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Short communication

The global impacts of domestic dogs on threatened vertebrates

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ABSTRACT

Domestic dogs (*Canis familiaris*) have a near-global distribution. They range from being feral and free-ranging to owned and completely dependent on humans. All types of domestic dogs can interact with wildlife and have severe negative impacts on biodiversity. Here, we use IUCN Red List data to quantify the number of threatened species negatively impacted by dogs, assess the prevalence of different types of dog impact, and identify regional hotspots containing high numbers of impacted species. Using this information, we highlight key research and management gaps and priorities. Domestic dogs have contributed to 11 vertebrate extinctions and are a known or potential threat to at least 188 threatened species worldwide. These estimates are greater than those reported by previous assessments, but are probably conservative due to biases in the species, regions and types of impacts studied and/or reported. Predation is the most frequently reported impact, followed by disturbance, disease transmission, competition, and hybridisation. Regions with the most species impacted are: South-east Asia, Central America and the Caribbean, South America, Asia (excluding SE), Micro/Mela/Polynesia, and Australia. We propose that the impacts of domestic dogs can be better understood and managed through: taxonomic and spatial prioritisation of research and management; examining potential synergisms between dogs and other threatening processes; strategic engagement with animal welfare and human health campaigns; community engagement and education; and mitigating anthropogenic effects such as resource subsidies. Such actions are essential for threatened species persistence, especially given that human and dog populations are expected to increase both numerically and geographically in the coming decades.

1. Introduction

Introduced mammalian predators have caused numerous species extinctions (Doherty et al., 2016), with the best understood impacts being those of cats (*Felis catus*) (Medina et al., 2011) and rats (*Rattus rattus, R. norvegicus,* and *R. exulans*) (Jones et al., 2008). However, a third introduced predator that affects many species—but has received surprisingly less attention—is the domestic dog (*Canis familiaris*). While Hughes and Macdonald (2013) reported domestic dog impacts on 21 threatened (classed as Vulnerable, Endangered, or Critically Endangered) vertebrate species, and both Bellard et al. (2016) and Doherty et al. (2016) estimated that more than 100 species are affected, here we suggest these assessments under-estimate the true impacts of domestic dogs on threatened vertebrates.

The domestic dog descended from the grey wolf (*Canis lupus*) and was domesticated by humans at least 14,000 years ago (Frantz et al., 2016). There are now an estimated one billion domestic dogs across their near-global distribution (Gompper, 2014). Domestic dogs are typically omnivorous, surviving on foods ranging from wild prey and carrion to human-derived foods—either provisioned or scavenged (Vanak and Gompper, 2009). Domestic dogs encompass feral and free-ranging animals to those owned and completely dependent on humans; all can interact with wildlife.

Domestic dogs can negatively impact wildlife through direct preda-

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tion (Ritchie et al., 2014), fear-mediated behavioural changes (i.e. 'risk effects') (Banks and Bryant, 2007; Zapata-Ríos and Branch, 2016), competition (Vanak et al., 2014), harassment (Weston and Stankowich, 2014), hybridisation (Bassi et al., 2017; Bergman et al., 2009), and disease transmission (Furtado et al., 2016). Reducing these impacts is a global conservation issue (Hughes and Macdonald, 2013; Young et al., 2011). Further, the scale and urgency of this problem is likely to be exacerbated as the human population expands geographically and increases by a projected 2.3 billion by the year 2050 (United Nations, 2015).

To effectively design, prioritise and implement conservation plans and actions, we urgently need to know how and where dogs affect wildlife; but such a comprehensive global assessment does not exist. In a recent analysis of invasive mammalian predator impacts, Doherty et al. (2016) identified 156 threatened or extinct vertebrate species negatively impacted by domestic dogs. Here, we refine this estimate by using a more targeted search strategy to quantify how many threatened species are negatively impacted by domestic dogs, assess the prevalence of different types of dog impact, and identify regional hotspots containing high numbers of affected species. Using this information we highlight key research and management gaps and priorities. Our work also builds on that of Hughes and Macdonald (2013) who conducted a literature-based review of dog impacts, and that of Bellard et al. (2016) who used databases to determine the number of vertebrate species threatened by more than 200 invasive alien species. The findings and recommendations presented here relate only to domestic dogs, as we recognise that some native dogs (e.g. the dingo, *Canis dingo*) are important trophic regulators, despite being initially introduced into a new ecosystem by humans (Ritchie et al., 2014).

