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Domestic cats and their impacts on biodiversity: A blind spot in the application of nature conservation law

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Abstract

1. Free-ranging domestic cats *Felis catus*, from owned pets to feral cats, impact biodiversity through predation, fear effects, competition, disease and hybridization. Scientific knowledge regarding these impacts has recently increased, making it timely to assess the role of nature conservation legislation in this connection. We do so with particular regard to the obligations of governments around the world under international wildlife law.
2. First, we provide an overview of current knowledge, based on a literature review, concerning the ways in which domestic cats impact wildlife; the resulting effects on native species' populations and ecosystems; and available strategies for addressing these issues. In light of this knowledge, using standard legal research methodology, we then identify and interpret relevant legal instruments, with a particular focus on international wildlife treaties. Lastly, we identify and assess factors that may influence the implementation of relevant obligations.
3. The outcomes of this analysis indicate that numerous legal obligations of relevance to free-ranging domestic cats already apply under global treaties such as the Convention on Biological Diversity, Convention on Migratory Species and World Heritage Convention, and a range of regional legal instruments for biodiversity conservation. Of particular significance are obligations concerning (a) invasive alien species; (b) protected areas and (c) protected species.
4. Many national authorities around the world are currently required, under international law, to adopt and implement policies aimed at preventing, reducing or eliminating the biodiversity impacts of free-ranging domestic cats, in particular by (a) removing feral and other unowned cats from the landscape to the greatest extent possible and (b) restricting the outdoor access of owned cats.
5. Factors that can influence or impair the application of these obligations include considerations of feasibility, scientific uncertainty, the interests of cat owners and the (perceived) interests of domestic cats themselves. Even if such factors may to some extent explain why many authorities have hitherto failed to take effective action to address the threats posed by free-ranging domestic cats, from a legal

perspective these factors provide little ground for justifying non-compliance with international wildlife law.

KEYWORDS
Convention on Biological Diversity, Convention on Migratory Species, domestic cat *Felis catus*, feral cat, international law, invasive alien species, nature conservation law, protected areas

1 | INTRODUCTION

Around the world, domestic cats *Felis catus*—from free-ranging pets to feral cats—impact wildlife in various ways, and to various degrees. Impacts include predation, competition, disturbance, disease transmission and hybridization (see Section 2.1 below). Much legislation exists, at national and international levels, aimed at the conservation and restoration of wildlife and biodiversity. The application of these nature conservation laws to domestic cats and their impacts is the focus of this paper. The paper emphasizes the obligations of governmental authorities and the actions imposed by existing international law with regard to domestic cats. This analysis is timely because scientific evidence has grown rapidly over the past 15 years and now clearly documents cats' large-scale negative impacts on wildlife (see Section 2.2 below). Notwithstanding this growing awareness of their negative impact on wildlife, domestic cats continue to inhabit a place that is, at best, on the periphery of international wildlife law. No doubt, there are political, sociological and psychological explanations for this regulatory oversight but the implications for wildlife conservation are profound. This article speaks directly to this legal 'blind spot', highlighting the urgent need for a more consistent and focused application of international wildlife laws to this issue.

In this desktop study, we first identified the ways in which domestic cats impact wildlife, the degrees to which they do so, and available remedial measures, based on a review of existing research published in the scientific literature. We have analysed wildlife law in light of these facts, using standard legal research methodology. This involved identifying relevant legal instruments and provisions therein, whereby we largely limited our analysis to international law; interpreting these provisions in accordance with the applicable rules of interpretation (for international law, these are the rules codified in the 1969 Vienna Convention on the Law of Treaties); and applying these provisions to domestic cats and their impacts on wildlife. We then proceeded to identify and assess potential factors influencing the application of the law, including feasibility, scientific uncertainty, and the (perceived) interests of domestic cats themselves and of their owners.

The geographical scope of the study is global, and we combine general discussions of applicable legal instruments with concrete illustrations. Substantively, the scope is confined to nature conservation law (alternatively referred to as wildlife law or biodiversity law), that is, legal instruments expressly aimed at the conservation and/or restoration of native fauna and flora and their habitats. Thus, we do not analyse public health law, tort law, animal welfare law, urban and land use planning law, or any other area of law of relevance to domestic cats. Likewise, the study does not address the impacts of free-roaming cats on human interests, such as the transmission to people of potentially serious diseases like toxoplasmosis (Aguirre et al., 2019; Gerhold & Jessup, 2013), the killing of pets, and nuisances such as defecation in playgrounds and private yards and the (often nocturnal) noise produced by cats in heat.

Section 2 provides an overview of current knowledge regarding the ways in which domestic cats impact wildlife; the resulting effects on native species' populations and ecosystems; and available strategies for responding to these issues. It does so in sufficient detail to enable a meaningful analysis of the law in light of this knowledge. Section 3 then addresses the central concern of this paper, which is 'what the law requires' in this regard, by presenting and discussing the main results of our legal analysis. Following that analysis, Section 4 identifies and evaluates factors that can influence the application of relevant legal obligations. Section 5 offers concluding observations.

2 | DOMESTIC CATS AND WILDLIFE

Domestic cats descend from wildcats *Felis silvestris*, and since their domestication in the Near East (and perhaps Egypt) approximately 10,000 years ago, they have travelled with people to virtually all corners of the world (Driscoll et al., 2007; Ottoni et al., 2017). Domestic cats inhabit all continents except Antarctica, and feral populations presently exist in even the remotest archipelagoes (Courchamp, Chapuis, & Pascal, 2003). Cats are popular as pets and mousers. In addition, stowaway, runaway and intentionally released cats have established free-ranging cat populations in numerous places, and many of these have become 'feral' in the sense that they are fully independent of people. Domestic cats are very adaptive in terms of food, habitat and climate, and are intensive breeders—they reach reproductive age between 7 and 12 months and can have up to three litters a year. Pet cats generally receive food, shelter and health care from their owners, and stray cats also often receive food and other forms of care (e.g. vaccinations) from humans. These 'subsidies' ease

or remove the constraints of limited food availability, intraspecific competition and disease, and enable domestic cats in many areas to reach high densities, far higher than those of similar-sized wild predators such as wildcats (Beutel, Reineking, Tiesmeyer, Nowak, & Heurich, 2017; Coleman & Temple, 1993; Crooks & Soulé, 1999; Legge et al., 2017; Sims, Evans, Newson, Tratalos, & Gaston, 2008). Worldwide, at present domestic cats are likely to be orders of magnitude more numerous than all individuals of all wild cat species added together (Hunter, 2015).

There is a continuum of human control over the food provisioning, reproduction and movement of domestic cats, from fully indoor to fully feral cats (Crowley, Cecchetti, & McDonald, 2019). In this study, we are concerned with all domestic cats which spend part or all of their life outdoors beyond the full control of humans. We use the term 'free-ranging' as covering all such cats—from owned pets allowed to roam outdoors, through barnyard cats and colonies of stray cats receiving food from people, to feral cats living completely independently of humans. All such free-ranging domestic cats have the potential to impact wildlife.

2.1 | Ways in which domestic cats impact wildlife

The most direct way in which domestic cats influence wildlife is through predation. This is perhaps also the most significant way, given the high numbers and densities of cats in many areas, coupled with their hunting instinct, which can be strong even in well-fed pet cats (Coman & Brunner, 1972). Cats are opportunistic hunters, and prey items include a wide range of animals, including birds, mammals, reptiles, amphibians, fish, and invertebrates like butterflies and dragonflies. To illustrate, the 14,370 prey items brought home by a sample of 986 British pet cats in a 5-month survey period in 2003 included 20 mammal species (e.g. mice, voles, shrews, squirrels, stoats, rabbits and bats), 44 bird species, four reptile and three amphibian species and some invertebrates (Woods, McDonald, & Harris, 2003). To provide another example, a recent citizen science survey in Italy rendered records of 2,042 animals killed by 145 cats, involving no less than 207 different species (Mori et al., 2019). Whereas most cat prey tends to consist of small animals, domestic cats have been documented to prey on medium-sized animals weighing up to 4 kg (e.g. Fancourt, 2015).

Of all free-ranging domestic cats, feral cats hunt the most as hunting is their sole source of food. However, it is estimated that the great majority of other unowned cats also hunt (over 80% according to Loss, Will, & Marra, 2013), and around 50%–80% of owned cats which are allowed outdoors (Loss, Will, Longcore, & Marra,2018; Loss et al., 2013; Loyd, Hernandez, Carroll, Abernathy, & Marshall, 2013). Studies confirm that typically only a fraction of hunted prey is brought back to the house or the farm, for instance 23% (Loyd et al., 2013) or 10% (Krauze-Gryz, Gryz, & Żmihorski, 2019). Factors that may influence owned cats' predation rates and species caught, other than the location of their home, include the cats' age and condition, the extent they are fed and cared for, the use of bells and other anti-predation devices, the time of day cats are allowed outside, and the time of year (see, e.g. Barratt, 1998; Kays & DeWan, 2004; Krauze-Gryz, Zmihorski, & Gryz, 2017; Silva-Rodríguez & Sieving, 2011; Van Heezik, Smyth, Adams, & Gordon, 2010; Woods et al., 2003).

An indirect way in which prey species can be affected by free-ranging domestic cats is through disturbance or fear effects caused by the cats' mere appearance, presence or scent. As documented in a range of studies reviewed by Loss and Marra (2017), such fear or intimidation effects can influence foraging and defence behaviours, stress responses, energy income and body condition, vulnerability to other predators, and reproductive investment and output. For instance, Bonnington, Gaston, and Evans (2013) found that even briefly confronting blackbirds *Turdus merula* with a taxidermied cat near their nest reduced subsequent feeding of the young by one-third, and significantly increased the risk of subsequent nest predation by corvids. Another indirect impact is competition, which occurs when domestic cats exploit the same food, space and/or shelter as other species. For example, every mouse eaten by a cat cannot be eaten by a hawk (George, 1974). Domestic cats can, furthermore, impact wildlife through disease transmission. A broad range of vertebrates can be affected by cat-transmitted diseases like toxoplasmosis, rabies or feline leukaemia (Dubey, 2002; Gerhold & Jessup, 2013; Hartley & Dubey, 1991; Loss & Marra, 2017; Work et al., 2000).

Yet another way of domestic cats impacting native species conservation is hybridization, which can result when domestic cats mate with wildcats or other wild cat species (Macdonald et al., 2010). Hybridization can result in the extinction of native species both directly and indirectly. Of particular significance to this analysis, hybridization can lead to 'genetic swamping', where interbreeding with domestic cats produces hybrid populations in which no remaining individuals can properly be described as the native, wild cat species (Todesco et al., 2016). Incidentally, blurring taxonomic distinctions between wild cat species and domestic cats can undermine the application of species-based conservation laws, where such distinctions determine whether a species is an appropriate focus for conservation action (Fitzpatrick, Ryan, Johnson, Corush, & Carter, 2015, but see Chan, Hoffman, & Oppen, 2019).

2.2 | Impacts on individuals, populations, species and ecosystems

The range of impacts that domestic cats have on wildlife of the kinds described above, and which often act in combination, are increasingly well documented at multiple ecological scales: from individuals and populations of species through to ecological processes and ecosystems. Section 2.1 illustrates the breadth of different impacts that domestic cats have on wildlife. The current section analyses the *implications* of these different impacts from domestic cats on native wildlife. There remains some scientific uncertainty about these implications, particularly at broader, ecosystem scales and in the context of complex interactions with other species. However,

the research synthesized below demonstrates that, even in relation to the more complex questions of population impacts, ecosystem health and ecological interactions, there is growing evidence of negative impacts from domestic cats.

