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PERSPECTIVES AND PARADIGMS

A science-based policy for managing free-roaming cats

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Abstract Free-roaming domestic cats (i.e., cats that are owned or unowned and are considered 'at large') are globally distributed non-native species that have marked impacts on biodiversity and human health. Despite clear scientific evidence of these impacts, free-roaming cats are either unmanaged or managed using scientifically unsupported and ineffective approaches (e.g., trap-neuter-release [TNR]) in many jurisdictions around the world. A critical first initiative for effective, science-driven management of cats must be broader political and legislative recognition of free-roaming cats as a non-native, invasive species. Designating cats as invasive is important for developing and implementing science-based management plans, which should include efforts to prevent cats from becoming free-roaming, policies focused on responsible pet ownership and banning outdoor cat feeding, and better enforcement of existing laws.

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Using a science-based approach is necessary for responding effectively to the politically charged and increasingly urgent issue of managing free-roaming cat populations.

Keywords Domestic cat · *Felis catus* · Feral cat · Human-wildlife conflict · Pet cat · Trap-neuter-release

Walk through nearly any city or rural area around the world and the domestic cat (*Felis catus*) is ubiquitous. Even in national parks of the United States, cats are the most widely distributed non-native animal (Redford et al. 2017). Though identified for over a century as a non-native predator in many parts of the world (e.g., Darwin 1859; Forbush 1916), free-roaming domestic cats (owned and unowned outdoor cats considered 'at large;' Schweitzer and Gillin 2020, Lepczyk and Calver 2022) have more recently been recognized as a global threat to biodiversity. Cats are opportunistic predators that have been recorded to eat hundreds of different species across many major animal taxa (e.g., Lepczyk et al. 2004; Bonnaud et al. 2011; Woolley et al. 2019). The result is that cats have contributed to the extinction of at least 63 species of terrestrial vertebrates around the world (Doherty et al. 2016), threaten another 430 species of conservation concern (Doherty et al. 2016), and kill billions of animals annually in just North America (Loss et al. 2013) and China (Li et al. 2021) alone. Free-roaming domestic cats also threaten the genetic integrity of wild felids such as the Scottish wildcat (*Felis silvestris silvestris*, a sub-species of the European wildcat) by hybridization (Fredriksen 2016).

Cats also harbor zoonotic pathogens, several of significant health concern (e.g., rabies, plague) to humans and wildlife (Gerhold and Jessup 2013), including pathogens transmitted to marine mammals from fecal runoff (Shapiro et al. 2019). Notably, cats are the most commonly reported rabid domestic animal in the United States, with recent cases showing a marked increase (Ma et al. 2022). Furthermore, they are a definitive host for *Toxoplasma gondii*, a parasite of serious concern to animal and human health (Aguirre et al. 2019).

Finally, cats impose significant financial costs to society. A recent analysis in Australia estimated the annual costs to residents of two cat-dependent diseases (toxoplasmosis and cat scratch disease) at AU $6.06 billion (range AU$2.11–10.7 billion) and the costs to livestock production from toxoplasmosis and sarcocystosis at AU$11.7 million (range AU$7.67–18.3 million) (Legge et al. 2020). Likewise, the InvaCost database (Diagne et al. 2020), which presents comprehensive global data on reported costs of invasive species, indicates that cats were the costliest invasive species between 1960 and 2020, with total expenses related to management (control or eradication) and damages (e.g., to birds) at $45.54 billion (Fantle-Lepczyk 2022).

Because cat ownership is increasing in many parts of the world (Fig. 1), it is very likely that the number of outdoor free-roaming cats is also increasing, posing increased problems for the environment. At the same time, despite growing scientific evidence of their ecological impacts, free-roaming cats are largely unmanaged in many countries, as well as in many states and municipalities in the United States. Contributing to this lack of management are complex economic, sociological, and legal issues (Pimentel et al. 2005, Lohr et al. 2014, Schweitzer and Gillin 2020). For instance, costs of managing free-roaming cats can vary markedly, depending upon the approach used (e.g., Lohr et al. 2013), and stakeholders can vary in their views of how to manage cats (Hall et al. 2016;

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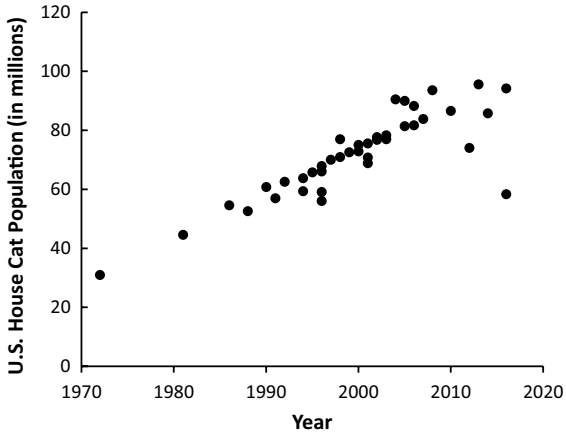

