Received: 23 October 2019 | Revised: 20 July 2020 | Accepted: 27 July 2020
DOI: 10.1111/conl.12748

Conservation Letters
A journal of the Society for Conservation Biology
Open Access
WILEY

POLICY PERSPECTIVE

Protected areas are now the last strongholds for many imperiled mammal species

Michela Pacifici[1] | **Moreno Di Marco**[2,3] | **James E. M. Watson**[3,4]

[1] Global Mammal Assessment Programme, Department of Biology and Biotechnologies, Sapienza Università di Roma, Rome, Italy

[2] Department of Biology and Biotechnologies, Sapienza Università di Roma, Rome, Italy

[3] School for Earth and Environmental Sciences, University of Queensland, Brisbane, Australia

[4] Wildlife Conservation Society, Global Conservation Program, Bronx, New York

Correspondence
Michela Pacifici, Global Mammal Assessment programme, Department of Biology and Biotechnologies, Sapienza Università di Roma, Rome, Italy.
Email: michela.pacifici@uniroma1.it

Funding information
H2020 Marie Skłodowska-Curie Actions, Grant/Award Number: 2017-793212; Centre of Excellence for Environmental Decisions, Australian Research Council

Abstract
The global network of terrestrial protected areas (PAs) has experienced a fourfold expansion since the 1970s. Yet, there is increasing debate around the role of the global PA estate in covering and sustaining threatened species, with serious ramifications for current PA financing and the setting of post-2020 global conservation targets. By comparing "past" (1970s) and current distribution range of 237 mammals, and measuring the proportion of range covered by PAs in the past and in the present, we show that a small number of PAs have now become the last bastions of hope for ensuring the persistence of many mammal species. For 187 species (~79% of those analyzed) the proportion of range covered by PAs has doubled over the time period, with 10% of all species now having most of their current range protected. This increase in proportional protection over time is largely due to a retreat of species distribution (outside existing PAs) and, in smaller part, to PA expansion. It is clear that adequately resourcing those PAs critical in sustaining mammal species is now essential, to avert a worldwide rapid mammal loss.

KEYWORDS
extinction, mammal conservation, population loss, protected areas, range collapse

1 | INTRODUCTION

A fourfold expansion in the global network of terrestrial protected areas (PAs) has occurred since the 1970s, and today PAs cover ~15% of the terrestrial planet (UNEP-WCMC & IUCN, 2016). Recent works have shown the number of threatened vertebrates included in PAs is increasing as a consequence of an expanding PA estate (Venter et al., 2014) and there is evidence that some PAs have been effective at maintaining, or even enhancing wildlife populations (Geldmann et al., 2013; Walston, Stokes, & Hedges, 2016). For example, species like the tiger (*Panthera tigris*) and lion (*Panthera leo*) have clearly benefited from the use of fences and antipoaching measures employed within PAs (Geldmann et al., 2013; Karanth, Nichols, Kumar, & Hines, 2006). Yet, there is increasing conjecture around the role of the global PA estate in covering and sustaining imperiled species, as PA coverage is biased toward locations that are less expensive to protect and sometimes of limited importance for biodiversity (Visconti et al., 2019; Venter et al., 2014).

Signatory nations of the Convention of Biological Diversity (CBD) are now focusing on generating a new, post-2020 PA target that includes a further increase of global PA coverage (Convention on Biological Diversity, 2020). But the uncertainty of how effective PAs have been in saving imperiled species has serious ramifications for current PA financing (Watson, Dudley, Segan, & Hockings, 2014), and is likely to impact international debate on the best post-2020 strategy for PAs (Visconti et al., 2019). As such, assessments around the effectiveness of the PA estate to conserve biodiversity are increasingly important for policy discussions and financing (Coad et al., 2019).