Studies in various countries have quantified cat predation on individuals of several species groups. In Canada, domestic cats—from pets to ferals—are estimated to kill between 100 and 350 million birds per year (Blancher, 2013). Even at the lowest end of 100 million, this makes predation by domestic cats 'probably the largest human-related source of bird mortality in Canada' (Blancher, 2013; also Calvert et al., 2013). In Australia, feral and pet cats together are estimated to kill an average of 377 million birds per year, that is, a million birds per day (Woinarski et al., 2017); as well as an average of 649 million reptiles, with cat predation reported for 258 reptile species (Woinarski et al., 2018). Many more cats roam the United States, and their aggregate predation tally runs into the billions, with an estimated 1.3–4.0 billion birds, 6.3–22.3 billion mammals, 258–822 million reptiles and 95–299 million amphibians killed by free-ranging domestic cats each year (Loss et al., 2013). Again, this makes domestic cats the top source of direct human-related mortality for birds and small mammals in the United States, easily eclipsing other sources such as mortality from poisons and pesticides and collisions with structures and vehicles (Longcore et al., 2012; Loss et al., 2013; Loss, Will, & Marra, 2015).

Similar studies in Europe reiterate the negative impacts of cat predation on individuals within populations of native species. For example, one study estimated that owned cats in the United Kingdom, in a 5-month survey period, brought home 57 million mammals, 27 million birds and five million reptiles and amphibians, implying they killed several times these numbers (Woods et al., 2003). A Dutch report estimated that 141 million animals are predated by cats on average in the Netherlands per year, with pet cats responsible for almost two-thirds of this number (Knol, 2015). Another study used data from bird ringing programmes in Belgium and France to gauge cat predation on garden birds, noting that such predation was a leading cause of death reported by observers, on par with window collisions, and that cat-related mortality had increased by 50% between 2000 and 2015 (Pavisse, Vangeluwe, & Clergeau, 2019). An assessment of predation by farm cats in Poland estimated an average of 136 million birds and 583 million mammals are killed around Polish farms annually (Krauze-Gryz et al., 2019). As Crowley et al. (2019, p. 19) summarize the evidence, 'even when killing behaviour is not universal, large numbers of cats inevitably kill large numbers of wild animals'. Of course, even very low numbers of individuals lost to predation can amount to a severe impact on wildlife in small populations or fragile ecosystems. For example, a modest number of domestic cats is held responsible for the extinction of a species of small, flightless passerine, the Stephens Island wren *Traversia lyalli*, on a New Zealand island—although the popular account that this extinction was caused by a single cat owned by the lighthouse keeper is probably oversimplified (Galbreath & Brown, 2004).

Impacts other than predation have been studied to a much lesser extent, but this of course does not imply a lesser influence on biodiversity from the other impacts described in Section 2.1. Consider, for instance, all the billions of prey items consumed by domestic cats which are not available to native mammalian, reptilian and avian predators (Loss & Marra, 2017). Similarly, cat-transmitted diseases like toxoplasmosis are likely to be a significant cause of mortality for a range of vertebrate species, including threatened species (Dubey, 2002; Gerhold & Jessup, 2013; Hartley & Dubey, 1991; Work et al., 2000).

Furthermore, different direct and indirect impacts from cats will often act in tandem on populations of native species (Loss & Marra, 2017). For example, many bird and mammal species will simultaneously undergo direct predation and indirect fear effects (e.g. Mahlaba, Monadjem, McCleery, & Belmain, 2017). The fosa *Cryptoprocta ferox*, Madagascar's top native predator, appears to suffer from 'considerable competition' through consumption of shared prey by free-ranging domestic cats (Merson, Dollar, Tan, & Macdonald, 2019) and is also at risk from toxoplasmosis (Rasambainarivo, Farris, Andrianalizah, & Parker, 2017). Wildcats are subject to the same combination of competition and disease, with hybridization added to the mix. Concerns over hybridization with domestic cats also exist for some other species, for example, the rusty-spotted cat *Prionailurus rubiginosus* in India and Sri Lanka (Kittie & Watson, 2014).

Hybridization, disease, competition, disturbance and predation by domestic cats do not just affect individual animals but also whole populations of species, in some cases to the point of extinction. Uncertainty remains regarding the exact magnitude of domestic cats' impacts at these population levels. Challenges for determining the population-level effects of cats include, *inter alia*, the difficulty of determining what proportions of cat-caused mortality are compensatory (affecting animals that would have died anyway) and additive (where mortality due to the impacts of domestic cats adds to overall mortality); and the general challenge of disentangling causes and effects in ecological systems (Baker, Molony, Stone, Cuthill, & Harris, 2008; Beckerman, Boots, & Gaeston, 2007; Hackländer, Schneider, & Lanz, 2014; Loss & Marra, 2017). The above considerations, however, including the sheer numbers mentioned, distinctly suggest the prevalence of such population-level impacts for both island and mainland wildlife populations, and many such impacts have already been documented—not only involving birds and mammals but also, for instance, lizards (Li, Belasen, Pafilis, Bednekoff, & Foufopoulos, 2014; Stokeld et al., 2018; Woinarski et al., 2018).

Domestic cats have also been implicated at broader scales, in the global extinction of at least 63 species—40 birds, 21 mammals, two reptiles—which is to say 26% of all known contemporary extinctions in these species groups (Doherty, Glen, Nimmo, Ritchie, & Dickman, 2016). Likewise, domestic cats currently endanger at least a further 367 species which are at risk of extinction (Doherty et al., 2016). In a ranking of alien species threatening the largest numbers of vertebrates worldwide, domestic cats came in third—only rats (*Rattus* spp.) and the chytrid fungus *Batrachochytrium dendrobatidis* that is wiping out amphibians around the world, are ahead of them (Bellard, Genovesi, & Jeschke, 2016).

Cats have played a particularly significant role in native species loss on some continents, on many islands, and among populations of

certain species groups. For example, they are a principal cause of the declines and extinctions of many of Australia's unique mammal species (Woinarski, Burbidge, & Harrison, 2015). To illustrate, one study showed that feral cats caused 65% of mortality for woylies *Bettongia penicillata*, a rare marsupial (Marlow et al., 2015). Another study used enclosures to assess the impact of feral cats on long-haired rats *Rattus villosissimus*, finding that these native rodents went extinct in areas frequented by cats but persisted in areas surrounded by cat-proof fences (Frank et al., 2014). At least 13 further studies demonstrate similar predation impacts on populations of other mainland vertebrates in New Zealand, Europe and North America (see Loss & Marra, 2017). Several of these studies revealed that predation of various bird species at study sites in the United Kingdom and the United States was so severe that the studied populations are likely to act as 'sinks', requiring immigration from areas with fewer cats to persist (Baker et al., 2008; Balogh, Ryder, & Marra, 2011; Smith, McKay, Richardson, Shipley, & Murphy, 2016; Thomas, Fellowes, & Baker, 2012; see also Loss & Marra, 2017). A recent Italian study provided further 'strong evidence that free-ranging domestic cats may seriously affect the conservation of [various] wildlife species, which are already suffering from population declines due to other causes, e.g. habitat loss' (Mori et al., 2019).

As the latter quote indicates, predation by cats also interacts with and exacerbates the effect of other threats to wildlife, increasing the risk of regional or global extinctions. For example, feral cats in Australia have been observed congregating outside their usual hunting territory in areas recently burned by wildfire because fires reduce ground cover for small native mammals which cats then hunt far more efficiently (McGregor, Legge, Jones, & Johnson, 2016). The impact of this behaviour may be increasingly devastating for small endemic mammals in areas where wildfires are becoming more severe and more common as a result of climate change (McGregor et al., 2016).

Whereas disturbance or fear effects are even harder to quantify with precision than direct predation effects, the aforementioned blackbird research (Bonnington et al., 2013) and several other empirical studies provide concrete indications that cat-caused fear effects are adversely influencing *inter alia* the foraging, space use and reproduction of impacted species' populations (Balbontín & Møller, 2015; Freeberg, Book, & Weiner, 2016; Tryjanowski et al., 2015). Indeed, the available evidence indicates that fear effects can exercise an even greater influence on prey populations than predation itself (Loss & Marra, 2017; Preisser, Bolnick, & Benard, 2005). As one study illustrated, even when urban songbird predation mortality from domestic cats is as low as 1%, fear effects from those same cats can still reduce bird abundance by 95% (Beckerman et al., 2007).

A documented example of a disease impact is the death of five members of the endangered puma (*Puma concolor*) subpopulation known as Florida panthers, caused by an outbreak of feline leukaemia virus which was traced back to a single domestic cat (Brown et al., 2008). Population impacts from cat-borne diseases appear likely for a further range of species (Loss & Marra, 2017). For example, significant mortality from toxoplasmosis has been documented for marsupials, Neotropical primates and even marine mammals (Gerhold & Jessup, 2013). Regarding the latter, *Toxoplasmosis gondii* oocysts from domestic cat scat can reach the marine environment through freshwater runoff from cities, and has been identified as a major cause of death in southern sea otters *Enhydra lutris nereis* off the California coast—both through direct mortality from the disease and increased vulnerability of infected otters to shark attacks—and as hampering the otter population's recovery (Conrad et al., 2005; Kreuder et al., 2003).

Domestic cats can also pose a real risk to wildcat conservation through hybridization, especially when wildcat densities are low, as documented for Hungary (Pierpaoli et al., 2003) and Scotland (Beaumont et al., 2001; Hubbard et al., 1992; Macdonald et al., 2010).

Finally, predation, disturbance, competition and other impacts of domestic cats can have broader impacts on ecological processes and ecosystems. Impacts of domestic cats are especially and notoriously strong on islands, particularly those islands where the native—and often endemic—fauna is unadapted to mammalian carnivores (Medina et al., 2011; Nogales et al., 2013). A meta-analysis of dozens of cat diet studies showed that on 40 islands around the world, at least 248 different species had been preyed on by feral cats—113 birds, 27 mammals, 34 reptiles, three amphibians, two fish and 69 invertebrates (Bonnaud et al., 2011). A significant proportion of the cat-induced extinctions of, and current risks to, species referred to above involve island species (Bellard et al., 2016; Doherty et al., 2016; Medina et al., 2011). Species extinctions caused by cats in fragile and often-remote island environments can cause ecological processes such as seed dispersal or pollination for native plants to break down (Medina et al., 2011). Furthermore, ecological functions that are lost when a species becomes extinct through cat predation or other impacts may not be replaced, as few species can independently return to island environments once a population is locally extinct. As a result, the transformation of island ecosystems triggered by the impact of cats may, without direct human intervention, be irreversible.

However, adverse ecological impacts of domestic cats on biodiversity are certainly not limited to islands. Given cats' large numbers, subsidized high densities and other traits mentioned above, their impacts can also be significant on 'mainlands', that is, continents and large islands (such as Madagascar, New Zealand and the UK), with a recent review concluding that there is 'overwhelming evidence demonstrating that cats affect mainland vertebrate populations' (Loss & Marra, 2017, p. 507). Highly disturbed or degraded mainland ecosystems, including areas heavily burnt by wildfire, may be particularly vulnerable to species impact and ecosystem impact by domestic cats (May & Norton, 1996; McGregor et al., 2016).

Of course, human impacts on biodiversity from overexploitation and land clearing are significantly more damaging than the harm caused by domestic cats (Maxwell, Fuller, Brooks, & Watson, 2016). Nevertheless, given the scale and diversity of their impacts on wildlife populations and ecosystems, it seems not to be an overstatement to say that domestic cats are among the 'most ubiquitous and environmentally damaging invasive predators on Earth' (Loss & Marra, 2017, p. 502).

2.3 | Strategies for reducing the impacts of domestic cats

The body of evidence reviewed above indicates that, from a biodiversity conservation perspective, preventing the spread, controlling the numbers, and ideally achieving the total removal of feral and other unowned cats is desirable and, in many places, an urgent priority. It also indicates the desirability of restricting the outdoor access of owned cats, given their cumulative impacts.