Fig. 1 Estimates of the U.S. pet cat population over time. Although feral cat populations have not been accurately assessed, the number of owned cats has increased significantly, as exemplified by the increase in the house cat population in the U.S. over time. Population estimates were derived from manufacturers of pet food, American Pet Products Manufacturers Association, American Veterinary Medical Association, and similar organizations

Crowley et al. 2020) or in how they perceive the problem (Leong et al. 2020). However, even when socioeconomic complexities are included, the debate over how to manage free-roaming cats is too frequently misrepresented by pro-outdoor cat advocates, who often appear uninterested in considering any negative effects of free-roaming cats and attack the science and scientists studying how cats adversely affect wildlife and the environment (Loss et al. 2018). This dynamic has impeded scientifically-based efforts to manage cats and has instead promoted less effective strategies such as trap-neuter-release (TNR) programs. TNR has proved largely ineffective at stabilizing and reducing cat populations, particularly after accounting for reductions to a cat population due to other strategies, such as permanent removal of animals for adoption or euthanasia (e.g., Foley et al. 2005; Longcore et al. 2009; Crawford et al. 2019). What is needed is a return to science-based decision-making and to a perspective that values ecosystem health in the management of free-roaming cats.

A science-based approach to managing free-roaming cats should start with broader political and legislative recognition that aligns with the consensus in the animal ecology, conservation, and welfare communities that their impact is distinct from that of indoor pet cats, and that they are a non-native, invasive species. The definition of invasive species varies little between jurisdictions and is primarily science-based. For example, the Conference of the Parties to the United Nations Convention on Biological Diversity defines an invasive alien species as "a species … introduced outside its natural past or present distribution" and "whose introduction and/or spread threaten biological diversity" (https://www.cbd.int/decision/cop/?id=7197). The United States defines an invasive species as a species that: 1) "with respect to a particular ecosystem, … is not native to that ecosystem," and 2) "whose introduction does or is likely to cause economic or environmental harm or harm to human health" (Exec. Order 13,112 as amended into Exec. Order 13,751).

As domesticated descendants of the African wildcat (*Felis silvestris lybica*) that are now widely considered a separate species, domestic cats are not native to any ecosystem anywhere in the world (Driscoll et al. 2007; Ottoni et al. 2017), and therefore, they clearly meet the definition of an alien or non-native species when they are free-roaming outdoors without restriction. Overwhelming evidence of cats' ecological impacts satisfies the second element of the definition almost globally, regardless of whether the focus is on individual wildlife health and mortality, sustainability of wildlife populations, ecosystem integrity, economic impact to livestock, or human health (Lepczyk et al. 2015; Loss and Marra 2017; Aguirre et al. 2019; Stelzer et al. 2019).

Despite the clear scientific basis for categorizing free-roaming cats as an invasive species, the vast majority of jurisdictions have not done so. The European Union, for example, has yet to list cats on its List of Invasive Species of Union Concern (European Commission 2017). Only a handful of countries (e.g., Australia, Fiji, Korea, Mauritius, New Zealand, Palau) consider feral cats as invasive and specifically mention them among the species that should be controlled as part of their National Biodiversity Strategies and Action Plans (https://www.cbd.int/nbsap/), developed as part of their commitment to the Convention on Biological Diversity. In Australia, predation by feral cats is further listed as a "key threatening process" to wildlife, which is a precondition for creating a threat abatement plan under the Australia's *Environment Protection and Biodiversity Conservation Act 1999*. In New Zealand, the Department of

Conservation controls feral cats on public conservation land "as part of a wider programme targeting other invasive species…." (https://www.doc.govt.nz/nature/pests-and-threats/animal-pests/feral-cats/). In the United States, cats are largely ignored under the National Invasive Species Management Plan (National Invasive Species Council 2016). A 2018 survey of state invasive species policies identified only five U.S. states that list cats as invasive species (Alaska, Georgia, Hawai 'i, New Jersey, and West Virginia), and three others that list them as non-native and "potentially" invasive (Florida, Montana, and Texas). In 2018, the Western Governors' Association (a non-partisan association of U.S. state governors representing 22 states) listed cats 13th on their list of the 25 most impactful invasive terrestrial species, based on a survey of its member states' wildlife management officials (http://westgov.org/images/editor/WGA_Top_50_Invasive_Species_List.pdf). Despite these few exceptions, the absence of cats on most state and national invasive species lists indicates a frequent disconnect between official policy and broad professional and scientific consensus related to wildlife and invasive species management.