We collected data on past (1970s) distribution ranges for a total of 237 mammal species (Table S1) by combining a public database on past distribution maps for terrestrial non-volant mammals (Pacifici et al., 2019) with literature-based information on bat distributions. We measured species' range changes, and the past and present overlay of the ranges with PAs at different spatial resolutions for sensitivity testing (see Supporting Methods). Due to the 50-year timeframe considered, the changes in distribution we observed are related to relatively recent human activities (Pacifici et al., 2020) and may underestimate historical contractions in species' ranges.

Our results show that many imperiled species have now become almost completely dependent on PAs for their persistence. We chose mammals because they are a well-studied taxon which has highly suffered from human impact in recent years despite having a crucial role in providing and maintaining services and functions associated with sustaining balanced ecosystems (Di Marco, Venter, Possingham, & Watson, 2018; Pacifici et al., 2020). Our analysis represents all major taxonomic mammal orders and biogeographic regions, with the exception of the Palearctic region for which we have a relatively lower number of species (Figure S1). Although large-bodied orders are usually better represented in mammal distribution analyses as they are more studied (Monsarrat & Kerley, 2018), we improved the Pacifici et al. (2019) database—which did not include volant mammals—so as to balance the number of large charismatic species and small less-known mammals and obtain more generalizable results (Figure S2, Table S4). Small mammals (< 3 kg) represent 53% of the species in our database, although our data might underrepresent those species that live in very small areas and for which local extinctions are not realistically contemplated

2 PROTECTED AREAS ARE ESSENTIAL FOR MANY IMPERILED MAMMALS

There have been clear increases in PA coverage for 224 (i.e., 94%) of the mammal species in our analysis (Figure 1a, Table S2), with an average 12% additional coverage since 1970s. For 187 species (~79%) the proportion of range covered by PAs has at least doubled in the last 50 years, with 10% of all species now having more than half of their distribution range protected (Figures 1a, 2). This pattern of increased protection relative to range size was especially true in the tropics (Figure S3), with some areas, like the Sunda Islands and Central-Eastern Africa, standing out for the high number of charismatic species surviving now almost exclusively in PAs (Figure 2).

Importantly, the majority of species ($n = 147$, 62%) experienced contractions of their distribution range alongside an increase in percentage PA cover (Table S2). Large-bodied mammals (here defined as those species with body mass >20 kg, following MacDonald & Willis, 2013) are the most significant examples of the trend of net loss of distribution range and proportional increase in PA coverage (Figure 1b, c). The increased in percentage coverage of PAs was only due to a net increase in the extent of PAs within the range of the species (i.e., no range reduction) in 33% of cases, while for 53% of species, the increase in proportional protection over time is almost entirely due to a net decline of their distribution outside existing PAs (Table S2). For example, ~80% of the range of the Indian rhinoceros (*Rhinoceros unicornis*) is currently protected compared to 3% in the 1970s, after the species has lost a dramatic 99.7% of its distribution in just 50 years (Table S1); about 87% of the remaining individuals currently occur in just two PAs (Kaziranga National Park in India and Chitwan National Park in Nepal; Walston et al., 2016). Likewise, the percentage range protection of the Addax in Africa (*Addax nasomaculatus*) has increased from 3% in the 1970s up to 59% today, after a 97% range contraction (Figure 2).

For 26 other mammal species, we found no reduction in species' distribution and an increase in range protection from PA expansion (Table S2). An example is the puma (*Puma concolor*), a widespread species that occurs from Canada to Chile. This species showed no significant changes in its distribution but a 17% increase in PA coverage (Table S2). Puma is a very adaptable species, found in every major habitat type of the Americas (Nielsen, Thompson, Kelly, & Lopez-Gonzalez, 2015), and it widely occurs in Brazil, the country where annual rate of land protection is the highest in the world (UNEP-WCMC et al., 2018). There were also a few ($n = 14$) species that had no change in percentage range protected, mostly located in eastern and Midwestern United States and Mexico (Figure S1); these are some of the areas with the lowest PA expansion over the past two decades (UNEP-WCMC et al., 2018).

