their regular food. Use visual and verbal cues to find the new locations and move with them – it is an effective methodology. Cats are intelligent and opportunistic, and will go where it works for them and you, when worked with properly."
ADDRESSING PERCEIVED CONCERNS ABOUT HEALTH RISK
"I also parasite treated areas with diatomaceous earth (food grade), so that there were no potential complaints about bugs. I previously 'flea treated' sleeping patches in gardens, under shrubs, in sleeping boxes with 'Frontline spray'—we never had flea issues. Mosquitoes used to feast on me in the early days until I fixed up the area with clean, regularly refreshed water bowls, and got rid of old pots and containers from the hoarder's place—access was all I needed and then it was fixed quickly!"

in multiple languages (**Table 6B**). Others addressed nuisance issues by relocating feeding areas and addressing parasite control concerns.

TABLE 7 | What were the outcome of these attempts to resolve these complaints or issues?

	Neighbors ($n = 14$)	People working adjacent ($n = 7$)	People living ($n = 12$)
Very unsuccessful	4 (29%)	3 (43%)	3 (25%)
Somewhat unsuccessful	3 (21%)	1 (14%)	2 (17%)
Neither successful nor unsuccessful	1 (7%)	1 (14%)	1 (8%)
Somewhat successful	3 (21%)	1 (14%)	4 (33%)
Very successful	3 (21%)	1 (14%)	2 (17%)

Respondents were asked how successful they thought the outcomes of their attempts to resolve the issues with neighbors and people who lived where the colony was located. For example, for conflicts with neighbors, 42% of respondents believed their attempts to resolve the complaint were somewhat or very successful, but 57% felt they were somewhat or very unsuccessful resolving disputes with those working near the colonies (**Table 7**). One respondent reported that the "main complaints came from anti-cat members of the university community. We did not approach them directly—actions (and results) spoke louder than words."

In free-form comments, respondents gave examples where complaint resolution was unsuccessful, despite attempts to explain TNR. For example, "when I spoke to neighbors and advised the cats were desexed, microchipped and vaccinated, it was rejected and they treated me as a liar." For some respondents, lack of stakeholder supported resulted in them stopping TNR at that site. "Council rangers were called by an aggressive resident. The ranger was sarcastic and dismissive because the cats were not chipped to the resident feeding them. We tried to explain she was elderly and had dementia, and that this was the first step before continuing to remove suitable cats. We stopped due to fear of reprisal, and the cats have continued to breed," without council involvement and "some residents wouldn't allow us to return the cats or were hostile to the cats. As a result, they were brought into foster care, regardless of whether they were socialized or not, and we stopped TNR at that site."

Current Perceptions of Various Stakeholders to TNR

Perceptions of Current Awareness and Attitudes of the Agency Legally Responsible for Investigating Animal Cruelty

Respondents were asked which agency they believed was legally responsible for investigating animal cruelty in their state and most (68%, 15/22) believed it was the RSPCA, while 18% (4/22) indicted they thought it was the local government agency (council). The most common response was that the agency responsible for animal cruelty was not aware of TNR occurring at that location (41%) and 22% believed the agency were aware, but did not acknowledge their awareness (**Table 8**).

TABLE 8 | Perceived current awareness and attitudes to TNR by authorities responsible for animal welfare, landowners, neighbors, workers, and residents living where this colony was located.

Reasons	Agency legally responsible for investigating animal cruelty (%), ($n = 27$)	Landowners or authorities responsible for land (%), ($n = 26$)	Neighbors (%), ($n = 28$)	Workers (%), ($n = 21$)	Residents (%), ($n = 27$)
Threatened to take legal action	2 (7%)	2 (8%)	2 (7%)	2 (10%)	1 (4%)
Very antagonistic but took no direct action to prevent occurrence	3 (11%)	3 (12%)	2 (7%)	0	2 (7%)
Tension Only	0	1 (4%)	1 (4%)	1 (5%)	2 (7%)
I do not think they were aware of it occurring	11 (41%)	5 (19%)	4 (14%)	5 (24%)	3 (11%)
Stakeholder/s were aware of it but did not acknowledge they were aware of it occurring	6 (22%)	5 (19%)	5 (18%)	0	4 (15%)
Stakeholder/s supported it but did not provide assistance with resources (in-kind or cash)	1 (4%)	3 (12%)	8 (29%)	3 (14%)	5 (19%)
Stakeholder/s supported it and provided assistance with access to resources (e.g., human resources, desexing vouchers or assistance with desexing, traps, other assistance or cash)	0	2 (8%)	3 (11%)	1 (5%)	5 (19%)
Don't know	2 (7%)	2 (8%)	1 (4%)	4 (19%)	1 (4%)
Not applicable	2 (7%)	3 (12%)	2 (7%)	5 (24%)	4 (15)

Respondents could select more than one response (n = respondents for each question).

Two (7%) respondents reported they were threatened with legal action in Brisbane, Queensland; one indicated a summons for feeding non-domestic cats was issued, and another volunteer was fined for feeding "non-domestic" cats and for removing two kittens for adoption. In free-form comments, one respondent reported that a NSW colony managed by a small welfare group was privately supported by the RSPCA, because of unclear legal interpretation of the law relating to unowned community cats. Another NSW respondent indicated that their local veterinarian would destroy surrendered stray cats. In NSW, Western Australia (WA) and Victoria, respondents reported the RSPCA were either not supportive of TNR, unwilling to assist with cat management, or unable to support TNR due to current shelter overcrowding. One respondent said the "RSPCA offered to kill them for a fee, if we trapped them and took them in."

Perceptions of Current Awareness and Attitudes of Those Stakeholders in the Vicinity of the Colony (Landowners, Neighbors, Workers, and Residents)

More landholders were aware of TNR activities currently, compared with when the colony commenced (16 compared to 10). Support was more polarized with more reporting negative attitudes including threatening to take legal action (2 vs. 1), and more reporting supportive attitudes including providing assistance with access to resources (1 vs. 2) (**Tables 3**, **8**).

The most common response regarding current behavior of neighbors and residents was that authorities supported it, but did not provide assistance with resources, either in-kind or cash. However, some reported negative feedback ranging from either tension or antagonism but no direct action, to neighbors and residents threatening to take legal action. In contrast, the most common response (24%) regarding behavior of workers was that respondents did not think workers were aware TNR was occurring (**Table 8**).

Most Influential Stakeholders Currently and Why They Supported TNR

In free-form comments, 21 respondents stated that stakeholders who supported TNR included residents and tolerant or supportive neighbors (10, 48%), cat rescue groups ($n = 4$), cat welfare agencies ($n = 2$), other private supportive individuals and friends ($n = 2$), municipal council staff ($n = 1$), university staff ($n = 1$) and supportive veterinarians ($n = 1$). Seven said that they were the most influential stakeholder supporting TNR, either alone ($n = 5$), or with help from friends ($n = 2$).

Free-form comments stated several council offices became tolerant of TNR after receiving qualified information on TNR. "Council's 'solution' to feral cat problems was to issue fines to anyone feeding them. I told them that we were desexing the cats, and rehoming where possible. They were fine with this," or "they just didn't care, the council companion animal officer said it was on private land so it was not their problem." Other stakeholders accepted the cats over time if the issues resolved. "Most people have either grown fond of the remaining cats, or are benign and don't care, because it is managed and not a problem."

When respondents were asked their opinion on stakeholder's main reasons for supporting TNR, the most common beliefs were that TNR was a humane approach to managing community cats (86%), to improve the welfare of cats and kittens (86%), and they believed TNR is an effective strategy to reduce the community cat population over time (83%) (**Table 9**). A few nominated reasons associated with cat-related complaints such as noise, smell or

TABLE 9 | Thinking about those who support TNR occurring at this colony, what are their main reasons for this? Respondents could select more than one reason.

Reasons	Number and % of respondents nominating reason why stakeholders supported TNR occurring with this colony (%), ($n = 29$)
Because it is a humane approach to managing community cats	25 (86%)
To improve the welfare of the cats/kittens	25 (86%)
Because it is an effective strategy to reduce the community cat population over time	24 (83%)
To improve the health of the cats/kittens	21 (72%)
To resolve complaints related to smell from cats	6 (21%)
To resolve complaints related to wildlife injury/deaths	6 (21%)
To resolve complaints related to noise from cats	5 (17%)
Because an organization was funded to do a TNR program	1 (3%)

TABLE 10 | For respondents involved in TNR as part of an organization, support provided by the organization to the community to undertake TNR activities ($n = 14$)*.

Support provided	Number and % of respondents who indicated the type of supppt their organization provides to the community to undertake TNR
Advice on TNR	11 (79%)
Training sessions on TNR	3 (21%)
Traps	12 (86%)
Food	8 (57%)
Discounted/ free desexing	13 (93%)
Discounted/ health care for cats/kittens	8 (57%)

**Although only 10 respondents to question 1 of the survey indicated they were part of an organization, 14 answered this question later in the survey. It is unknown if the additional four were loosely connected with an organization and therefore chose to answer the question, or if they misread the question. We have included the answers from all 14 respondents.*

TABLE 11A | Thinking about those who do not support TNR occurring at this colony, what are their three main reasons for this? (Respondents = 19).

Theme	Number and % of respondents nominating reason why TNR was not supported
Don't like cats/animals	11 (58%)
Ignorance	7 (37%)
Wildlife predation	7 (37%)
Legislation regarding unowned cats	4 (21%)
Support culling	2 (10%)
Apathy	2 (10%)
Fear that it will lead to too many/more cats	2 (10%)
Welfare concerns	2 (10%)
Nuisance	2 (10%)
Spread disease to people	1 (5%)

wildlife predation. Another respondent indicated stakeholder support was likely due to cats providing rodent control, and commented TNR was supported "to stabilize the colony without removing it, because it is managing a massive rodent issue."

The most common method of supporting TNR work was by providing cash or food (5/11, 45%), often through fundraising efforts, and one assisted with adoptions. Some stakeholders then became involved in TNR themselves (2/11, 18%). Another commenced community relationship development and provided ongoing education to other stakeholders. One supportive veterinarian provided pro-bono desexing. Another respondent stated that their veterinarian introduced them to a cat adoption center and expounded the merits of TNR to the council. As a result, the council provided workers to remove kittens.

Organizational Support to the Community for TNR

Of the 30 respondents to the opinions section of the questionnaire, 36% conducted TNR as part of an organization. If the organization provided support for the community to do TNR, the most common support provided was discounted or free desexing (93%), traps (86%), and advice on TNR (79%) (**Table 10**). Training sessions on TNR were less commonly offered (21%).

Main Challenges

In free-form comments, the major challenges nominated by 15 respondents were uncooperative stakeholders (47%, $n = 7$). Respondents commented that one of the major challenges was from unsupportive stakeholders who did not like cats or animals (37%) and had negative opinions toward cats. Others mentioned difficulty catching poorly socialized cats (29%), lack of financial support (27%) and unorganized feeding, leading to multiple sources of food for cats, making trapping more difficult (20%). One respondent indicated that a veterinary clinic preferred euthanasia rather than trying TNR. Other challenges cited were ambiguous legislation or perceptions that culling was successful for population control ($n = 1$), threats to native wildlife ($n = 3$), or the perception that TNR would increase the cat population ($n = 1$).

The Main Reasons for Those Who Do Not Support TNR Occurring at This Colony

Respondents were asked what they believed were the three main reasons for those who did not support TNR occurring at this colony. The main reasons cited were related to not liking cats or animals (58% of respondents), ignorance (37%) and concerns about wildlife predation (37%) (**Table 11A**).

In free-form comments about reasons those who did not support TNR occurring at this colony, respondents who cited a belief that it was ignorance, or a lack of interest in humane control options also suggested these stakeholders attitudes were

TABLE 11B | Opinions on the lack of support toward TNR.

IGNORANCE
"Some people think they should all have homes found, but they don't understand that these cats are feral and hard to home."
"Non-supporters think it is more humane to just put them all down if they can't be rehomed."
LACK OF INTEREST
"They have no interest in it. I believe they would think it unnecessary."
ISSUES WITH COUNCIL BY-LAWS
"Brisbane City Council cat and kitten trapping program will never support TNR due to stating cats and kittens that are trapped are all feral, and that it is illegal to do TNR, or to rehabilitate and rehome them."
"TNR is actively discouraged by council rangers. They imply illegality without providing more details to the home owner."
DISLIKE OF CATS
"They don't want cats around"
"Most of them want the cats gone. Poof!"

influenced by a personal dislike of cats. Respondents cited council by-laws as a deterrent to support for TNR (**Table 11B**).

DISCUSSION

This study of perceived stakeholder support and opposition for "grass-roots" TNR activities in urban Australia provides an insight to the challenges faced by respondents conducting TNR. Key findings of our study were that the main reasons respondents initiated TNR was because they believed it was a humane and effective way to manage community cats. They frequently encountered issues with authorities, landowners, neighbors, and people living and working in the area. Nearly all took action to resolve these issues, although resolution was not always successful. This study highlights the difficulty for individuals and community cat welfare organizations involved in TNR to manage urban cat colonies when it is not supported by government by-laws or major welfare agencies such as the RSPCA. These findings support the need for legislative change to facilitate best-practice TNR.

Demographics of Respondents

The 30 respondents in this study were surveyed about their perceptions of awareness and attitudes of stakeholders to their TNR activities. Stakeholders, defined as a person, group or organization that had an active interest in the TNR activity, typically represented organizations involved with compliance to relevant legislation, or were individuals in the vicinity of the colony being managed. The demographics of the respondents to questions on stakeholder support reflected the demographics of the entire cohort, on whom we have reported various aspects of their TNR activities and effect on colony size. Respondents were predominately female and 39% were aged 46–55 years of age (2). The gender bias toward females aligns with reports of more caring attitudes toward animals and more frequent involvement in feeding stray cats (40–42). However, selection bias may have skewed these results; and a recent Australian study found a similar proportion of males and females fed urban stray cats (43). Further research that minimizes selection bias is required to clarify the gender ratios of cat feeders in different geographical locations.

Reasons Why Respondents Began TNR for That Colony

The main reasons cited by respondents' for beginning TNR was that it was an effective way to reduce the community cat population over time and a humane approach to cat management. Overseas research consistently shows that, provided best practice is implemented, TNR reduces cat numbers in colonies over time (13, 18, 21, 44–47). Two studies in Florida have separately demonstrated significant reductions in cat populations when TNR was initiated (18, 40). Of particular interest is a larger study that used shelter cat intake as a surrogate measure of free roaming cats in a whole zip code in Florida (21). When cats were desexed at a rate of 60 per 1,000 residents, shelter intake dropped from 13 to 4 cats per 1,000 residents and was 66% lower after 2 years. In contrast, in the control area where an average of 8 cats were desexed per 1,000 residents, shelter intake decreased only 12%, and shelter euthanasia and intake rates were 17.5 and 3.5-fold higher, respectively, compared to the treatment zip code. Reduction in cat colony size is also demonstrated in Australian populations. For example, a 31% decrease in colony size occurred over 2 years in colonies managed by respondents to this stakeholder attitudes survey, and a reduction from 69 to 15 cats occurred, despite influx of immigrant cats in a program run by the University of NSW (8).

Other major reasons for involvement with TNR were concerns for cat welfare and to improve cat health within the colony. Similar reasons were cited in Florida; the most cited motivations were sympathy and ethical concerns to care for hungry, injured or unowned cats, and most did not want cats killed (40). A recent study in Brisbane, Australia, found that 79% of residents preferred TNR to lethal methods (43).

Authorities and policy makers often cite concern for cat welfare as a reason not to support TNR. For example, the Australian Veterinary Association do not support TNR, citing poor welfare once released. This belief is not supported by evidence. Similar levels of welfare and life expectancy have been reported between pet and colony cats in Australia and New Zealand (8, 34). In the USA, unowned cats had similar rates of infectious diseases as owned cats (8, 40, 44, 46, 48, 49). One Australian study found that the prevalence of feline immunodeficiency virus (FIV) was lower in shelter cats than owned cats with outdoor access (50).

Awareness by Authorities at Commencement of TNR and Permissions Sought

In Australia, state government laws pertaining to biosecurity and domestic animal management are typically administered by councils (local government area similar to counties in USA). Councils also have their own by-laws relating to registration (licensing), microchipping, and cat containment. In addition,

the RSPCA is responsible for animal welfare in most states. At the commencement of TNR, nearly half of the respondents believed the authorities were not aware of their work in the colony. Some believed the authorities were aware but did not prevent it. One respondent was threatened with legal action. More than half the respondents sought permission, mainly from property owners and councils, and none requested permission from state government authorities or RSPCA. Those that requested permission received it, although only one was given proof in writing.

In some Australian states, the term "domestic cats" includes urban strays with no identified owner. For example in Tasmania, residents are prohibited from abandoning cats under animal welfare legislation. Respondents in our study clearly were not "abandoning" cats; cats were fed daily, provided routine healthcare (such as antihelmintics and vaccinations), and most kittens were vaccinated, and treated for fleas and intestinal parasites (2). However, 18% of respondents reported that the agency they thought responsible for investigating animal cruelty was very antagonistic and some respondents reported they threatened legal action.

To decrease cat intake and euthanasia in shelters and pounds, local government and major welfare agencies typically aim to educate cat owners about the importance of desexing. This focus on cat owners ignores research showing that most cats entering shelters and pounds are semi-owned or stray. In Brisbane it has been demonstrated that 15% of respondents had fed stray cats, and 9% of respondents in an internet survey had fed them daily. Hence, semi-ownership is common and most respondents of the Brisbane study disagreed with legislation that prohibited stray cats being fed without a permit (42, 43). Authorities need to focus on semi-owners and stray cats, and should be aware and supportive of managed TNR programs. Evidence clearly demonstrates the long-term success of TNR in reducing cat numbers (13) and that TNR has greater community support than culling (43, 51–53).

Perceptions of Awareness and Behavior of Various Stakeholders at Commencement and at the Time of Reporting

Only one third of respondents perceived that stakeholders supported TNR occurring at the site. These stakeholders represented those legally responsible for the land where the colony was located or individuals living or working in the vicinity. Some reported negative attitudes, ranging from tension to threatening to take legal action. Complaints were mostly from neighbors (68% of respondents), and some were from people working adjacent to the colony (33%). This may have reflected colony location; most were at private residences. At the time of reporting, support was more polarized than at commencement, as more stakeholders became aware of TNR in the area.

Previously, instances of conflict between cat caregivers and property owners have been reported by 86% of welfare workers involved with TNR (54). Conflict can discourage volunteers from working with welfare organizations (54). In our study, respondents reported removing cats to foster homes and stopping TNR after residents were antagonistic.

An Australian study demonstrated that support for non-lethal management involving desexing was generally greater amongst those who owned pet cats, fed stray cats or were female and younger. In contrast, those who did not own pet cats, were aware of stray cats in their vicinity but did not feed them, or were male and older were more likely to choose lethal management. The only significant predictor of choice of lethal management was a belief that cats spread disease to humans (43). This was also mentioned by one of our respondents as a main reason for lack of stakeholder support.

Public Health Concerns

Urban stray cats are often portrayed to be disease ridden, however a study of 553 cats in Northern Florida found them to be of no greater disease threat to humans or pets than pet cats (49). The National Association of State Public Health Veterinarians (NASPHV) state there are potential risks to human public health by zoonotic diseases including rabies, bartonellosis and toxoplasmosis (55). Rabies is the most serious of these diseases and does not occur in Australia. In USA, when comparing unowned to owned cats, there are similar or lower prevalence rates of many potentially fatal feline diseases and diseases of concern to humans, such as *Toxoplasma gondii* and *Bartonella henselae* (cat scratch fever) (49). Many of the diseases of concern to humans are transmitted via bites or fleas, and for these diseases, transmission from pet cats is more likely than from stray cats, where close contact with humans is less likely (56, 57).

Australia has some of the highest infection rates for *Toxoplasma gondii* in cats in the world (58). After infection, cats shed oocysts (eggs) for 2-to-3 weeks, after which they acquire immunity (59). TNR programs likely reduce environmental contamination with toxoplasma oocysts more than trap and kill programs because mature cats are desexed and returned to their home location or colony. Their mature age means they are more likely to have previously been infected, and are immune to toxoplasmosis (60, 61). Additionally, if cats older than 1 year become infected, they shed fewer oocysts than younger cats (62). In contrast, in trap and kill programs, young immunologically naïve kittens are continuously being born, become infected and shed *Toxoplasma* oocysts.

Actions by Respondents to Resolve Complaints and Issues

Of respondents reporting issues or complaints, over 90% took action to try to resolve the issues, most commonly meeting one to one to explain the program and educate. Other actions included letterbox flyers to explain the program, community meetings or providing cat deterrents. One respondent detailed how she personalized the individual cats in the colony with pictures and their stories in multiple languages on the community notice board. A proactive response to stakeholders' concerns is recommended by the ASPCA in their handbook on TNR (63). Conflict over cat management can arise from preconceptions, and clashes of goals, values and beliefs, which are in-turn influenced by gender, age, and level of education of the parties

(54). Gaining trust, avoiding conflict, and listening to alternative opinions are suggested as a strategy for caregivers (64). The success of these types of approaches is supported by a study with respondents from 24 states in the USA. Dialogue and debate, along with empirical evidence, were necessary for identifying common goals on animal management and welfare (41).

Influential Stakeholders Who Facilitated TNR Initially at the Colony

The most influential stakeholders who facilitated TNR were from community cat welfare agencies and rescue groups, municipal staff, veterinarians, tolerant neighbors, and supportive members of the public. One respondent indicated that she only enlisted assistance from close friends due to concerns about the illegality of TNR. Some influential stakeholders provided education on trapping, and some provided financial assistance for desexing and medical care. Long-term success of a control program depends on financial support, individual commitment and public support. It requires the interaction between informed individuals working in the field and the authorities who can make supportive decisions on humane stray cat management based on scientific evidence.

Reasons for Stakeholder Support

The main reasons perceived for stakeholder support were population reduction and improving cat welfare and health, which were similar to the reasons given by our respondents, and those cited in the literature (51). In an Irish study, stakeholders demonstrated a positive attitude toward cat management if they had made an informed decision that TNR was an effective way to control cat populations (65).

Economic benefits also result from population reduction via TNR. In Santa Clara County, shelter costs for low-cost spay and neuter programs were ∼$23.21 per cat compared to husbandry costs for the average litter size of 3.5 kittens approaching $900 (51, 66). Effective lethal control requires killing 15-to-20 times more cats than current rates in Australia and is prohibitively expensive for municipalities with limited budgets (7, 67, 68). Despite a number of reports in the literature of effective large-scale TNR programs, there are none from Western countries of effective trap and kill programs (13–15, 21).

Support Provided by Organizations to the Community to Undertake TNR

Respondents participating in TNR as part of an organization indicated that support was provided through discounted or free desexing, provision of traps and advice on TNR. Stakeholders participated themselves or provided dialogue to municipal authorities or welfare organizations. The resources of large influential stakeholders were not used to support TNR, because it is illegal in most parts of Australia. In contrast, in USA there is support for TNR from most of the major welfare organizations, including Humane Society USA (HSUS), American Society for Prevention of Cruelty to Animals (ASPCA), Society for Prevention of Cruelty to Animals (SPCA) and Best Friends. In addition, foundations with substantial financial resources such as the Maddie's Fund and PetSmart Charities, contribute grants of up to $500,000 for TNR (69, 70).

Main Challenges

Lack of resources was an impediment, but if TNR were legalized, this could be addressed by recruiting community members who are already feeding unowned cats to participate in resourcing. Municipalities, welfare agencies and individuals could support items which have a direct cost, such as the provision of traps and funding for desexing.

Some respondents reported difficulty catching cats, as catching poorly socialized cats frequently takes more time than anticipated, with an average of 6 days to trap the whole colony reported in one study from USA (46). Multiple food sources compounded this issue.