2. Methods

We used IUCN Red List data to assess taxonomic and geographic trends in the species impacted by domestic dogs and the types of impacts. For all threatened species in the taxonomic classes Amphibia, Aves, Mammalia and Reptilia, we downloaded data on taxonomy and conservation status from the IUCN Red List in November 2016 (version 2016-2) using the inbuilt search and export functions ($n = 5926$ species). Threatened species were those listed as Vulnerable, Endangered, Critically Endangered, Extinct or Extinct in the Wild. We then used a custom script (Script A1 in Appendix A) in R version 3.2.4 (R Core Team, 2016) to download additional Red List information on each species' range and major threats.

We filtered this database in Microsoft Access by searching the 'major threats' section for any of the following keywords: dog*, *Canis lupus familiaris, Canis familiaris*, and domestic. We used this last term because our previous experience revealed that some threat assessments referred to "domestic carnivores/predators/pets" without explicitly naming dogs or cats. This search returned 421 records, which we inspected to determine whether domestic dogs were identified as a known or potential threat to each species ($n = 192$ species). We did not consider 'hunting using dogs' in and of itself to be an impact of dogs, unless during hunting exercises the species experienced harassment or predation by dogs as a non-target species. We cross-checked this list against previous reviews (Hughes and Macdonald, 2013; Young et al., 2011) and added seven additional threatened species recorded as being negatively affected by domestic dogs that were not revealed in our Red List search.

For each of the 199 affected species (Table A1 in Appendix A), we recorded information on taxonomic classification (class, order, family), Red List status and region (Table A2 in Appendix A). Information on species distributions was sourced primarily from the Red List. Based on information contained in the threats section, we classified the impacts of dogs on each species as one or more of the following: predation, competition, disease transmission, disturbance (e.g. chasing, harassment), or hybridisation. If dogs were not mentioned in a species' Red List assessment (i.e. seven species sourced from previous reviews), we drew on published literature to classify impacts. We did not classify the origin of dogs (e.g. village dogs, feral dogs) because most assessments provided insufficient information to do so. We present summary information regarding the number of extinct and threatened species impacted by dogs, based on: taxonomic class; the regions where they occur, or occurred; and type of dog impacts.

Table 1
List of species for which domestic dogs *Canis familiaris* are named as contributing to their extinction.

Common name	Species name
Thick-billed Ground-dove	*Alopecoenas salamonis*
Cape Verde Giant Skink	*Chioninia coctei*
–	*Contomastix charrua*
New Zealand Quail	*Coturnix novaezelandiae*
–	*Dusicyon avus*
Dieffenbach's Rail	*Hypotaenidia dieffenbachii*
Auckland Merganser	*Mergus australis*
Choiseul Pigeon	*Microgoura meeki*
Marcano's Solenodon	*Solenodon marcanoi*
Tonga Ground Skink	*Tachygyia microlepis*
Hawaiian Rail	*Zapornia sandwichensis*

3. Results and discussion

3.1. Global impact of domestic dogs on threatened vertebrates

Domestic dogs have contributed to 11 vertebrate extinctions (Table 1) and are a known or potential threat to 188 threatened species worldwide. This includes 96 mammal (33 families), 78 bird (25 families), 22 reptile (10 families), and three amphibian (three families) species (Fig. 1a; Table A1). Of these threatened species, 30 are classed as Critically Endangered (two of which are classed 'possibly extinct'), 71 Endangered, and 87 Vulnerable (Table A1). Predation is the most frequently reported impact, followed by disturbance, disease transmission, competition, and hybridisation (Fig. 1b). Impact type was not reported for 26 species. Regions with the most species impacted are: South-east Asia (30 species), Central America and the Caribbean (29), South America (28), Asia (25 species, excluding SE), Micro/Mela/Polynesia (24) and Australia (21; Fig. 2). The remaining regions contain 1–16 threatened species negatively impacted by domestic dogs (Table A2). The high concentration of threatened species in the tropical and sub-tropical archipelagos of the Caribbean, South-east Asia and Micro/Mela/Polynesia may be related to either the high dog to human population ratios (Gompper, 2014), high native species richness (Willig et al., 2003), and/or insular nature of these regions.