Many different lethal and non-lethal methods exist to remove feral and other free-ranging cats from the landscape, including trapping, shooting and poisoned baits. Successful eradication of feral cats has occurred on many dozens of islands (Campbell et al., 2011), often with positive results for native fauna. For example, various seabird studies on islands have identified increased bird abundance and activity and improved breeding success after feral cat eradication (e.g. Dilley, Schramm, & Ryan, 2017; Ratcliffe et al., 2010; Robinson, Gadd, Johnston, & Pauza, 2015), despite complex interactions with other introduced predators such as black rats *Rattus rattus* (e.g. Hughes, Martin, & Reynolds, 2008). At least 13 of the world's most threatened species—those listed as endangered or critically endangered on the IUCN Red List—have already clearly benefited from feral cat eradication (Nogales et al., 2013). Feral cat control occurs on many other island and mainland locations. A case in point is Australia's ambitious feral cat removal programme that is part of its Threatened Species Strategy (Department of the Environment, 2015). In addition to more traditional means, machines that release a targeted poison spray on passing cats (Lysaght, 2017) are being employed in pursuit of the policy's target of removing 2 million feral cats by 2020. Removal plans in places where cats prey upon other harmful alien species (rats, mice, rabbits) should of course anticipate and take into account the overall consequences on native wildlife of cat removal, and ideally incorporate the latter into a comprehensive multi-species eradication strategy (Bergstrom et al., 2009; Nogales et al., 2013; see also Van Heezik et al., 2010).

Many other measures exist that can mitigate or remove some of the impacts of free-ranging domestic cats on wildlife. These include fencing, the use of cat bells, bibs and other anti-predation devices, vaccination, neutering, limiting pets' outdoor hours (including by imposing curfews), limiting the number of cats per owner and agreeing on cat-free zones (e.g. Denny & Dickman, 2010). Such measures may be voluntary or prescribed by regulations. Importantly, however, these various mitigation measures tend to come with limitations impairing their effectiveness. To illustrate, the use of fences to keep cats out of sensitive natural areas or inside their owners' gardens (or out of other people's gardens) can have undesirable side effects, *inter alia* by blocking other species too, and can be costly to erect and maintain at large scales. For example, the use of cat-proof fencing to protect wildlife can be a successful strategy, especially where complete eradication is unfeasible, and is particularly advanced and on the rise in Australia—where the world's longest (44 km) cat-proof fence was completed in 2018 (BBC, 2018). Yet, the few dozen current cat-free exclosures still cover only a fraction of the country (Legge et al., 2017 reported 0.004%). Furthermore, the cost and effort of constructing and maintaining predator-proof fencing can be rapidly undone. For example, a storm in 2012 in Northern Australia damaged part of a fence that had been constructed to protect a population of endangered greater bilbies *Macrotis lagotis*. A small number of feral cats entered the sanctuary and killed the entire sanctuary population, estimated at more than 100 adult bilbies and 150 juveniles, or approximately one-seventh of the entire population of the species (Platt, 2013).

Measures other than fencing tend to address only one or two of domestic cat's wildlife impacts, and typically only to a limited extent. Strict regulation of cat ownership—through *inter alia* obligatory registration, microchipping, neutering and vaccination—and of cat breeding and trade can help prevent new or increased stray and feral populations, but will not resolve predation and fear effects as long as cats are allowed to roam free. Comparable limitations are inherent to trap-neuter-release programs for stray cats (Jessup, 2004; Lepczyk et al., 2010; Longcore, Rich, & Sullivan, 2009). Curfews are also a partial solution at best, and will relieve or burden different species groups depending on the time (Van Heezik et al., 2010). Mitigation of predation can furthermore be pursued by fitting cats with bells, bibs or coloured or sonic collar-mounted devices. Whereas such anti-predation devices have been shown to reduce predation rates, sometimes significantly, none of them is fully effective in preventing all predation even in one species group (e.g. birds); they are less effective for fledgling birds; do not prevent predation of nestlings and eggs; and will increase rather than decrease fear effects; not to mention the limited readiness of owners to fit their pets with these devices; or the practical difficulties involved in fitting them on stray and feral cats (Calver, Thomas, Bradley, & McCutcheon, 2007; Hall, Fontaine, Bryant, & Calver, 2015; Nelson, Evans, & Bradbury, 2005; Pemberton & Ruxton, 2019; Thomas et al., 2012; Van Heezik et al., 2010; Wilson, Okunlola, & Novak, 2015; Woods et al., 2003).

Altogether, it seems that the only effective ways of preventing and addressing the many, and cumulative, impacts of free-ranging domestic cats on wildlife are (a) to ensure that owned cats are not allowed outdoors (other than in cat-proof enclosures or on a leash); and (b) to remove feral and other unowned cats from the landscape to the greatest extent possible. Some hurdles, and possible justifications for not implementing these strategies, are discussed in Section 4.

3 | WHAT THE LAW REQUIRES

Addressing the threats posed by free-ranging domestic cats is clearly in conformity with, and arguably necessary for, the fulfilment of states' political commitment to the achievement of the non-legally binding but high-profile sustainable development goals (SDGs), especially SDG 15 on halting biodiversity loss (United Nations, 2015). The central question for this paper, however, is whether governments are also *required* to address these threats on account of legally binding commitments.

3.1 | Invasive alien species law

Many obligations already exist, which require governments to prevent, mitigate or eliminate the threats posed to native biodiversity by alien species—also commonly referred to as exotic or non-native species. According to a representative definition adopted by the Conference of the Parties (COP) of the 1992 Convention on Biological Diversity (CBD), an 'alien species' is a species introduced through 'human agency, indirect or direct' into areas which do not constitute its 'natural range'; and it will be considered 'invasive' when it threatens native biodiversity (CBD COP Decision VI/23, 2002). As a domesticated species, domestic cats 'have no native range' (Loss & Marra, 2017), and their ubiquitous adverse impacts on native wildlife around the world make them an invasive alien species *pur sang*, and indeed one of the 'world's worst invasive alien species' (Lowe, Browne, Boudjelas, & Poorter, 2000).

Article 8(h) of the CBD imposes an obligation on virtually all the world's governments (with the United States as significant absentee) to '[p]revent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species'. Clearly, in light of current knowledge on the impacts of domestic cats on native biodiversity, this obligation is highly relevant for present purposes, and it has indeed influenced the adoption of national policies and regulations targeting domestic cats (e.g. Riley, 2019). Notably, however, like most CBD obligations, Article 8(h) does not set out an unconditional obligation of result, as it is subject to the wording 'as far as possible and as appropriate'. This may provide parties with a considerable margin of discretion to decide what, in their circumstances, is possible and appropriate. The word 'possible', in particular, may significantly delimit the obligation's scope vis-à-vis the poorest countries. Conversely, discretion is evidently not limitless either. For instance, it would seem difficult for a developed country with a laissez-faire policy on feral and other free-roaming cats to argue that it is fulfilling its obligations under the CBD in good faith.

A range of other international legal instruments set out further requirements of relevance to domestic cats as invasive alien species. For instance, the 2003 (revised) African Convention on the Conservation of Nature and Natural Resources unconditionally requires its parties to 'strictly control the intentional … introduction, in any area, of species which are not native to that area'—again clearly including domestic cats—alongside obligations to strictly control, 'as far as possible', accidental introductions of alien species, and to 'endeavor to eradicate those already introduced where the consequences are detrimental to native species' (Article IX(2)(h)). Another example is the 2001 Agreement on the Conservation of Albatrosses and Petrels (ACAP), requiring its parties to 'take measures to the extent feasible to control and, where possible, eradicate non-native taxa … that are, or may be, detrimental to populations of albatrosses or petrels' (Annex 2, par. 1.4.2; see also Article III(1)(b)). Likewise, parties to the 1995 Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA) must 'prohibit the introduction into the environment of non-native species … which may be detrimental' to the vulnerable waterbird populations targeted by the Agreement; ensure the taking of 'appropriate precautions to avoid the accidental escape' from captivity of such alien species; and 'take measures to the extent feasible and appropriate, including taking', to ensure that already introduced aliens 'do not pose a potential hazard' to waterbird populations (Annex 3, par. 2.5). In addition, parties 'shall establish appropriate measures, ideally to eliminate or otherwise to mitigate the threat from non-native terrestrial predators to breeding migratory waterbirds on islands and islets' (Annex 3, par. 4.3.10). The relevance of all of these provisions to domestic cats and their impacts is evident. Examples from other instruments include the following:

- 1979 Convention on the Conservation of Migratory Species of Wild Animals (CMS), Articles III(4)(c) and V(5)(e);
- 1992 Convention for the Conservation of the Biodiversity and the Protection of Wilderness Areas in Central America, Article 24;
- 1985 Protocol concerning Protected Areas and Wild Flora and Fauna in the Eastern African Region (East Africa Protocol), Article 7;
- 1995 Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (Mediterranean Protocol), Article 13;
- 1979 Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), Article 11(2)(b);
- 1992 European Union (EU) Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive), Article 22(b).

For the sake of brevity, we limit ourselves to listing these provisions, while stressing the existence of differences between them, and the context-dependent nature of their application. An instrument of potential future relevance (as domestic cats are not currently listed) is the 2014 EU Regulation 1143/2014 on the Prevention and Management of the Introduction and Spread of Invasive Alien Species. Many national laws likewise aim to prevent introductions of invasive alien species, and when this fails, to control or eradicate them when feasible.

3.2 | Protected area law

Also relevant are rules concerning protected areas designated for species that are or may be adversely impacted by domestic cats. Such rules occur in national legislation around the world and in many international legal instruments. For instance, controlling feral and other free-ranging cats can be crucial to meet obligations regarding the conservation of birds and other native animals inhabiting wetland sites listed under the 1971 Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention). Similar considerations may apply to sites listed under the 1972 UNESCO Convention concerning the Protection of the World Cultural and Natural Heritage. To illustrate, controlling feral cats on the Galápagos Islands—listed as World Heritage—is apparently part of Ecuador's duty under the Convention to 'do all it can …, to the utmost of its own resources' to ensure the site's protection and conservation (Article 4), and the

same is true of Australia with respect to Macquarie Island (where feral cats have been eradicated along with several other invasive alien species) and Kakadu National Park. Furthermore, the 1991 Agreement on the Conservation of Bats in Europe (EUROBATS) sets out a 'fundamental obligation' to identify bat roosts and other sites of importance for bat conservation, and to 'protect such sites from damage or disturbance' (Article III(2)). To meet this obligation, it can be necessary to safeguard such sites from domestic cats (Ancillotto, Venturi, & Russo, 2019).

Of the many more examples that could be given we single out the especially strict obligations of EU member states regarding the conservation of sites forming part of the Natura 2000 protected area network established under the Habitats Directive and the 2009 EU Directive 2009/147/EC on the Conservation of Wild Birds (Birds Directive). For each site, member state authorities must take 'the necessary conservation measures' which 'correspond to the ecological requirements' of the species for which the site was designated, and also 'take appropriate steps to avoid' any significant 'disturbance' (Habitats Directive, Article 6(1)-(2))—with the latter term covering adverse effects broadly (European Commission, 2000; CJEU Case C-404/09, *Commission v Spain*, 2011). According to the Court of Justice of the EU (CJEU), which is tasked with interpreting and enforcing EU law, the above requirements are obligations of result rather than effort, meaning that member states are expected to do what it takes to conserve or restore the species concerned within the corresponding Natura 2000 areas (e.g. CJEU Case C-117/00, *Commission v Ireland*, 2002). If what it takes is controlling invasive predators, then that is what must be done, as illustrated by a 2007 case in which the CJEU clarified Ireland's obligation to address sandwich tern *Thalasseus sandvicensis* predation by American mink *Neovison vison* (CJEU Case C-418/04, *Commission v Ireland*, 2007). To provide a cat example, feral cats pose a threat to the endangered Zino's petrel *Pterodroma madeira* at its remaining breeding sites on Madeira (BirdLife International, 2018). As these sites have Natura 2000 status, there is no doubt that EU law requires the Portuguese authorities to keep up the current cat trapping programme there or to otherwise prevent predation by cats (see further Trouwborst & Somsen, 2019).