Uncooperative stakeholders was another significant challenge, and respondents cited ambiguous legislation and perceptions that TNR would increase cat populations as impediments. Legislation pertaining to abandonment of cats and feral pests must be amended in Australia. This would allow major animal welfare organizations with substantial resources such as the RSPCA to recruit caretakers without threat of litigation. These organizations are less likely to be confronted by unsupportive stakeholders because their principles are supported by peer-reviewed literature, and they are potentially better placed to develop and maintain community relations. Furthermore, they would benefit substantially by reducing cat intake into their shelters. They can also better leverage economies of scale to reduce desexing costs by undertaking large-scale desexing programs, possibly in conjunction with universities training veterinary students (71). Both in Australia and overseas, successful collaborations between cat welfare groups and universities with veterinary schools have occurred (17, 72). Amending legislation obstructive to TNR and implementing best practice, will minimize the risk of complaints and help protect the cats.

Limitations

The biggest limitation of this study is the small data set. The length of the survey, taking ∼1 h to complete, meant that only 53% of respondents completed questions pertaining to this second part of the study. This study also highlights the difficulty in collecting data on TNR activities when TNR is not supported by government laws or major welfare agencies such as the RSPCA. One of the obstacles to research on TNR in Australia is the concern of potential respondents to the consequences of detection by municipal councils or animal welfare organizations legally responsible for animal welfare, which may deter participation. We used Maggie's Rescue to collect the data because of concerns that participants could be traced if data were collected directly by the university, which is government funded and subject to Freedom of Information legislation. Our approach to collecting data via snowball sampling makes it difficult to determine sampling error or deduce inferences about the entire population of people involved in TNR activities across Australia. This method also has the potential for bias because respondents were self-selected and were generally computer and Internet literate with readily available access to the Internet.

CONCLUSIONS

This paper highlights the challenges faced by volunteer careers in the urban setting. It is the first study to report stakeholder support for "grass-roots" TNR activities in urban Australia. Comments by respondents provide a rich insight to the diverse challenges faced when conducting TRN in urban environments in Australia. TNR and caring for unowned cats in the urban environment is illegal in most jurisdictions in Australia. Respondents worked alone or with trusted friends, self-funding their activities in often difficult situations. They initiated TNR at those colonies because they believed it was a humane and effective way to manage community cats. Respondents frequently encountered complaints from authorities, landowners, neighbors, and people living and working in the area. Nearly all took action to resolve these issues, although their actions were only partially successful. Two respondents were threatened by legal action, and although no respondents were fined for releasing or "abandoning" cats, respondents reported that volunteers were fined for feeding or removing kittens for adoption in Brisbane Queensland, which has some of the most restrictive legislation of all Australian states.

Based on the previously reported effectiveness of these respondents in decreasing colony size through TNR (2), and similar reports in the literature from Australia and internationally, it is recommended that TNR be legalized in Australia in urban and periurban areas. This may reduce antagonism with stakeholders, and also facilitate greater resources being made available for desexing, feeding, and health care by large welfare agencies, so best practice can be undertaken, including that for dispute resolution.

AUTHOR CONTRIBUTIONS

JR: conceived the study. JR and KT: designed the questionnaire. JR and AH: analyzed the data and wrote the paper with input from KT.

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Integrated Return-To-Field and Targeted Trap-Neuter-Vaccinate-Return Programs Result in Reductions of Feline Intake and Euthanasia at Six Municipal Animal Shelters

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For decades, animal shelters in the U.S. have sought to reduce the number of cats that are impounded and euthanized. Since the 1990s, low-cost sterilization campaigns aimed at owned cats have achieved varying levels of success in meeting these objectives. Over a similar time period, the use of trap-neuter-vaccinate-return (TNVR), as a humane alternative to the lethal management of stray and feral cats, has proliferated. Because of the limited scope of many TNVR programs, the impacts of such efforts on shelter metrics have often proven difficult to measure. In the past decade, two new variants of TNVR, return-to-field (RTF) and high-impact targeting, have exhibited the capacity to contribute to significant reductions in shelter intake and euthanasia. The present study examines changes in feline intake and euthanasia, as well as impacts on associated metrics, at municipal shelters located in six diverse U.S. communities after integrated programs of RTF and targeted TNVR (collectively termed "community cat programs," CCPs) were implemented. A total of 72,970 cats were enrolled in six 3-year CCPs, 71,311 of whom (98%) were sterilized, vaccinated, and returned to their location of capture or adopted. A median reduction of 32% in feline intake, as well as a median decline of 83% in feline euthanasia occurred across the six CCPs; median feline live-release rate increased by 53% as a result of these simultaneous declines in cat admissions and euthanasia. The integration of RTF and targeted TNVR protocols appears to result in greater feline intake and euthanasia reductions than programs lacking such an integrated approach.

Keywords: return-to-field (RTF), trap-neuter-vaccinate-return (TNVR), targeted TNVR, unowned free-roaming cats, community cat program (CCP), feline intake, feline euthanasia, animal sheltering

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INTRODUCTION

Unlike some countries (e.g., Italy), the U.S. has no national laws governing the management of free-roaming domestic cats; relevant local and state laws vary considerably. In addition, each animal shelter typically has its own relevant policies and guidelines. The focus of the present study is the impact of relevant policy changes—not the laws—regarding the admission and disposition of community cats following the implementation of innovative programs intended to humanely

manage the population of unowned, free-roaming cats (often referred to as "stray" or "feral," terms typically used interchangeably in the U.S. and Canada, but referred to as "community cats" throughout this paper). The legal aspects of such programs have recently been taken up by others, including the American Bar Association (1, 2).

Open-admission shelters, facilities that generally accept any animal in need, including those with little chance of being rehomed due to issues of age, health, or temperament (3), are often either operated directly by municipalities or by private organizations under government contract. In recent decades, municipalities across the United States have expended substantial resources aimed at reducing the number of cats admitted to and euthanized at such shelters. Government-funded low-cost (or no-cost) sterilization campaigns, often focused on owned cats in underserved communities, have been associated with reductions in feline intake and euthanasia (4–6). Nevertheless, data going back to the 1990s from a number of states have revealed varying trends in these shelter metrics (7–9). A proliferation in the use of trap-neuter-vaccinate-return (TNVR) as a method of managing community cats has occurred over a similar time period. Declines in colony size associated with such programs (10–12), including the elimination of individual colonies (13, 14), and reduction (15) or elimination (16) of kitten births, have been documented. Nevertheless, because TNVR has been historically conducted on a limited scale, often at the colony level, the impact of such programs on the intake and euthanasia of cats at municipal shelters is unclear.

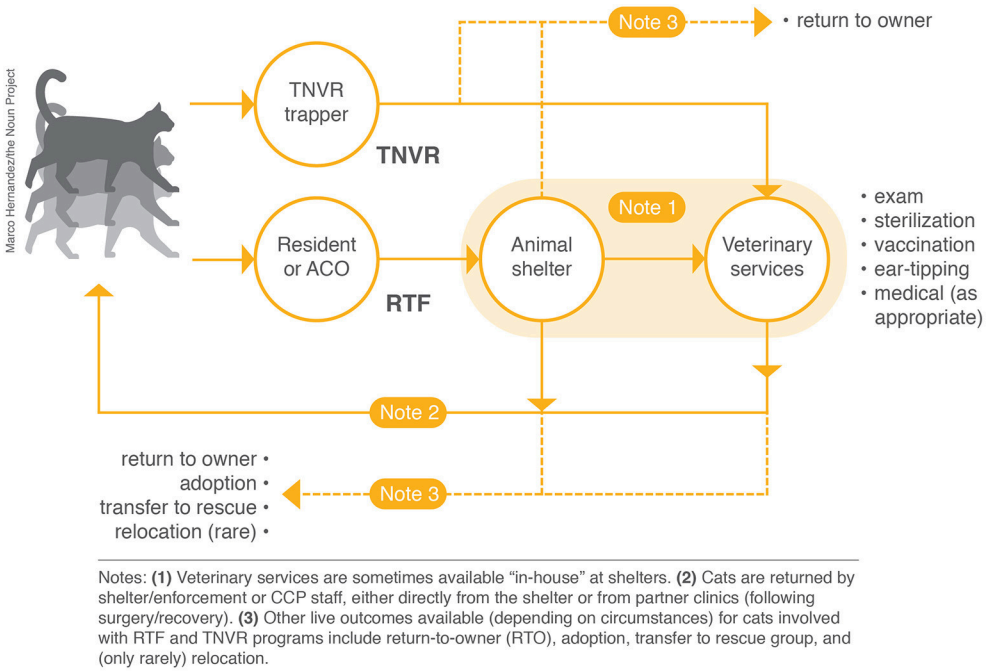
Two new, scaled-up variants of TNVR, high-impact targeting and return-to-field (RTF), have been developed over the past decade and appear to have transformative potential for reducing the intake and euthanasia of cats at municipal shelters. Targeted TNVR is a systematic approach whereby efforts to trap, sterilize, vaccinate, and return cats are concentrated in areas known to have a high-density of community cats; these targeted areas are also often a source of high feline intake at municipal shelters. RTF programs (sometimes called Feral Freedom or shelter-neuter-return, SNR) are similar in that they involve the sterilization, vaccination, and return of cats. However, these programs are shelter-based rather than community-based; RTF programs are essentially TNVR programs for cats designated as "strays" upon admission to the shelter (either brought by residents or impounded by enforcement staff). RTF programs are, like TNVR programs, implemented with the 2-fold aim of reducing (i) the number of cats who, either due to temperament or lack of shelter space, would otherwise likely be euthanized, and (ii) community cat populations (**Figure 1**). Significant reductions in the intake and euthanasia of cats from targeted areas have been observed at municipal shelters where high-impact targeted TNVR has been implemented (17, 18); shelters employing RTF programs have witnessed sharp, yet comparatively smaller, declines in both measures (19, 20).

In 2012, Best Friends Animal Society received more than $1.6 million in grant funding from PetSmart Charities®, Inc. to begin partnering with municipal shelters across the country to initiate 3-year community cat programs (CCPs), which integrate both RTF and targeted TNVR (Total PetSmart Charities® funding for the six CCPs described in this article was $3.7 million; Best Friends funding was $2.2 million). The CCPs have been generally modeled after the Feral Freedom program, the first large-scale RTF initiative in the U.S., established in 2008 in Jacksonville, Florida, where feline euthanasia was reduced by 92% over 6 years. An important distinction, however, is that the CCPs incorporate both RTF and targeted TNVR components from the onset, whereas in Jacksonville targeted TNVR was not added to RTF efforts until almost 3 years after program inception (20). In the case of the CCPs, targeted TNVR efforts were coordinated (and in large part executed) by Best Friends staff in collaboration with the partner shelters. An examination of one of the inaugural CCPs, in Albuquerque, New Mexico, revealed significant reductions in feline intake and euthanasia over the course of the program, as well as improvements in other associated metrics at the municipal shelter (21). Six CCPs had run to their scheduled conclusions as of year-end 2017. The present study, using various shelter metrics (e.g., feline intake, euthanasia, live-release rate [live outcomes divided by intake (22)], and dead cat collections) summarizes the results of these six CCPs and presents an analysis of the data.

MATERIALS AND METHODS

The first two CCPs were initiated at municipal shelters in Albuquerque and San Antonio, Texas, in 2012, followed by the launching of programs at municipal shelters or facilities with municipal sheltering contracts in Baltimore, Maryland, in 2013 and Philadelphia, Pennsylvania, Tucson, Arizona, and Columbus, Georgia in 2014 (**Table 1**). Programs at each of these open-admission shelters were scheduled to run for 36 months; however, Baltimore, Philadelphia, Tucson, and Columbus were each extended for as many as 3 months because of surplus funds. For the purposes of this investigation, results from only the originally scheduled 3-year program period for each CCP was examined, whether or not the program was extended. In Albuquerque, as described elsewhere (21), a stepwise movement toward the adoption of TNVR as the preferred method of community cat management, including a year-long pilot RTF program at the municipal shelter, preceded the CCP. No formal shelter-based RTF or targeted TNVR initiatives took place prior to the initiation of the CCPs at the other locations.

All of the CCPs included integrated implementation of RTF and targeted TNVR components. In general, the RTF component of each CCP was structured so that the vast majority of healthy community cats brought to the shelter from anywhere within their respective service areas, including individuals who could be easily treated for minor injuries or illnesses, were enrolled in the program. Best Friends staff (the number of whom varied by program, but ranged between one and three), arranged for the cats to be sterilized either in-house (when a clinic was present on site) or at a local private high-quality, high-volume spay-neuter clinic. Best Friends personnel, or less frequently, trained volunteers, then returned the cats to the locations where they were trapped. Funding for San Antonio was limited to 14 zip codes; nonetheless, eligible cats brought to the shelter from outside of those zip codes were enrolled into the RTF program



Notes: **(1)** Veterinary services are sometimes available "in-house" at shelters. **(2)** Cats are returned by shelter/enforcement or CCP staff, either directly from the shelter or from partner clinics (following surgery/recovery). **(3)** Other live outcomes available (depending on circumstances) for cats involved with RTF and TNVR programs include return-to-owner (RTO), adoption, transfer to rescue group, and (only rarely) relocation.

FIGURE 1 | Visual representations of TNVR and RTF programs.

and returned to locations of origin by Best Friends staff or volunteers until Program Year 2 when the city began paying for sterilization surgeries and assigning field services staff (often called animal control officers) the task of returning such cats. In Philadelphia, cats were returned to their location of capture by field services staff for the duration of the program.

Before being returned to the field, in addition to being sterilized, all CCP cats were ear-tipped and received vaccinations against rabies and rhinotracheitis/calciviris/panleukopenia (FVRCP), as well as flea treatment and an antibiotic injection (cefovecin sodium, sold under the brand name Convenia®), as appropriate. General protocol called for all free-roaming cats without serious illness or injury to be returned to locations of capture after recovery from sterilization surgery; however, over time, as feline intake declined and more shelter space became available at a number of the CCP locations, some sociable cats were made available for adoption or transferred to private rescue groups (organizations, typically of non-profit tax status, that specialize in the rehoming of adoptable cats). Microchipping was not part of CCP protocol. Relocation (the release of cats at outdoor sites other than location of origin) was not done unless their home environments were deemed too dangerous for safe return (e.g., demolition of a building)—a situation that occurred only rarely.

Targeted TNVR was performed in parts of CCP shelter service areas that were determined to be sources of high feline intake. The methods behind this strategy varied by program inasmuch as each CCP shelter determined how best to allocate and prioritize program resources. For example, Baltimore and San Antonio focused on areas from which the highest frequency or most serious resident complaints were generated, while Philadelphia used admission data to determine locations from which the most cats had been brought to the shelter by residents. Columbus utilized the personal field experience of the program coordinator (who had previously served as the community's animal control officer) to target areas known to be populated by large numbers of community cats until such time that sufficient data was available from the shelter to identify "hot spots" based upon intake numbers alone; targeting hot spots based upon shelter stray cat intake data was also the practice followed by Albuquerque. Tucson concentrated trapping efforts on areas that were identified as sources of high kitten intake. Cats trapped, neutered, and vaccinated as part of targeted trapping efforts were returned to their locations of capture without being admitted to CCP shelters and therefore did not contribute to feline intake totals.

Moreover, in order to make full use of information obtained about the locations of origin of RTF cats, targeted trapping also was performed at RTF release sites when circumstances allowed. Such sites were targeted based upon a hypothesis, known as the "red-flag cat model" which supposes that locations within a community capable of sufficiently supporting one free-roaming cat are likely home to additional unsterilized cats (20, 21). Thus, the initial cat trapped and returned to a new location acts as an indicator, or red flag, alerting program staff to the potential presence of other cats. The red-flag cat model was utilized to varying degrees by all six CCPs. Cats originating from red-flag cat model sites were not separately tracked by the CCPs; however, the number of cats enrolled at each site were tracked by program component (RTF or TNVR) and program year (calendar year for

TABLE 1 | Community Cat Program (CCP) locations, shelter name, service areas and size, and program periods.

CCP location	Shelter operator	Service area	Service area size (human population)*	Program period
Albuquerque, New Mexico	Albuquerque Animal Welfare Department	Bernalillo County	674,000	April, 2012–March, 2015
San Antonio, Texas	San Antonio Animal Care Services	Bexar County	1,826,000	April, 2012–March, 2015
Baltimore, Maryland	Baltimore Animal Rescue and Care Shelter	City of Baltimore	621,000	July, 2013–June, 2016
Philadelphia, Pennsylvania	Animal Care and Control Team of Philadelphia	City of Philadelphia	1,566,000	July, 2014–June, 2017
Tucson, Arizona	Pima County Animal Care Center	Pima County	1,010,000	July, 2014–June, 2017
Columbus, Georgia	Columbus Consolidated Animal Care and Control	Muscogee County	199,000	July, 2014–June, 2017

**Human population data obtained from U.S. Census Bureau QuickFacts.*

Albuquerque). Therefore, for the purposes of this study, locations at which both RTF and targeted TNVR activity occurred during the same year were categorized as red-flag cat model sites.

Programs of concentrated community outreach were used in the neighborhoods where targeted TNVR took place, including some or all of the following tactics: door-to-door canvassing (a.k.a. block walking), the distribution of door hangers, targeted mass mailings, the hosting of educational events, and the use of cargo vans, wrapped with program-specific messaging, for transport of the cats.

Data Collection

All CCP-related data were obtained from Best Friends. Procedural details about individual CCPs were obtained via telephone interviews and email correspondence with program coordinators. Dead cat collection data were acquired from individual municipalities or CCP shelters.

CCP staff entered relevant program data (e.g., number of surgeries, sex, age, etc.) into a database built and maintained by Best Friends. Ongoing results were assessed monthly to evaluate the progress of each CCP toward overall sterilization surgery goals. Chameleon software was used to track shelter metrics for Albuquerque, Tucson, and San Antonio; PetPoint software was utilized for Baltimore and Philadelphia; a Lotus Notes program was employed for Columbus. All shelters entered data in real time or on a daily basis.

Shelter metrics tracked specifically as part of the CCPs included live intakes, live outcomes [adoption, transfer to private rescue, return-to-owner (RTO)], and other outcomes (euthanasia, died in care). Intake and euthanasia data were recorded by age: adult and kitten (the age threshold distinguishing kittens from adults varied by CCP, as follows: Albuquerque: $\leq$ 5 mos.; Baltimore: $\leq$ 4 mos.; Philadelphia, Tucson, Columbus, and San Antonio: $\leq$ 6 mos.); admissions of kittens $\leq$2 months of age was tracked separately for Albuquerque, Philadelphia, Tucson, and San Antonio; euthanasia of kittens $\leq$2 months of age was tracked separately for Philadelphia, Tucson, and San Antonio. The number of cats sterilized, whether as part of the RTF or targeted TNVR component of the CCP, as well as the number of cats returned to their trapping sites, adopted, or transferred to private rescue groups were documented. The tracking of welfare outcomes for cats returned to trapping sites was not part of CCP protocol.

Data Analysis

Shelter cat intake and euthanasia results for 12-month periods matching CCP program dates were compared to a baseline of shelter results for a corresponding 12-month period immediately preceding the initiation of the Albuquerque and San Antonio CCPs, and for the calendar year immediately preceding the Baltimore, Philadelphia, Tucson, and Columbus programs. A similar process was employed to assess results for other shelter metrics (i.e., live-release rate, adoptions, and RTO) as well, except for Albuquerque, for which other metrics were tracked on a calendar-year basis. The number of cats enrolled in the RTF component of each CCP was compared to the number enrolled in the targeted TNVR component for each program year; red-flag cat model results were calculated by matching the number of RTF cats returned to specific sites with the number of cats discovered as a result of targeted TNVR efforts at those same sites and during the same program or calendar year (depending on the available data). Due to the small sample size involved (e.g., 3 program years), varied effort (e.g., returning nearly all RTF cats in the early days of the program while relatively fewer RTF cats were returned later in the program) over the course of the CCP, and inherent year-to-year variation in shelter metrics, no statistical analysis was attempted. Each CCP shelter determined the manner in which to track its data. This was driven largely by the system (e.g., fiscal year, calendar year) used by the municipality itself. The authors acknowledge that uniformity in the tracking of shelter data would have allowed for more straightforward comparisons of some of the results among the various programs.

RESULTS

Enrollment and Surgeries

A total of 72,970 cats were enrolled in the six 3-year CCPs. Sterilization surgery was performed on 69,091 (95%) of the enrolled cats. Targeted TNVR conducted as part of the six programs resulted in 54,653 (79%) of the sterilizations, while RTF

TABLE 2 | Number of RTF and TNVR surgeries performed annually in each of six 3-year CCPs and percentage of surgery total (in parentheses).

CCP location (human population)	PY1		PY2		PY3		Total surgeries
	RTF	TNVR	RTF	TNVR	RTF	TNVR	
Albuquerque, NM	964	2,759	759	3,222	464	2,870	11,038
(674,000)	(26)	(74)	(19)	(81)	(14)	(86)	–
San Antonio, TX	877	4,265	238	4,289	245	3,285	13,199
(1,826,000)	(17)	(83)	(5)	(95)	(7)	(93)	–
Baltimore, MD	724	2,803	332	3,299	305	2,804	10,267
(621,000)	(21)	(79)	(9)	(91)	(10)	(90)	–
Philadelphia, PA	1,474	3,299	1,428	2,802	1,152	3,635	13,790
(1,566,000)	(31)	(69)	(34)	(66)	(24)	(76)	–
Tucson, AZ	1,084	2,164	1,642	4,357	736	4,134	14,117
(1,010,000)	(33)	(67)	(27)	(73)	(15)	(85)	–
Columbus, GA	758	1,553	734	1,752	523	1,360	6680
(199,000)	(33)	(67)	(30)	(70)	(28)	(72)	–

TABLE 3 | Number of RTF and TNVR surgeries performed annually per 1,000 human residents in each of six 3-year CCPs.

CCP location (human population)	PY1		PY2		PY3		Mean	
	RTF	TNVR	RTF	TNVR	RTF	TNVR	RTF	TNVR
Albuquerque, NM (674,000)	1.4	4.1	1.1	4.8	0.7	4.3	1.1	4.4
San Antonio, TX (1,826,000)	0.5	2.3	0.1	2.3	0.1	1.8	0.2	2.1
Baltimore, MD (621,000)	1.2	4.5	0.5	5.3	0.5	4.5	0.7	4.8
Philadelphia, PA (1,566,000)	0.9	2.1	0.9	1.8	0.7	2.3	0.8	2.1
Tucson, AZ (1,010,000)	1.1	2.1	1.6	4.3	0.7	4.1	1.1	3.5
Columbus, GA (199,000)	3.8	7.8	3.7	8.8	2.6	6.8	3.4	7.8

efforts accounted for 14,439 (21%) of the total surgeries. The combined number of cats sterilized across the six CCPs fluctuated by program year: Year 1: 22,724; Year 2: 24,854; Year 3: 21,513. In aggregate, the percentage of cats sterilized as part of the RTF component of the CCPs decreased each program year: Year 1: 26% (5,881); Year 2: 21% (5,133); Year 3: 16% (3,425) (**Tables 2**, **3**). Overall, the number of female cats sterilized exceeded males 36,184 (52%)−32,907 (48%), and significantly more adults were sterilized than kittens, 49,509 (72%)−19,582 (28%).

Disposition

In total, 60,613 cats (83%) were returned to their trapping sites as part of the six CCPs; 10,698 (15%) were adopted or transferred to private rescue; 459 (0.6%) were returned to owner or otherwise released without undergoing surgery; 349 (0.5%) were euthanized for serious health concerns; 204 (0.3%) were relocated because they could not be safely retuned to locations of capture; 140 (0.2%) died perioperatively (**Table 4**). Of the cats returned to trapping sites, 44,670 (74%) were adults, 13,986 (23%) were kittens and the age of 1957 (3%) was unknown. Cats originated from a total of 12,912 sites across the six programs with the median number of cats per site ranging from 2–5 (**Figure 2**).

Euthanasia and Intake

A median decline of 83% in overall feline euthanasia occurred at the six shelters when results from the end of the third year of each program are compared to baseline results (**Table 5** and **Figure 3**). Tucson observed the largest decline in euthanasia on a percentage basis (91%) while Philadelphia experienced the largest drop in absolute numbers (4,084 cats). Among the six CCPs, Baltimore experienced the smallest percentage decrease in the euthanasia of cats (59%); Columbus had the smallest decline in absolute terms (1,272 cats). Over the same periods, the euthanasia of kittens declined by a median of 87%; the euthanasia of "newborn" kittens ($\leq$ 2 months) fell by a median of 85% at the three shelters (Philadelphia, San Antonio, and Tucson) where such data were tracked. The largest decline in the euthanasia of kittens, both on a percentage basis and in absolute terms, was observed by Tucson (95% and 2,305 cats, respectively), while the smallest reduction, by either measure, occurred at Baltimore (64% and 364 cats, respectively). Euthanasia of cats per 1,000 residents in each of the respective shelter's service areas declined by a median of 84%; on the same basis, kitten euthanasia declined by a median of 87% (**Table 6**).