More-widespread designation of free-roaming cats as an invasive species is important for building support both formally and informally for active management to reduce the harmful effects of cats. The designation often triggers specific legal requirements in wildlife conservation treaties and laws. Notably, under Article 8(h) of the Biodiversity Convention (ratified by 196 countries in the world), "[e]ach Contracting Party shall, as far as possible and as appropriate: …[p]revent the introduction [of], control, or eradicate those alien species which threaten ecosystems, habitats or species…" The Parties to the Convention included the control of invasive species as one of their priority targets for 2020 and are expected to continue the priority as part of their post-2020 framework (Convention on Biological Diversity 2010).

The global consensus that an invasive species designation should trigger management is also reflected at the national and subnational levels. A survey found that between 1980 and 2015, 154 national or subnational laws or regulations across 70 countries included provisions clearly addressing the management of invasive species (Turbelin et al. 2016). These laws typically require or promote efforts to prevent the release of invasive species, or to control, remove, and/or eradicate them.

Listing free-roaming cats as invasive thus can place the issue within the global consensus supporting the science-based management and control of invasive species. Such a designation is not, strictly speaking, always necessary to manage free-roaming cats because laws aimed at protecting conservation areas or threatened species can also provide legal authority for managing the threats that cats pose (Trouwbourst et al. 2019; Trouwburst and Semsan 2019). Nonetheless, listing free-roaming cats as invasive can do more than provide a scientific basis for legislative or policy action. The designation frames the policy discussion of how to manage free-roaming cats within the widely accepted goal of managing all invasive species, presenting the opportunity to expand support from decision-makers and the general public. Comparing how free-roaming cats are treated to how other invasive species in a jurisdiction are treated can also help build support for stronger cat management efforts. Designating cats as invasive thus could be an important predicate for taking effective action, but alone, it will neither identify what policy measure should be adopted, nor will it prevent all public opposition or ensure compliance with the laws. It will however help keep focus on the goal of reducing ecological impacts when evaluating cat management practices, as is the goal with other invasive species.

Designation could be valuable, for example, in evaluating politically appealing programs such as TNR that have grown rapidly around the globe [e.g., Israel (Gunther et al 2011), Italy (Natoli et al. 2006), Japan (Kazato et al. 2020)]. In the United States, Alley Cat Allies (an advocacy organization for TNR) estimates that the number of municipalities where TNR programs are legally allowed increased by 1,900% between 2003 ($n=23$) and 2014 ($n=430$; Holtz 2014). This increase excludes locations where TNR is implemented without any consideration of legal status. TNR avoids the need for lethal control, and it encourages public participation in feeding cats. Under TNR, unowned outdoor cats are taken to veterinarians, sterilized, and returned to their place of capture, usually in less than 24 h. Sterilized cats may join a colony of cats where caretakers feed them until they die, and in most cases the cats receive no further veterinary support. Often, this approach is combined with regulatory changes that attempt to limit or

eliminate a property owner's or land manager's ability to trap and remove unowned cats, as well as any personal liability for trapping, releasing, and feeding cats. The legal basis for these regulatory changes remains untested.

Although TNR has appeal to those wishing to avoid euthanasia as a solution, it is not effective at reducing feral cat numbers at scale. As shown by demographic modeling (Andersen et al. 2004; Foley et al. 2005), the proportion of the cat population that is needed to be spayed or neutered (in a population not supplemented with food) must exceed 70% or more to reduce cat numbers through decreasing births in a population. This decrease has only been achieved once at a meaningful scale (Gunther et al. 2022), where the authors noted the need to implement TNR at high intensity, sustain the effort over long time scales, and over all contiguous areas. In fact, this one example cost more than one million dollars ($US) over 9 years of TNR implementation (Gunther et al. 2022). Notably, two other large, intensive, and well-funded TNR efforts, conducted in California and Florida over eleven (1992–2003) and six years (1998–2004), respectively, failed to reduce cat numbers (Foley et al. 2005). Feeding at TNR sites increases reproduction for unsterilized individuals, attracts new cats through immigration and abandonment, attracts wildlife seeking a food resource (e.g., skunks *Mephitis mephitis*, raccoons *Procyon lotor*, Virginia opossum *Didelphis virginiana*, grey fox *Urocyon cinereoargenteus*), and results in increased interactions with wildlife and subsequent opportunities for spreading disease. Notably, skunk, raccoon, and fox are the wild (non-domestic) species that most commonly transmit rabies to humans and pets in North America (Ma et al. 2022). Under TNR, cats remain on the landscape, where they continue to depredate prey, spread disease, and remain exposed to the elements such as rain, cold, and storms. Despite the strong scientific evidence of TNR's ineffectiveness, TNR has become politically popular; is well-financed by non-governmental organizations, local governments, and corporate pet stores; receives favorable widespread attention in the media (Gow et al. 2022); and encourages guilt-free disposal of unwanted cats (Longcore et al. 2009; Lepczyk et al. 2010).