3.3 | Species protection law

A third, and especially significant category concerns legislation requiring the taking of specific actions with regard to certain species of conservation concern. Typically, such species protection rules apply anywhere the species involved occurs, not only within protected areas but also in the broader landscape beyond. The application of such rules may be triggered when the species involved are—actually or potentially—preyed upon or otherwise impacted by domestic cats.

The following international instruments set out conservation obligations of this kind with respect to long lists of designated species, most of which are included in an annex or appendix:

- CMS (Appendix I);
- ACAP (Annex 1);
- 1986 Australia-China Agreement for the Protection of Migratory Birds and their Environment (Annex);
- 1940 Convention on Nature Protection and Wild-Life Preservation in the Western Hemisphere (Annex);
- 1936 Mexico-United States Convention for the Protection of Migratory Birds and Game Mammals (migratory birds listed in Article IV);
- 1990 Protocol concerning Specially Protected Areas and Wildlife in the Wider Caribbean Region (Annex II);
- 1968 African Convention on the Conservation of Nature and Natural Resources (Annex);
- East Africa Protocol (Annex II);
- 2001 Convention on the Conservation of Wildlife and their Natural Habitats in the Countries of the Gulf Cooperation Council (Gulf Wildlife Convention; Appendix II);
- Mediterranean Protocol (Annex II);
- AEWA (Annex 3, Table 1, Column A);
- EUROBATS (Annex 1);
- Bern Convention (Appendix II);
- Habitats Directive (Annex IV);
- Birds Directive (all bird species native to EU member states).

The myriad species to which the conservation obligations in these instruments apply, include many birds, mammals (e.g. bats, rodents, shrews, carnivores), lizards and other species that are subject to, or potentially vulnerable to predation or other impacts by domestic cats.

A few examples may serve to demonstrate how this body of law is relevant to the impact that cats have on native wildlife. Red brown lemurs *Eulemur rufus* are one of the species included in Annex II of the East Africa Protocol, and there is evidence of domestic cats preying on these lemurs (see, e.g. Merson et al., 2019). Consequently, controlling or eradicating cats in areas where these lemurs live may be necessary for Madagascar to comply with its duty under Article 4 of the Protocol to 'take all appropriate measures to ensure the strictest protection of the endangered wild fauna species listed in annex II'.

Similarly, the wildcat features on Appendix II of the Bern Convention and Annex IV of the Habitats Directive. Accordingly, it would seem that addressing the threats posed to Scottish wildcat conservation by hybridization with domestic cats is mandatory for the United Kingdom to meet its obligations to 'take appropriate and necessary legislative and administrative measures to ensure the special protection' of the wildcat (Bern Convention, Article 6), and (until Brexit) to 'take the requisite measures to establish a system of strict protection' for the species (Habitats Directive, Article 12; on the application of these two provisions to hybridization, see Trouwborst, 2014). Regarding the Habitats Directive, the CJEU has repeatedly affirmed that the application of Article 12 requires the adoption of 'coherent and coordinated measures of a preventive nature'

and the implementation of 'concrete and specific protection measures' for each Annex IV species (e.g. Case C-340/10, *Commission v Cyprus*, 2012). The Court recently confirmed that Article 5 of the Birds Directive likewise requires the taking of 'concrete and specific protection measures' for birds (CJEU Case C-441/17, *Commission v Poland*, 2018). This evidently includes measures dealing with threats posed by domestic cats where they arise. Incidentally, where feral cats are removed by shooting in wildcat habitat this should be done with care according to the Guidelines on the Conservation of the Wildcat adopted in 1992 by Bern Convention parties, which indicate that feral cats in such areas should preferably be removed with live traps, and if shot then only by 'specifically authorized personnel' (par. 7–8) so as to avoid the accidental killing of wildcats.

All of the legal instruments listed above also feature variously phrased 'taking' prohibitions, as crucial elements of the protection regimes for listed species. Parties are typically required to prohibit the killing and capturing of animals belonging to listed species, and often also the taking of eggs, the destruction of nests or resting places and disturbance generally. Exceptions to these prohibitions tend to be allowed only when particular, sometimes quite restrictive, conditions are met.

For instance, CMS parties which are range states of any species listed in the Convention's Appendix I—which includes numerous birds—'shall prohibit the taking of animals belonging to such species' (Article III(5)). The term 'taking' in the CMS covers 'taking, hunting, fishing, capturing, harassing, deliberate killing, or attempting to engage in any such conduct' (Article I(1)(i)). Exceptions may be made to these prohibitions only for scientific purposes, to enhance the survival of the protected species, for traditional subsistence use, or if 'extraordinary circumstances so require', with the additional conditions that such exceptions must be 'precise as to content and limited in space and time' and should 'not operate to the disadvantage of the species' (Article III(5)).

The prohibitions required under the EU Birds and Habitats Directives are of particular interest for their broad scope of application, for the way they have been interpreted by the CJEU, and generally for their elevated enforceability and associated considerable practical significance (Born, Cliquet, Schoukens, Misonne, & Van Hoorick, 2015). For *all* bird species naturally occurring in the wild in the EU, Article 5 of the Birds Directive requires member states to prohibit *inter alia*:

1. 'deliberate killing or capture by any method';
2. 'deliberate destruction of, or damage to, their nest and eggs or removal of their nest';
3. 'taking their eggs in the wild' and
4. 'deliberate disturbance of these birds particularly during the period of breeding and rearing, in so far as disturbance would be significant having regard to the objectives of this Directive'.

Member state authorities may derogate from these prohibitions only for a limited number of reasons, and on condition that there is 'no other satisfactory solution' (Article 9(1)). For a range of non-avian species listed in Habitats Directive Annex IV—including various mammals, reptiles and other species susceptible to predation or other impacts from domestic cats—Article 12(1) of the Directive requires a range of prohibitions similar to those under the Birds Directive, which may only be derogated from under strict conditions (Article 16). The CJEU has clarified that member states must not only prohibit the killing, capturing, disturbing and other indicated acts regarding the species concerned but also take all measures necessary to ensure that these prohibitions are not violated in practice (see, e.g. CJEU Case C-103/00, *Commission v Greece*, 2002; Case C-340/10, *Commission v Cyprus*, 2012).

As an interpretive analysis of the Directives in light of CJEU case law shows (Trouwborst & Somsen, 2019), the Court's broad interpretation of the term 'deliberate'—as encompassing unwanted but accepted side effects—brings the act of allowing domestic cats to roam free within the scope of the various prohibitions. For instance, western green lizards *Lacerta viridis/bilineata* and agile frogs *Rana dalmatina* are listed in Annex IV of the Habitats Directive, and are distinctly prone to predation by domestic cats (Mori et al., 2019). The same is true, to provide some further examples, of many bat species (Ancillotto, Serangeli, & Russo, 2013; Ancillotto et al., 2019), with all *Microchiroptera* species listed in Annex IV; and certain dormouse *Gliridae* species (Cortens & Verbeylen, 2007), most of which are in Annex IV. Thus, allowing one's cat to wander free in the habitat of these lizards, frogs, bats or dormice within the EU would apparently involve accepting the possibility of such Annex IV animals being killed, and therefore amount to 'deliberate killing' which the member state in question is bound to prohibit and actually prevent. The same applies with regard to all other Annex IV species vulnerable to domestic cats' impacts, and also to 'all species of naturally occurring birds in the wild state in the European territory of the Member States' (Birds Directive, Article 1). The occurrence of native birds across the full extent of EU member states' territories supports the far-reaching conclusion that all EU member states are presently legally required to ensure that letting cats roam free outdoors is forbidden *and* effectively prevented (Trouwborst & Somsen, 2019). It should be noted, furthermore, that the possible exceptions in the Birds and Habitats Directives offer little scope for derogating from the required prohibitions (Trouwborst & Somsen, 2019).

Similar interpretive issues arise with regard to many other legal instruments, including those listed previously, and many domestic laws too. To provide one illustration of the latter, according to the US Migratory Bird Treaty Act of 1918 'it shall be unlawful at any time, by any means or in any manner, to pursue, hunt, take, capture, kill, attempt to take, capture, or kill, … any migratory bird, any part, nest, or egg of any such bird' (Section 2). The extent to which this taking prohibition may cover actions regarding free-roaming domestic cats continues to be a matter of debate, as do questions regarding the duties of authorities to remove cats posing a threat to birds, both under this Act and the Endangered Species Act of 1973 (Sanchez, 2018).

4 | APPLYING THE LAW

The above analysis demonstrates the existence of a significant number of international legal obligations to address the threats posed by domestic cats to wildlife. Some of these obligations leave considerable discretion to individual countries, whereas others are quite unconditional and far-reaching. The exact set of obligations incumbent on a particular government depends on which legal instruments are in force for the country involved. Determining the degree to which a government is complying with international wildlife law, for present purposes, would require a focused analysis of the applicable obligations in relation to the country's domestic legislation, policy and actions, and the situation 'on the ground' as regards domestic cats and native wildlife. This is not the place to attempt such analyses. Some general observations appear warranted, however. Meaningful cat control and eradication strategies are being pursued in various countries, and this evidently appears to be in line with the international obligations reviewed above. Yet, in many other places feral and stray cat populations are largely tolerated, and hardly anywhere do domestic regulations forbid cat owners from letting their pets roam free outdoors. This raises the suspicion that, overall, governments' compliance with the international legal obligations identified above is partial at best, and that a considerable blind spot persists when it comes to applying nature conservation obligations to domestic cats.

As will be recalled, the scope of various obligations—and therefore the degree of (non-)compliance—partly hinges on what is 'possible', 'feasible' and/or 'appropriate'. While the EU law obligations discussed above do not provide authorities with discretion in any of these regards, the reasons why they are nevertheless not fully complied with may also revolve around considerations of possibility and appropriateness (Trouwborst & Somsen, 2019). It seems helpful for present purposes, therefore, to identify and concisely assess such considerations.

4.1 | Practical, economic and legal feasibility

The financial cost and technical feasibility of measures to address the wildlife impacts of domestic cats are such considerations and, depending on the specific circumstances, could conceivably inform the interpretation of what is 'possible' or 'feasible' in connection with states' obligations under the CBD, ACAP or other treaties.

To illustrate, propositions to eradicate feral cats, for instance from an entire island, are likely to face questions regarding their technical and practical feasibility; their financial costs; and potential obstacles arising from domestic law, for instance animal welfare or hunting regulations (see, e.g. Takahashi, 2004). We also note the potential applicability of requirements concerning the assessment of the potential environmental impacts of large-scale eradication efforts. Regarding technical feasibility, as Nogales et al. (2013, p. 808) observe, methodological advances like aerial broadcast baiting techniques are making feral cat eradications 'increasingly feasible on larger and more complex islands'. Successful examples of island eradication projects demonstrate important lessons for future eradication efforts, including opportunities to overcome both technical and practical feasibility concerns (e.g. Bergstrom et al., 2009; Towns, West, & Broome, 2012). Continental-scale eradication projects may present a far greater challenge for establishing technical and practical feasibility (and thus for what is 'possible'). In such cases, cat eradications could focus more productively on priority areas such as biodiversity hotspots, critical species habitat or areas of particular vulnerability to the impacts of cats (see, e.g. Department of the Environment, 2015). Regarding economic feasibility, even if costs indeed tend to be high for such campaigns (Oppel, Beaven, Bolton, Vickery, & Bodey, 2010), provided they are not entirely prohibitive it should be realized that the benefits of eradication 'accumulate in perpetuity', assuming that cats are prevented from re-establishing (Nogales et al., 2013, p. 805). Regarding any obstacles posed by national legislation to eradication or other measures, it is important to note the basic principle of public international law that incompatibility with domestic law can never serve as a justification for not complying with international obligations (Vienna Convention on the Law of Treaties, Article 27). Theoretically, conflict could also arise with other international obligations, although this appears unlikely. Even a dedicated pet welfare treaty like the 1987 European Convention on the Protection of Pet Animals indicates that 'nothing in this Convention shall affect the implementation of other instruments for the protection of animals or for the conservation of threatened wild species' (Article 2(3); see also Trouwborst & Somsen, 2019).