Overall feline intake dropped by a median of 32% at the six shelters; Columbus experienced the largest decline (45%) while the smallest decline (1%) in feline intake was observed at San Antonio (**Table 5** and **Figure 4**). Kitten intake declined by a median of 40% across the six shelters, while the admission of newborn kittens dropped by a median of 41%, at the four facilities (Albuquerque, Philadelphia, San Antonio, and Tucson) for which such data were available. Overall feline intake fell by a median of

TABLE 4 | Disposition of cats in each of the six 3-year CCPs, 3-year totals and percentage by category.

CCP (human population)	RTC (%)	Adopt or transfer to rescue (%)	RTO (%)	Released without surgery (%)	Euthanized (%)	Relocated (%)	Died (%)	Other (%)	Total (%)*
Albuquerque, NM	10,738	946	1	1	20	6	34	–	11,746
(674,000)	(91)	(8)	(0.01)	(0.01)	(0.2)	(0.1)	(0.3)	–	(100)
San Antonio, TX	11,904	1,060	0	16	38	75	22	507	13,622
(1,826,000)	(87)	(8)	(0)	(0.1)	(0.3)	(0.6)	(0.2)	(4)	(100)
Baltimore, MD	8,796	2,156	0	11	104	67	24	–	11,158
(621,000)	(79)	(19)	(0)	(0.1)	(0.9)	(0.6)	(0.2)	–	(100)
Philadelphia, PA	12,508	2,085	43	0	93	11	15	–	14,755
(1,566,000)	(85)	(14)	(0.3)	(0)	(0.6)	(0.1)	(0.1)	–	(100)
Tucson, AZ	10,639	3,557	330	4	53	8	32	–	14,623
(1,010,000)	(73)	(24)	(2)	(0.03)	(0.4)	(0.1)	(0.2)	–	(100)
Columbus, GA	6,028	894	22	31	41	37	13	–	7066
(199,000)	(85)	(13)	(0.3)	(0.4)	(0.6)	(0.5)	(0.2)	–	(100)
Total	60,613	10,698	396	63	349	204	140	507	72,970
	(83)	(15)	(0.5)	(0.1)	(0.5)	(0.3)	(0.2)	(0.7)	(100)

**Some totals exceed 100% due to rounding; RTC, returned to colony; cats released without surgery had already been sterilized; Other, unspecified outcome.*

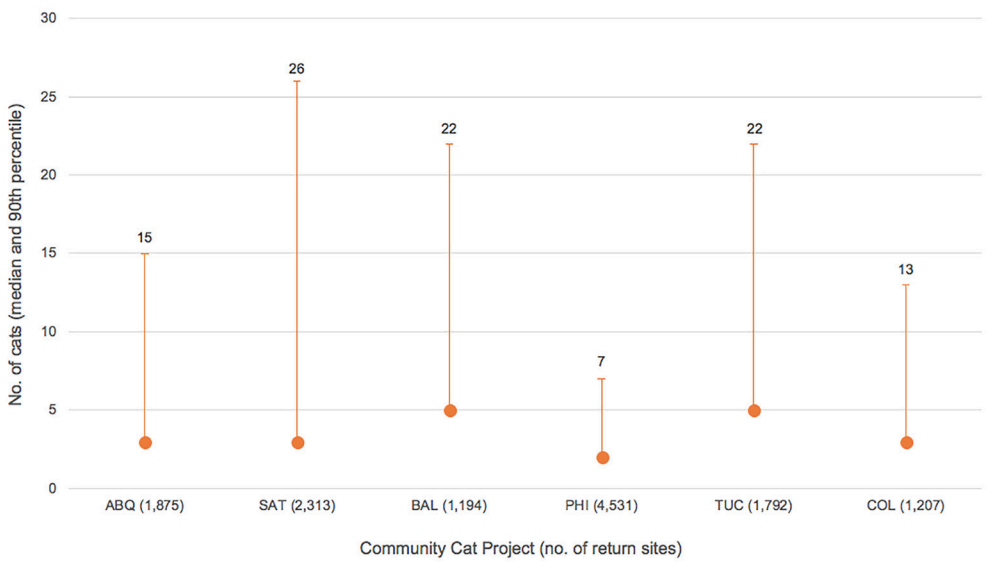


FIGURE 2 | Number of cats corresponding to source/return sites across six CCPs, with median figures (shown as solid dots) giving an approximation of median colony size.

33% per 1,000 residents across the six CCPs, while a 40% drop in the intake of kittens occurred (**Table 6**).

Live-Release Rate

The live-release rate for cats at the six CCP shelters increased by a median of 53% over the 3-years of the CCPs. The largest gain, 168%, was at San Antonio (from 31 to 83%). Philadelphia observed the smallest increase (17%, from 63 to 74%); however, the baseline live-release rate there was, by comparison, more than double that of San Antonio (**Table 5**).

Adoptions

Changes in the absolute number of cats adopted over the course of the six CCPs varied significantly (median of −8%), ranging from an increase of 118% for San Antonio to a decline of 82% for Columbus (**Table 5**). Measured as a proportion of feline intake, however, the adoption rate for cats increased (median of 45%) at all locations (in large part due to reductions in feline intake), except for Baltimore (−5%). When the number of cats transferred to private rescue groups for adoption are added to the adoptions originating directly from the shelters themselves, increases (median of 39%) were observed at all CCP locations.

TABLE 5 | Common shelter metrics before and after implementation of each 3-year CCP (absolute numbers and percentages by category).

Shelter metrics	CCP location											
	Albuquerque		San Antonio		Baltimore		Philadelphia		Tucson		Columbus	
	Before	After (% change)	Before	After (% change)	Before	After (% change)	Before	After (% change)	Before	After (% change)	Before	After (% change)
Feline intake	9,776	6,102 (−38)	6,661	6,581 (−1)	6,977	5,999 (−14)	19,017	12,791 (−33)	7,635	5,266 (−31)	3,329	1,842 (−45)
Per 1,000 residents	15	9 (−40)	4	4 (0)	11	10 (−9)	12	8 (−33)	8	5 (−38)	16	9 (−44)
Kittens*†	4,441	2,468 (−44)	3,810	4,283 (12)	2,978	1,823 (−39)	8,868	5,313 (−40)	5,072	2,903 (−43)	1,487	1,104 (−26)
≤ 2 mos. of age†	2,803	1,672 − (40)	2,706	4,241 (57)	–	–	5,729	3,347 (−42)	4,479	2,143 (−52)	–	–
Feline euthanasia	3,023	480 (−84)	4,167	763 (−82)	2,140	869 (−59)	6,055	1,971 (−67)	2,980	269 (−91)	1,493	221 (−85)
Per 1,000 residents	5	1 (−80)	2	0.4 (−80)	3	1 (−67)	4	1 (−75)	3	0.3 (−90)	7	1 (−86)
Kittens*†	1,462	149 (−90)	2,489	340 (−86)	568	204 (−64)	2,372	493 (−79)	2,424	119 (−95)	669	84 (−87)
≤ 2 mos. of age†	–	–	1,875	276 (−85)	–	–	1,965	360 (−82)	2,327	113 (−95)	–	–
Euthanasia rate (%)	31	8 (−74)	63	12 (−81)	32	15 (−53)	32	15 (−53)	39	5 (−87)	45	12 (−73)
Kittens*† (%)	33	6 (−82)	65	8 (−88)	19	11 (−42)	27	9 (−67)	48	4 (−92)	45	8 (−82)
Live release rate (%)	61	90 (48)	31	83 (168)	63	79 (25)	63	74 (17)	51	83 (63)	54	85 (57)
Adoptions	4,264	3,333 (−22)	893	1,947 (118)	3,228	2,648 (−18)	4,853	4,911 (1)	3,375	3,682 (9)	380	68 (−82)
RTO	297	277 (−7)	69	139 (101)	54	84 (56)	150	228 (52)	140	111 (−21)	43	45 (5)
DOA cats	2,220	1,689 (−24)	8,002	10,299 (29)	4,215‡	3,336‡ (−21)	712§	328§ (−54)	575	495 (−14)	N/A	N/A –

*Kitten definitions varied by shelter: Albuquerque ≤ 5 mos.; Baltimore ≤ 4 mos.; San Antonio, Philadelphia, Tucson, Columbus ≤ 6 mos. †All kittens in Albuquerque, regardless of age, tracked by calendar year (year-end 2011 to year-end 2015), rather than program year. ‡Cat and dog data combined (no further breakdown available). §Only DOA cats brought to the shelter by the public are included; data for those picked up by municipality were unavailable.

RTO

In aggregate, the number of RTO cats increased by 17%, from 753 to 884 cats across the six CCPs, although Albuquerque (297–277) and Tucson (140–111) experienced declines. Median RTO as a percentage of shelter feline intake increased from 1.2% prior to CCP inception to 2% after completion of the respective programs.

Red-Flag Cat Model

A total of 15,658 cats (22% of the total cats enrolled in the six CCPs) originated from 1,817 red-flag cat model sites, where both RTF and targeted TNVR took place during the same 12-month period. Almost two thirds of these were TNVR cats (10,297), which amounts to 19% of all cats sterilized as part of targeted TNVR efforts. On average, 4 TNVR cats (median of 2) were enrolled in CCPs for each RTF cat returned to red-flag cat model locations.

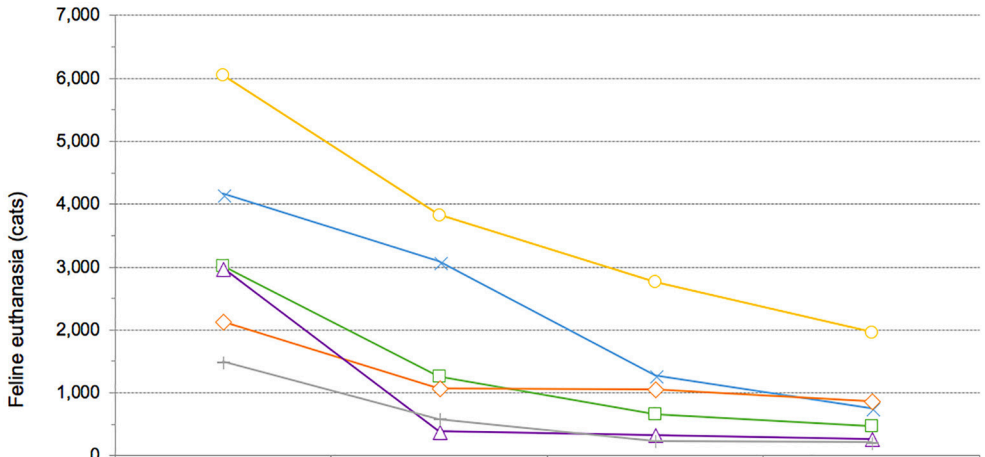
DOA

Data for cats classified as "dead on arrival" (DOA) were mixed across the six CCPs, and comparisons were made difficult due to uneven tracking and reporting (**Table 5**). Albuquerque and Tucson, for example, documented reductions of 24 and 14%, respectively. Baltimore observed a 21% reduction in the *total* number of dead animals picked up, but no breakdown by species was available. The most significant reduction (54%) was associated with Philadelphia; however, the only data available were for "stray" cats brought to the shelter by the public as DOA; no data for cats picked up by the municipality were available. As a result, the total number of DOA cats remains unknown for this CCP. San Antonio, by contrast, observed a significant increase (29%) in DOA cats over the course of the CCP. A year-by-year breakdown, however, shows an initial increase of 36% from 2011 to 2012 followed by a 17% decrease from 2012 to 2015, roughly mirroring the initial increase in feline intake and subsequent decline (**Figure 4**). No data were available for Columbus.

DISCUSSION

Impact of CCPs on Feline Euthanasia and Intake

As has been documented in other communities where RTF programs have been implemented at open-admission municipal shelters (19–21), significant reductions in feline euthanasia (median of 83%) were observed across all six CCPs (**Figure 3**). The declines in overall feline euthanasia at four of the six CCP shelters (Albuquerque, Tucson, San Antonio, and Columbus) exceeded 80% over 3 years, surpassing reductions witnessed over 4-year periods in Jacksonville and San José, where RTF programs resulted in reductions of approximately 70% (19, 20, 23). Even larger declines in the euthanasia of kittens (median of 87%) occurred at all CCP locations. Despite significant differences in the communities served by the six CCP shelters, both in terms of geography and population size, each experienced sharp declines in feline euthanasia, which strongly corroborates previous research (19, 21). Integration of targeted TNVR with RTF appears to be generally associated with more rapid declines in euthanasia. Results after 32 months (including an 8-month



	Baseline	PY1	PY2	PY3
ABQ	3023	1268	668	480
SAT	4167	3093	1281	763
BAL	2140	1076	1059	869
PHI	6055	3831	2767	1971
TUC	2980	391	336	269
COL	1493	587	241	221

FIGURE 3 | Changes in feline euthanasia at six CCP shelters, comparison of baseline level to euthanasia during each of three program years (PY).

pilot period) of an ongoing CCP in Las Vegas, Nevada, further support these findings (as with the other CCPs, data for the Las Vegas program was obtained from Best Friends), as feline euthanasia dropped by 80% (from 8,439 to 1,705) at the facility there, which provides municipal animal care and control services. RTF surgeries (5,748) represent 66% of total Las Vegas program sterilization surgeries (8,704 or 4 per 1,000 residents) over this period.

In addition, the feline euthanasia rate (calculated by dividing the number of cats euthanized for reasons other than owner request by the total number of live feline intakes) dropped by a median of 74% across CCP locations. A median euthanasia rate of 36% existed before integrated RTF and targeted TNVR programs began; the same measure at the conclusion of the respective CCPs was 12%. As a point of reference, Shelter Animals Count reported for 2016 a feline euthanasia rate of 25% (calculated by dividing the total number of cats euthanized, less owner-requested euthanasia, by the total number of outcomes minus owner-requested euthanasia) among its 627 participating organizations categorized as municipal shelters or organizations with municipal sheltering contracts. Shelter Animals Count functions as a national database of sheltered animals and follows the Base Data Matrix specified by the National Federation of Humane Societies; all data are contributed on a voluntary basis and were self-reported by 3,535 total participant organizations, which included municipal shelters and shelters with government contracts, as well as rescue groups with government contracts and shelters and rescues without such contracts, in 2016 (24).

Reductions in feline intake (median of 32%) across the six CCP shelters (**Figure 4**) varied more than reductions in euthanasia. As stated above, the largest reduction occurred at Columbus (45%), while San Antonio experienced the smallest decline (1%) over the course of the 3-year program. A spike of 52% in feline intake during Year 1 at San Antonio was followed by a reduction in Year 2 (35%) that approximated the median decline (33%) experienced at the other CCP locations over the entirety of their programs; intake was virtually flat in Year 3 of the San Antonio program, declining by just 2 cats. Possible explanations for the anomalous increase in feline intake experienced during San Antonio's first year include a particularly sharp increase in awareness of community cats among the residents there and, a surge in the use of the municipal shelter as a resource for cats, due at least in part to new perceptions among residents of the shelter as a "cat-friendly" facility (20). Additional factors that might have contributed include the faster movement of cats in and out of the facility as cats returned to the field typically spent no more than 24 h in care at the shelter, rather than being kept for 4 days (prior to likely euthanasia) as was the practice before initiation of the CCP. Unfortunately, a definitive explanation for the increase in intake during the first program year of the San Antonio CCP was not readily apparent from the available evidence.

Notwithstanding the initial spike in intake witnessed by San Antonio, the median decline in overall feline intake among the six CCPs surpassed in 3 years the reductions in intake observed over 4-year periods in Jacksonville and San José (similar to the results for euthanasia noted above), where such declines were 30 and 27%, respectively. Again, implementation from the onset of concurrent RTF and targeted TNVR programs is the likely reason for these favorable results. The ongoing CCP in Las Vegas provides additional evidence in support of the strong association between such integrated community cat management programs and rapid reductions in feline intake: the Las Vegas shelter

TABLE 6 | Impact of CCPs on shelter feline intake and euthanasia per 1,000 human residents.

Common shelter metrics	CCP location					
	Albuquerque	San Antonio	Baltimore	Philadelphia	Tucson	Columbus
Mean annual sterilizations per 1,000 human residents	5	2	6	3	5	11
FELINE INTAKE Per 1,000 HUMAN RESIDENTS						
Before program	15	4	11	12	8	16
After program	9	4	10	8	5	9
Change (%)	−40	0	−9	−33	−38	−44
FELINE EUTHANASIA Per 1,000 HUMAN RESIDENTS						
Before program	5	2	4	4	3	7
After program	0.7	0.4	1	1	0.3	1
Change (%)	−86	−80	−75	−75	−90	−86
KITTEN* INTAKE Per 1,000 HUMAN RESIDENTS						
Before program	7	2	5	6	5	7
After program	4	2	3	3	3	6
Change (%)	−43	0	−40	−50	−40	−14
KITTEN* EUTHANASIA Per 1,000 HUMAN RESIDENTS						
Before program	2	2	0.9	2	2	3
After program	0.2	0.2	0.3	0.3	0.1	0.4
Change (%)	−90	−90	−67	−85	−95	−87
DEAD CATS COLLECTED Per 1,000 HUMAN RESIDENTS						
Before program	3.3	4.4	6.8†	0.4	0.6	N/A
After program	2.7	5.9	5.8†	0.2	0.5	N/A
Change (%)	−17	34	−15†	−50	−17	N/A

**Kitten definitions varied by shelter: Albuquerque ≤ 5 mos.; Baltimore ≤ 4 mos.; San Antonio, Philadelphia, Tucson, Columbus ≤ 6 mos. Kitten data was tracked by program year for all CCPs, except Albuquerque, where it was tracked only by calendar year. †Reflects collection of all dead animals—no break down by species available. Before program = 12-month period immediately preceding program period for Albuquerque and San Antonio (except for Albuquerque kitten data); calendar year immediately preceding year of program initiation for Baltimore, Philadelphia, Tucson, and Columbus.*

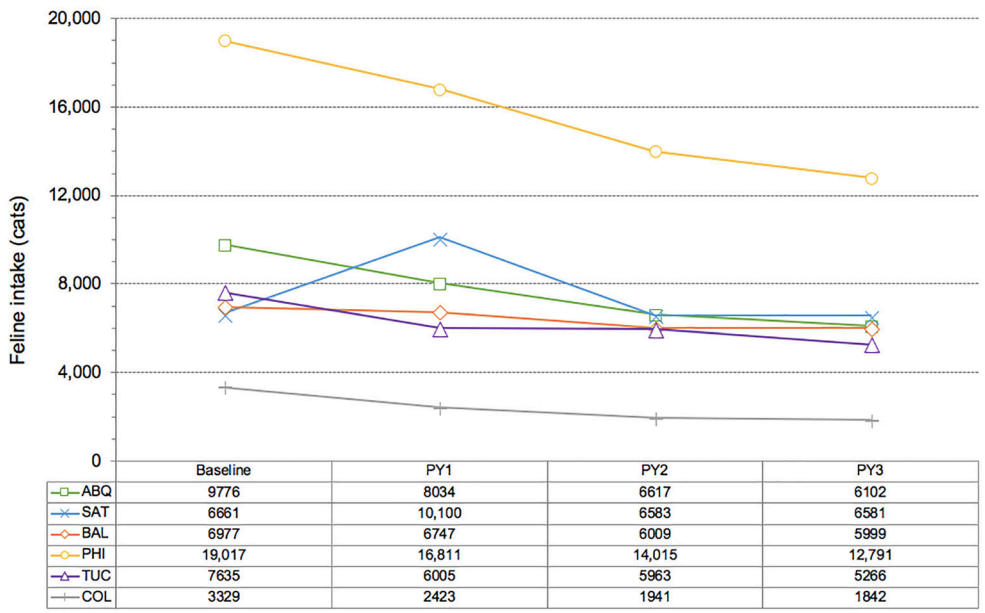


FIGURE 4 | Changes in feline intake at six CCP shelters, comparison of baseline level to intake during each of three program years (PY).

observed a 39% decline (from 13,424 to 8,220) in feline intake 32 months after the implementation of CCP protocols.

The median reduction in the intake of kittens (40%) at the six CCP shelters exceeded the median drop in total feline intake (32%), with Albuquerque observing the largest decline (44%). San Antonio was the only program to see an overall increase in kitten intake (12%), which occurred in a fashion similar to what was previously described concerning total feline intake, whereby a surge in the admission of kittens (69%) happened in year one, followed by a combined decline of 33% during years 2 and 3 of the program. Significant reductions in feline intake associated with targeted TNVR efforts have been documented elsewhere and attributed to "several factors" (17). However, the dramatic reductions in kitten intake in particular, documented across all six CCPs, suggests an impact (the extent of which is, admittedly, unknown) on reproductive capacity in the CCP service areas, since any other programs that might account for the observed reductions (e.g., diverting kittens to private rescue groups without admission to the shelter) were implemented only on a small scale where they existed at all.

TABLE 7 | Annual reduction in feline intake for each of six 3-year CCPs per 1,000 human residents in each corresponding shelter service area, and comparison to similar programs in other communities.

Community/program (source)	Baseline	Year 1	Year 2	Year 3	Year 4	Year 5
Albuquerque	15	12	10	9	–	–
San Antonio	4	6	4	4	–	–
Baltimore	11	11	10	10	–	–
Philadelphia	12	11	9	8	–	–
Tucson	8	6	6	5	–	–
Columbus	16	12	10	9	–	–
San José (17)	10	9	8	7	8	7
Jacksonville (21)	16	15	15	11	11	11
Alachua, target (15)	13	9	4	–	–	–
Alachua, non-target (15)	16	15	14	–	–	–

Baseline = 12-month period immediately preceding program period for Albuquerque and San Antonio; calendar year immediately preceding year of program initiation for all others.

Impact of CCPs on Other Shelter Metrics

As stated above, live-release rate increased significantly (median of 53%) across all six CCPs. The median live-release rate at the six shelters increased from 57% prior to CCP inception to 83% after the completion of the respective programs; post-CCP live-release rates (range: 74–90%; **Table 5**) compare favorably to a live-release rate of 69% for municipal shelters and shelters with government contracts participating in the Shelter Animals Count database in 2016 (24).

Post-CCP RTO rates (2%) were below the average RTO rate for municipal shelters and shelters with government contracts participating in the Shelter Animals Count database in 2016 (3%) (25), but consistent with results from a national survey of U.S. households, which found that 2% of lost cats were recovered by contacting a local shelter (26). Multiple survey-based studies have indicated that the most common method by which lost cats are reunited with their owners is cats returning home on their own (26, 27). Consequently, it is likely that an unknown percentage of cats returned as part of RTF efforts were actually lost pets who, at some point after being returned, found their way back to their owners (and likely at a rate of reunification greater than would have occurred had these cats been admitted to the shelter).