3 | AN URGENT NEED TO IDENTIFY THOSE JEWELS IN THE PROTECTED AREA ESTATE

We did not set out to prove PAs are effective at preventing future extinctions, but to simply assess if (and why) mammal species are increasingly found in protected land and

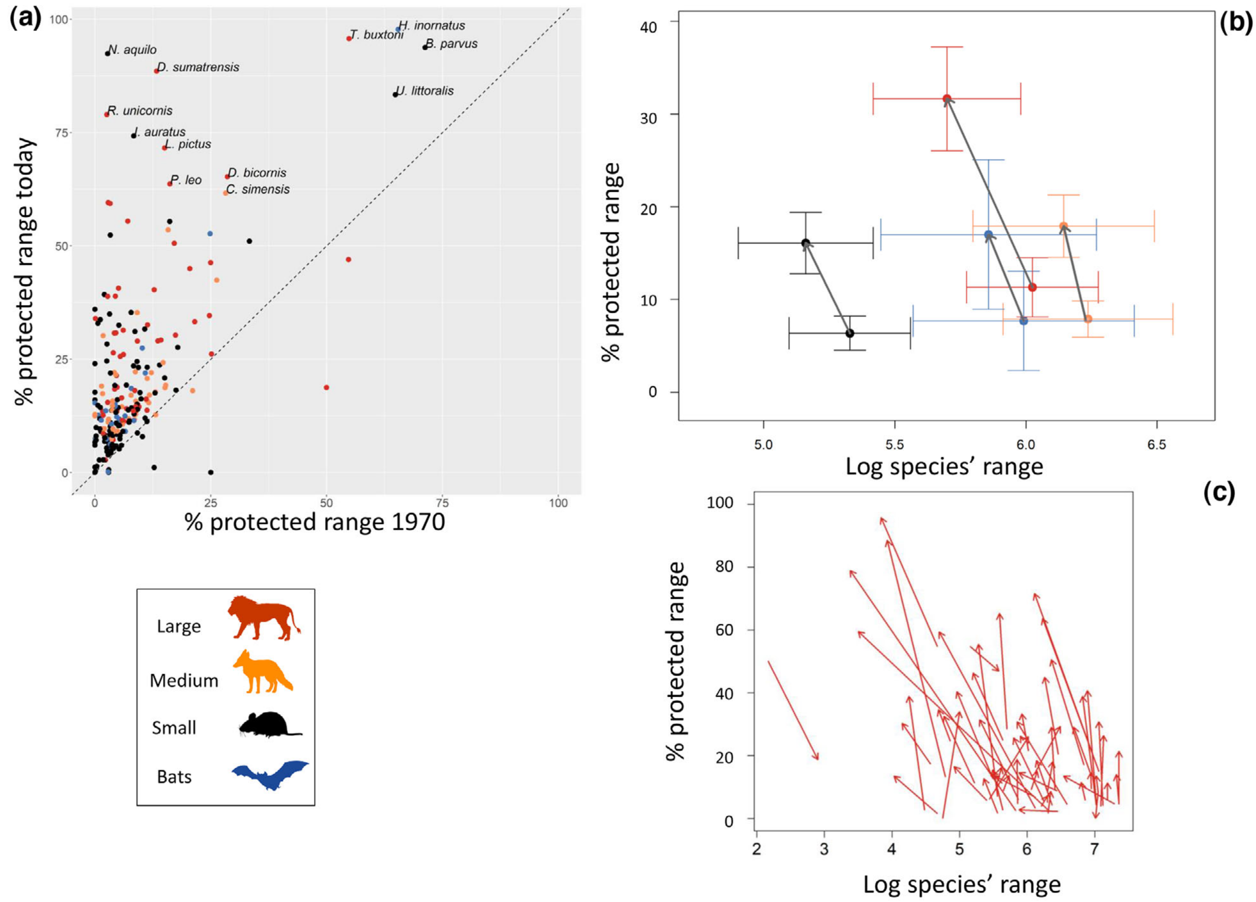

FIGURE 1 Changes in protected area coverage within mammal ranges since the 1970s. (a) Comparison between current and past protected area coverage within species ranges divided by body mass and locomotion: large-bodied non-volant mammals, ≥20 kg, in red; medium-bodied nonvolant species, 3–15 kg, in orange; small-bodied nonvolant species, ≤3 kg, in black; bats in blue. (b) Past and present relationship between species' range size and protected area coverage; arrows direction goes from past to current data, with error bars representing 95% confidence intervals. (c) Trends of large-bodied species (arrows direction goes from past to current data)

to explore the policy consequences of this. Our results are unequivocal, and supported also by a sensitivity analysis (Figure S4)—there are clear increases in PA coverage for 94% of the mammal species, and for 79% of species the proportion of range covered by PAs has at least doubled in the last 50 years (Table S2). The most likely explanation is that PAs, especially when well resourced, managed, and well-placed within the wider landscape, have every chance in halting the threatening processes causing mammal decline (Coad et al., 2019; Edgar, Stuart-Smith, Willis, & Nature, 2014; Watson et al., 2014). Another key aspect that emerged