3.2. Future research and management of dog-wildlife interactions

Our assessment reveals that the number of threatened species (Vulnerable, Endangered, or Critically Endangered) negatively impacted by domestic dogs is almost nine times higher than the literature-based assessment of Hughes and Macdonald (2013), and ~30–50% higher than previous database reviews (Bellard et al., 2016; Doherty et al., 2016). These discrepancies suggest that the global impacts of domestic dogs on wildlife are grossly underestimated. Further, taxonomic biases in research and publication are apparent. Seventy-eight per cent of studies describing domestic dog-wildlife interactions were on mammals, 16% on birds, 12% on reptiles, and only one study on amphibians (Hughes and Macdonald, 2013). By contrast, we found that mammals and birds made up more similar proportions of the species listed as negatively impacted by dogs (48 and 39%, respectively). Dogs can severely impact non-mammals, particularly ground-dwelling birds (e.g. Hunt et al., 2010), so we urgently need to understand the importance of these effects across taxonomic groups.

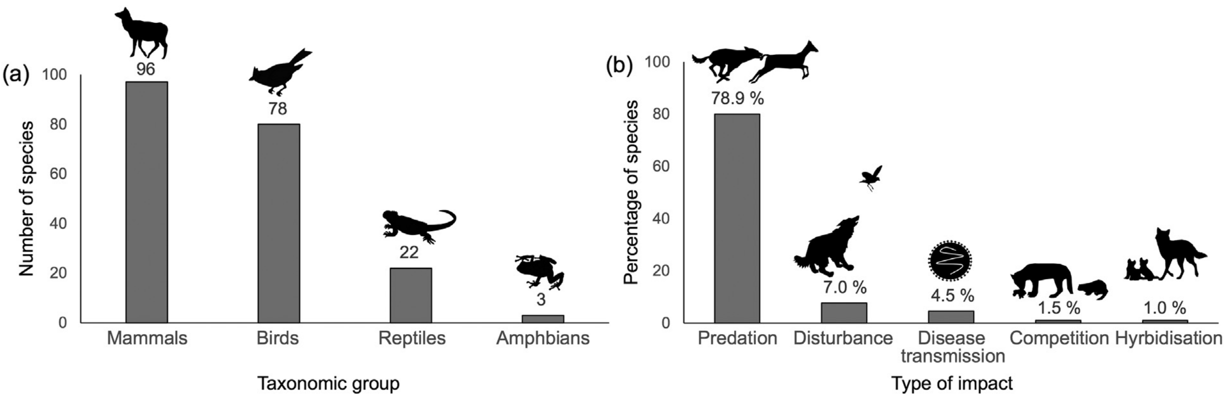

Fig. 1. (a) Number of extinct or threatened vertebrate species that are, or were, negatively impacted by domestic dogs *Canis familiaris*; (b) Percentage of extinct or threatened vertebrate species that are, or were, affected by different types of dog impact.

The strength of dog impacts on threatened species, and how they compare to other threats, such as habitat loss or hunting, is unclear. Studies rarely quantify the impact of domestic dogs on wildlife populations (Hughes and Macdonald, 2013). An important and timely unknown in this regard is how domestic dogs may impact native top predators (e.g. wolves, and bear and cat species) (Lescureux and Linnell, 2014; Wierzbowska et al., 2016), and how in turn this could affect top predator reintroduction and rewilding. Further, none of the Red List assessments contained information on the non-consumptive effects (i.e. predation risk and fear) of dogs on wildlife behaviour and demographics. These risk effects could be substantial, but appear under-studied and/or reported, thus impeding their evidence-based management. Addressing these important knowledge gaps will require a multi-disciplinary approach involving ecological, cultural, social and economic perspectives (Hughes and Macdonald, 2013; White and Ward, 2010), on account of the complex relationships that exist between humans and dogs (Miller et al., 2014; Treves and Bonacic, 2016).

Increased understanding of factors that exacerbate domestic dog impacts on vertebrates is also required. For example, urbanization and road construction can facilitate dog access to primary habitats, potentially resulting in synergistic effects with wildlife poaching and road-kill (Doherty et al., 2015). Some areas identified as hotspots of domestic dog impacts have also been identified as hotspots for increasing pressure from urbanization (Seto et al., 2012) and road-building (Laurance et al., 2014), thus indicating strong potential for harm. Even in less urbanised areas, more subtle anthropogenic landscape modification may compound the effects of domestic dogs on wildlife. For instance, the mere presence of dogs on trails can displace native fauna (Banks and Bryant, 2007), while supplementary food provisioning (e.g. rubbish tips) can inflate dog abundance, potentially resulting in hyperpredation of wildlife, facilitation of hybridisation and increased disease transmission (Newsome et al., 2015). As humans further encroach on primary habitat, domestic dog impacts on wildlife may increase.