Impact of CCPs Compared to Similar Programs in Other Communities

The size of the human population served by each of the six CCP shelters varied, from ∼200,000 (Columbus) (28) to almost 1.9 million (San Antonio) (29), and fluctuations of up to 8% in population size took place over program periods at some sites (29). To account for these differences in population size, feline intake (**Table 7**) and euthanasia (**Table 8**) results were also examined on a normalized (per 1,000 human residents) basis. Median reductions in feline intake (33%) and euthanasia (84%) calculated in this manner varied little from median reductions (32 and 83%, respectively) derived from the absolute intake and euthanasia data reported above. A comparison of these results with those from Jacksonville and San José (**Tables 7**, **8**) found that the median 3-year decline in intake at CCP shelters exceeded reductions over the same number of years in Jacksonville (30%) and San José (26%). The median reduction in euthanasia per 1,000 human residents at CCP sites also surpassed declines over the same period in both Jacksonville (71%) and San José (69%). Unlike the CCPs, which featured fully integrated RTF and targeted TNVR elements throughout, RTF was the primary focus of the programs in Jacksonville and San José; however, a formalized targeted TNVR component (as noted above) was added to the Jacksonville program in its third year, and an *ad hoc* targeting effort similar to the red-flag cat model utilized at CCP sites was operated concurrently with the RTF initiative in San José. The specific impact of targeted TNVR efforts on results produced by the RTF-based programs in Jacksonville and San José is difficult to quantify; however, based upon the greater median reductions in intake and euthanasia at CCP locations, the benefits of combining targeted TNVR and RTF are apparent. Results of a 2-year targeted TNVR campaign in Alachua County, Florida offer the clearest evidence of the impact of targeting on feline intake and euthanasia at a municipal shelter. A 69% reduction in intake and a 95% decline in euthanasia occurred in the targeted area (zip code 32601) vs. reductions of 13% in intake and 30% in euthanasia for the remainder of the county, where no targeting took place (17) (**Tables 7**, **8**). The totality of these results suggests that the integration of targeted TNVR and RTF programs exhibits the greatest capacity for reducing the intake and euthanasia of cats on a community-wide scale.

Analysis of Source/Return Site Characteristics

Cats originated from a total of 12,912 unique sites across the six CCPs, with medians for individual CCPs ranging from 2 to 5 cats (**Figure 2**). These values are less than those documented by Nutter in rural North Carolina (median: 10 cats across 11 discrete

TABLE 8 | Annual reduction in feline euthanasia for each of six 3-year CCPs per 1,000 human residents in each corresponding shelter service area, and comparison to similar programs in other communities.

Community/Program (source)	Baseline	Year 1	Year 2	Year 3	Year 3	Year 5
Albuquerque	5	2	1	0.7	–	–
San Antonio	2	2	0.7	0.4	–	–
Baltimore	3	2	2	1	–	–
Philadelphia	4	3	2	1	–	–
Tucson	3	0.4	0.3	0.3	–	–
Columbus	7	3	1	1	–	–
San José (17)	7	6	3	2	2	2
Jacksonville (21)	13	11	7	4	4	3
Alachua, target (15)	8	2	0.4	–	–	–
Alachua, non-target (15)	10	7	7	–	–	–

Baseline = 12-month period immediately preceding program period for Albuquerque and San Antonio; calendar year immediately preceding year of program initiation for all others.

colonies) (13), Natoli et al. in Rome, Italy (median: 12 cats across 103 discrete colonies) (30), and Tan et al. in urban parts of Australia (median: 12 cats across 44 discrete colonies (31), but comparable to those documented in an urban Chicago, Illinois, neighborhood (median: 0–6 cats across 20 discrete colonies) (12). Data from the present study are not necessarily inconsistent since the median values from the previous studies refer to colony size prior to sterilization efforts and were based upon colony censuses. The CCP data, by contrast, reflect only the number of cats enrolled in the CCPs.

Examination of source/return site data reveals that the maximum number of cats returned to a single location can be deceiving. Data from Albuquerque, for example, show that 205 cats originated from one site: a mobile home community (approximately 0.33 km^2 in size) for which shelter staff used a common address when recording intake (and, as appropriate, return) information. Similar situations were observed in other CCP communities. For this reason, 90th percentile (as opposed to maximum) was chosen to represent the upper-end of the number of cats present at each source/return site. Results of this analysis correspond well with those of Natoli et al. who reported that colonies of 21 or more cats were uncommon in Rome, Italy (30).

Implications of the Red-Flag Cat Model

As stated above, on average, 4 TNVR cats (median of 2) were enrolled in CCPs for each RTF cat returned to red-flag cat model locations; these results are similar to what was previously documented by Albuquerque (where such information was tracked by calendar year) (21). It was not uncommon for a dozen or more cats to be enrolled at the same location as a result of targeted TNVR in response to a single cat being brought to the shelter; one site targeted by San Antonio had 116 cats enrolled in such a fashion, which is illustrative of the potential of the red-flag cat model (and integration of RTF and targeted TNVR programs in general). The red-flag cat model was employed as part of each CCP as staffing and circumstances on the ground allowed, which varied by program location; for example, Baltimore enrolled the most TNVR cats across the greatest number of red-flag cat model sites during Year 1, while Columbus experienced this peak in Year 2 and Philadelphia and Albuquerque in Year 3 (Tucson and San Antonio saw the number of red-flag cat model sites and total number of TNVR cats trapped at such sites peak in different program years).

General Health of Cats Enrolled in the CCPs

Consistent with what has been observed at other locations where RTF (19) and targeted TNVR (17) programs have been implemented, the cats enrolled in all of the CCPs were generally in good health, as was evidenced by the low incidence of cats requiring euthanasia due to serious health concerns (0.5%) or dying in care (0.2%). As mentioned above, the welfare outcomes for cats returned to locations of origin were not tracked as part of the CCPs; in fact, little research on this topic could be found. A single example was uncovered from a published report describing the RTF program in Jacksonville, where for more than a year at the beginning of the program cats were microchipped for the purpose of tracking the number that "would be hit by cars… starve to death, be attacked by dogs, and many other hypothetical tragedies that should nullify the program" (32). The report concluded: "After more than a year of such identification absolutely none of the more than 6,000 feral cats with a microchip were ever identified as falling into any of those theoretical situations" (32). Indeed, the microchipping of cats as part of the Jacksonville RTF program was discontinued when "no evidence of mistreatment of returned cats turned up" (20). Further research in to the welfare outcomes associated with cats of shelter origin returned to the field after sterilization and vaccination is warranted. Considerable data, however, including what has been reported above, have been published in support of the assertion that community cats are in generally good health upon enrollment in programs that revolve around TNVR and its variants (12, 17, 19, 21, 33).

Analysis of DOA Data

DOA data from Albuquerque and Tucson (reductions of 24 and 14%, respectively) were comparable to the 20% reduction (from 1,629 to 1,308) reported following 4 years of RTF in San José (19) (**Table 5**). San Antonio documented many more DOA cats than any other CCP (more than 20 times that of Tucson). Neither the initial increase (described previously) nor the greater overall DOA numbers could be explained by those who provided the data. The reductions observed by Albuquerque and Tucson—as well as those suggested by the "combined" data from Baltimore and incomplete data from Philadelphia—would seem to support the hypothesis that targeted sterilization efforts decreased the number of community cats in CCP service areas, and is consistent with evidence from elsewhere suggesting that neutered male cats "lose interest in mating with females which considerably reduces their inclination to roam" (19, 34–36). The data from San Antonio, however, are less consistent. Given the increasing popularity of TNVR (37) and RTF programs (25) and concerns for the welfare of cats being returned (38), this is an important area of investigation for future studies.

LIMITATIONS

As has been encountered elsewhere (12, 21, 39), the limitations of the present study include those commonly experienced when conducting a retrospective investigation, which is bound by the constraints of the available data. For instance, some types of data were tracked differently across the CCPs: overall feline intake, euthanasia, euthanasia rates, and surgery counts were tracked by program year for all six locations, but Albuquerque tracked other metrics (e.g., live-release rate, RTO, kitten results) only by calendar year; baseline results for Albuquerque and San Antonio reflect 12-month periods immediately preceding program initiation, whereas baselines presented for Baltimore, Philadelphia, Tucson, and Columbus reflect end-of-year results for the calendar year immediately preceding those programs. Cats originating from red-flag cat model sites were not separately tracked by the CCPs; however, the number of cats enrolled at each site were tracked by program component (RTF or TNVR) and program year (calendar year for Albuquerque). Therefore, for the purposes of this study, locations at which both RTF and targeted TNVR activity occurred during the same year were categorized as red-flag cat model sites. Moreover, shelter metrics were not formally tracked by zip code; therefore, an assessment of the impact of targeted TNR on intake and euthanasia for specific zip codes, as has been formulated elsewhere (17), was not attempted.

Community cats were enrolled in the CCPs as they were discovered and trapped or brought into the shelters. Return site information, including location and the surgery records of individual cats, was entered into an internal Best Friends database. Such information was updated throughout the program as cats were trapped, sterilized, and returned; however, records of the number of cats at each colony site upon entry into the CCP are incomplete. Therefore, assessment of changes in colony size over the course of the program was not possible. In addition, the welfare outcomes for cats returned to sites of origination were not specifically recorded, precluding analysis.

CONCLUSIONS

Significant and rapid reductions of feline euthanasia and intake occurred across all CCPs (the single anomaly being the largely unexplained rise in intake during Year 1 of the San Antonio program), highlighting the effectiveness of integrating RTF and targeted TNVR. Use of the red-flag cat model, which was employed as part of all CCPs, improved the efficiency of targeted TNVR efforts. It was found that cats enrolled via the RTF and targeted TNVR components of all CCPs were in good general health, corroborating prior research (17, 21, 33). In general, the number of cats found at source/return sites was small, which is consistent with results of previous research conducted on community cats residing in urban environments (12, 30). Although cat-specific DOA data were not obtainable for all locations, the available evidence generally supports the hypothesis that significant declines in dead cat collections suggest a combination of fewer community cats and reduced roaming on the part of sterilized individuals (19).

DATA AVAILABILITY

The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

AUTHOR CONTRIBUTIONS

PW conceived of the research idea. DS collected and examined the data. Both authors wrote/edited the paper.

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Predation and Risk Behaviors of Free-Roaming Owned Cats in Auckland, New Zealand via the Use of Animal-Borne Cameras

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Free-roaming cats are at increased risk of injuring themselves as well as other domestic and fauna species, yet relatively little is known about the frequency at which risk and predation behaviors occur in a typical day. In this study, cat risk, and predation behavioral information was collected using animal-borne video cameras and global positioning system (GPS) units that were attached to break-free cat collars. The observation period was one to three consecutive days for 37 convenience sampled free-roaming owned cats in Auckland, New Zealand. Video footage was manually reviewed and all predation and risk behavior events were recorded. These included stalking, pursuing, and seizing prey as well as altercations with other cats, ingesting harmful substances, and venturing into hazardous locations such as roads and storm drains. During the observation period, 23 of the 37 cats (62.2%) engaged in a total of 121 predation events. Of these, 40 resulted in successful prey capture with 18 of the 40 captures involving New Zealand native fauna species. Invertebrates were the most common taxa preyed upon ($n = 55$; 46%), followed by skinks ($n = 8$; 7%). No mammalian, avian or amphibian prey were captured and no cat took prey back to their residence. A total of 326 risk behaviors were observed for 32 out of the 37 cats (86.5%) with the most common being cats venturing onto the road ($n = 132$; 41%). Younger cats (aged 1–6 six years) engaged in significantly more predation and risk behaviors than older cats (aged 7 years and above). Sex, breed, number of cats in a household, and geographic location were not found to be predictors of cats' participation in predation or risk behaviors. Given the high frequency of predation and risk behaviors in free-roaming owned cats, it may be beneficial to educate owners about strategies to minimize risk such as housing them indoors, containing them to their properties or monitoring their time spent outdoors.

Keywords: owned cat, free-roaming cat, predation, risk behavior, cat behavior, native fauna species, welfare, cat management

INTRODUCTION

The New Zealand Animal Welfare (Companion Cats) Code of Welfare 2007 defines companion cats (*Felis catus*) as domestic cats that cohabitate with humans and depend on humans for their welfare (1). Internationally, this category of cats is generally referred to as "owned" and this term will be used throughout the rest of this paper. Domestic cats are commonly kept in New Zealand, with ∼1,134, 000 owned across the country (2). An estimated 90% of New Zealand's owned cats can free-roam without being monitored by their owners, having access to the outdoors during the day, night, or always (3), compared with 97% in Britain (4), 80% in Sydney, Australia (5), and 64–76% in the USA (6). When allowed to roam freely, companion cats are capable of hunting fauna species and engaging in behaviors that may cause themselves harm, such as fighting with other cats, ingesting harmful substances, and running onto roads (7). Consequently, there is growing interest in developing recommendations for owners to mitigate these risks.

It is important to protect native fauna species for the benefit of New Zealand's biodiversity. Cats can kill a range of species, with mammals, birds, invertebrates, and reptiles reported as being common prey taxa brought home by owned cats in New Zealand (8–10), many of which include New Zealand native fauna species (11). New Zealand native fauna is particularly vulnerable to predation by mammalian predators such as cats, given that it evolved in the absence of mammalian quadrupeds (12, 13). For example, van Heezik et al. (10) reported that the survival of three bird populations in urban Dunedin, New Zealand, was negatively affected by owned cat predation, including those of two native species (fantail [*Rhipidura fuliginosa*] and bellbird [*Anthornis melanura*]). However, cats are also recognized as being potential population regulators of other introduced predators and competitors, controlling the number, and subsequently the predation impacts of these species (14). This highlights the complexity of the situation, with a possible positive effect of cats controlling introduced species that can threaten native species. It has been suggested that cat management should be conducted in tandem with the management of other introduced species to avoid a surge in the numbers and, therefore, hunting rates of other predatory species that cats prey upon, such as rats (*Rattus* spp.) and mice (*Mus musculus*) (8, 14). This phenomenon, in which populations of medium-sized predators rapidly increase in ecosystems after the removal of larger carnivores, is known as "mesopredator release," and can potentially lead to adverse effects on the ecosystem (15).

Venturing onto the road, fighting with other cats, and consuming potentially toxic solids and liquids are examples of common risk behaviors associated with free-roaming cats that can result in distress, injury, disease, and/or death (16–19). The longevity of owned cats varies among studies: reported as a median of >12.5 years in purebred insured cats in Sweden (20), mean of 8.4 ± 5.6 years in Taiwan (21), median of 14.0 years in the UK (22), and an "average" longevity of 12.1 years in the USA (whether this was a median or a mean value was not specified). Both the UK and Swedish studies suggested the existence of two distinct subpopulations of cats: those with a propensity for earlier death (with a large number of road traffic accident-related deaths among these younger cats) and cats that survive to an older age (20, 22). Although these studies did not discuss outdoor access as a risk factor, it is likely that the cats who died due to road traffic accident-related mortality had outdoor access. This highlights one of the considerable risks to which free-roaming owned cats are exposed. The different attitudes to outdoor access for owned cats may affect trauma-related mortality and longevity; daily outdoor access has been reported to vary from over 90% of UK cats to 80% of Australian cats, and 50–60% of cats in the USA (5, 23, 24).

Cat owners may be aware of some dangers their cats face whilst free-roaming, but may not be aware of other risks. For example, venturing onto the road and climbing into storm drains or on the edges of roofs (19). It has been theorized that cat owners may be more likely to engage in cat management methods where they are made aware of the benefits to their cat's welfare, in contrast to engaging in cat management simply out of concern for the preservation of fauna species (19, 25). By being informed about the danger of allowing their cats to free-roam owners could be encouraged to manage their cats more closely by housing them indoors, containing them to their properties, or monitoring their time outdoors. This will likely benefit the welfare of their cats as well as help reduce predation impacts on native fauna species.

Many factors may influence a cat's engagement in predation, the species of animal they prey upon, and their risk behaviors. These include age, sex, location (for example, urban, suburban, or rural), provision of outdoor access, breed, time of day, provision of food, and the number of owned cats in the household. Age is suggested to be a predictor of predation behavior in some studies with younger cats reported to engage in hunting more than older cats (26), although age has not been found to influence predation rates in other studies (27). Sex and breed have not been shown to be predictors of hunting rates (26–28) but are predictors of cats venturing onto the road. For example, male cats and non-pedigree cats are reportedly more likely to venture onto roads and be involved in road accidents than female and pedigree cats (16, 19). Cats living near populations of native fauna species (a situation that may be more common in rural and suburban areas than in urban areas) will presumably capture more native prey than other cats (27, 29). These are contradictory ideas that, to date, have not been tested. Cats housed indoors at night engage in fewer risk behaviors and may capture fewer prey items than those cats allowed outside all day and night (19). However, Rochlitz (17) found that cats kept indoors at night were just as likely to be involved in a road accident as cats always provided outdoor access. The presence of other owned cats in a household may facilitate (24, 30) or hinder (31) engagement in predatory behaviors, and so too may the absence of other cats (32).

The current study investigated owned cat risk and predation behavior using animal-borne cameras. To date, no research into the predation and risk behaviors of owned cats employing animal-borne technology has been conducted in New Zealand.

Abbreviations: 1080, Sodium fluoroacetate; D1, Day one; D2, Day two; D3, Day three; DOC, Department of Conservation; GPS, Global Positioning System; NZCAC, New Zealand Companion Animal Council; SH, Successful hunter.

Previous studies in this country have used alternative methods to determine the prey items of owned cats' prey, such as owner survey methodologies to investigate prey taken back to an owned cat's residence, stomach content analysis and scat analysis (9, 10, 33). Whilst these methods provide insight into the predation behaviors of cats, information regarding whether any prey was scavenged or lost/left *in-situ* is unable to be collected (34, 35).

The use of animal-borne video cameras allows this information to be collected and can provide a more accurate depiction of cat predation behaviors than other methods. To the authors' knowledge, no research has been undertaken in New Zealand to identify or quantify the extent to which free-roaming cats engage in risk behaviors. The current study aimed to better understand free-roaming owned cats in Auckland, New Zealand, in terms of their engagement in predation and risk behaviors, home ranges, and activity levels[1] via the use of animal-borne camera and global positioning system (GPS) technologies. The factors that may act as predictors of these behaviors were also investigated. It is anticipated that this research could be used to assist in determining how owned cats can be managed, both for the protection their welfare and that of native fauna species.

MATERIALS AND METHODS

Participant Selection

Cat owners for the study were recruited via an all-staff e-mail listserv advertisement at Unitec Institute of Technology sent on October 30th 2016 and via two advertisements, ∼1 month apart, on the New Zealand Companion Animal Council Facebook page. The advertisements provided a brief description of the research and, as an incentive to participate, owners were offered the chance to view a selection of their cat's footage upon completion of the research. To ensure interested owners knew and agreed with what the research entailed, each was emailed a research participant information sheet that outlined the research in full as well as a consent form which required their signature. Interested owners were also asked a series of questions to confirm that their cat(s) met the following study inclusion criteria:

- The cat lived in the Auckland Region.
- The cat was over 6 months of age to facilitate their adaption to carrying the weight of the camera.
- The cat had access to the outdoors (i.e., not an indoor only cat).
- The cat was classified as an owned cat (1).
- The cat was able to be safely handled by their owner.
- The cat was seen/handled by their owner every day.

Seventy-two cat owners responded to the advertisements. Of these, 35 owners with a total of 51 cats met the eligibility criteria. Due to study resource limitations, the 29 owners that contacted the research team first were selected to participate in the research study, totalling 41 owned cats. Nine households had multiple cats participate. However, with technological issues and one cat rejecting wearing the camera, useable footage was collected from 37 of the 41 participating cats, representing 26 households across Auckland. With the small pool of eligible cats from a potentially non-representative sample of owners, we focused on characterizing the range of predation and risk behaviors among free-roaming owned cats rather than trying to make accurate inferences about the true prevalence of these behaviors across all free-roaming owned cats.

Ethical approval for this research was obtained from the University of Auckland AEC (Auckland, New Zealand; Reference 001595).

Technology

Video footage to observe cat engagement in predation and risk behaviors was collected using KittyCam© animal-borne cameras (National Geographic, Washington, D.C., USA) and GPS data were collected using animal-borne GPS units (Petrek, Auckland, New Zealand). KittyCams© are part of National Geographic's Crittercam© series and have been developed specifically for use on domestic cats. Crittercams© have been used in numerous studies since their conception in 1987, investigating the behaviors of a variety of both aquatic and terrestrial animal species, including domestic cats (7, 19, 36, 37). KittyCams© are rectangular, waterproof units that weigh 90 g each. These units were attached to a break-free cat collar ("AlleyCat" in size small; Rogz, Cape Town, South Africa) with cable ties and sat underneath the cat's chin, collecting video footage from their point of view (19). An infrared light-emitting diode (LED) positioned next to the KittyCam© camera lens allowed for recording in darkness. In-built motion sensors prompted the KittyCam© to record when cats were moving and stop when they were not moving, conserving battery power and memory card space. KittyCams© had the capacity to record 10–12 h of footage before requiring charging. Programmable settings included the timing of activation and deactivation of the KittyCam©, duration of recording once motion ceased and the intensity of movement required before recording was initiated. Each KittyCam© had an internal very high frequency (VHF) transmitter for use in locating missing units.

GPS data were collected using waterproof Petrek© GPS units (Petrek, Auckland, NZ). Each unit weighed 30 g, and was attached to the back of the break-free collars. To pinpoint and record a cat's location the GPS units used cell phone networks and sat on the back of a cat's neck. GPS accuracy ranged from 0.5 to 30 m+ based on signal strength and quality. The GPS units updated each cat's location every 5 min or when a signal was available and required charging at 24 h intervals. The GPS capability was used as the primary method of assisting with the location of missing collar sets (i.e., a collar with one camera and one GPS unit attached). The GPS data on cat movements and home ranges will be presented in another manuscript.

The break-free collars were set to the highest load setting to accommodate the weight of the cameras and GPS units. Each collar came equipped with a bell, which was removed because bells have, in the study of Gordon et al. (28), been shown to alert prey items to a cat's presence, potentially reducing the capture of birds by 50% and rodents by 61%. In contrast, bells on cat collars were not shown to significantly reduce the

[1]This information will be presented in another publication.

amount of prey captured by cats in the study by Morgan et al. (38). VHF telemetry equipment (Sirtrack® receiver—R-1000 Telemetry receiver, antenna—3 element folding yagi antenna) was used as a secondary method of locating missing cameras where they could not be found using the GPS units.

Experimental Protocol

Collar sets were deployed on pre-arranged dates between 1st November 2016 and 11th April 2017.

Owned cats wore one collar set per 24-h period with the intention of collar sets being changed after each period for three consecutive days. A 3-day recording period per owned cat was chosen because it represented a balance between sample size and the amount of data collected per cat, based upon resource availability.

Cat owners were taught to attach the collars to the cats to minimize the potential distress associated with being handled by an unfamiliar person. Owners were instructed to remove the collars if they had concerns about the cats' welfare. Inability to adjust to the collars may have caused the cats distress, potentially impacting their welfare and the accuracy of the data collected (39, 40). Collar sets were collected upon completion of the data collection period. Video footage was downloaded and the KittyCams© and GPS units were prepared for successive deployments. A maximum of two cats wore collars at one time to be logistically manageable for the research team. If a collar was lost from a cat during the recording period, another collar was not attached to reduce the risk of losing further equipment. Although the GPS data are not reported in this paper, participating cats were wearing GPS devices at the same time as the KittyCams and this detail has been included to improve the reproducibility of the study and to allow discussion about weight of the cameras and GPS units that may have impacted the participating cats' behavior.

During the researcher's visit, cat owners were asked the following information about their cats: age, sex, breed, sterilization status (sterilized or entire), location (rural, suburban, and urban), when the cats were let outside (outdoors all the time, inside at night, inside sometimes), whether or not they had worn a collar before (yes, no, unsure), and whether it was a multi-cat household (yes or no). Information on temperature (deg C) and weather conditions (dry, light rain, or heavy rain/thunderstorms) was collected from the MetService website, as these factors may have influenced the likelihood of cats spending time outdoors and engaging in predatory or risk behaviors on any given day. Cat age was categorized into two groups: 1–6 years and 7 years and above. These groupings allowed for comparison with the findings of Morgan et al. (38), who used similar age groups. Breed was categorized into domestic (including domestic long hair, domestic medium hair, and domestic short hair) and other breeds.

Data Processing

For various reasons including technological malfunction and one cat refusing to wear the collar set, video footage was only able to be collected from 37 owned cats. Altogether, 22 cats (48%) were observed for 3 days, nine cats (20%) were observed for 2 days, and 15 cats (33%) were observed for 1 day for a total of 99 observation days. A total of 179.8 h of footage was collected.

The video footage was reviewed manually by the research team to characterize the frequency and duration of predation events and risk behaviors during the observation period. Predation events were defined as when the footage indicated a cat was stalking, pursuing, or seizing prey items (defined as all the animals that cats were observed attempting to capture or successfully capturing). Similar definitions have been described previously by Loyd et al. (7) and McGregor et al. (41). All predation behaviors were documented, including those that resulted in unsuccessful prey capture and instances of scavenging. Risk behaviors that participating cats were likely to display were defined prior to data collection, being modeled on those presented by Loyd et al. (7). These behaviors included "altercations with other cats," "venturing onto the road," "climbing underneath car," "ingesting solids not provided by owner/carer," "ingesting liquids not provided by owner/carer," "climbing on edge of roof," "climbing into storm drain," and "other." All observed risk behaviors were recorded.