from our work is that when dealing with spatial analysis on species distribution and PAs, the resolution and resampling technique must be carefully selected. We found for those species with very small, fragmented distributions, simply resampling polygons at a coarser resolution may lead to a loss of ecological signal (Table S3, Figure S4).

There is growing body of species-specific evidence around why PAs are effective at maintaining mammal populations. For example, despite a disastrous 82% reduction in global distribution (Table S1), the tiger population in Rajiv Gandhi (Nagarahole) National Park in India has increased by 400%, due to improved reserve management aimed at maintaining high prey densities (Karanth et al., 2006). Likewise, South-African lions subpopulations showed an overall 12% increase since 1993, with a peak of +1,400% in the well-budgeted Tembe Elephant Park (South Africa, Bauer et al., 2015), despite a global species decline of 43%.

In Latin America, the amount of range under protection of the white-lipped peccary (*Tayassu pecari*), a declining species classified as Vulnerable by the International Union for Conservation of Nature (IUCN), has increased sevenfold since the 1970s (Suárez et al., 2009; Figure 1c). In the Yasuni Biosphere Park and Reserve in Ecuador, the species has been the subject of an intensive commercial bushmeat trade in the last 3 decades, with peaks in the years 2005–2007 (Suárez et al., 2009). A successful collaboration between TRAFFIC, the Ministry of Environment and local communities planned targeted actions for the