When determining what actions come within the scope of states' CBD obligation to, 'as far as possible and as appropriate … control or eradicate those alien species which threaten ecosystems, habitats or species' (Article 8(h)), due account should arguably be taken of the best available scientific information. An example of a study which appears eminently suited to inform the application of this treaty obligation is Nogales et al. (2013), identifying 12 islands where eradication appears feasible in terms of the islands' size and human population ('possible' sensu Article 8) and where the imminent extinction of 12 critically endangered species could be prevented by eradicating cats (apparently making such eradications 'appropriate' sensu Article 8). Arguably, the greater the risks posed by domestic cats to native wildlife are, the stronger the arguments would need to be for a CBD party to claim that addressing those risks would not be appropriate.

It can clearly be maintained that curbing the threats posed by *pet* cats is also necessary to comply with CBD Article 8(h) and similar provisions, requiring governments to exclude, control or eradicate certain alien species. Prohibiting cat owners from allowing their pets outdoors without supervision is a mere act of legislation, which does not face anything like the practical feasibility issues associated with feral cat eradication attempts. The effective enforcement of such prohibitions will likely require allocation of resources, particularly in the first period after enactment. Once behaviour change has set in, the mechanisms of habit and social control can

be expected to lessen the demands on law enforcement and help ensure any such ban is complied with. A parallel can be drawn, for instance, with national bans on smoking in public places.

A comparison of these feasibility issues with other drivers of biodiversity loss is instructive. Effective solutions to the free-ranging cat problem are evidently much easier to attain than the transition of mainstream agriculture, fisheries and logging into sustainable activities, addressing climate change, or other 'transformative changes' called for in the 2019 global assessment by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Díaz et al., 2019; IPBES, 2019). Compared to such issues, free-ranging cats are also a 'problem that can be reversed in a relatively short time' (Marra & Santella, 2016, p. 172), and with rewards in terms of biodiversity recovery that can be expected to be significant.

4.2 | Scientific uncertainty

Uncertainty regarding the precise impacts of domestic cats on wildlife is another conceivable motive for authorities to refrain from undertaking decisive action (Calver, Grayson, Lilith, & Dickman, 2011; Lilith, Calver, Styles, & Garkaklis, 2006; Loss & Marra, 2017). A general principle specifically devised to guide decision-making under uncertainty is the precautionary principle (or precautionary approach). According to this principle, which has become a fundamental feature of international and domestic wildlife law, preventive or remedial action is warranted where there are reasonable grounds for concern that significant environmental harm will result in the absence of such action, even if some uncertainty persists (e.g. CBD, Preamble; 2003 African Convention, Article IV; AEWA, Article II; ACAP, Article II; 2007 Treaty on the Functioning of the European Union, Article 191). The precautionary principle gives the benefit of any doubt to wildlife conservation (Trouwborst, Loveridge, & Macdonald, 2019). To provide one example, the CBD COP has determined that '[l]ack of scientific certainty about the various implications' of an invasive alien species for biodiversity 'should not be used as a reason for postponing or failing to take appropriate eradication, containment and control measures' (CBD COP Decision VI/23, 2002). Thus, in light of the vast evidence concerning the impacts of domestic cats that has accumulated in recent years, any remaining uncertainty regarding the details of such impacts does not provide a valid justification for failing to effectively address them (see also Calver et al., 2011; Lilith et al., 2006; Loss & Marra, 2017).

4.3 | The interests of domestic cats

Another candidate reason for inaction regarding free-ranging domestic cats concerns the interests and welfare of the cats themselves, for instance with a view to the obesitas or stress that might result from indoor confinement of pet cats without sufficient space and stimuli (Abbate, 2019; Palmer & Sandøe, 2014; Rochlitz, 2005). First, however, it is not at all clear that letting cats roam free is, overall, in their best interest, given the risks of being run over, killed by larger animals (e.g. dogs or coyotes *Canis latrans*), contracting disease, getting poisoned, and the stress and fights resulting from high cat densities—and increasing numbers of owners keep their cats permanently indoors for precisely such reasons (Egenvall et al., 2010; Jessup, 2004; Moreau, Cathelain, & Lacheretz, 2003; Palmer & Sandøe, 2014; PDSA (The People's Dispensary for Sick Animals), 2016; Rochlitz, 2004).

Second, and more to the point for present purposes, even when assuming that roaming free outdoors would be in domestic cats' best interest, it is still difficult to appreciate on what objective grounds the interests of cats should be considered to outweigh the interests of the wild animals impacted by them—for example, the interest of a cat in realizing its instinctive urge to pursue, catch and kill prey versus the interest of a bird in avoiding stress, fear, pain and death, or the interest of a population or species in surviving (see also Chapron, Epstein, & López-Bao, 2019). (Incidentally, a desire to roam free is evidently not exclusive to cats, and many dogs, parrots, chickens, pigs, snakes and other pets would gladly embrace any opportunity to wander off and explore by themselves. Yet, in many countries, they are denied this freedom by national laws which require pets to be kept under control of their owners at all times. Again, it is not clear on what grounds domestic cats should someway be an exception to this rule).

Within the current context, at any rate, considerations of domestic cat welfare cannot be weighted so heavily as to narrow the scope of the various obligations imposed by international wildlife law. That is, cat welfare considerations would not appear to make free-ranging cat management 'inappropriate' in terms of Article 8 of the CBD, or somehow justify non-compliance. Preferential treatment for domestic cats as compared to wild organisms would also appear to sit uneasily with the conviction of the United Nations General Assembly that 'every form of life is unique, warranting respect *regardless of its worth to man*' (1982 World Charter for Nature, A/RES/37.7, emphasis added). The CBD and the Bern Convention likewise profess this 'intrinsic value' of biodiversity (CBD, Preamble) and wild fauna (Bern Convention, Preamble), respectively.

For feral and other unowned cats, there is evident scope for taking animal welfare considerations into account in the choice of measures used in eradication and control efforts required by international and domestic wildlife law—a case in point being the increasing availability of more humane toxins, including those with high target specificity and which act quickly, reducing the suffering experienced by an affected animal (Marra & Santella, 2016; Nogales et al., 2013).

4.4 | The interests of cat owners

Broadly similar considerations apply with regard to the wishes and preferences of cat owners and other people taking an interest in

domestic cats, such as caretakers of free-ranging cat colonies. Letting cats roam free, whether for pest control purposes or in the perceived interests of cats themselves, is an entrenched habit around the world. Studies show that many cat owners are opposed to banning the free roaming of domestic cats, although the degree of this opposition varies between countries (Ash & Adams, 2003; Crowley et al., 2019; Lilith et al., 2006; McDonald, Maclean, Evans, & Hodgson, 2015; Thomas et al., 2012). Several UK studies are particularly illustrative. According to Crowley et al. (2019, p. 18), cat owners 'rarely perceived a strong individual responsibility for preventing or reducing' predation by their pets. Likewise, McDonald et al. (2015, p. 2751) found that many owners 'do not accept that cats are harmful', including owners of highly predatory cats, and moreover found that providing owners with ecological information regarding cats' wildlife impacts does little or nothing to change their views. In various countries, domestic cat management has become a rather contentious and emotive issue, and some opponents of restricting the movement of pet cats and removing stray and feral populations have resorted to disinformation campaigns (Loss & Marra, 2018) and threats of violence against policymakers and scientists (Loss et al.,2018; Marra & Santella, 2016; and personal experience of the present paper's first author after publication of Trouwborst & Somsen, 2019).

Whereas letting domestic cats roam free may be a strong habit (e.g. Crowley et al., 2019), it is also clearly harmful. Many other strong habits in many places have changed in the past, including through prohibitions, after their adverse impacts became apparent. Examples include emptying chamber pots into the street, spraying DDT, driving cars when under influence of alcohol, and smoking in workplaces and certain public places (Marra & Santella, 2016). In these and numerous other instances, the freedom of individual members of society to do as they wish (farmers, drivers, smokers) have been restricted in the interest of society at large.

Again, it is difficult to see why the harmful habit of letting cats roam free should be treated any differently. In particular, it is unclear on what grounds the private interests of those wishing to let domestic cats roam outdoors for whatever reason should outweigh the core public interest of biodiversity conservation (and that of public health); the interests of the impacted wild animals themselves (Chapron et al., 2019); or indeed the private interests of neighbours who wish to keep their properties and immediate surroundings free from digging, defecating, urinating, scratching, crying and yowling cats, and from dangerous pathogens, or quite simply do not wish to witness the stress, suffering (e.g. McRuer, Gray, Horne, & Clark, 2017) and death caused by these non-native predators to other animals. A comparison with dogs is instructive. In various parts of the world, free-roaming dogs are still largely tolerated despite their adverse impacts on biodiversity (e.g. Doherty et al., 2017; Gompper, 2014; Young, Olson, Reading, Amgalanbaatar, & Berger, 2011), public safety concerns and different types of nuisance. In an increasing number of places, however, owners are expressly forbidden from letting their dogs roam free—not only in residential areas but also in natural areas and the wider countryside—and active enforcement of such regulations occurs, albeit to different degrees (e.g. Miller, Ritchie, & Weston, 2014; Parsons et al., 2016; Schneider, Maguire, Whisson, & Weston, 2019).

The reluctance of administrators and legislators to effectively address the free-ranging domestic cat problem, or even to expressly recognize it as a problem, may be motivated in part by the anticipated unpopularity of such actions with parts of their constituencies (Marra & Santella, 2016; Trouwborst & Somsen, 2019). To illustrate, the exclusion of feral cats from at least the first stage of New Zealand's policy to rid the country of invasive predators (Russell, Innes, Brown, & Byrom, 2015) was 'very likely because of anticipated strong social opposition to their control' (Rouco, Torre-Ceijas, Martín-Collado, & Byrom, 2017). Insofar as such unpopularity considerations play a role here and in other countries, this would offer an *explanation* for the current pervasive failure to comply with international wildlife law in this regard, but evidently not a legally valid *justification* for such non-compliance.

5 | CONCLUSIONS

Biodiversity loss is one of the most pressing contemporary global crises (IPBES, 2019). It is also well established that free-ranging cats pose a significant threat to biodiversity conservation and restoration worldwide, and that remedying this threat is relatively easy when compared to other drivers of biodiversity loss. The above analysis of international wildlife law carried out in light of the available knowledge on domestic cats' impacts shows that many national authorities around the world are currently actually *required*, under public international law, to adopt and implement policies aimed at preventing, reducing or eliminating the biodiversity impacts of free-ranging domestic cats, by (a) removing feral and other unowned cats from the landscape to the greatest extent possible and (b) restricting the outdoor access of owned cats. Furthermore, the above assessment of factors that might influence this implementation—regarding feasibility, uncertainty, and the interests of cats and cat owners—demonstrates that these provide little justification for failing to take effective preventive and remedial action.

Clearly, what is needed to effectively address the biodiversity impacts of domestic cats is not so much the negotiation of some new treaty or other ways of reforming international wildlife law, but foremost the consistent implementation of the obligations it already imposes.