Owing to human affinity for felines, perceived opposition to euthanasia of unadoptable cats, and the political placebo effect of TNR, pro-outdoor cat advocates argue that all outdoor cat management options other than TNR are unacceptable. However, recent socioecological research suggests that these alternatives are not as unpalatable to the public as they are often portrayed. In Hawai 'i, 87% of people across all stakeholder groups, including many in the animal welfare community, desired a reduction in numbers of outdoor cats (Lohr and Lepczyk 2014), an objective that TNR programs rarely achieve, evaluate, or even consider as part of their mission. These same stakeholders approved of humane lethal control of cats and considered TNR to be the least preferred legal management technique (Lohr et al. 2014). Likewise, a survey across six nations found that the majority of both cat owners and non-owners from five of these nations (Australia, New Zealand, the USA, China, and Japan) believed that there is a need for cat legislation (Hall et al. 2016). In Australia, the Australian Veterinary Association does not endorse TNR because "… 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" (https://www.ava.com.au/policy-advocacy/policies/companion-animals-management-and-welfare/management-of-cats-in-australia/).

Designating the free-roaming cat as an invasive species frames free-roaming cat policy in the context of the scientific case for effective invasive species management and helps to keep the focus on reducing ecological impacts. Of course, successfully controlling free-roaming cat populations will also involve many steps beyond this key designation. **First**, management emphasis should start with strategies that prevent cats from becoming free-roaming in the first place. Policies promoting and subsidizing sterilization, vaccination, microchipping, and containment of pet cats need to be developed, encouraged, and enforced to focus on maintaining cats indoors or under owner control. Mandatory cat spay-neuter and microchipping laws, accompanied by low-cost and free spay-neuter and microchip services for disadvantaged communities, would reduce the number of kittens and ultimately population numbers. Likewise, cats allowed outdoors should be on a leash or restrained in open-air enclosures, and (where financially and socially feasible) all cats should be microchipped and licensed so that lost cats can be more easily reunited with their owners (Lord et al. 2009). **Second**, better-enforced abandonment laws (which

exist in many countries and virtually every U.S. state) could reduce cat abandonment, a primary source of unowned cats. **Third**, local, state, and national government agencies must ban (with enforcement) outdoor cat feeding sites and end TNR as a purported population management tool. **Fourth**, funding organizations must hold accountable the recipients of any funding that supports cat management by evaluating goals and objectives of programs to require cat population reduction, as well as requiring and reviewing data on program effectiveness. Without valid data and the ability to independently evaluate these data in a scientifically rigorous manner, determining success or failure of a project is not possible. A valuable template for many of these recommendations to be placed into a policy framework is the Tasmanian Government's *Cat Management Act of 2009*, which has been regularly updated and amended (https://www.legislation.tas.gov.au/view/html/inforce/current/act-2009-089).

Where prevention is too late and cats are established and negatively affecting wildlife, active management should be implemented to reduce cat populations on public lands, and removal (without return) should be defended as a right of landowners on private lands, as it is in Poland (Wierzbowska et al. 2012). In this context, the welfare of cats, not just human perceptions of their welfare, must be objectively considered when management options are weighed. Free-roaming cats have shorter lifespans, resulting from vehicular trauma, predation, disease, harsh weather, and fighting (Lacheretz et al. 2002). For these reasons, organizations such as the People for the Ethical Treatment of Animals oppose maintaining outdoor colonies of cats except under limited circumstances (https://www.peta.org/about-peta/faq/what-is-petas-stance-on-programs-that-advocate-trapping-spaying-and-neutering-and-releasing-feral-cats/). Finally, it is important to note that removal need not mean euthanasia for all cats. Rehoming and adoption of socialized cats, to the extent practicable, can and should be a significant component of any management program.