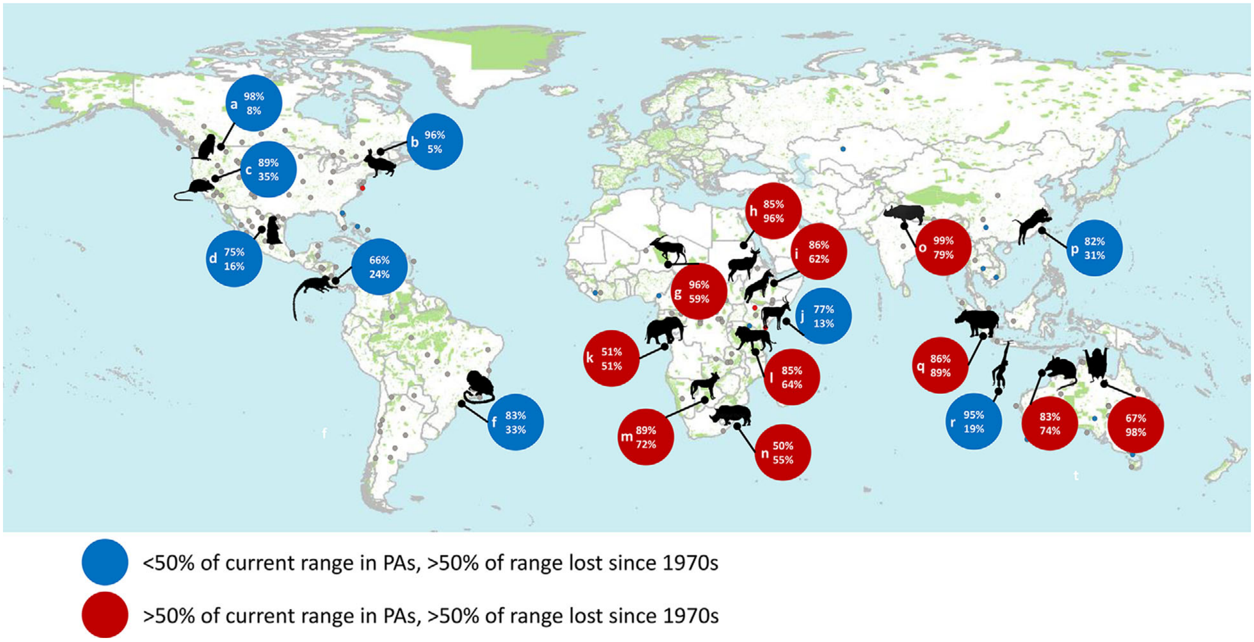

FIGURE 2 Top 20 species of mammals threatened by range reduction. The figure highlights species with the highest percentage range contraction since 1970s. Red circles represent species for which protected areas represent the last bastions (> 50% range is protected). Blue circles show species with very high rates of range decline, and relatively small portions of the current distribution protected (< 50%). In each big circle, percentage values at the top indicate range loss, while those at the bottom represent the amount of range currently protected. Protected areas are represented in green. Small dots represent the centroid of the range of the other species in the original sample. A full species list of the top 20 mammals threatened by range reduction (big circles) is provided in Table S1

different consumer groups, targeted to reducing the consumption of wild meat while providing alternative sources of protein to local populations (Phelps, Biggs, & Webb, 2016).

The saiga antelope (*Saiga tatarica*) lost > 70% of its range (Table S2) and is currently listed as Critically Endangered by the IUCN. Population estimates for Mongolia, where animals are mostly concentrated in two PAs (Sharga Nature Reserve and Mankhan Nature Reserve), suggest that the population is growing (Milner-Gulland, 2015), probably due to rigorous conservation efforts since 1993 when reserves have been established to protect most of the remaining distribution range of the species (IUCN SSC Antelope Specialist Group, 2018). What these examples show is identifying those PAs that play a vital role for highly threatened species is a priority: they should get appropriate levels of funding to ensure effective management and be upsized and upgraded if needed. Our analysis, while not claiming to be comprehensive across all threatened species, indicates that many PAs in East and South-East Asia and Sub-Saharan Africa are a priority for conservation investment, as they contain enormous percentages of threatened terrestrial mammals ranges. Efforts should be made to systematically identify PAs across every continent which play a disproportionally important role in maintaining species current distributions; this should be taken into account when threatened species belonging to any taxonomic group are strictly related to PAs management and effectiveness, as these PAs are essential to these species' long-term security.

For those international policy forums that deal with PAs, greater clarity must be made in specific protected area text that showcases the roles different PAs play in abating the conservation crisis. This is especially timely, given the world's governments will soon adopt a post-2020 biodiversity framework. This plan will likely contain biodiversity targets that define the global conservation agenda for at least the next decade and, while it is still unknown what the actual targets will be (and still the subject of much debate; Visconti et al., 2019), it is clear that PAs will play an important role in this wider conservation agenda. Our research provides more evidence that conservation policy development and implementation must be built on a platform that is clear on the overall goals of conservation (Visconti et al., 2019). This is because some PAs play more of a critically important role for mammal conservation than others, and these must be identified and targeted for resources. Therefore, policy makers must be clear on the different roles PAs will play in achieving these goals. By clearly specifying the different roles PAs play within the wider conservation agenda, there will be a shift in focus toward objective assessments on PAs through the world, focusing on which ones need more resourcing and what are the best ways to identify key funding gaps and priorities (Coad et al., 2019). At the same time, it will lead to more effective monitoring and reporting of PAs by nations, including states and trends of threatened species, which should underpin the adaptive management of PAs.