Finally, whereas we have tried to be as comprehensive as possible, this paper necessarily provides little more than an initial mapping and exploration of the relevant issues. There remains ample scope for further and more in-depth research regarding specific legal instruments, wildlife species, countries, and possibilities to improve the law's application, from raising awareness of the various obligations through to their use in litigation.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

E.M.C. conceived the idea, and A.T. and E.M.C. jointly designed the study. All authors contributed research. A.T. wrote a first incomplete draft of the manuscript, P.C.M. drafted substantial additions, and all authors contributed to subsequent versions. All authors gave final approval for publication.

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REFERENCES

Abbate, C. E. (2019). A defense of free-roaming cats from a hedonist account of feline well-being. *Acta Analytica*. https://doi.org/10.1007/s12136-019-00408-x

Aguirre, A. A., Longcore, T., Barbieri, M., Dabritz, H., Hill, D., Klein, P. N., … Sizemore, G. C. (2019) The one health approach to toxoplasmosis: Epidemiology, control, and prevention strategies. *EcoHealth*, *16*, 378–390. https://doi.org/10.1007/s10393-019-01405-7

Ancillotto, L., Serangeli, M. T., & Russo, D. (2013). Curiosity killed the bat: Domestic cats as bat predators. *Mammalian Biology*, *78*, 369–373. https://doi.org/10.1016/j.mambio.2013.01.003

Ancillotto, L., Venturi, G., & Russo, D. (2019). Presence of humans and domestic cats affects bat behaviour in an urban nursery of greater horseshoe bats (*Rhinolophus ferrumequinum*). *Behavioural Processes*, *164*, 4–9. https://doi.org/10.1016/j.beproc.2019.04.003

Ash, S. J., & Adams, C. E. (2003). Public preferences for free-ranging domestic cat (*Felis catus*) management options. *Wildlife Society Bulletin*, *31*, 334–339.

Baker, P. J., Molony, S., Stone, E., Cuthill, I. C., & Harris, S. (2008). Cats about town: Is predation by free-ranging pet cats (*Felis catus*) likely to affect urban bird populations? *Ibis*, *150*, 86–99. https://doi.org/10.1111/j.1474-919X.2008.00836.x

Balbontín, J., & Møller, A. P. (2015). Environmental conditions during early life accelerate the rate of senescence in a short-lived passerine bird. *Ecology*, *96*, 948–959. https://doi.org/10.1890/14-1274.1

Balogh, A. L., Ryder, T. B., & Marra, P. P. (2011). Population demography of Gray Catbirds in the suburban matrix: Sources, sinks and domestic cats. *Journal of Ornithology*, *152*, 717–726. https://doi.org/10.1007/s10336-011-0648-7

Barratt, D. G. (1998). Predation by house cats, *Felis catus* (L.), in Canberra, Australia. II. Factors affecting the amount of prey caught and estimates of the impact on wildlife. *Wildlife Research*, *25*, 475–487. https://doi.org/10.1071/WR97026

BBC. (2018). Australian cat-proof fence protects endangered species. BBC News, 24 May 2018. https://www.bbc.com/news/world-australia-44235185

Beaumont, M., Barratt, E. M., Gottelli, D., Kitchener, A. C., Daniels, M. J., Pritchard, J. K., & Bruford, M. W. (2001). Genetic diversity and introgression in the Scottish wildcat. *Molecular Ecology*, *10*, 319–336. https://doi.org/10.1046/j.1365-294X.2001.01196.x

Beckerman, A. P., Boots, M., & Gaeston, K. J. (2007). Urban bird declines and the fear of cats. *Animal Conservation*, *10*, 320–325. https://doi.org/10.1111/j.1469-1795.2007.00115.x

Bellard, C., Genovesi, P., & Jeschke, J. M. (2016). Global patterns in threats to vertebrates by biological invasions. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1823), 20152454. https://doi.org/10.1098/rspb.2015.2454

Bergstrom, D. M., Lucieer, A., Kiefer, K., Wasley, J., Belbin, L., Pedersen, T. K., & Chown, S. L. (2009). Indirect effects of invasive species removal devastate World Heritage Island. *Journal of Applied Ecology*, *46*, 73–81. https://doi.org/10.1111/j.1365-2664.2008.01601.x

Beutel, T., Reineking, B., Tiesmeyer, A., Nowak, C., & Heurich, M. (2017). Spatial patterns of co-occurrence of the European wildcat *Felis silvestris silvestris* and domestic cats *Felis silvestris* in the Bavarian Forest National Park. *Wildlife Biology*, wlb.00248. https://doi.org/10.2981/wlb.00284

BirdLife International. (2018). *Pterodroma madeira*. The IUCN Red List of Threatened Species, 2018, e.T22698062A132622973.

Blancher, P. P. (2013). Estimated number of birds killed by house cats (*Felis catus*) in Canada. *Avian Conservation Ecology*, *8*, 3. https://doi.org/10.5751/ACE-00557-080203

Bonnaud, E., Medina, F. M., Vidal, E., Nogales, M., Tershy, B., Zavaleta, E., … Horwath, S. V. (2011). The diet of feral cats on islands: A review and a call for more studies. *Biological Invasions*, *13*, 581–603. https://doi.org/10.1007/s10530-010-9851-3

Bonnington, C., Gaston, K. J., & Evans, K. L. (2013). Fearing the feline: Domestic cats reduce avian fecundity through trait-mediated indirect effects that increase nest predation by other species. *Journal of Applied Ecology*, *50*, 15–24. https://doi.org/10.1111/1365-2664.12025

Born, C., Cliquet, A., Schoukens, H., Misonne, D., & Van Hoorick, G. (Eds.). (2015). *The Habitats Directive in its EU environmental law context: European nature's best hope?* Abingdon/New York, NY: Routledge.

Brown, M. A., Cunningham, M. W., Roca, A. L., Troyer, J. L., Johnson, W. E., & O'Brien, S. J. (2008). Genetic characterization of feline leukemia virus from Florida panthers. *Emerging Infectious Diseases*, *14*, 252–259. https://doi.org/10.3201/eid1402.070981

Calver, M. C., Grayson, J., Lilith, M., & Dickman, C. R. (2011). Applying the precautionary principle to the issue of the impacts by pet cats on urban wildlife. *Biological Conservation*, *144*, 1895–1901. https://doi.org/10.1016/j.biocon.2011.04.015

Calver, M., Thomas, S., Bradley, S., & McCutcheon, H. (2007). Reducing the rate of predation on wildlife by pet cats: The efficiency and practicality of collar-mounted pounce protectors. *Biological Conservation*, *137*, 341–348. https://doi.org/10.1016/j.biocon.2007.02.015

Calvert, A. M., Bishop, C. A., Elliot, R. D., Krebs, E. A., Kydd, T. M., Machtans, C. S., & Robertson, G. J. (2013). A synthesis of human-related avian mortality in Canada. *Avian Conservation Ecology*, *8*, 11. https://doi.org/10.5751/ACE-00581-080211

Campbell, K. J., Harper, G., Algar, D., Hanson, C. C., Keitt, B. S., & Robinson, S. (2011). Review of feral cat eradications on islands. In C. R. Veitch, M. N. Clout, & D. R. Towns (Eds.), *Island invasives: Eradication and management* (pp. 37–46). Gland & Auckland: IUCN & CBB.

Chan, W. Y., Hoffman, A. A., & Van Oppen, M. J. H. (2019). Hybridization as a conservation management tool. *Conservation Letters*, *12*, e12652. https://doi.org/10.1111/conl.12652

Chapron, G., Epstein, Y., & López-Bao, J. V. (2019). A rights revolution for nature. *Science*, *363*, 1392–1393. https://doi.org/10.1126/science.avv56601

Coleman, J. S., & Temple, S. A. (1993). Rural residents' free-ranging domestic cats: A survey. *Wildlife Society Bulletin*, *21*, 381–390.

Coman, B. J., & Brunner, H. (1972). Food habits of the feral house cat in Victoria. *Journal of Wildlife Management*, *36*, 848–853. https://doi.org/10.2307/3799439

Conrad, P. A., Miller, M. A., Kreuder, C., James, E. R., Mazet, J., Dabritz, H., … Grigg, M. E. (2005). Transmission of *Toxoplasma*: Clues from the study of sea otters as sentinels of *Toxoplasma gondii* flow into the marine environment. *International Journal for Parasitology*, *35*, 1155–1168. https://doi.org/10.1016/j.ijpara.2005.07.002

Cortens, J., & Verbeylen, G. (2007). *Verspreiding van en beschermingsmaatregelen voor de eikelmuis (Eliomys quercinus) in Vlaams-Brabant*. Mechelen, Belgium: Natuurpunt Studie.

Courchamp, F., Chapuis, J. L., & Pascal, M. (2003). Mammal invaders on islands: Impact, control and control impact. *Biological Review*, *78*, 347–383. https://doi.org/10.1017/S1464793102006061

Crooks, K. R., & Soulé, M. E. (1999). Mesopredator release and avifaunal extinctions in a fragmented system. *Nature*, *400*, 563–566. https://doi.org/10.1038/23028

Crowley, S. L., Cecchetti, M., & McDonald, R. A. (2019). Hunting behaviour in domestic cats: An exploratory study of risk and responsibility among cat owners. *People and Nature*, *1*, 18–30. https://doi.org/10.1002/pan3.6

Denny, E. A., & Dickman, C. (2010). *Review of cat ecology and management strategies in Australia*. Canberra, Australia: Invasive Animals Cooperative Research Centre.

Department of the Environment. (2015). *Threat abatement plan for predation by feral cats*. Canberra, Australia: Department of the Environment.

Díaz, S., Settele, J., Brondízio, E. S., Ngo, H. T., Agard, J., Arneth, A., … Zayas, C. N. (2019). Pervasive human-driven decline of life on Earth Points to the need for transformative change. *Science*, *366*, eaax3100. https://doi.org/10.1126/science.aax3100

Dilley, B. J., Schramm, M., & Ryan, P. G. (2017). Modest increases in densities of burrow-nesting petrels following the removal of cats (*Felis catus*) from Marion Island. *Polar Biology*, *40*, 625–637. https://doi.org/10.1007/s00300-016-1985-z

Doherty, T. S., Dickman, C. R., Glen, A. S., Newsome, T. M., Nimmo, D. G., Ritchie, E. G., … Wirsing, A. J. (2017). The global impacts of domestic dogs on threatened vertebrates. *Biological Conservation*, *210*, 56–59. https://doi.org/10.1016/j.biocon.2017.04.007

Doherty, T. S., Glen, A. S., Nimmo, D. G., Ritchie, E. G., & Dickman, C. R. (2016). Invasive predators and global biodiversity loss. *Proceedings of the National Academy of Sciences of the United States of America*, *113*, 11261–11265. https://doi.org/10.1073/pnas.1602480113

Driscoll, C. A., Menotti-Raymond, M., Roca, A. L., Hupe, K., Johnson, W. E., Geffen, E., … Macdonald, D. W. (2007). The near Eastern origin of cat domestication. *Science*, *317*, 519–523. https://doi.org/10.1126/science.1139518

Dubey, J. P. (2002). A review of toxoplasmosis in wild birds. *Veterinary Parasitology*, *106*, 121–153. https://doi.org/10.1016/S0304-4017(02)00034-1

Egenvall, A., Bonnett, B. N., Häggström, J., Ström Holst, B., Möller, L., & Nødtvedt, A. (2010). Morbidity of insured Swedish cats during 1999–2006 by age, breed, sex, and diagnosis. *Journal of Feline Medicine and Surgery*, *12*, 948–959. https://doi.org/10.1016/j.jfms.2010.08.008

European Commission. (2000). *Managing Natura 2000 sites: The provisions of Article 6 of the 'Habitats' Directive 92/43/EEC*. Brussels: European Commission.