Australia provides a potential model for how cat management practices and policies can become more science-driven. Growing concern over the environmental and public health impacts of cats in Australia has led to a nationwide policy of management to control cat populations. A Threatened Species Commissioner was appointed in 2014 to champion practical conservation actions to recover threatened native species, with a key focus on removing feral cats (in the Australian context, i.e., cats neither directly nor indirectly provisioned by people, which excludes unowned cats in urban areas). A broad strategy to protect threatened species set targets for culling two million feral cats, application of control measures on over 10 million hectares, and establishing cat-free havens on both the continental mainland and offshore islands (Commonwealth of Australia 2015). In addition to these initiatives, funds totaling $29.98 million (Australian) were allocated to a Threatened Species Recovery Hub in 2015, with its first focus on reducing impacts of introduced predators on threatened mammals (http://www.nespthreatenedspecies.edu.au/).

Concurrently, Australia's state governments are making their own provisions directed mainly at unowned cats in cities and towns. For example, under the *Queensland Biosecurity Act 2014* (https://www.daf.qld.gov.au/business-priorities/biosecurity/policy-legislation-regulation/biosecurity-act-2014), it is illegal to release cats into the environment or to feed them, unless food is used to lure cats into traps. The Act also requires local governments in Queensland to prepare their own biosecurity plans. In response, the Brisbane Local Government Area (LGA) has developed a plan that includes specific provision for removing unowned cats from areas where they threaten biodiversity, reducing numbers of unowned cats in other areas where they may impact the environment or public health, and educating the community about impacts of unowned cats (Read et al. 2020). The Australian Capital Territory has released its *Cat Plan 2021–2031* (ACT Government 2021) with the vision that all cats in the territory "will be owned, wanted and cared for by responsible owners." The plan incorporates eight strategies to reduce the flow of unowned cats into the environment, reduce the numbers and impacts of semi-owned, unowned, and feral cats using "trap, desex and adopt", and improve the welfare and management of owned cats. While much of Australia's feral cat population exists in remote areas of the country, a separate plan, developed by the non-profit organization Getting 2 Zero, focuses on reducing numbers of unowned cats in urban areas through the Australian Cat Action Plan (ACAP; https://www.g2z.org.au/pdf/G2Z%20Australi

an%20Cat%20Action%20Plan%2025June%202018.pdf). ACAP includes twelve strategies that together aim to reduce the flow of cats into the unowned cat population and to remove (and rehome where possible) unowned cats.

In the United States, communities have also begun to develop policies to manage outdoor cats. For example, the covenant of the Spain Bridge Meadows subdivision in Bozeman, MT, dictates that "Cats shall not be allowed outside of the dwelling unit. Cats are to be housed in this manner to ensure that they do not prey upon the wild birds and other wild animals, which reside in the open space of the subdivision" (https://spainbridgemeadows.org/wp-content/uploads/2019/07/Recorded-Covenants.pdf). These national and local initiatives demonstrate that political will and understanding of the problem are possible and can catalyze government and community-led efforts to implement solutions that reflect the scientific evidence, the will of stakeholders, and the knowledge of land managers, rather than the desires of well-funded, pro-outdoor cat advocacy organizations or local humane societies whose main purview concerns companion animals.

Other nations have similar initiatives to those described above for Australia and the United States. For example, New Zealand, Mauritius, and Palau have reported actions taken to trap or remove cats from specific conservation areas. Addressing the global problem of free-roaming cats will require development of country-specific solutions that reflect the socioeconomic conditions and the needs and interests of various stakeholders, but starting from the scientific determination that cats qualify as invasive species should help to maintain focus on the goal of effectively responding to the threats cats pose to wildlife. Different nations and cultures will have varying views of cats and different approaches to policy-making. However, our overarching argument is that formally recognizing cats as invasive species sets a unifying, scientifically-based starting point that is reflected in a global narrative set by the Convention on Biological Diversity, and that can help individual countries manage cats in a scientifically sound way.

We urge creation of scientifically supportable local, state, and federal policies to address free-roaming cats in urban and wild environments, beginning with their designation as invasive species. Such a scientifically-based designation can be made in a less politically-charged environment unattached to any specific policy proposal. Once listed, the frame for public debate, including the strong pushback that can be expected in some countries from the pro-outdoor cat lobby, will be better positioned to focus on what steps are necessary to reduce the harmful ecological effects of cats by achieving effective management of their populations. This frame would help governments resist TNR and other ineffective, but politically convenient, policy options and to support policies that promote responsible pet ownership and improve cat welfare. TNR, while socially attractive to some individuals as a way to avoid euthanasia lacks a sound scientific basis and avoids the hard decisions necessary to ensure human and cat welfare, conservation of protected species, and attainment of sustainable ecosystems. We will not solve the global problem of over-abundant cat populations overnight but insisting on a science-based approach to this highly charged political issue should lead to change in our lifetimes that will result in healthier ecosystems, cats, and people.

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