The KittyCam© internal motion sensors provided a simple method of determining the total amount of time cats were active whilst wearing the collars. Daytime footage for each cat (i.e., that collected between 6 a.m. and 6 p.m.) was combined to determine the amount of time they spent active during the day; night time activity levels were determined in a similar fashion.

Statistical Analysis

Basic descriptive statistics were provided on the demographic characteristics of the cats included in the study population as well as the frequency and characteristics of the predation and risk behavior events. To evaluate factors influencing predation and risk behavior, two binary outcome variables were created for each cat observation day: had at least one predation event (yes or no) and had at least one risk behavior event (yes or no). Mixed-effects logistic regression models with individual cat as the random effect were then used to evaluate the following risk factor variables: age (under 6, 7 years, or older), sex (male or female), breed (domestic or other), season of year (winter, spring, summer, or fall), weather (sunny, light rain, heavy rain/thunderstorms), whether the cat had previously worn a collar (yes or no), location (urban, suburban, or rural), and when allowed outside access (all the time or partial day). Although we attempted running a mixed-effects negative binomial with counts as the outcome, the models would not converge, likely due to the relatively small sample size and so we chose the more conservative mixed-effects logistic regression to account for the repeated measures in individual cats. An initial univariable screen was performed to identify factors that were associated with the outcome of interest with a p-value of < 0.20 for inclusion in the multivariable model. As only one variable reached significance, a multivariable analysis was not performed. The results were reported as odds ratio (ORs) with 95% confidence intervals. All statistical analysis were performed in the R statistical software package (42).

TABLE 1 | Summary of cat demographics.

Variable	Categories	Number (%) of owned cats
Age (years)	0–6	18 (49%)
	7+	19 (51%)
	Unknown	0 (0%)
Sex	Male	18 (49%)
	Female	19 (51%)
Location	Urban	5 (14%)
	Suburban	26 (70%)
	Rural	6 (16%)
Outdoor access	At all times	24 (65%)
	Inside at night	13 (35%)
Multi-cat household	Yes	20 (54%)
	No	16 (43%)
	Unknown	1 (3%)
	6+	n/a
Breed	Non-pedigree	27 (73%)
	Pedigree	10 (27%)
Number of days of footage recorded	1	22 (60%)
	2	9 (24%)
	3	6 (16%)

RESULTS

Cat Demographics

Owned cats were aged between 1 and 13 years; mean 6.7 years (±4.0) (**Tables 1**, **2**). Eighteen owned cats (49%) were male (**Tables 1**, **2**). Nineteen owned cats (51%) were female, all cats were sterilized (100%) (**Tables 1**, **2**).

Predation Results

During the 90 observation days for owned cats, there were 121 predation events. Owned cat predation events ranged from 2 s to 6 min in length, with a mean of 35.5 s (±44.07). Forty (33%) of the 121 owned cat predation events resulted in successful prey capture, 56 (46%) in unsuccessful capture, 22 (18%) in undetermined success, and three (3%) in scavenging (**Table 3**). Invertebrates were the most common taxa preyed upon by owned cats ($n = 55$; 46%), followed by skinks ($n = 8$; 7%). Owned cats did not capture any mammalian, avian or amphibian prey, though an already deceased unidentified bird was scavenged (**Table 4**). Fifty-seven (47%) prey items hunted by owned cats could not be identified to phylum level (**Table 4**). Twelve owned cat predation events (0.1%) resulted in the successful capture of native species (**Table 5**).

Risk Behavior Results

During the 90 observation days for owned cats, there were 326 risk behavior events recorded. The incidence of each risk behavior and the number of cats that participated in each risk behavior varied. The most common risk behavior observed was cats venturing onto the road (**Table 6**). Three altercations (27%) between owned cats that did not live together resulted in physical contact and eight (73%) did not, involving only growling, and swiping. Solids ingested that were not provided by owners included twigs, discarded food, and potted plants, while liquids included water from paddling pools, freshwater streams, puddles, and roof gutters. The counts of "other" risk behaviors witnessed included a cat climbing on Pink Batts® (glass wool home insulation).

Factors Influencing Predation and Risk Behaviors

There was considerable variability within and between cats in both the number of predation events and the number of risk behavior events observed on any given day. The maximum number of predation and risk behavior events observed in 1 day were 10 and 25, respectively. **Table 7** shows the daily counts of predation events and risk behavior events for the 22 cats with three complete observation days. While most owned cats had a relatively low number of events, some cats were clearly more active than others. There were 36/99 (36.4%) cat observation days with at least one predation event and 74/99 (74.7%) cat observation days with at least one risk behavior event to include in the mixed-effect logistic regression models. For predation events, age was the only significant predictor. Cats that were over 7 years of age were 0.20 times as likely to have at least one predation event compared with cats 6 years of age and under (OR: 0.20, 95% CI 0.09–0.42, $p < 0.001$). None of the variables in the model for risk behaviors achieved significance.

Activity Results

Owned cats recorded between 0.36 and 8.0 h of footage each in total, with a mean of 4.9 h (±2.4).

Owned cats spent 86.35% of the time inactive and 13.65% of the time active; hunting comprised 0.09% of active time and engagement in risk behaviors comprised 0.18%. The remaining time spent active included behaviors such as grooming, walking, and ingesting food and water provided by their owners.

DISCUSSION

This study reports the first observations of predation and risk behaviors of owned cats in New Zealand using animal-borne cameras and demonstrates that predatory and risk behaviors were commonly displayed by the cats.

Most of the identified prey species in the current study were invertebrates. No mammals, amphibians or birds were preyed upon and only one case of a bird being scavenged was observed. This is in contrast to studies that used owner survey methodologies to investigate prey taken back to an owned cat's residence in New Zealand. In these studies, it was reported that mammals or birds were most commonly taken back, followed by invertebrates and reptiles, with other prey species being taken infrequently, including amphibians and fish (9, 10, 33). Loyd et al. (7), using animal-borne camera technology, found that reptiles were successfully captured most frequently, followed by mammals, invertebrates, birds, and amphibians. This research closely resembles the results of the current study, suggesting that different methodologies may be a factor in

TABLE 2 | Individual cat demographics.

Cat	Age (years)	Sex	Location	Outdoor access	Multi-cat	Breed	No. of days of footage collected
1	2	Male	Rural	At all times	Yes	Burmese	3
2	2	Male	Rural	At all times	Yes	Burmese	3
3	2	Female	Suburban	At all times	No	DSH	3
4	6	Female	Rural	At all times	Yes	Burmese	3
5	11	Female	Suburban	Inside at night	No	DSH	3
6	4	Male	Suburban	Inside at night	Yes	DSH	3
7	3	Female	Urban	At all times	Yes	DSH	2
8	3	Male	Rural	At all times	No	Siamese	2
9	13	Male	Rural	At all times	No	DSH	2
10	8	Male	Suburban	Inside at night	Yes	Burmese	2
11	13	Male	Suburban	Inside at night	Yes	DSH	3
12	12	Female	Suburban	At all times	No	DSH	1
13	1	Male	Suburban	Inside at night	No	DSH	2
14	11	Male	Suburban	At all times	No	DSH	3
15	7	Female	Suburban	Inside at night	No	DSH	3
16	3	Female	Rural	At all times	Yes	DLH	3
17	11	Female	Urban	At all times	Yes	Russian blue	3
18	3	Male	Suburban	Inside at night	No	DMH	2
19	2	Female	Suburban	Inside at night	No	DSH	1
20	7	Female	Suburban	Inside at night	Yes	DSH	3
21	8	Female	Suburban	Inside at night	No	DSH	3
22	11	Female	Suburban	At all times	No	DSH	3
23	1	Male	Urban	At all times	No	Norwegian forest cat	3
24	2	Male	Suburban	Inside at night	Yes	Burmese	1
25	4	Male	Suburban	At all times	Yes	DSH	3
26	5	Female	Suburban	At all times	Yes	DSH	2
27	10	Male	Suburban	At all times	Yes	DSH	3
28	10	Female	Suburban	At all times	Yes	DSH	3
29	9	Male	Suburban	Inside at night	No	DSH	3
30	4	Female	Suburban	At all times	No	DSH	3
31	6	Female	Suburban	At all times	No	DMH	2
32	9	Female	Urban	At all times	Yes	Russian white	3
33	12	Male	Urban	At all times	Yes	DSH	3
34	12	Female	Suburban	At all times	Yes	DSH	1
35	10	Female	Suburban	At all times	Yes	DSH	2
36	2	Male	Suburban	At all times	No	DLH	1
37	8	Male	Suburban	Inside at night	Unknown	Bengal	1

TABLE 3 | Fate of successfully captured prey items.

Prey fate	Count
Killed and fully or partially consumed	33
Captured and released	5
Killed and left *in-situ*	1
Unknown	1
Total	40

determining prey composition data. A higher rate of prey identification in the current study may also have altered prey composition results.

Cats are opportunistic and generalist predators capable of killing a variety of prey species (7, 27, 43). Invertebrates and small reptiles may have been more abundant during the seasons in which data were collected and, consequently, were the easiest targets for predation by the opportunistic companion cats. This may explain why these species accounted for the majority of prey captured. Other possible explanations for the absence of mammalian and avian prey include individual cat prey preferences and a short data collection period which did not cover multiple seasons. It is possible that the seasons in which data were collected may affect prey abundance and availability (44–47). In addition, it has been suggested that an infrared LED, such as that next to the KittyCam© camera lens, which allowed for recording in darkness, may influence the behavior of potential

prey (37, 48). However, it allows information to be collected that would otherwise be missed (48). Prey activity patterns change during a 24-h period (27), likely influencing what cats hunt at different times of the day. Accordingly, to gain the most accurate representation of cat predation behaviors, it was necessary to use the LED.

New Zealand native fauna species comprised 15% of observed predation events and 30% of successful prey captures. Previous research using owner survey methods has suggested that native fauna species comprise 4 to 40% of owned cat prey (9, 10, 33). The capture of native species occurred in all locations (urban, suburban, and rural) and did not occur in one location significantly more than another. This is an interesting result given the common perception that cats living in rural areas or areas of ecological significance hunt native fauna species to a greater extent than cats living elsewhere (25, 49). The results of the current study suggest that popular opinion regarding cat predation behavior may not always be correct, and that the enforcement of management techniques based on cat location (e.g., cat exclusion zones) may not do enough to mitigate the depredation of native fauna species, if not accompanied by other management techniques. There was a low level of observed cat predation of huhu beetles (*Prionoplus reticularis*), copper skinks (*Oligosoma aeneum*) and wētā (e.g., *Hemideina* and *Hemiandrus* spp.) in this study. However, Huhu beetles are common in New Zealand forest habitats and copper skinks are common in the North Island of New Zealand (50–52). Captured wētā were not identified to species level, which meant the conservation status of the captured wētā was not determined.

No prey items were taken back to a cat's residence, indicating that predation information based exclusively on the prey items a cat takes home may greatly underestimate the amount of prey items captured by owned cats. Loyd et al. (7) drew the same conclusion upon observing that cats brought home only 23% of prey they captured. Underestimation of invertebrate capture may be especially common, with 31 invertebrates being

TABLE 4 | Prey identification by taxa.

Species	Count
Invertebrates	
Wētā*	16
Blowfly (Calliphoridae)	1
Unidentified fly	1
Cicada* (Cicadidae)	13
Huhu beetle* (*Prionoplus reticularis*)	1
Cricket* (Gryllidae)	1
Cellar spider (Pholcidae)	1
Unidentified moth	1
Praying mantis (Mantodea)	4
Monarch butterfly* (*Danaus plexippus*)	1
Reptilian	
Plague skink (*Lampropholis delicata*)	7
Copper skink* (*Oligosoma aeneum*)	1
Avian	
Unidentified bird	1
Unidentified insect	15
Unidentified	57
Total	121

**Indicates a New Zealand native species.*

TABLE 6 | Risk behaviors displayed by study cats.

Behavior	Count	No. of cats involved
Altercations with other cats	11	5
On road	132	12
Climbing underneath car	3	2
Ingesting solids not provided by owner	33	15
Ingesting liquids not provided by owner	98	22
Climbing on the edge of roof	40	8
Climbing into storm drain	1	1
Other	8	1
Total	326	

TABLE 5 | Predation event outcome by prey species.

Successful	Count	Not successful	Count	Unknown success	Count	Scavenged	Count
Wētā*	11	Weta	5	Blowfly	1	Cicada*	1
Unidentified fly	1	Cellar spider	1	Cicada*	1	Unidentified bird	1
Plague skink	3	Plague skink	4	Monarch butterfly*	1	Unidentified insect	1
Cicada*	10	Copper skink*	1	Unidentified insect	1		
Huhu beetle*	1	Cicada*	1	Unidentified	18		
Cricket*	1	Unidentified moth	1				
Unidentified insect	7	Praying mantis	4				
Unidentified	6	Unidentified insect	6				
		Unidentified	33				
Total	40	Total	56	Total	22	Total	3

**Indicates a New Zealand native species.*

TABLE 7 | Count of predation behaviors and risk behaviors per day for the 22 owned free-roaming cats with three full observation days.

	Predation behaviors				Risk behaviors			
Cat	**Day 1**	**Day 2**	**Day 3**	**Total**	**Day 1**	**Day 2**	**Day 3**	**Total**
1	6	8	0	14	7	5	2	14
2	0	0	2	2	11	0	1	12
3	4	0	1	5	0	0	0	0
4	1	0	2	3	1	3	5	9
5	0	0	0	0	3	0	5	8
6	2	6	9	17	2	8	18	28
11	0	3	2	5	0	5	6	11
14	2	0	0	2	6	0	5	11
15	0	1	0	1	0	2	1	3
16	1	0	10	11	4	1	3	8
17	0	0	0	0	4	3	3	10
20	0	0	0	0	0	0	1	1
21	1	0	0	1	5	3	1	9
22	0	0	0	0	2	2	0	4
23	0	0	0	0	2	4	9	15
25	0	3	1	4	25	18	9	52
27	2	0	0	2	2	0	1	3
28	0	2	0	2	0	7	1	8
29	0	0	0	0	2	5	0	7
30	4	0	0	4	14	4	8	26
32	0	1	0	1	6	5	2	13
33	0	0	0	0	1	2	2	5

captured and/or killed *in-situ* in the current study, 12 of which were native species. The capture data in this study were collected largely during warmer months when the abundance of some prey species, including invertebrates, has been found to be highest (44, 47). This in turn may have produced results that overestimate invertebrate predation, if extrapolated throughout the rest of the year. However, with ∼300 New Zealand native terrestrial invertebrate species threatened with extinction (53), it is suggested that the effect of cat predation on the survival of invertebrate species should be the focus of future research. Targeted conservation efforts may be required to save native invertebrate species from extinction due to predation by animals, including cats but also other species such as rats (*Rattus rattus, Rattus norvegicus, Rattus exulans*), mice (*Mus musculus*), and hedgehogs (*Erinaceus europaeus*), protecting them in their role as regulators of healthy ecosystem functioning (54, 55).

Young cats captured more prey than older cats in this study, which supports the results of previous studies (9, 10, 26). This result suggests that management of younger cats could be prioritized over the management of older cats to more effectively reduce predation rates. In line with the findings of previous studies (26–28), sex, and breed did not appear to influence predation rates. However, the results from the statistical modeling must be interpreted with caution given the small sample size and difficulty fitting robust mixed-effects models to the data. Although not significant in our models, there have been varying hypotheses on how the number of cats in a home may influence predatory behaviors (24, 30–32). In future studies, it would also be useful to assess other cat demographic management factors such as feeding, sterilization status, health status, temperament, socioeconomic, and environmental characteristics of the neighborhood, and density of other free-roaming cats. These factors may influence both the likelihood of seeking and encountering prey as well as potential exposures to risk.

Five cats engaged in altercations with cats they did not live with, with three altercations resulting in physical contact between the cats. Cats may sustain wounds when fighting that can become infected or contract diseases transmitted by contact with carrier cats, such feline immunodeficiency virus (FIV) (56, 57), though lower rates of infectious diseases, including FIV, have been observed in sterilized cats than in non-sterilized cats (58–60). Venturing onto the road was the most common risk behavior that participating cats engaged in, putting them at risk of injury and/or death if they were hit by a vehicle. Of the 116 owned cats hit by vehicles that Rochlitz (61) collected data on over an 11-month period, 28 died because of the accident and most others sustained injuries ranging in severity from minor to life-threatening. Two owned cats climbed underneath and up into various parts of a car, including the wheel well. Whilst this behavior puts cats at risk of injury and death should they become trapped, it appears not to be as significant a risk to cat welfare as other behaviors witnessed in this study. A similar result was observed by Loyd et al. (19), with only one cat climbing into a car engine in their study.

Participating cats also frequently ingested plant material and water from potentially contaminated sources. Numerous common plants are toxic to cats, including lilies (*Lilium* spp.), aloe vera (*Aloe vera*) and daffodils (*Narcissus* spp.). Ingestion of these plants can result in vomiting, diarrhea, and kidney and cardiac failure (62). There is also a risk that cats, especially those living near areas of ecological significance, will consume poisons laid to kill invasive pest species. Sodium fluoroacetate (1080) is routinely used in New Zealand to kill mammalian pests such as brushtail possums (*Trichosurus vulpecula*), rats and stoats (*Mustela erminea*) (63). Free-roaming cats may encounter and ingest 1080 and become ill or die, given that the lethal dose for an average-sized adult cat is less than that for a possum (64). Given the propensity for cats to scavenge, sub-lethal doses of 1080 may be ingested if cats consume animals killed by the poison, resulting in vomiting, staggering and drowsiness before being excreted, with no long-term effects on health reported (64, 65). Cats that consume water from puddles may inadvertently ingest toxins such as car coolants and oils, insecticides, and pesticides, which can result in sickness or death (19, 66–68).

Cats were often observed climbing on the edges of house, shed or garage roofs, and one owned cat was seen climbing into a stormwater drain. These behaviors put cats at risk of serious injury or death should they fall from a roof or get trapped in a

drain. Twenty percent of the cats in the study of Loyd et al. (19) climbed on roofs and in trees, a similar percentage to that of the current study, suggesting that this is a common risk behavior that cat owners should be aware of Loyd et al. (19) also witnessed 20% of the cats in their study climbing into storm drains—a far higher percentage than that of the current study—indicating that this may be more of a concern for owners in the USA where their study was conducted, possibly due to the increased ease in which cats can access the drain systems there. Risk behaviors classed as "Other" involved one owned cat climbing on Pink Batts® insulation, which can cause minor cuts and skin irritation as well as respiratory issues if inhaled or ingested. Whilst not commonly observed, these risk behaviors highlight the range of risks that free-roaming cats routinely encounter.

The sterilization status of cats may influence their behavior; reduced aggression has reported in sterilized stray female cats compared to entire stray female cats (69). In addition, roaming, fighting, and aggressive behaviors can be associated with higher risk of injury and infectious disease (20, 70, 71). Aggression, fighting, and roaming have been reported to decrease after sterilization (72, 73). All participating cats were sterilized; consequently, the influence of sterilization status on companion cat predation and risk behaviors, and activity levels could not be determined in the current study. Little conclusive research has been reported on whether sterilization status impacts on cat predation and risk behaviors, and activity levels. Nonetheless, the majority of companion cats are reportedly sterilized in New Zealand: companion cat sterilization levels have been reported to be as high as 90% in Auckland, New Zealand (74) and 93% nationwide (2). Therefore, the overall behavior of companion cats is considered unlikely to differ substantially from that found in the current study.

The current study is the first of its kind in New Zealand and it would be useful to replicate the study in other parts of the country outside of Auckland to determine whether the results are applicable on a nationwide scale and to further explore animal characteristics that may be influencing behavior. We acknowledge that our study population was small and that the owners were potentially non-representative due to voluntary response bias. However, as our objective was to characterize the range of predation and risk behaviors exhibited by cats rather than estimate the true prevalence, there were likely enough data to achieve information saturation (75). It is unclear why no mammalian or avian species were captured in the current study. It is possible that the weight or novel feeling of the camera may have disrupted cats' normal behaviors and subsequently their prey choice (76). However, it is noted, that Loyd et al. (7) observed cats capturing mammals and birds whilst wearing the same cameras. The added weight of the GPS unit may have been a determinant in the disruption of cat behavior and prey choice, with Coughlin and van Heezik (76) observing that cats behaved differently when a "heavy" device (136 g) was worn compared to a "light" device (36 g). For the majority of cats, we were only able to obtain footage from a single observation day and it was therefore difficult assess whether the patterns of behavior were likely to remain consistent over time.

It is suggested that in future research, sequential assessments of the same cats over time are performed and it may also be beneficial to "train" participant cats to wear the monitoring gear prior to capturing data. It is also recommended that future research collect data across all four seasons to ascertain the effect that changes in prey abundance has on overall predation rates and prey composition. The climate in Auckland is subtropical, with the weather being characterized by mild winters and relatively warm and humid summers (77). Spring and autumn are mild with more rainfall experienced in spring than in autumn. Average temperatures between summer and winter vary less than in other countries, fluctuating by no more than 14°C (77). Cats may be less likely to roam over winter months when the weather is less hospitable (78), although no seasonal variation was found in a study in Perth, Australia (79), and it was found in another study conducted in Christchurch, New Zealand that companion cats were more active in a wetland during winter rather than in summer (80). It is possible that a smaller home range size may influence predation and risk behaviors. With the limited resolution of the camera footage, there were some difficulties in accurately identifying prey items and so it is possible that the distributions reported in this study do not reflect the true distribution of species that cats routinely prey on.

The information presented here could be used to educate cat owners on the welfare advantages of managing their cats more closely, i.e., by housing them indoors, containing them to their properties using cat enclosures and containment systems, or monitoring their time spent outdoors. Education material (verbal, reading material, posters/videos in waiting room) could be provided by veterinarians when animals visit their clinics and at adoption locations (by animal shelters, animal welfare organizations, rescue organizations, and pet stores). The potential benefits of containing cats to an owner's property would need to be highlighted (such as the protection of cats from injury and the protection of native wildlife) as well as the different containment options available and advice on enrichment [e.g., (29)]. Owners' attitudes regarding their cat's "need" to roam would also need to be addressed. However, it is important to be aware that constraining the natural behaviors of cats, such as confining them indoors, have possible welfare implications due to boredom and inactivity. Therefore, suitable education on the needs of and appropriate enrichment, space, and housing requirements for contained cats is vital to allow them to express normal behaviors (24, 29, 81).

Changing the way cats are managed in New Zealand could also reduce the predation of native fauna species. Controlling cat roaming is not a popular idea in New Zealand, with only 5% of owned cats being housed indoors (3); however, the containment of other pets (e.g., dogs) is common practice and widely accepted, suggesting that an attitude change toward closer management of owned cats is possible. Predation and risk behaviors occurred both on and away from owners' properties in the current study (with the exception of venturing onto the road). Therefore, it is important to note that containing cats to their owner's properties will reduce, but not eliminate, their participation in these behaviors.

CONCLUSION

This study is the first reporting on observations of predation and risk behaviors of owned cats in New Zealand using animal-borne cameras. Predatory behaviors were commonly displayed by the cats although no mammalian, amphibian, or avian species were preyed upon. Most of the identified prey species were invertebrates. Risk behaviors were commonly observed and included cats venturing onto the road; ingestion of plant material and water from potentially contaminated sources; altercations with other cats; and climbing on the edges of house, shed, or garage roofs, and into a storm water drain. Given the high frequency of risk behaviors in free-roaming owned cats, it is suggested that cat owners should be educated about strategies to minimize risk to their cats such as safely containing their cats or monitoring their time spent outdoors.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of University of Auckland. This protocol was approved by the University of Auckland AEC (Auckland, New Zealand; Reference 001595).

AUTHOR CONTRIBUTIONS

SB, AD, GA, and JW oversaw the design and implementation of the study. SB performed the data collection. MG, SB, NG, and GA analyzed the data. SB, SZ, and MG wrote the paper. SB, SZ, MG, JW, AD, NG, and GA reviewed the manuscript.