Fancourt, B. A. (2015). Making a killing: Photographic evidence of predation of a Tasmanian pademelon (*Thylogale billardierii*) by a feral cat (*Felis catus*). *Australian Mammalogy*, *37*, 120–124. https://doi.org/10.1071/AM14044

Fitzpatrick, B. M., Ryan, M. E., Johnson, J. R., Corush, J., & Carter, E. T. (2015). Hybridization and the species problem in conservation. *Current Zoology*, *61*, 206–216. https://doi.org/10.1093/czoolo/61.1.206

Frank, A. S. K., Johnson, C. N., Potts, J. M., Fisher, A., Lawes, M. J., Woinarski, J. C. Z., … Legge, S. (2014). Experimental evidence that feral cats cause local extirpation of small mammals in Australia's tropical savannas. *Journal of Applied Ecology*, *51*, 1486–1493. https://doi.org/10.1111/1365-2664.12323

Freeberg, T. M., Book, D. L., & Weiner, R. L. (2016). Foraging and calling behavior of Carolina chickadees (*Poecile carolinensis*) in response to the head orientation of potential predators. *Ethology*, *122*, 10–19. https://doi.org/10.1111/eth.12438

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

George, W. G. (1974). Domestic cats as predators and factors in winter shortages of raptor prey. *Wilson Bulletin*, *86*, 384–396.

Gerhold, R. W., & Jessup, D. A. (2013). Zoonotic diseases associated with free-roaming cats. *Zoonoses and Public Health*, *60*, 189–195. https://doi.org/10.1111/j.1863-2378.2012.01522.x

Gompper, M. E. (Ed.). (2014). *Free-ranging dogs and wildlife conservation*. Oxford, UK: Oxford University Press.

Hackländer, K., Schneider, S., & Lanz, J. D. (2014). *Einfluss von Hauskatzen auf die heimische Fauna und mögliche Managementmaβnahmen*. *Institut für Wildbiologie und Jagdwirtschaft report*. Vienna, Austria: Universität für Bodenkultur.

Hall, C. M., Fontaine, J. B., Bryant, K. A., & Calver, M. C. (2015). Assessing the effectiveness of the Birdsbesafe® anti-predation collar cover in reducing predation on wildlife by pet cats in Western Australia. *Applied Animal Behaviour Science*, *173*, 40–51. https://doi.org/10.1016/j.applanim.2015.01.004

Hartley, W. J., & Dubey, J. P. (1991). Fatal toxoplasmosis in some native Australian birds. *Journal of Veterinary Diagnostic Investigation*, *3*, 167–169. https://doi.org/10.1177/104063879100300213

Hubbard, A. L., McOris, S., Jones, T. W., Boid, R., Scott, R., & Easterbee, N. (1992). Is survival of European wildcats *Felis silvestris* in Britain threatened by interbreeding with domestic cats? *Biological Conservation*, *61*, 203–208. https://doi.org/10.1016/0006-3207(92)91117-B

Hughes, B. J., Martin, G. R., & Reynolds, S. J. (2008). Cats and seabirds: Effects of feral domestic cat *Felis silvestris catus* eradication on the population of sooty terns *Onychoprion fuscata* on Ascension Island, South Atlantic. *Ibis*, *150*(suppl. 1), 122–131. https://doi.org/10.1111/j.1474-919X.2008.00838.x

Hunter, L. (2015). *Wild cats of the world*. London, UK: Bloomsbury.

IPBES. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES/7/10/Add.1, 29 May 2019.

Jessup, D. A. (2004). The welfare of feral cats and wildlife. *Journal of the American Veterinary Medical Association*, *225*, 1377–1383. https://doi.org/10.2460/javma.2004.225.1377

Kays, R. W., & DeWan, A. A. (2004). Ecological impact of inside/outside house cats around a suburban nature preserve. *Animal Conservation*, *7*, 273–283. https://doi.org/10.1017/S1367943004001489

Kittie, A. M., & Watson, A. C. (2014). Rusty-spotted cat in Sri Lanka: Observations of an arid zone population. *Cat News*, *40*, 17–19.

Knol, W. (2015). *Verwilderde huiskatten: Effecten op de natuur in Nederland*. KNJV report nr. 15-1. Amersfoort, The Netherlands: Koninklijke Nederlandse Jagersvereniging.

Krauze-Gryz, D., Gryz, J., & Żmihorski, M. (2019). Cats kill millions of vertebrates in Polish farmland annually. *Global Ecology and Conservation*, *17*, e00516. https://doi.org/10.1016/j.gecco.2018.e00516

Krauze-Gryz, D., Zmihorski, M., & Gryz, J. (2017). Annual variation in prey composition of domestic cats in rural and urban environment. *Urban Ecosystems*, *20*, 945–952. https://doi.org/10.1007/s11252-016-0634-1

Kreuder, C., Miller, M. A., Jessup, D. A., Lowenstine, L. J., Harris, M. D., Ames, J. A., … Mazet, J. A. (2003). Patterns of mortality in southern sea otters (*Enhydra lutris nereis*) from 1998–2001. *Journal of Wildlife Diseases*, *39*, 495–509. https://doi.org/10.7589/0090-3558-39.3.495

Legge, S., Murphy, B. P., McGregor, H., Woinarski, J., Augusteyn, J., Ballard, G., … Zewe, F. (2017). Enumerating a continental-scale threat: How many feral cats are in Australia? *Biological Conservation*, *206*, 293–303. https://doi.org/10.1016/j.biocon.2016.11.032

Lepczyk, C. A., Dauphiné, N., Bird, D. M., Conant, S., Cooper, R. J., Duffy, D. C., … Temple, S. A. (2010). *Conservation Biology*, *24*, 627–629. https://doi.org/10.1111/j.1523-1739.2009.01426.x

Li, B., Belasen, A., Pafilis, P., Bednekoff, P., Foufopoulos, J. (2014). Effects of feral cats on the volution of anti-predator behaviours in island reptiles: Insights from an ancient introduction. *Proceedings of the Royal Society B: Biological Sciences*, *281*, 20140339. https://doi.org/10.1098/rspb.2014.0339

Lilith, M., Calver, M., Styles, I., & Garkaklis, M. (2006). Protecting wildlife from predation by owned domestic cats: Application of a precautionary approach to the acceptability of proposed cat regulations. *Austral Ecology*, *31*, 176–189. https://doi.org/10.1111/j.1442-9993.2006.01582.x

Longcore, T., Rich, C., Mineau, P., MacDonald, B., Bert, D. G., Sullivan, L. M., … Drake, D. (2012). An estimate of avian mortality at communication towers in the United States and Canada. *PLoS ONE*, *7*, e34025. https://doi.org/10.1371/journal.pone.0034025

Longcore, T., Rich, C., & Sullivan, L. M. (2009). Critical assessment of claims regarding management of feral cats by trap-neuter-return. *Conservation Biology*, *23*, 887–894. https://doi.org/10.1111/j.1523-1739.2009.01174.x

Loss, S. R., & Marra, P. P. (2017). Population impacts of free-ranging domestic cats on mainland vertebrates. *Frontiers in Ecology and the Environment*, *15*, 502–509. https://doi.org/10.1002/fee.1633

Loss, S. R., & Marra, P. P. (2018). Merchants of doubt in the free-ranging cat conflict. *Conservation Biology*, *32*, 265–266. https://doi.org/10.1111/cobi.13085

Loss, S. R., Will, T., Longcore, T., & Marra, P. P. (2018). Responding to misinformation and criticisms regarding United States cat predation estimates. *Biological Invasions*, *20*, 3385–3396. https://doi.org/10.1007/s10530-018-1796-y

Loss, S. R., Will, T., & Marra, P. P. (2013). The impact of free-ranging domestic cats on wildlife of the United States. *Nature Communications*, *4*, 1396. https://doi.org/10.1038/ncomms2380

Loss, S. R., Will, T., & Marra, P. P. (2015). Direct mortality of birds from anthropogenic causes. *Annual Review of Ecology, Evolution, and Systematics*, *46*, 99–120. https://doi.org/10.1146/annurev-ecolsys-112414-054133

Lowe, S., Browne, M., Boudjelas, S., & De Poorter, M. (2000). *100 of the world's worst invasive alien species: A selection from the Global Invasive Species Database*. Auckland: Invasive Species Specialist Group.

Loyd, K. A. T., Hernandez, S. M., Carroll, J. P., Abernathy, K. J., & Marshall, G. J. (2013). Quantifying free-roaming domestic cat predation using animal-borne video cameras. *Biological Conservation*, *160*, 183–189. https://doi.org/10.1016/j.biocon.2013.01.008

Lysaght, G. (2017). Fighting feral cats with lasers and poison spray in remote Australia. ABC News. https://www.abc.net.au/news/2017-12-18/feral-cat-management-in-the-apy-lands/9269240

McDonald, J. L., Maclean, M., Evans, M. R., & Hodgson, D. J. (2015). Reconciling actual and perceived rates of predation by domestic cats. *Ecology and Evolution*, *5*, 2745–2753. https://doi.org/10.1002/ece3.1553

Macdonald, D. W., Yamaguchi, N., Kitchener, A. C., Daniels, M., Kilshaw, K., & Driscoll, C. (2010). Reversing cryptic extinction: The history, present, and future of the Scottish wildcat. In D. W. Macdonald & A. J. Loveridge (Eds.), *Biology and conservation of wild felids* (pp. 471–491). Oxford, UK: Oxford University Press.

Mahlaba, T. A. M., Monadjem, A., McCleery, R., & Belmain, S. R. (2017). Domestic cats and dogs create a landscape of fear for pest rodents around rural homesteads. *PLoS ONE*, *12*, e0171593. https://doi.org/10.1371/journal.pone.0171593

Marlow, N. J., Thomas, N. D., Williams, A. A. E., Macmahon, B., Lawson, J., Hitchen, Y., … Berry, O. (2015). Cats (*Felis catus*) are more abundant and are the dominant predator of woylies (*Bettongia penicillata*) after sustained fox (*Vulpes vulpes*) control. *Australian Journal of Zoology*, *63*, 18–27. https://doi.org/10.1071/ZO14024

Marra, P., & Santella, C. (2016). *Cat wars: The devastating consequences of a cuddly killer*. Princeton, NJ and Oxford, UK: Princeton University Press.

Maxwell, S. L., Fuller, R. A., Brooks, T. M., & Watson, J. E. M. (2016). Biodiversity: The ravages of guns, nets and bulldozers. *Nature*, *536*, 143–145. https://doi.org/10.1038/536143a

May, S. A., & Norton, T. W. (1996). Influence of fragmentation and disturbance on the potential impact of feral predators on native fauna in Australian forest ecosystems. *Wildlife Research*, *23*, 387–400. https://doi.org/10.1071/WR9960387

McGregor, H. W., Legge, S., Jones, M. E., & Johnson, C. N. (2016). Extraterritorial hunting expeditions to intense fire scars by feral cats. *Scientific Reports*, *6*, 22559. https://doi.org/10.1038/srep22559

McRuer, D. L., Gray, L. C., Horne, L., & Clark, E. E. (2017). Free-roaming cat interactions with wildlife admitted to a wildlife hospital. *The Journal of Wildlife Management*, *81*, 163–173. https://doi.org/10.1002/jwmg.21181

Medina, F. M., Bonnaud, E., Vidal, E., Tershy, B. R., Zavaleta, E. S., Josh Donlan, C., … Nogales, M. (2011). A global review of the impacts of invasive cats on island endangered vertebrates. *Global Change Biology*, *17*, 3503–3510. https://doi.org/10.1111/j.1365-2486.2011.02464.x

Merson, S. D., Dollar, L. J., Tan, C. K. W., & Macdonald, D. W. (2019). Effects of habitat alteration and disturbance by humans and exotic species on fosa *Cryptoprocta ferox* occupancy in Madagascar's deciduous forests. *Oryx*. https://doi.org/10.1017/s003060531800100x

Miller, K. K., Ritchie, E. G., & Weston, M. A. (2014). The human dimensions of dog-wildlife interactions. In M. E. Gompper (Ed.), *Free-ranging dogs and wildlife conservation* (pp. 286–304). Oxford, UK: Oxford University Press.