Domestic dog management occurs within complex social-ecological systems (Dorresteijn et al., 2015). Dogs compete with and prey upon wildlife and other introduced species (Ritchie et al., 2014), prey upon livestock (Home et al., 2017), and attack and spread disease to humans and other domestic animals (Bergman et al., 2009). When dog populations are wholly or partially dependent on humans, unique management challenges arise. For example, underfed domestic dogs are more likely to prey on wildlife than adequately fed dogs (Silva-Rodríguez and Sieving, 2011). Local engagement and community support are often key to successful management programs. Greater uptake by communities may be achieved by integrating human health and animal welfare objectives into dog management, rather than focusing solely on species conservation. This is especially true when farmers use dogs to protect crops and livestock. To reduce dog population densities, measures such

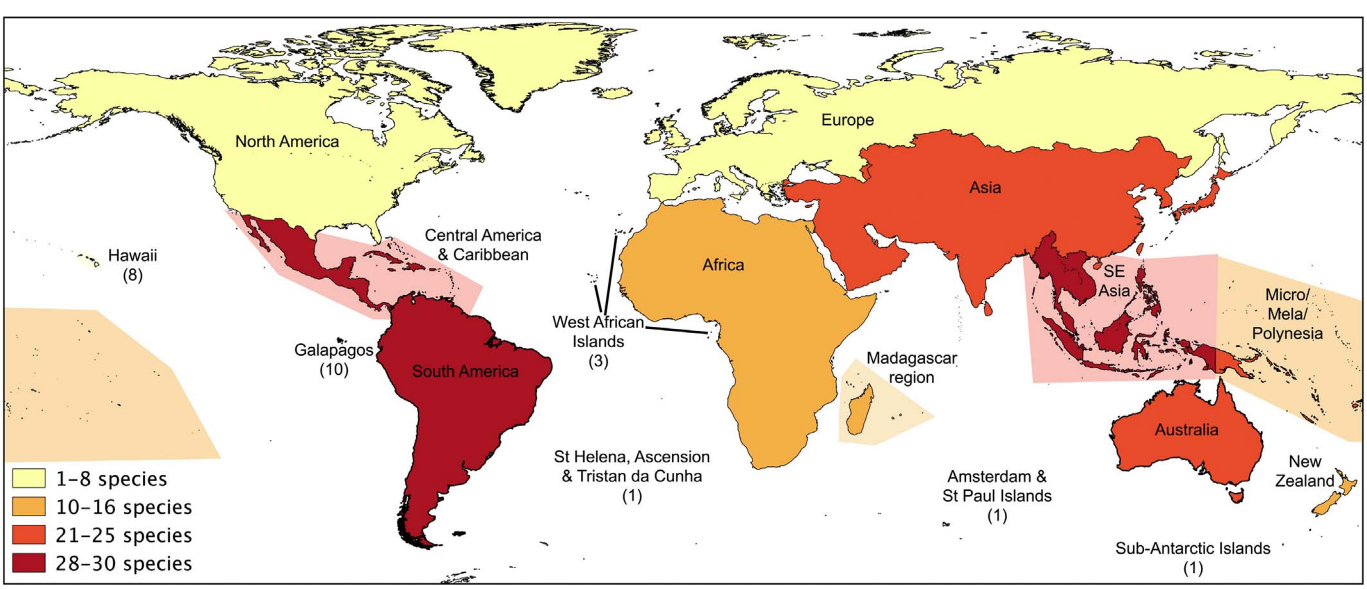

Fig. 2. Regional concentrations of threatened species negatively impacted by domestic dogs *Canis familiaris*. Number of species is given in parentheses for some small island regions. Also see Table A2 in Appendix A.

as Capture-Neuter-Vaccinate-Release are often used (e.g. Schurer et al., 2014), but can be ineffective in achieving sustained reduction of dog populations, especially in areas of high dog densities. Instead, management may be most effective when focused on responsible dog ownership (including restricting dog movement; e.g. Parsons et al., 2016), reducing food subsidies, and removing un-owned dogs (Miller et al., 2014; Vanak and Gompper, 2010).

In conclusion, domestic dogs pose a risk to nearly 200 threatened vertebrate species worldwide, and this estimate is likely conservative owing to reporting biases. To ensure persistence of these threatened species, the impacts of domestic dogs must be better understood and managed. We propose this can be achieved by taxonomic and spatial prioritisation of research and management; examining potential synergisms between dogs and other threatening processes; strategic engagement with animal welfare and human health campaigns; community engagement and education; and mitigating anthropogenic effects such as resource subsidies. Such actions are critically important, particularly because human and domestic dog populations are expected to both grow numerically and expand geographically in the coming decades.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.biocon.2017.04.007.

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