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A Long-Term Lens: Cumulative Impacts of Free-Roaming Cat Management Strategy and Intensity on Preventable Cat Mortalities

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This study used a previously developed stochastic simulation model (1) to estimate the impact of different management actions on free-roaming kitten and cat mortality over a 10-year period. These longer-term cumulative impacts have not been systematically examined to date. We examined seven management scenarios, including: (1) taking no action, (2) low-intensity removal, (3) high-intensity removal, (4) low-intensity episodic culling, (5) high-intensity episodic culling, (6) low-intensity trap-neuter-return (TNR), and (7) high-intensity TNR. For each scenario we tracked within the model the number of kittens born, the number of kittens surviving to adulthood, and the number of adults removed using lethal control over the entire 10-year simulation. We further defined all kitten deaths and lethal removal of adults as "preventable" deaths because they could potentially be reduced by certain management actions. Our simulation results suggested that the cumulative number of preventable deaths over 10 years for an initial population of 50 cats is highest for a "no-action" scenario, estimated at 1,000 deaths. It is lowest for a high-intensity TNR scenario, estimated at 32 deaths, a 31-fold difference. For all management scenarios tested, including removal and culling, the model predicted fewer preventable deaths than for a no-action scenario. For all management scenarios, the model predicted that the higher-intensity option (defined in terms of the proportion of animals sterilized or removed within a given time period) would result in fewer preventable deaths over time than the lower-intensity option. Based on these findings, we conclude that management intensity is important not only to reduce populations more quickly, but also to minimize the number of preventable deaths that occur over time. Accordingly, the lessons for the animal welfare community are both encouraging and cautionary. With sufficient intensity, management by TNR offers significant advantages in terms of combined lifesaving and population size reduction. At lower intensity levels, these advantages are greatly reduced or eliminated. We recommend that those who seek

to minimize suffering and maximize lifesaving for free-roaming cats attempt to balance prospective goals (i.e., saving lives tomorrow) with proximate goals (i.e., saving lives today), and recognize that thoughtful choice of management strategies can ensure that both of these complementary goals are achieved.

Keywords: free-roaming cats, trap-neuter-return, cat management, population dynamics, simulation model, lifesaving

INTRODUCTION

Trap-neuter-return (TNR) programs vary substantially in scope, scale, intensity, and duration, but most employ a combination of sterilizing, vaccinating, feeding, and caring for free-roaming cats. Specific goals of TNR programs can include population stabilization or reduction (1–6); reducing shelter admissions, crowding, and deaths (7); mitigating nuisance behaviors (8, 9); reducing predation on wildlife (10); improving cat welfare (11, 12); and reducing numbers of cats that die from the risks and hardships of living outdoors (5, 11–15).

The results of TNR programs are most commonly quantified by the number of cats sterilized. Other metrics that may be considered include the numbers of cats returned to the point of origin, vaccinated, or fed, as well as indicators of health [see (15–17) for examples]. Less commonly, changes in population size may be tracked as an indicator of impact (18). What is rarely considered is that changes in the numbers of births, deaths, and immigration events that may result from management efforts could have multiplicative consequences that—over time—outweigh the more obvious and immediate management impacts.

Longer-term cumulative effects (defined in this model as effects occurring over a 10-year period) of different free-roaming cat management approaches have not been explored systematically, and little guidance exists to address these prospective concerns when creating and evaluating management strategies and goals. In this paper, we estimate the cumulative demographic consequences and the population end points of several different cat population management approaches that are currently available, including TNR, using a published simulation model of free-roaming cat population dynamics (1). We relate these outcomes to "lifesaving," a focal concept in the animal welfare field[1,2] (19), and specifically to the number of "preventable" deaths that occur under different management scenarios. We define preventable deaths as those that could likely be reduced or eliminated using an alternative population management approach, specifically the deaths of kittens under 6 months old that fail to reach adulthood, and the deaths of any cats due to lethal management.

Although there is considerable diversity and complexity to stakeholder views, public debate about free-roaming cat management and policy has been polarized and sometimes antagonistic (10, 13, 14, 20–23). One set of stakeholders prioritizes quickly and permanently eliminating outdoor cat populations, by lethal means if necessary (13, 14, 20, 22, 23). This position is often motivated by concerns about cat predation on native wildlife species and threats of disease transmission. Another cohort of stakeholders prioritizes non-lethal management, including TNR. These proponents often emphasize that TNR has the capacity to successfully reduce and stabilize cat populations in a humane fashion over time, in addition to meeting animal welfare goals (11, 12).

In this analysis, we use a predictive simulation model to evaluate the relative effectiveness of different population management strategies for free-roaming cats in terms of both cumulative preventable deaths and population size reduction. We then consider the implications of these results for establishing best management practices. Specifically, we explore whether current competing paradigms of cat management could become more convergent and possibly synergistic when viewed from a longer-term perspective. If so, then combining these goals into a more integrated paradigm for "best management practices" at realistic time scales could lead to better outcomes for cats at the individual and population levels, mitigate predation risk to wildlife, and reduce conflict among stakeholders.

METHODS

In 2014, we developed an individual-based stochastic model to simulate free-roaming cat population dynamics using the software package *Vortex* version 9.99b (24) to estimate the demographic outcomes associated with various management scenarios (1). We used this model, now updated to *Vortex* version 10.2 (25), to generate the new results that are presented in this report. Model details are detailed in Miller et al. (1) and summarized briefly here.

The model is structured as a series of sequential 6-month time steps. During each time step, probabilistic age-specific birth and death rates are applied to each individual in the simulated population, along with specified management actions. These operations result in changes to population size and age-sex structure that collectively define the starting point for the next time step. Model parameters such as birth and death rates were determined by literature review or expert judgment (1) to reflect typical population function, and management scenarios were defined *a priori* to reflect a realistic range of possibilities. In addition, kitten mortality was structured to increase as the population approached its carrying capacity, as higher population density will create more stressful conditions (e.g., greater disease transmission, more competition for food)

[1]http://shelteranimalscount.org/docs/default-source/DataResources/sac_basicdatamatrix.pdf?sfvrsn=2 (accessed October 16, 2018).
[2]https://www.maddiesfund.org/lifesaving.htm (accessed October 16, 2018).

TABLE 1 | Summary of numerical input values for baseline demographic models.

Model input parameter	Baseline value
GENERAL MODEL SETUP	
Model timestep	6 months
Number of iterations for each scenario	1,000
Number of populations	2: Focal population, Neighborhood
POPULATION DEMOGRAPHICS	
Initial population size	Focal population = 50; Neighborhood = 200
Sex ratio (initial population and new litters)	50:50
Age of first breeding	6 months (females and males)
Female breeding rate (producing litters)	48% ("winter"); 92% ("summer")
Average annual number of litters per female	1.4
Average litter size	3.5
Male breeding rate	100% of intact males available for breeding
Kitten mortality to 6 months	75% (low density) to 90% (high density)
Adult mortality (6-month interval)	5.2% (10% annually)
METAPOPULATION STRUCTURE	
Disperser characteristics	Age 6–24 months; 75% male
Mean dispersal rate per timestep	2% of source population size
Cost to dispersal (survival rate)	75% survival of dispersers
Litter abandonment (per timestep)	Mean of 3 kittens into focal population

that will result in more individuals dying within 6 months after being born (see also **Supplementary Materials**).

Unlike most simulation models for free-roaming cats (26–30), our model incorporated demographic connectivity between our "focal" population and cats in surrounding areas by allowing dispersal (consisting of both immigration into and emigration out of a given population) and abandonment of owned pet cats to occur probabilistically. Immigration rates averaged 2% of the extant source population (comprised of individuals aged 0.5–2 years and 75% male) per time step, and abandonment rates averaged one litter with approximately three surviving kittens per time step. Population dynamics that were not explicitly incorporated into the model included more complex forms of density dependence, differential longevity of sterilized cats (31), and postulated differential male fecundity mediated by social stratification (32, 33). The 6-month time step was not intended to suggest that births, deaths, or management actions do or should occur at these time intervals, but represented a temporal resolution that in our judgment best matched available field data [e.g., seasonal breeding documented in (17, 34)] and balanced computational tractability with biological realism. A summary of baseline model input parameter values is presented in **Table 1**.

For this analysis, we simulated a set of discrete management scenarios over a 10-year (or 20-time-step) period. Although these scenarios do not represent all management options, they do represent typical approaches for which real-world precedents exist, particularly in the municipal settings where a blend of removal, culling, and TNR programs may co-exist. Simulations began with the focal and neighborhood populations composed of 50 and 200 cats, respectively. Individuals in these populations were initially distributed across age- and sex-class according to the stable age distribution, which is calculated automatically by the model in accordance with the stated reproductive and survival rates. With this initialization procedure, no long-term model "burn-in" was necessary and simulation results were not adversely biased by non-steady-state demographic dynamics. Furthermore, we assume that each population is at its maximum long-term abundance within its given habitat; in other words, each of the populations are at the ecological carrying capacity, where growth beyond this abundance cannot be sustained by the available local resources (see **Supplementary Materials**).

The focal population was tracked over time as it changed due to management and other factors. The focal population was surrounded by a larger "neighborhood" population of 200 cats that was not managed and provided a source of potential immigrants.

The following scenarios were simulated:

1) No action: In this scenario, no attempt was made to manage the focal population. It provided a baseline against which other active management scenarios were compared.
2) Remove-low intensity: This scenario involved trapping and removing 25% of the cats in the focal population during each time step. We assumed for this analysis that these cats were euthanized after removal, though we recognize that adoption could be an alternative in some real-world settings. Because the number of cats in the population changed over time, the number of cats removed during each time step varied over time. This scenario approximates ongoing, steady removal of free-roaming cats by an animal control agency.
3) Remove-high intensity: This scenario is identical to "remove-low intensity," except that 50% of the cats in the focal population were removed (and assumed to be euthanized) during each time step. This scenario approximates the eradication programs that are sometimes pursued in protected wildlife habitat.
4) Cull-low intensity: This scenario involved removing and euthanizing 25% of the cats present in the population during the initial time step, and then taking no action until the population recovered to its carrying capacity over several time steps, at which point another 25% cull was performed. This cycle was repeated throughout the 10-year period. This represents the episodic removals that may be conducted by animal control agencies in response to nuisance complaints or other concerns.
5) Cull-high intensity: This scenario is identical to "cull-low intensity," except that episodic culls removed 50% of the existing population.
6) Sterilize-low intensity: This is a TNR scenario in which 25% of the intact (i.e., non-sterilized) cats in the focal population were trapped, sterilized, and returned during each time step. Because the number of intact cats in the population changed over time, the number of cats trapped and sterilized varied across time steps. This scenario reflects the lower-intensity TNR efforts that sometimes occur. Given the influx rates we

structured in the model, this level of sterilization intensity is expected to eventually generate a sterilization rate of ∼60% over most of the simulation period, which leads to a small population size reduction over time.

7) Sterilize-high intensity: This scenario is the same as "sterilize-low intensity," except that 75% of the intact cats present in the population were trapped, sterilized, and returned during each time step. This scenario represents the higher-intensity "targeted" TNR programs that occur in some areas (15, 35, 36). Given the influx rates we structured in the model, this management intensity generates a sterilization rate of over 80% throughout nearly all of the simulation trajectory, which reduces initial population size by about half over time.

The word "intensity" is hereafter omitted from scenario names for brevity.

For each of these scenarios, 1,000 model iterations were performed, with each iteration generating a unique set of results due to the stochastic variability in demographic factors that define the model structure (1). For each iteration, we tracked multiple output metrics on a time-step basis, which included:

1) Number cats removed or sterilized;
2) Number of kittens born locally;
3) Net number of cats that disperse or are abandoned into the focal population (total cats coming in minus those that emigrate out);
4) Number of cats present at the beginning and end of the time step, categorized by age and sterilization status;
5) Number of kittens (cats under 6 months of age) and adults that die of "natural" causes, which excludes cats that are euthanized as part of a management scenario.

Final population size after 10 years was determined by computing the average number of living cats across all 1,000 iterations in each scenario at the end of the last time step. For computational tractability, each of the output metrics listed above was averaged across a random subset of 100 iterations for each time step and each scenario, and then summed over all time steps to produce cumulative outcome estimates for each management scenario. As a basis for comparing cumulative management outcomes, we identified two specific types of mortality that could be tracked in the model and that we assumed were undesirable from an animal welfare perspective: (1) deaths of kittens prior to reaching adulthood, and (2) deaths of cats by lethal management actions. We further postulated that both types of death can be reduced by taking appropriate management actions (i.e., sterilization to reduce the number of kittens that are born and subjected to potential mortality, and reducing or eliminating lethal management) and therefore collectively defined these as "preventable" deaths. We acknowledge that free-roaming cats sometimes die from outdoor hazards (including predation, vehicles and other accidents, starvation, extreme weather, and lack of medical care) that may be reducible by other kinds of management actions. However, while we included these events in our specification of baseline age-specific mortality rates, our model did not explicitly assign cause of hazard-based death for each individual. Consequently, these deaths were excluded from our definition and calculation of preventable deaths.

We used two approaches to characterize the role of dispersal and abandonment into the focal population. First, the origin (either locally-born or born elsewhere) of each cat in the population over a 10-year period was tabulated within the model. Second, each of the initial 50 cats in the focal population was assigned two unique (but "virtual") genetic variants (alleles) at a specified locus in *Vortex*, resulting in 100 diagnostic alleles within the starting population. All cats from the neighborhood population were assigned different alleles. Each kitten that was produced from a specific mating pair was assigned one random allele from each parent, permitting the simulated genetic composition of the focal population to be tracked over time.

To investigate the scalability of our results, we repeated our previously published model of sterilization-based management (75% of intact individuals sterilized per time step) over a series of larger starting population sizes (250, 500, 1,000, 2,500, and 5,000 individuals) while holding constant all other parameters used in the original 50-cat model and maintaining the original number of iterations. The number of individuals present in neighborhood populations that served as a reservoir of possible immigrants was also scaled proportionally (with 1,000, 2,000, 4,000, 10,000, and 20,000 respectively, compared to the neighborhood population size of 200 in the original models for the 50-cat focal population). We then examined the resulting population trajectories for different initial population sizes for degree of correspondence.

Finally, we determined the number of cats remaining under each scenario at the end of 10 years, and the origin of these cats. These results allowed us to evaluate tradeoffs and synergies between reducing the number of preventable deaths and reducing population size. More detailed examination of management optimization that also incorporates cost efficiencies will be presented elsewhere.

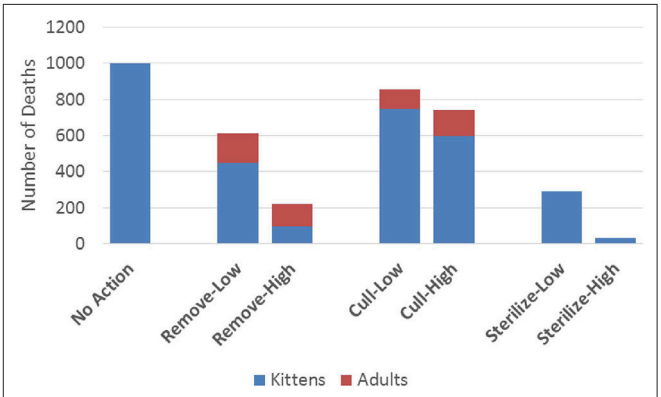

FIGURE 1 | Cumulative number of preventable deaths (kittens that do not survive beyond 6 months of age plus all adults euthanized in "cull" and "remove" scenarios) over a 10-year period for all management scenarios. Parameters of each management scenario are defined in the Methods section.

It is important to note that simulations are approximations of reality, not absolute predictions of future system behavior, and should be interpreted accordingly. However, our model was parameterized using best available empirical information, and we believe that it effectively captures the critical relationships and dynamics of free-roaming cat population function [see (1)]. The numerical output from the model is consistent with expectations based on an array of population studies [e.g., (26, 27, 34, 37–39)]. For example, kitten mortality outcomes and birth rates are in line with empirical data, in addition to making biological sense. Furthermore, there are real-world precedents for all of our tested management scenarios. We are therefore confident that this model provides a robust platform for systematically comparing and contrasting the likely outcomes of different management scenarios.

RESULTS

All management actions that we simulated reduced the number of preventable deaths over 10 years in comparison to taking no action (**Figure 1**). This reduction was moderate for both

TABLE 2 | Scenario-specific outcomes (numbers of cats) from simulation modeling.

	No action	Remove-low	Remove-high	Cull-low	Cull-high	Sterilize-low	Sterilize-high
Final population size (Mean)	49.53	26.37	6.80	44.69	39.01	38.74	25.80
SD	3.76	11.38	3.24	5.31	8.90	8.37	7.42
Cumulative number of cats removed or sterilized (Mean)	0	168.02	127.32	109.90	142.55	100.03	103.60
Cumulative preventable deaths, kittens plus adults (Mean)	1000.89	614.91	222.50	858.43	737.98	290.32	32.13
SD	97.63	118.08	37.81	84.15	83.56	62.35	13.00
Min	731	323	144	640	549	154	7
Max	1254	890	347	1111	963	477	75
Cumulative preventable deaths, kittens only (Mean)	1000.89	447.07	95.72	745.97	598.68	290.32	32.13
SD	97.63	114.55	31.52	83.88	78.99	62.35	13.00
Min	731	196	38	543	418	154	7
Max	1254	760	204	980	809	477	75
Cumulative kittens born in focal population (Mean)	1145.86	596.02	127.81	931.91	771.29	336.81	37.80
SD	111.32	156.17	42.84	101.96	96.22	72.93	15.82
Min	860	254	49	688	522	172	11
Max	1404	990	273	1175	1006	544	86
Cumulative kittens surviving to 6 months (Mean)	144.97	148.95	32.09	185.94	172.61	46.49	5.67
SD	33.45	47.31	13.59	36.51	30.80	14.21	4.31
Min	77	47	2	98	93	13	0
Max	263	313	74	282	260	75	16
Cumulative adults ever in focal population (Mean)	241.54	247.97	134.32	279.84	269.04	146.51	107.10
SD	35.19	50.10	17.88	38.57	35.57	17.63	10.62
Min	173	139	91	202	186	96	84
Max	353	432	184	380	365	187	133
Cumulative adults born in focal population (Mean)	188.43	192.95	81.07	228.35	216.06	93.74	54.54
SD	32.37	45.58	13.28	35.87	30.73	13.67	4.09
Min	122	93	51	146	137	62	47
Max	303	350	122	321	301	123	65
Cumulative adults born outside focal population (Mean)	53.11	55.02	53.25	51.49	52.98	52.19	52.56
SD	9.50	11.10	8.72	10.61	11.11	11.08	8.52
Min	25	26	31	25	32	0	33
Max	79	86	74	82	84	82	71
Living adults at 10-year mark born in focal population (Mean)	34.88	18.11	1.05	33.40	28.77	16.49	1.73
SD	5.64	11.14	1.71	6.56	8.40	7.37	2.07
Min	21	0	0	11	0	3	0
Max	48	47	9	48	47	32	10
Living adults at 10-year mark born outside focal population (Mean)	14.52	8.44	4.42	10.45	10.01	22.30	23.86
SD	4.63	3.70	2.72	3.75	3.95	5.47	6.09
Min	5	1	0	4	0	12	13
Max	28	22	15	23	20	37	41

Sections labeled as "cumulative" were totaled over the 10-year simulation after averaging results across 100 randomly chosen iterations within each time step. Other sections refer to population status at the end of the 10-year simulation, with means based on averaging across all 1,000 iterations. SD, standard deviation; Min, minimum value; Max, maximum value.

of the cull scenarios and for the remove-low scenario, larger for the sterilize-low and remove-high scenarios, and largest for the sterilize-high scenario, which resulted in 31 times fewer preventable deaths than the no action scenario (see **Table 2** for detailed quantitative outputs for all scenarios). Preventable deaths were comprised mostly of kittens in all scenarios except remove-high, where it was roughly equal to adult preventable deaths (i.e., lethal removals). The large differences in number of kitten deaths among scenarios was mostly a function of the different number of kittens that were locally-born, as illustrated in **Figure 2** (1,146 kittens born locally for no action, 38 for sterilize-high). In contrast, the proportion of all kittens born that survived to 6 months or beyond was relatively small across scenarios, ranging from 20 to 25% for lethal management scenarios and 13 to 16% in all other scenarios (**Table 2**). This observed difference is consistent with the inclusion of density-dependent kitten survival, where populations that remain near their local carrying capacity will be subject to more stressful conditions and, subsequently, lower survival rates among the youngest age class.

The cumulative number of adult cats that ever lived in the focal populations over a 10-year period was slightly increased in both of the cull scenarios in comparison to the no-action scenario, and reduced by about one-half in the remove-high scenario and both sterilize scenarios (**Figure 3**). Final population size at the 10-year point was reduced only slightly by culling, reduced about one-half by sterilize-high, and reduced the most by remove-high. Remove-low and sterilize-high both resulted in similar ending populations that were about one-half of their original size (**Figure 3**). However, under remove-low management, a much higher number of cats cumulatively lived in the focal population, and substantially more kittens were born and died than in sterilize-high management. Sterilize-low also had substantially more kitten births and deaths than sterilize-high and resulted in only a modest decline in population size at end of 10 years (**Figure 3**). **Figure 4** provides a graphical summary of each scenario's outcome for cumulative preventable deaths and final population size.

Although dispersal and abandonment rates into the focal population were fixed within stochastic bounds through the simulations, their cumulative impacts varied substantially across scenarios. At the 10-year point, the proportion of living cats in the focal populations that were born outside the focal population was much higher under the sterilize-high scenario (>90%) than under a no-action scenario (30%) (**Figure 5**), and little changed by any non-sterilization management option. In partial contrast, influx measured by the frequency of non-local alleles in the focal population at the 10-year mark was

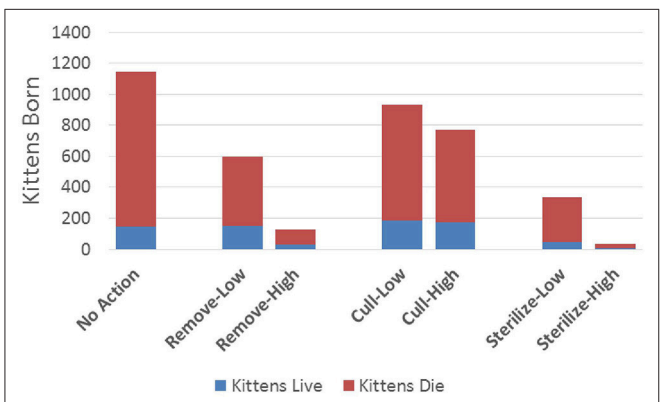

FIGURE 2 | Cumulative number of kittens born in the focal population over 10 years under different management scenarios. "Kittens Live" shows the number that survive beyond six months of age and "Kittens Die" shows the number that die before six months. Parameters of each management scenario are defined in the Methods section.

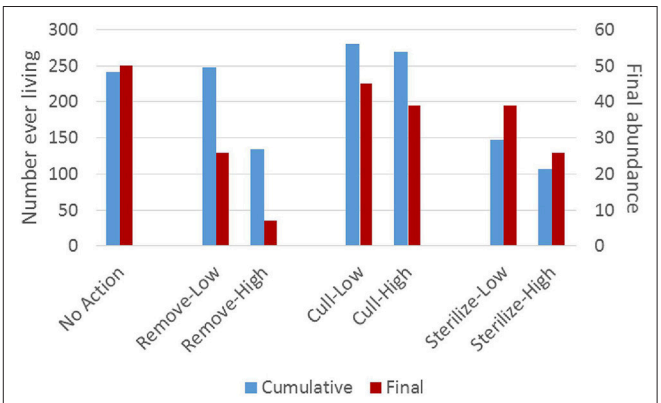

FIGURE 3 | Cumulative number of adult cats (>6 months of age) ever living in the focal population (left-hand vertical axis) and final population size at the 10-year mark (right-hand vertical axis). Parameters of each management scenario are defined in the Methods section.