Moreau, D., Cathelain, P., & Lacheretz, A. (2003). Comparative study of causes of death and life expectancy in carnivorous pets (II). *Revue de Médecine Vétérinaire*, *154*, 127–132.

Mori, E., Menchetti, M., Camporesi, A., Cavigioli, L., Tabarelli de Fatis, K., & Girardello, M. (2019). Licence to kill? Domestic cats affect a wide range of native fauna in a highly biodiverse Mediterranean country. *Frontiers in Ecology and Evolution*. https://doi.org/10.3389/fevo.2019.00477

Nelson, S. H., Evans, A. D., & Bradbury, R. B. (2005). The efficacy of collar-mounted devices in reducing the rate of predation of wildlife by domestic cats. *Applied Animal Behaviour Science*, *94*, 273–285. https://doi.org/10.1016/j.applanim.2005.04.003

Nogales, M., Vidal, E., Medina, F. M., Bonnaud, E., Tershy, B. R., Campbell, K. J., & Zavaleta, E. S. (2013). Feral cats and biodiversity conservation: The urgent prioritization of island management. *BioScience*, *63*, 804–810. https://doi.org/10.1525/bio.2013.63.10.7

Oppel, S., Beaven, B. M., Bolton, M., Vickery, J., & Bodey, T. W. (2010). Eradication of invasive mammals on islands inhabited by humans and domestic animals. *Conservation Biology*, *25*, 232–240. https://doi.org/10.1111/j.1523-1739.2010.01601.x

Ottoni, C., Van Neer, W., De Cupere, B., Daligault, J., Guimaraes, S., Peters, J., … Geigl, E.-M. (2017). The palaeogenetics of cat dispersal in the ancient world. *Nature Ecology & Evolution*, *1*, 0139. https://doi.org/10.1038/s41559-017-0139

Palmer, C., & Sandøe, P. (2014). For their own good: Captive cats and routine confinement. In L. Gruen (Ed.), *Ethics of captivity* (pp. 135–155). Oxford, UK: Oxford University Press.

Parsons, A. W., Bland, C., Forrester, T., Baker-Whatton, M. C., Schuttler, S. G., McShea, W. J., … Kays, R. (2016). The ecological impact of humans and dogs on wildlife in protected areas in eastern North America. *Biological Conservation*, *203*, 75–88. https://doi.org/10.1016/j.biocon.2016.09.001

Pavisse, R., Vangeluwe, D., & Clergeau, P. (2019). Domestic cat predation on garden birds: An analysis from European ringing programmes. *Ardea*, *107*, 103–109. https://doi.org/10.5253/arde.v107i1.a6

PDSA (The People's Dispensary for Sick Animals). (2016). *PDSA animal welfare report 2016*. Telford, UK: PDSA.

Pemberton, C., & Ruxton, G. D. (2019). Birdsbesafe® collar cover reduces bird predation by domestic cats (*Felis catus*). *Journal of Zoology*. https://doi.org/10.1111/jzo.12739

Pierpaoli, M., Birò, Z. S., Hermann, M., Hupe, K., Fernandes, M., Ragni, B., … Randi, E. (2003). Genetic distinction of wildcat (*Felis silvestris*) populations in Europe, and hybridization with domestic cats in Hungary. *Molecular Ecology*, *12*, 2585–2598. https://doi.org/10.1046/j.1365-294X.2003.01939.x

Platt, J. R. (2013). 3,000 feral cats killed to protect rare Australian bilbies. Scientific American. https://blogs.scientificamerican.com/extinction-countdown/feral-cats-killed-protect-bilbies/

Preisser, E. L., Bolnick, D. I., & Benard, M. F. (2005). Scared to death? The effects of intimidation and consumption in predator-prey interactions. *Ecology*, *86*, 501–509. https://doi.org/10.1890/04-0719

Rasambainarivo, F., Farris, Z. J., Andrianalizah, H., & Parker, P. G. (2017). Interactions between carnivores in Madagascar and the risk of disease transmission. *EcoHealth*, *14*, 691–703. https://doi.org/10.1007/s10393-017-1280-7

Ratcliffe, N., Bell, M., Pelembe, T., Boyle, D., Benjamin, R., White, R., … Sanders, S. (2010). The eradication of feral cats from Ascension Island and its subsequent recolonization by seabirds. *Oryx*, *44*, 20–29. https://doi.org/10.1017/S003060530999069X

Riley, S. (2019). 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. *Frontiers in Veterinary Science*. https://doi.org/10.3389/fvets.2018.00342

Robinson, S., Gadd, L., Johnston, M., & Pauza, M. (2015). Long-term protection of important seabird breeding colonies on Tasman Island through eradication of cats. *New Zealand Journal of Ecology*, *39*, 316–322.

Rochlitz, I. (2004). The effects of road traffic accidents on domestic cats and their owners. *Animal Welfare*, *13*, 51–55.

Rochlitz, I. (2005). A review of the housing requirements of domestic cats (*Felis silvestris catus*) kept in the home. *Applied Animal Behaviour Science*, *93*, 97–109. https://doi.org/10.1016/j.applanim.2005.01.002

Rouco, C., De Torre-Ceijas, R., Martín-Collado, D., & Byrom, A. E. (2017). New Zealand shouldn't ignore feral cats. *BioScience*, *67*, 686. https://doi.org/10.1093/biosci/bix068

Russell, J. C., Innes, J. G., Brown, P. H., & Byrom, A. E. (2015). Predator-free New Zealand: Conservation country. *BioScience*, *65*, 520–525. https://doi.org/10.1093/biosci/biv012

Sanchez, A. (2018). *Detailed discussion of feral cat and wild bird controversy*. Animal Legal & Historical Center, Michigan State University College of Law. https://www.animallaw.info/article/detailed-discussion-feral-cat-and-wild-bird-controversy#id-20

Schneider, T. J., Maguire, G. S., Whisson, D. A., & Weston, M. A. (2019). Regulations fail to constrain dog space use in threatened species beach habitats. *Journal of Environmental Planning and Management*. https://doi.org/10.1080/09640568.2019.1628012

Silva-Rodríguez, E. A., & Sieving, K. E. (2011). Influence of care of domestic carnivores on their predation on vertebrates. *Conservation Biology*, *25*, 808–815. https://doi.org/10.1111/j.1523-1739.2011.01690.x

Sims, V., Evans, K. L., Newson, S. E., Tratalos, J. A., & Gaston, K. J. (2008). Avian assemblage structure and domestic cat densities in urban environments. *Diversity and Distributions*, *14*, 387–399. https://doi.org/10.1111/j.1472-4642.2007.00444.x

Smith, S. B., McKay, J. E., Richardson, J. K., Shipley, A. A., & Murphy, M. T. (2016). Demography of a ground nesting bird in an urban system: Are populations self-sustaining? *Urban Ecosystems*, *19*, 577–598. https://doi.org/10.1007/s11252-016-0532-6

Stokeld, D., Fisher, A., Gentles, T., Hill, B. M., Woinarski, J. C. Z., Young, S., & Gillespie, G. R. (2018). Rapid increase of Australian tropical savanna reptile abundance following exclusion of feral cats. *Biological Conservation*, *225*, 213–221. https://doi.org/10.1016/j.biocon.2018.06.025

Takahashi, M. A. (2004). Cats v. birds in Japan: How to reconcile wildlife conservation and animal protection. *Georgetown International Environmental Law Review*, *17*, 135–159.

Thomas, R. L., Fellowes, M. D. E., & Baker, P. J. (2012). Spatio-temporal variation in predation by urban domestic cats (*Felis catus*) and the acceptability of possible management actions in the UK. *PLoS ONE*, *7*, e49369. https://doi.org/10.1371/journal.pone.0049369

Todesco, M., Pascual, M. A., Owens, G. L., Ostevik, K. L., Moyers, B. T., Hübner, S., … Rieseberg, L. H. (2016). Hybridization and extinction. *Evolutionary Applications*, *9*, 892–908. https://doi.org/10.1111/eva.12367

Towns, D. R., West, C. J., & Broome, K. G. (2012). Purposes, outcomes and challenges of eradicating invasive mammals from New Zealand islands: An historical perspective. *Wildlife Research*, *40*, 94–107. https://doi.org/10.1071/WR12064

Trouwborst, A. (2014). Exploring the legal status of wolf-dog hybrids and other dubious animals: International and EU law and the wildlife conservation problem of hybridization with domestic and alien species. *Review of European, Comparative and International Environmental Law*, *23*, 111–124. https://doi.org/10.1111/reel.12052

Trouwborst, A., Loveridge, A. J., & Macdonald, D. W. (2019). Spotty data: Managing international leopard (*Panthera pardus*) trophy hunting quotas amidst uncertainty. *Journal of Environmental Law*, https://doi.org/10.1093/jel/eqz032

Trouwborst, A., & Somsen, H. (2019). Domestic cats (*Felis catus*) and European nature conservation law—Applying the EU Birds and Habitats Directives to a significant but neglected threat to wildlife. *Journal of Environmental Law*. https://doi.org/10.1093/jel/eqz035

Tryjanowski, P., Morelli, F., Skórka, P., Goławski, A., Indykiewicz, P., Møller, A. P., … Zduniak, P. (2015). Who started first? Bird species visiting novel bird feeders. *Scientific Reports*, *5*, 11858. https://doi.org/10.1038/srep11858

United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable. Resolution a/RES/70/1.

Van Heezik, Y., Smyth, A., Adams, A., & Gordon, J. (2010). Do domestic cats impose an unsustainable harvest on urban bird populations? *Biological Conservation*, *143*, 121–130. https://doi.org/10.1016/j.biocon.2009.09.013

Wilson, S. K., Okunlola, I. A., & Novak, J. A. (2015). Birds be safe: Can a novel cat collar reduce avian mortality by domestic cats (*Felis catus*)? *Global Ecology and Conservation*, *3*, 359–366. https://doi.org/10.1016/j.gecco.2015.01.004

Woinarski, J. C. Z., Burbidge, A. A., & Harrison, P. L. (2015). Ongoing unraveling of a continental fauna: Decline and extinction of Australian mammals since European settlement. *Proceedings of the National Academy of Sciences of the United States of America*, *112*, 4531–4540. https://doi.org/10.1073/pnas.1417301112

Woinarski, J., Murphy, B. P., Legge, S. M., Garnett, S. T., Lawes, M. J., Comer, S., … Woolley, L. A. (2017). How many birds are killed by cats in Australia? *Biological Conservation*, *214*, 76–87. https://doi.org/10.1016/j.biocon.2017.08.006

Woinarski, J. C. Z., Murphy, B. P., Palmer, R., Legge, S. M., Dickman, C. R., Doherty, T. S., … Stokeld, D. (2018). How many reptiles are killed by cats in Australia? *Wildlife Research*, *45*, 247–266. https://doi.org/10.1071/WR17160

Woods, M., McDonald, R. A., & Harris, S. (2003). Predation of wildlife by domestic cats *Felis catus* in Great Britain. *Mammal Review*, *33*, 174–188. https://doi.org/10.1046/j.1365-2907.2003.00017.x

Work, T. M., Massey, J. G., Rideout, B. A., Gardiner, C. H., Ledig, D. B., Kwok, O. C. H., & Dubey, J. P. (2000). Fatal toxoplasmosis in free-ranging endangered 'Alala' from Hawaii. *Journal of Wildlife Diseases*, *36*, 205–212. https://doi.org/10.7589/0090-3558-36.2.205

Young, J. K., Olson, K. A., Reading, R. P., Amgalanbaatar, S., & Berger, J. (2011). Is wildlife going to the dogs? Impacts of feral and free-roaming dogs on wildlife populations. *BioScience*, *61*, 125–132. https://doi.org/10.1525/bio.2011.61.2.7

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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