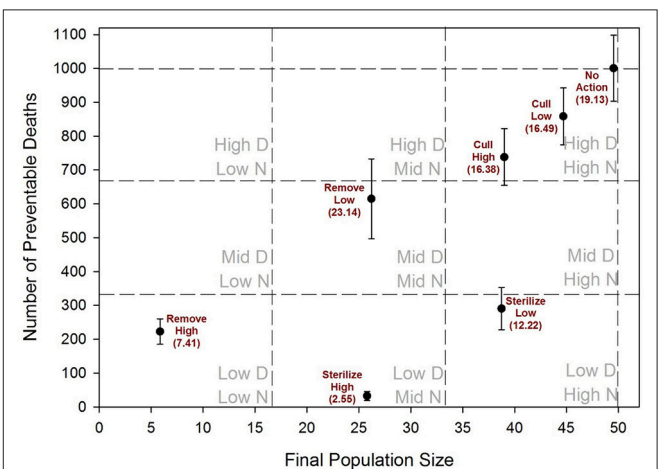

FIGURE 4 | Comparison of management scenarios across a combination of two outcome types; the number of preventable deaths (as defined in Methods) and final population size at the end of 10 years. The squares defined by the dashed lines represent High, Intermediate (Mid), and Low values for premature deaths (=D) and final population size (=N). Error bars give standard deviations across 100 model iterations, with 95%CI values given in parentheses.

higher under remove and sterilize scenarios than under a no-action scenario. The cull scenarios had relatively little effect on allelic frequencies.

For the scalability analysis, **Figure 6** illustrates that the proportional change in focal population size over a 10-year simulation was very consistent across all tested initial population sizes at the 75% sterilization intensity.

DISCUSSION

Management of free-roaming cats may have demographic effects that extend across multiple generations and are relevant from a lifesaving perspective. Although we recognize that many factors are not included in our analysis that could affect cat lifespan and quality of life [see (12, 40, 41)], our results suggest that from a cat welfare perspective, we cannot maximize our prospective goals (i.e., saving lives tomorrow) by focusing only on maximizing our proximate goals (i.e., saving lives today). Instead, balancing these goals effectively requires attention to management strategy.

In our judgment the most important findings of this analysis are that:

1) Cumulative preventable deaths, particularly of kittens, over 10 years are much lower for higher-intensity sterilization (TNR) than for all other scenarios.
2) Lower-intensity TNR is comparable to higher-intensity removal in terms of cumulative preventable deaths, but it is less effective at reducing population size.
3) Lack of management (i.e., the no-action scenario) results in more cumulative preventable deaths, particularly of kittens, than any active management option. This includes lethal removal.
4) Under high-intensity TNR, the proportion of cats in the final population that were born elsewhere is the highest of all management options (**Figure 5**, **Table 2**). For this reason, reducing abandonment and, where possible, immigration in conjunction with high-intensity TNR could improve outcomes more than for any other management option tested.
5) Culling is likely to be ineffective and inefficient in terms of cumulative preventable deaths and population size reduction.
6) Scalability results suggest that these conclusions apply across a wide range of focal population sizes.

Some of these results may seem counterintuitive, but they are logical consequences of the high reproductive capacity of cats, which can produce many more offspring than are needed to maintain a population at a given carrying capacity (34).

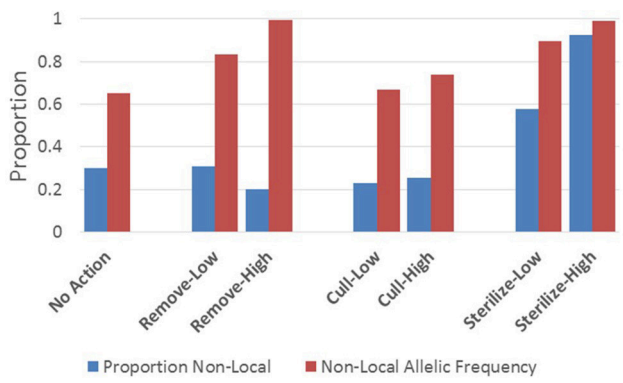

FIGURE 5 | Influx (abandonment and immigration) under all management scenarios indexed by: (1) the proportion of adult cats living at the 10-year mark that were born outside the focal population, and (2) frequency of non-local alleles in the final focal population at the 10-year mark. Parameters of each management scenario are defined in the Methods section.

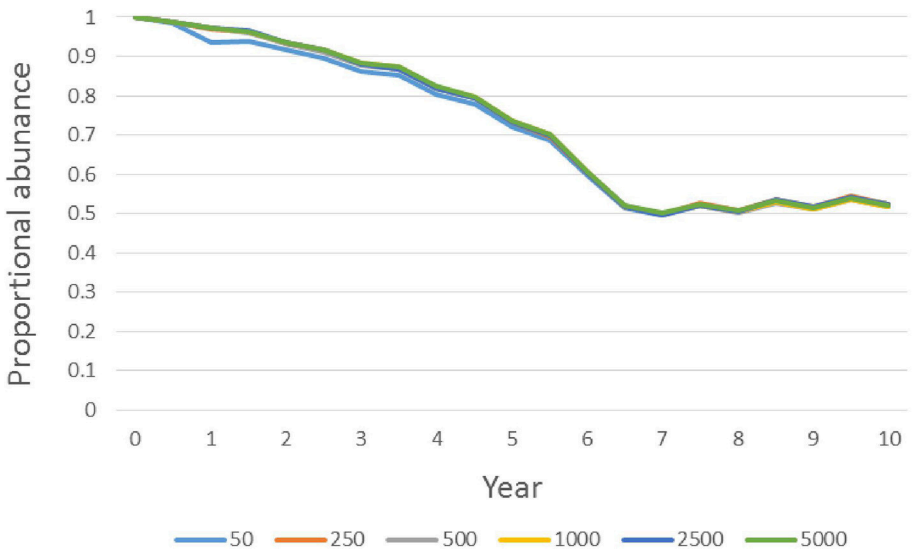

FIGURE 6 | Proportional population size (scaled to initial size) of focal free-roaming cat populations over time across a range of initial population size values for sterilization management where 75% of intact cats are sterilized during each six-month time step and returned to the population (i.e., Sterilize-High; see text for details). The legend indicates the colors of curves associated with different beginning population sizes. Curves for different initial sizes are almost entirely overlapping, so not all are visible.

Our analysis indicates that as a result of this reproductive capacity, kitten deaths usually comprise a large majority of overall mortalities that can be influenced by management actions or inactions. The animal welfare community has often emphasized preventing deaths from lethal management, but based on these findings may wish to also make reducing kitten deaths an equally explicit management and policy goal. The best management strategy for accomplishing this is to quickly suppress reproduction with high-intensity sterilization, leading to reduced population size over time, and then allow these changes to generate compounded benefits into the future. As a consequence, far fewer kittens will be exposed to intrinsically high mortality rates, and far fewer will die before reaching adulthood.

With sufficient intensity, TNR offers significant advantages in terms of minimizing preventable deaths while also substantially reducing population size. High-intensity TNR programs can be further improved by reducing abandonment, or by combining return to field for some cats with adoption for others [see (15, 36, 42, 43) for examples]. On the other hand, at lower sterilization intensities the longer-term lifesaving advantages of TNR become much less compelling because large numbers of kittens remain subjected to high mortality rates over time.

The choice of management strategy should ideally incorporate multiple factors, including population outcome, cat welfare, cat impacts on wildlife, cost effectiveness, ethics, practicality, tractability, likelihood of success, and political/public support. In addition, it should address local priorities and needs, which can vary substantially. We do not intend to suggest how these factors should be weighed by animal welfare professionals or other policy stakeholders, or to draw conclusions about the relative importance of preventable kitten deaths vs. deaths resulting from lethal management. Rather, we emphasize that management choices are likely to have large, persistent, and indirect effects on preventable mortality that can now be more explicitly considered as a result of this analysis. We further conclude that in the longer-term, the goals of reducing cat population size and minimizing preventable deaths are largely synergistic. Recognizing this potential compatibility may bring the interests of diverse stakeholders into better alignment and facilitate collaborative efforts.

For all these reasons, we believe it is appropriate for the animal welfare community to explicitly consider these broader perspectives in developing their goals and strategies for outdoor cat policy and management, and to recognize that TNR intensity is critically important not only to reduce population size, but also to minimize preventable deaths of kittens. We also emphasize the value of collecting standardized monitoring data in support of TNR programs to refine model-based guidance and to improve our understanding of best practices (18). Currently, some TNR practitioners are promoting the concept of "targeting" and focus of resources in locations of highest value for cat population management, which could lead to higher-intensity TNR implementations[3] (accessed October 27, 2018) (6). These concepts, along with use of appropriate tools and protocols to measure progress and outcomes (18, 44), should be further explored and evaluated as potential "best practices."

AUTHOR CONTRIBUTIONS

PM constructed and implemented simulation models. PM and JDB analyzed and summarized data. PM, JDB, VB, JRB, DL, MS, JL, and SZ contributed to simulation model design and construction. JDB, PM, JRB, and VB conceived and designed this study and wrote this report. DL, MS, JL, and SZ reviewed and edited this report.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fvets.2019.00238/full#supplementary-material

[3]http://support.petsmartcharities.org/site/DocServer/Targeted_TNR_RW_Summit_v3.pdf?docID=1402

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EMPIRICAL STUDY
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Implementing Nonlethal Solutions for Free-Roaming Cat Management in a County in the Southeastern United States

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From 2006 to 2017, stray or free-roaming cats ranged from 35 to 54% of all animals going into the public shelter in Hillsborough County, Florida. Shelter overcrowding of cats, including free-roaming, feral, or community cats, is a major problem in parts of the world. Issues with free-roaming cats include the welfare of the cats themselves, public health and zoonotic diseases, spread of diseases to other species or pet cats, public nuisance, and predation of wildlife. Animal control is a government function and ultimately a taxpayer issue. This paper describes three methods of humane, nonlethal management of free-roaming cat populations that were successfully applied in Hillsborough County, Florida: low-income spay/neuter vouchers; small- and large-scale trap, neuter, vaccinate, and return (TNVR); and return to field (RTF). The methods used were contrary to the long-accepted practice of using euthanasia to control cat populations and generated opposition among certain stakeholders. While the human population of the county increased by 14.6% from 2010 to 2017, the methods used to control free-roaming cats assisted in achieving a 51% decrease in intake since 2007 and increased the live-release rate to 81.8% of cats taken in at the Pet Resources Center in 2017. This paper examines how this change in intake was achieved despite opposition to these programs.

Keywords: free-roaming cat management, TNVR, animal control and management, nonlethal methods of animal control, social change for animals

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INTRODUCTION

Governmental agencies are responsible for controlling the excess population at public animal shelters (1). A major part of the excess consists of unlicensed, free-roaming cats, sometimes also referred to as *feral* (unsocialized) *cats*, *community cats* (which may be owned but unlicensed), and *strays*. This paper will use the term *free-roaming cats*. Free-roaming cats are any cats, whether owned, stray, or feral, that are free to roam the streets. There are a variety of estimates of the number of free-roaming cats in the United States. The highest estimate is 60–100 million; a more conservative estimate is 30–45 million (2). These cats can produce litters of 1–6 kittens and on average have kittens 1.6 times a year (3).

Attempts to manage the number of free-roaming cats have to balance multiple objectives: protect the welfare of the cats themselves, control threats to public health and constrain zoonotic disease, prevent the spread of disease to other species or to pet cats, and avoid nuisance and the predation of wildlife (2). In addition, the local governments responsible for implementing management programs have to find the money to pay for them (1, 4, 5).

This paper reports empirical results from a study of three nonlethal free-roaming cat management programs undertaken by the only open-access animal shelter in Hillsborough County and two non-profits in southwest Florida, where citizens and community organizations were able to significantly decrease shelter intake and increase the live-release rate. This location was selected for several reasons. First, animal control functions in Florida are a county responsibility. Second, the shelter chosen was the only open-admissions shelter in the county during the study period and because it was a government shelter, data were readily available about costs and the numbers of animals in the shelter. Third, this local community had the highest companion animal euthanasia rate in Florida (6, 7). Finally, the programs described were specifically targeted to the geographical area of the study.

When it became evident at the beginning of 2000 that the euthanasia rate for cats in the Hillsborough County Animal Services (HCAS) shelter was over 90%, private citizens and the Humane Society of Tampa Bay (HSTB) took steps to introduce a new approach. Although trap, neuter, vaccinate, and return (TNVR) had been practiced on a small scale in the county, local, state, and federal officials, including the Florida Fish and Wildlife Commission, claimed that TNVR was against state law. Opponents cited Florida Statutes 828.12 (cruelty to animals), 828.13 (abandonment), 379.231 (releasing non-native species in the wild), and 372.265 (regulation of foreign animals) and Florida Administrative Code 68A-4.005, aimed at wildlife and birds. These statutes were used to intimidate citizens and municipal agencies with the implication that they made TNR illegal. In fact, except for 828.12 and 13, these laws only applied to wildlife, not domestic animals. Florida Statutes 828.12 and 13 have since been interpreted by county governments not to be aimed at TNVR.

There was nonetheless a history of local initiatives. A local TNVR organization helped neuter cats and had a small sanctuary. In addition to opening a low-cost clinic that operated Monday to Friday, HSTB conducted a small clinic once a month to sterilize free-roaming cats. After it was founded in 2001, the Animal Coalition of Tampa (ACT) established a monthly all-volunteer clinic to sterilize up to 100 free-roaming cats at a time in borrowed veterinary clinics. In 2002, a county voucher program to assist individuals with the cost of spaying and neutering began to target people in poverty. In 2006, ACT opened a free-standing clinic (high quality, high volume, spay/neuter, HQHVSN) modeled after the Humane Alliance clinic in North Carolina (8). ACT then offered daily no-reservation free-roaming cat surgeries while continuing its once-a-month all-volunteer clinic for free-roaming cats. Both clinics served two underserved market segments: demographical and behavioral. Low income families have been identified by Chu et al. (9) as having a lower percentage of cats being neutered (51.4% as opposed to 90.7–96.2% for higher incomes). Benka and McCobb (10) and White et al. (11) found that a large number of owned cats had never seen a veterinarian with the main reason given as "too expensive." These two clinics met those needs for affordability and accessibility.

In 2002, a conference was held in Tampa to address the high rate of euthanasia of cats in Hillsborough County, with a follow-up conference in 2003. Finally, in April 2004, No More Homeless Pets in Hillsborough County (NMHP-HC) was established, bringing together HCAS, HSTB, ACT, Big Cat Rescue, and more than 35 other smaller rescue and animal rights groups to "end euthanasia as a primary means of animal population control and enhance the quality of life for dogs and cats in Hillsborough County" (12). The organization held quarterly meetings and started to benchmark the data collected by constituent groups about the treatment of cats in the county.

Separately, at the end of 2006, the American Society for the Prevention of Cruelty to Animals (ASPCA) announced a new national program called Mission Orange. It promised "intensive efforts on humane care and protection" in four cities, one of which was Tampa [(13), p. 3], where $600,000 was pledged over a three-year period to complement shelter adoption programs and to fund a larger number of targeted spay/neuter surgeries for dogs and for both owned and free-roaming cats.

BACKGROUND

Hillsborough County (1,052 square miles) is located at the midway point on Florida's west coast. There are three incorporated municipalities including Tampa, but most of the county is unincorporated. The population of the county is 1,408,566 (14) and has been growing steadily, by 19.8% from 1990 to 2000 and by 17.6% from 2000 to 2007. After slowing during the recession, it recovered and grew by a further 14.6% from 2010 to 2017.

A majority of the population lives in the urban part of the county, with only 3.5% living in census-defined rural areas. The population is 17% black and 28% Hispanic. The county is fourth in the state and fifty-ninth nationally for the value of its farm products (15). Approximately 15% of the population is at or below the poverty level. There are 580,323 housing units in the county (14).

These data point to substantial socioeconomic, cultural, and linguistic diversity in the local population, factors to which effective programs for cat management need to be sensitive (16). Nationally, the largest group of unaltered and free-roaming pets is to be found in areas of poverty, which also have the most limited availability of veterinary services (17, 18). The continuous flow of both people and their companion animals into the county meant that unless some way could be found to reduce the number of free-roaming cats entering the Hillsborough County animal shelter, the euthanasia rate of over 90% would persist. In 2005, for example, 19,936 free-roaming cats entered the shelter and only 1,345 (4.6%) survived. In 2007 there was a slight improvement as 18,637 entered the shelter and 1,837 (6.3%) survived.

DATA SOURCES AND METHODS

The data for the analysis that follows come from a variety of sources. Some is based on participant observation. The author was a member of the county Animal Advisory Committee for 8 years and a cofounder of both No More Homeless Pets–Hillsborough County (NMHP-HC) and the Animal Coalition of Tampa (ACT). Data from HCAS, later renamed Pet Resources (PRC) in 2014, are also used, including budgetary and workload information. Other documentary sources include the minutes of

meetings held by all the agencies involved. Field notes consisting of interviews, audio and video recordings, text and tape from all three agencies and e-mails have also been used.

THREE TARGETED PROGRAMS

Three targeted programs have been used over time to try to lower the intake of free-roaming cats at the Hillsborough County shelter to a point where the management focus could shift from the routine warehousing and euthanasia of animals to increasing live-release rates (LRR).

Low-Income Vouchers

Low-income voucher programs are Hillsborough County's oldest formal cat population control mechanism. They were pioneered in New Hampshire in 1994 and then spread to other states, cities, and counties (1). Most such programs across the country use federally established low-income program guidelines to qualify applicants, who must be enrolled in one of seven income-based programs (section 8 Housing; Medicaid; Temporary Assistance for Needy Families; Supplemental Security Income; Women, Infants, and Children; or the Supplemental Nutrition Assistance Program). Eligibility is established using verifiable documentation by agencies separate from the county animal control service. The programs have generally been successful in bringing down rates of animal intake and euthanasia at shelters (1, 19).

In 1981 Hillsborough County established a subsidized spay-neuter program whereby citizens who had their animals sterilized at a veterinarian's office could apply for a $20 rebate. The subsidy did not target low-income people and the majority of the people who took advantage of it were middle-income (B. Armstrong, personal communication, 2002).

The shift toward the New Hampshire model targeting the poor and away from the rebate was initiated in 2001 by the county Animal Advisory Committee (AAC):

> This committee advises and makes recommendations to the Board of County Commissioners [BOCC] and the Hillsborough County Pet Resources Department on issues concerning long-range plans [and] general policies [for] shelter programs and services in the County. Additionally, it advises the BOCC and county administrations regarding the revisions to the Animal Ordinance, animal-related resolutions, and policies concerning companion animals in Hillsborough County [1].

The Spay/Neuter Voucher Program (SNVP) established by the Hillsborough BOCC in 2002 provided sterilization surgery, a rabies vaccination, and a county license tag for a $10 copay. The SNVP replaced the earlier subsidized program. It was funded by the differential license fees charged to owners of intact animals. The fee reimbursements for male and female dogs and cats were set by the Hillsborough County Veterinary Medical Society (HCVMS) and have not been raised since 2002. A financial analysis of HCAS annual reports from 1997 to 2011 shows that the average cost per surgery to the county under this program is ∼$65 per animal. In contrast, in 1997 it cost the county $168 to catch, house, and dispose of an animal[2].

In the first year of the program, a number of issues arose about application procedures and how to cover additional costs for blood tests and other requirements demanded by some veterinarians. Those added requirements increased the $10 copay by hundreds of dollars in some cases. In 2004 and 2005 about 2,000 vouchers were used each year. There were also disagreements between HCVMS and the county over whether non-profit clinics (HSTB and ACT) had the right to perform voucher surgeries. Following a decision that the two non-profit clinics could participate in the program along with any for-profit veterinary clinic in the county, eventually non-profit clinics performed a majority of the surgeries. The Hillsborough Animal Health Foundation (HAHF), the educational arm of the HCVMS, established a third non-profit clinic in 2013. In 2018, 11 out of 125 clinics in the county were participating in the program, with the three non-profit clinics accounting for 67% of the surgeries performed (S. Trebatoski, personal communication, July 26, 2018).

The two non-profit clinics also played a key role in early promoting and marketing of the program. For example, they followed up with people who had applied for vouchers but did not use them, finding that HCAS rejected some applications because some low-income individuals could not properly fill out the form. They also realized that some low-income people worked when the clinics were open and could not afford to take time off from work to bring their pets in for surgery. Therefore, the clinics adjusted their surgery days and hours. One clinic also developed a transportation unit to help low-income people get to the clinic because buses did not allow pets on board. The number of vouchers redeemed increased from 3,000 in 2008 to almost 6,000 in 2009.

The demand for the program was so high that HCAS projected it would not have enough money from license tag sales to fund the program and stopped issuing vouchers between May and October 2010. After the program resumed with money from reserve funds, the County Administrator sent a letter to the Animal Advisory Committee asking for a recommendation on who could conduct a study to determine the number of targeted sterilizations that would be needed annually to sustain the reductions in impounds experienced since the SNVP was implemented (20). The results of this study along with the tasks of developing a feasible financial plan and minimizing the "administrative and geographic hurdles" encountered by users were incorporated into the charge for the HC Animal Services Task Force (21).

Peter Marsh, who had helped to establish the New Hampshire program, was retained to make this assessment. He recommended that the program should try to subsidize 7,500 surgeries a year, and since that time the actual number has varied between 6,000 and 7,500 (22). Marsh argued that there were a number of factors that affected the impoundment of free-roaming cats at the shelter, such as the discontinuation

[1]Hillsborough County Animal Advisory Committee (n.d.). Available online at: https://www.hillsboroughcounty.org/en/government/boards-and-committees/a-d/animal-advisory-committee

[2]Hillsborough County Animal Services Internal Financial Working Papers (n.d.). Animal Advisory Committee Handout.

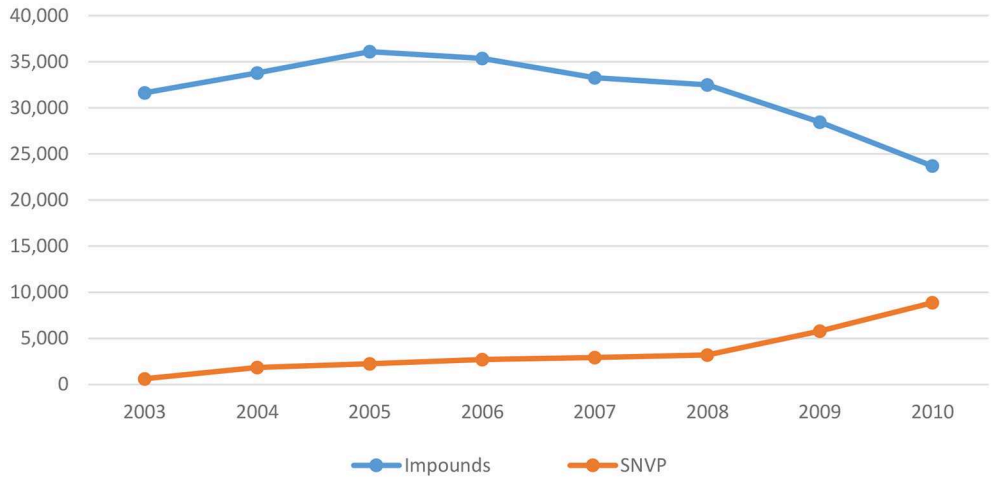

FIGURE 1 | Chart developed by Marsh (17) to display SNVP surgeries to HCAS intake.

of proactive trapping of stray cats by HCAS, a reduction in HCAS shelter hours, and the initiation of a policy to charge a surrender fee for owned cats. Nevertheless, Marsh wrote, "It appears that the SNVP has played a significant role in reducing HCAS impounds" and there is an inverse correlation ($r = -0.85$) between the decrease in intakes to the shelter and the number of redeemed vouchers. **Figure 1** displays the chart he provided to the committee (23).

Although the Spay/Neuter Voucher Program has had some success in bringing down the intake numbers and subsequent number of euthanized cats, it is not in and of itself sufficient to achieve the desired results (18, 24–27). For example, it is aimed only at cats owned by citizens whose income is at or below the poverty level. It is true that many of those cats are free roaming, but there is really no way to tell whether some of the cats treated through the program might actually be feral cats, strays, or unowned free-roaming cats. The majority of cats entering HCAS are labeled as "strays" (35–54% of all animals entering the shelter; **Table 1**). Other programs were developed to address those cats.

TABLE 1 | Cat intake as a percentage of total impounds, 2005–2017.

Calendar year	Total intake, all animals	Owned cats	Stray cats	Total cat intake
CY 2017	18,293	8.95%	41.07%	9,151
CY 2016	16,434	9.57%	38.43%	7,889
CY 2015	14,792	9.25%	35.42%	6,607
CY 2014	16,376	6.01%	44.20%	8,223
CY 2013	20,614	6.53%	48.75%	11,063
CY 2012	20,198	5.56%	46.88%	10,591
CY 2011	20,405	5.21%	47.87%	10,831
CY 2010	21,913	5.75%	50.78%	12,388
CY 2009	26,966	7%	54%	15,041
CY 2008	30,895	15%	45%	18,432
CY 2007	31,699	17%	42%	18,637
CY 2006	34,191	15%	40%	19,139
CY 2005	34,485			19,936

Source: Hillsborough County Animal Services/PRC monthly reports.

Trap-Neuter-Vaccinate-Return (TNVR): Beyond Small-Scale Efforts

The first trap-neuter-return organization in Hillsborough County, Fix, and Feed Feral, was incorporated in 1997. It was a small, all-volunteer organization in the northern part of the county that trapped and sterilized a small number of free-roaming cats and then returned them to the places where they were caught. It also had a barn sanctuary for cats that could not be returned.

Individuals and groups who wanted to practice TNVR in Hillsborough County in the early 2000s faced several challenges. They needed, first, to find veterinary clinics willing and able to handle free-roaming cats, a process that requires extra safety steps. Of the approximately 116 veterinary clinics in Hillsborough County at the time, fewer than 10 would admit free-roaming cats, and even fewer offered a discount to fix a free-roaming cat. A second challenge was cost, because even under the best of circumstances neutering can cost over $100 per cat. The third challenge was timing. Even though a clinic might be willing take a free-roaming cat, appointments are required at clinics and most free-roaming cats cannot easily be caught and fitted to normal clinic schedules. There is also a challenge involving the traps used to capture the cats: although Home Depot and Lowe's, for example, carry raccoon traps, which can be used for cats, they are not cheap and most people would not purchase such a trap unless they planned to catch more than one cat.

Some history is in order here. When HSTB opened a low-cost spay/neuter clinic in 2000 it performed 21 surgeries a day. During its monthly spay/neuter clinic for free-roaming cats it would accept up to 35 animals (J. Wagner, personal communication, 2001). The surgeries were organized on a private clinic model with a single veterinarian. Cats would be dropped off early in the morning and picked up later in the afternoon. These low-cost surgeries enabled some management of the population of animals owned by low-income families.

Then, in 2001 a new organization, the Animal Coalition of Tampa (ACT), was founded in Hillsborough County. It held once-a-month Spay Days beginning in January 2002 at various private clinics around the county. Modeled after the Feral Cat Coalition in San Diego (28), it was an all-volunteer effort, with multiple veterinarians, technicians, and lay assistants giving their time one Sunday a month. In their first full year (2002) they sterilized and ear-tipped 706 free-roaming cats. They also provided traps and training for caretakers. The traps were originally located in nine different depots around the county in volunteers' homes. Caretakers would make an appointment and then be sent to the closest depot to pick up their traps. If they did not know how to use them, volunteers would give them brief instructions on how to trap the cats. After Spay Day, the caretakers would return the traps to the depot.

But this was a small-scale operation. Extrapolating from Levy et al. (25), 12% of the households in a given geographical area feed a mean of 3.6 cats each. Based on US census data for households in Hillsborough County, this means that there were more than 210,000 free-roaming cats in the county. Thus, even the combined efforts of HSTB, ACT, and Fix and Feed Feral would be insufficient to slow the flow of cats and kittens into the HCAS shelter. The county needed to move from small-scale efforts to larger ones.

A step toward operating on a larger scale was taken when ACT opened a HQHVSN clinic to provide services for both owned and free-roaming cats. The Humane Alliance clinic in North Carolina began exporting its expertise in 2005. The ACT clinic in Hillsborough County was the ninth clinic to emulate the North Carolina original and the first to open in a populated urban area. After opening in March 2006, the ACT clinic spayed or neutered 1,701 cats during normal hours in that year. It continued to offer a once-a-month Spay Day, helping another 1,018 cats in 2006. As mentioned above, one of the challenges of free-roaming cat surgeries is the availability of trained staff to provide care for the cats when they come in during regular hours. ACT took free-roaming cats with no reservation necessary every day the clinic was open. The methods and medical protocols followed by these clinics are documented by [Looney et al. (29)] and by Griffin et al. (30).

As the ACT program grew, HSTB also tried to increase its spay/neuter efforts for free-roaming cats. As **Figure 2** shows, the number of community cats sterilized increased between 2002 and 2012 as both clinics focused on large-scale efforts. Using Mission Orange funds, HSTB hired a full-time TNVR coordinator. She controlled the loaned traps and organized trappers to help citizens trap free-roaming cats.

There was some dissention among the various parties involved in efforts to expand TNVR to control what the AAC called "community cats." Some local veterinarians, including the HCVMA and HAHF, along with some dog rescue groups wanted the effort stopped. This group's stance was that TNVR was illegal and posed a human health danger. A Citizen's Initiative on Community Cats was proposed to the BOCC in June 2011 by concerned trappers and caretakers. And the ASPCA for its part supported continuing efforts to conduct large-scale TNVR. The upshot was that on December 7, 2011, the BOCC passed a resolution recognizing that there was a community cat population continually producing offspring and noting that TN[V]R had been recognized by national organizations as a way of trying to manage the problem. The resolution further said that "the BOCC also recognizes TN[V]R programs. . . that both comply with federal, state, and local laws [and] with the

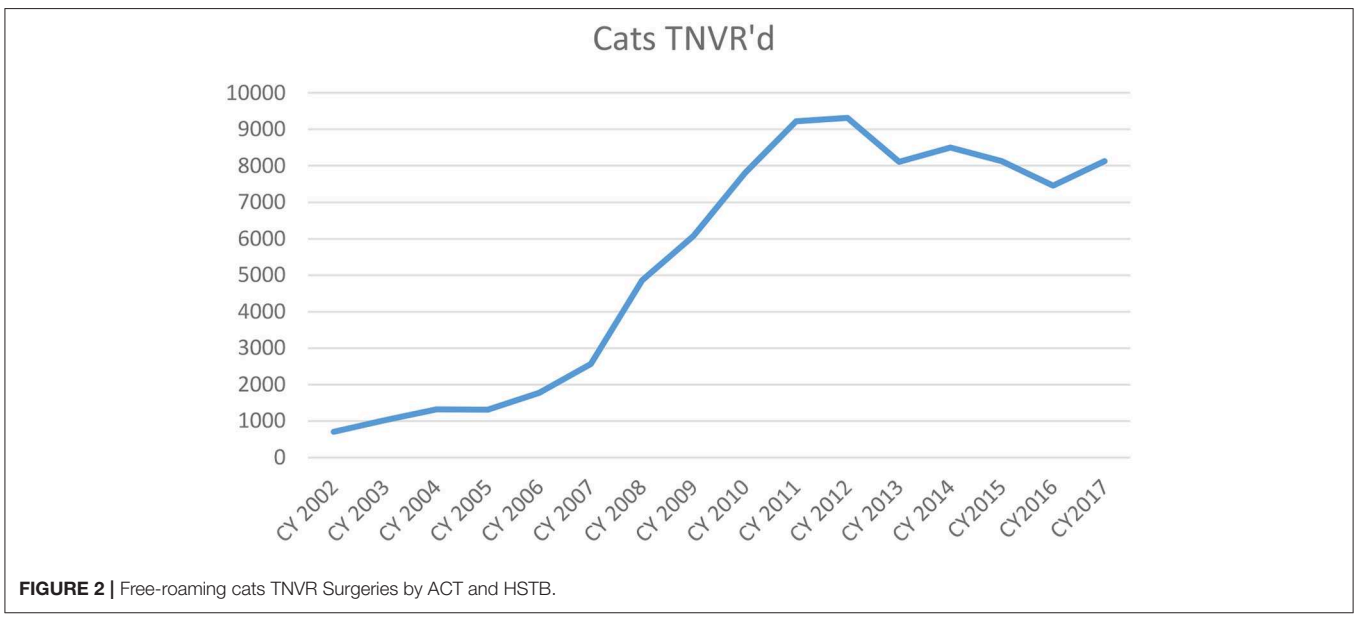

FIGURE 2 | Free-roaming cats TNVR Surgeries by ACT and HSTB.

guidelines of the ASPCA and HSUS for TN[V]R, as another means to reduce the community cat population in addition to trapping and euthanizing" (31).

In 2012 HSTB opened a larger animal hospital and reserved every Monday for treating free-roaming cats at low cost. It designed a cat patio that allowed trappers to drop off their cats in traps on Sundays and pick them up after surgery on Monday afternoons.

The BOCC took a further step toward supporting TNVR when in May 2013 it endorsed the "Be the Way Home" plan (32) developed by a county task force and the new Animal Services director, outlining 60 separate initiatives to increase the number of animals leaving the Animal Services shelter alive. The initiatives were divided into eight categories and covered all facets of shelter operations (marketing, volunteering, technology, revenue, intake, spay/neuter, adoptions and rescues, and return to owner). An ordinance (No. 13-33) passed in December 2013 provides the legal framework within which community cat programs still operate in the county.

A number of issues that caused controversy among interested groups and agencies as the "Be the Way Home" programs were implemented are addressed below in section The Opposition, discussing opposition to free-roaming cat management programs in the county.

Return-to-Field (RTF)

In 2008 the city of Jacksonville, in northeast Florida, started Project Feral Freedom, which targeted community cats admitted to a shelter. The project was the product of a close working relationship between a community group, First Coast No More Homeless Pets (FCNMHP), and the city. FCNMHP initially asked the director of Animal Care and Control for the city if it could pick up any ear-tipped cats turned into the Jacksonville shelter and return them to where they were picked up. The director's response was that FCNMHP could take all the free-roaming cats at the shelter (33), which it began to do in August 2008. FCNMHP picked up the cats, treated them, and returned them to where they were picked up. This was the genesis of Return to Field (RTF).

Other cities, including San Jose, Charleston, SC, San Antonio, Albuquerque, Baltimore, Philadelphia, Tucson, and Columbus, GA subsequently started similar programs (33–36). Hillsborough County decided to undertake its own Project Feral Freedom program in 2014.

RTF is the most radical of the three programs discussed in this paper because there was no known caretaker for the cats to go back to after sterilization. This arrangement was rationalized on the basis that the returned cats already had a home. It was not what people usually understood as a home, but the cats involved were thriving and healthy for the most part, which meant that they had found food sources and shelter close to where they were picked up. In that sense they did have a home (37).

As noted in **Table 1**, free-roaming cats (defined as strays by HCAS/PRC) make up a large percentage of the total intake and workload of the Hillsborough County shelter. Although the percentage of free-roaming cats taken in remained about the same from 2006 to 2017 (between 35 and 54%), total cat intake dropped by more than half over the same period.

TABLE 2 | Cats returned to field in Hillsborough County.

Calendar year	Returned to field
2014	1,015
2015	730
2016	829
2017	1,344
Total	3,918

It is hard to gauge the precise impact of the RTF program in Hillsborough County. While it is a targeted program aimed at a specific subset of healthy, adult, non-owned, free-roaming cats that are admitted to the only open-access shelter in the county, it is a small-scale effort (as shown in **Table 2**), chiefly because of funding constraints. In fact, there is at the moment no county funding for RTF. The cats are identified upon entry to HCAS/PRC and transported to HSTB for sterilization and shots, paid for by HSTB. Volunteers transport the cats from HSTB back to where they were captured and release them. Data on the cats was kept both by HCAS/PRC and HSTB. By way of comparison, between 2010 and 2014, in San Jose, California, a community of over a million people, 10,080 free-roaming cats were admitted to the animal shelter and treated prior to release, all at municipal expense. It is conceivable that if the Hillsborough County program were supported in the same way, it could achieve a higher than 90% live-release rate (LRR). The actual rate for cats in 2018 was 85.5%. Live release rate (LRR) is defined as live outcomes divided by intake [(38), p. 6], expressed as a percentage. In 2005 the LRR for HCAS (the only open-access shelter in the county) was 4.6%, indicating an increase of 80.9% by 2018.

Return-to-field programs are different from TNVR programs because they involve free-roaming cats that have been admitted to a shelter. This makes them part of the animal shelter and control system (39). They have been trapped by either animal control officers or members of the public. In the past, when cats were admitted to a shelter, they faced the almost certain prospect of being euthanized. Against this, the RTF alternative provides the hope that for suitable, healthy, free-roaming cats there will be a better outcome. The Million Cat Challenge–an initiative launched in 2014 by the shelter medicine programs at the University of California, Davis and the University of Florida veterinary schools to save the lives of one million cats over 5 years–offered this perspective on RTF: "No greater harm to communities is caused by returning shelter cats to their neighborhoods with the benefit of birth control and vaccines, and much is gained by engaging the community in a positive response" (37).

OTHER FACTORS AFFECTING FREE-ROAMING CAT MANAGEMENT

Social Media

During the time that free-roaming cat management programs have been evolving in Hillsborough County there has been a dramatic and universal change in communications technology,

a change that has mediated one of the most persistent problems that stands in the way of making free-roaming cat management a success, not just in this one county but more generally: how to find and connect people who will support such programs across the country. It is worth recalling that the first iPhone was released in 2007. From January 2007 to December 2014, according to AT&T, mobile data traffic increased by more than 100,000% [(40), p. 20]. Change.org, the most popular social mobilization website, also came to life in 2007. The ability to share information and images easily across platforms and networks, particularly through user-generated content, has had a major and positive impact on the animal welfare community. It facilitates the organizing of like-minded individuals. It allows people to contact each other easily and quickly about free-roaming cats in need of help, including their pictures, their locations, their numbers and, if they are in a shelter, their likely time to euthanasia. And it makes it easier to raise money, both for medical expenses and for general support (41).

National online communities such as Maddie's Pet Forum, Out the Front Door, and Vox Felina provide relevant information and let people ask questions. This gives local activists and caretakers a largely unconstrained avenue for both learning and connection. The Million Cat Challenge and Out the Front Door websites, ASPCA position statements, and open-source articles such as Spehar and Wolf's 2018 and 2019 papers on RTF and TNR are now readily available to all the stakeholders in the national conversation about free-roaming cat management, which means that no single group of stakeholders can now control that conversation.

So whereas in 1997 caretakers for free-roaming cats were essentially an underground resource and tried to remain hidden so that the cats would not be taken by their neighbors or animal control, they are now visible and organized and connected through listserves and other social media devices.

In Hillsborough County specifically, caretakers for free-roaming cats were reached and connected through social media by HSTB and ACT. The Tampa Bay Cat Rescuers' Facebook page, for example, has attracted 4,176 readers and followers (42).

This huge change in the ability of people who care about free-roaming cat management issues to be connected and to be engaged and to share information made its influence felt when the "Be the Way Home" plan was presented to the BOCC. More than 200 people showed up for the deliberations, many wearing identical green t-shirts to demonstrate their support for the plan to the county commissioners.

The Opposition

Opposition to free-roaming cat programs has come in the past from local and state governments, from some veterinarians, even from some animal welfare advocates, and from citizens who are worried about the impacts free-roaming cats might have on wildlife, especially birds. One opposition strategy has been for wildlife officials to assert that free-roaming cats are a form of wildlife and can therefore be regulated by wildlife protection agencies as a threat to other and more valuable species. Although the FWC finally stated that free-roaming cats were not considered wildlife, these claims that TNVR is illegal continue (43, 44).

Opposition to any change to the status quo in the county started with the discussion of the SNVP from 2002 to 2006. The principal opposition to free-roaming cat management in Hillsborough County surfaced in 2012 and 2013 when a task force was at work to consider options and when the "Be the Way Home" plan was being developed. The opposition was rooted in earlier efforts against the launch of the Citizens Initiative Community Cat Management Program in March 2011, when the HCVMA and HAHF helped organize other animal advocates ("dog people") into a citizens group. This group did not really understand cat issues and were heavily influenced by the fact that their veterinarians favored euthanasia of all free-roaming cats. Group members and those veterinarians spoke out against any plans aimed at nonlethal management of free-roaming cats during the many meetings during this time period.

During the debate on the task force report, a plan called AWAKE (43) was proposed suggesting that the county provide land, with no electricity or running water, to house a sanctuary for free-roaming cats to avoid creating a public health hazard. The assumption was that volunteers caring for free-roaming cats would be willing to drive to the southern part of the county to take care of them. The plan also anticipated weekly visits from a paid veterinarian and vet tech, but with no mention of how the plan would be financed. This plan is still accessible on the HAHF website. National groups such as Best Friends and Alley Cat Allies came out against the plan (45). Although the opposition has abated over the past few years, if any free-roaming cat is found to have rabies, the opponents of TNVR are revitalized (46, 47).

RESULTS AND DISCUSSION

The three targeted programs were integrated into the daily operations of the two clinics. Spay/neuter surgeries due to the first two programs started ramping up in 2002 along with the volume of spay/neuter surgeries for all cats and peaked in 2011. The RTF surgeries started in 2014. In the aggregate, over the period analyzed (2002–2017) more than 38,000 SNVP cat surgeries were performed, 86,000 TNVR surgeries were performed by ACT and HSTB (**Figure 2**), and 3,918 RTF surgeries were performed (**Table 2**). Volume and consistency are critical to the success in assisting in lowering the numbers of cats flowing into the shelter and subsequently being euthanized.

Figure 3 shows that until 2011–2012, the first two targeted programs (SNVP and large scale TNVR) jointly developed by the county and cat welfare groups for reducing the number of cats entering the shelter was working. Cat intake numbers were dropping; however, the chances of live release remained low. The LRR increased by only 8% from 2001 to 2010. The LRR in 2001 was 5.7%. It dropped to 4.6% by 2005 and then climbed slowly to 13.4% in 2010 (HCAS/PRC annual reports). Marsh (17) noted that there was a correlation ($r = 0.986$) between shelter intake and euthanasia in Hillsborough County from 1997 to 2009 (p. 7). After 2012, with a push from a new animal services director and mobilized citizens,

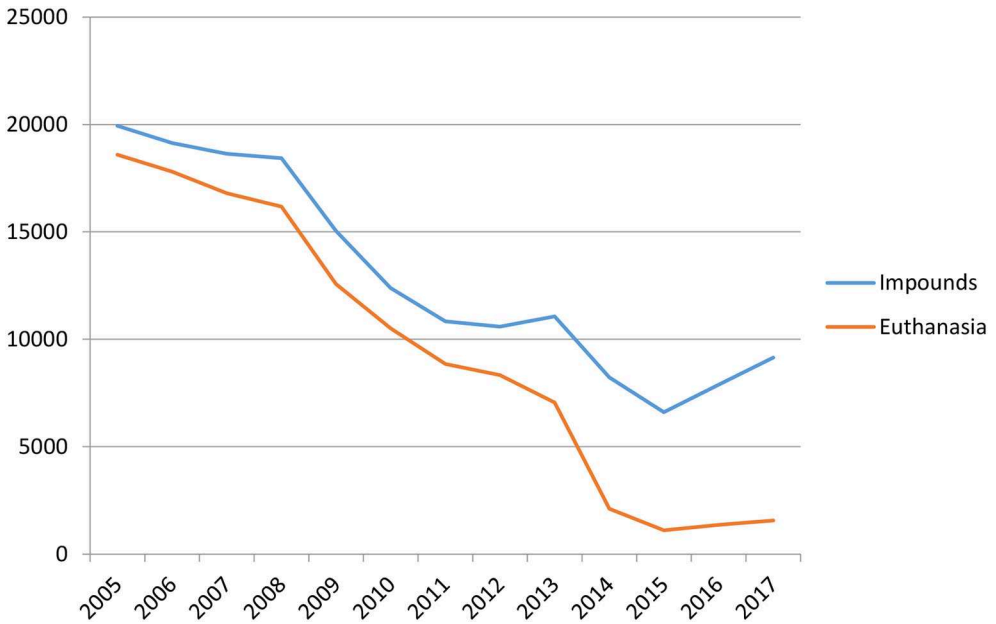

FIGURE 3 | Hillsborough County Animal Services cat intake and euthanasia, 2005–2017.

the rate steadily increased as reduced intake and a focus on live releases became county policy. The three targeted programs discussed above helped to bring about this shift. The rise in intakes in 2017 might be explained by the decrease in the number of low-cost vouchers issued and redeemed between 2015 and 2017, or by the fact that shelter hours for drop-off and intake by members of the public increased from 20 h a week in 2014 to 54 h a week in 2016. Because companion animal population management is a dynamic and complex problem, it is hard to be sure which variables explain most of the variance in the data. Other factors, including changes in shelter procedures, can also influence the numbers of cats flowing into the shelter and subsequently being euthanized. During this time period, four shelter directors were at the helm. Each changed procedures that could affect intake such as intake diversion, changing officers' duties, and shelter hours. Each of these has to be done with the consideration that abandonment may increase if you make it too hard for the citizens.

It is reasonably clear, however, that the citizens of Hillsborough County had three choices in the early 2000s. They could continue to live with an ongoing free-roaming cat problem. They could wait for the government to solve the problem. Or they could try to organize and mobilize a diverse set of skills in the local community to change the situation. Over the period of this study, they chose to change to nonlethal means of companion animal population control.

This empirical study of Hillsborough Country, Florida, demonstrates that there are several things a community can do to increase the live-release rate of cats from open access shelters. The first is to attempt to reduce shelter intake by performing affordable and accessible spay and neuter surgeries on two target populations: cats owned by low-income families and free-roaming cats. The second is to identify innovative techniques to return greater numbers of sterilized free-roaming cats to the field. The third is to get the entire community involved in any effort to improve the LRR from the open access shelter. Johnson and Cicirelli (34) report that impounds of cats and kittens in San Jose decreased from 70% of all intakes in 2010 to 23% in 2014 and that shelter euthanasia for cats suffering from feline upper respiratory infections decreased by 99%. Although comparable numbers are not available for Hillsborough County, feline intake decreased by 51% over a period of about a decade (see **Table 1**), even while the county population and the number of their pets increased substantially. The number of households in the county increased by 119,623 from 2004 to 2017, an increase of 26.9% (14, 48). According to the American Veterinary Medical Association, 30.4% of households own 2.1 cats (49). This is presumptive evidence that the three programs discussed in this analysis have had a positive impact. In 2017, the Hillsborough shelter took in 9,151 cats and had a live-release rate of 81.8 % (7,589). That is a notable achievement.

Advocates of better management for free-roaming cats need to be aware that it takes organization, leadership, and determination to adopt and implement new programs in the face of opposition. Those who can document their successes need to share what they have learned, and one of the goals of this paper is to contribute to such sharing of information.

Finally, the technological revolution that has provided new means to share information has connected the world more than ever before (40). A large number of citizens do not want their community to kill animals as a means of population control. Using technology to share innovative ideas and successful methods will ensure that these programs will be replicated.

CONCLUSIONS

Robertson wrote in 2008, "Feral cats are a result of human actions; we caused the problem and we should be responsible for a solution" (p. 373). Five years later, the Alliance for Contraception in Cats and Dogs (ACC&D) was able to say, "If TN[V]R is performed with sufficient intensity and for a sufficient duration, it can be effective in reducing population size, as long as dispersal (newly abandoned cats or other cats immigrating) into the treated population does not exceed a defined threshold level" (50). The three targeted programs introduced in Hillsborough County have operated at a fairly high level of intensity. Almost 128,000 targeted cat surgeries were performed along with other untargeted surgeries.

In the future, the likelihood is that new methods of high-volume, free-roaming cat reduction will be developed and that they will rely less than they do now on the work of volunteers. There are already 18 Humane Alliance clinics in Florida with a capacity for high-volume work and other local Humane Societies and SPCAs are adopting these methods.

AUTHOR CONTRIBUTIONS

The listed author participated as a member of the Animal Advisory Committee and co-founder of one of the participating organizations. FH gathered the material, interviewed participants, and wrote the paper.

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