4 | PROTECTED AREAS ARE NECESSARY BUT NOT SUFFICIENT TO HALT MAMMAL DECLINE

PAs are not the one-and-only panacea when it comes to effective conservation for imperiled mammals. The Earth surface has been drastically altered and fragmented by human activities, with natural lands usually converted into other land cover types (Haddad et al., 2015). This has led wildlife to be increasingly confined in evermore rare and sparse habitat patches, often only found in PAs, facing problems of isolation, increased vulnerability to stochastic events—for example, genetic drift, environmental and demographic stochasticity—and higher probability of local extinction due to the reduction of their populations (Newmark, 1995; Pacifici et al., 2020). For example, the Cape buffalo (*Syncerus caffer caffer*) populations inhabiting smaller isolated parks in Kenya and Uganda showed signs of genetic erosion, presumably because of the lower ecological carrying capacities of these reserves, hence restricting the effective population size of animals, and the small ratio between the size of the PA and the surrounding human-dominated landscape which reduces gene flow (Heller, Okello, & Siegismund, 2010).

Large carnivores isolated in small PAs have proven to be more vulnerable to human-induced mortality rather than to stochastic processes. For these mammals, conflicts with humans on reserve borders are the main cause of mortality, and species with relatively larger home ranges have a higher probability of going locally extinct (Woodroffe & Ginsberg, 1998). Conservation measures that aim only to combat stochastic events are therefore unlikely to avert extinction for these species with large area requirements. Instead, actions that seek to maximize PA size and connectivity between PAs are essential, as are efforts to mitigate carnivore persecution on PA borders and in buffer zones.

5 | WITHOUT WELL-FUNDED PROTECTED AREAS, THE FUTURE LOOKS GRIM FOR MAMMALS

Our research provides clear evidence of dramatic range declines for many mammal species, with distribution shrinkage toward PAs. The rate at which species have disappeared from their past (1970s) range has largely surpassed the rate by which PAs have been created, pointing to the obvious fact that we are running out of time to save these species. As the global community comes together and debates new post-2020 conservation goals (where protected area targets and future financing will play a central role), it is vital that the role that those well-placed PAs play in ensuring many mammal species persist in the wild is formally recognized. As species like the African wild dog (*Lycaon pictus*), dhole (*Cuon alpinus*), lion, and tiger face continuing conflict with people even inside well cited PAs (Woodroffe & Ginsberg, 1998; respectively 14%, 3%, 12%, 4% of their range losses have been inside PAs; Table S2), it is critical that PAs must be well financed and managed. This is the only chance for highly threatened, exploited species to survive

Many of the species we found retreating toward PAs are heavily affected by illegal trade, a market worth US $7–$23 billion a year (Nellemann et al., 2016). Mountain Nyalas (*Tragelaphus buxtoni*), for example, are widely persecuted for their meat and horns (Sillero-Zubiri, 2013) and today survive almost exclusively within PAs. Mountain Nyala is one of the few species in our list that lost vast portions of its range also within PAs (63%; Table S2). The situation is similar for white rhinoceros (*Ceratotherium simum*), black rhinoceros (*Diceros bicornis*), Indian rhinoceros, and Sumatran rhinoceros, whose horns are mainly used for traditional medicine and dagger handles in Asia (Biggs et al., 2013), with the vast majority of their current distributions (65–89%) being in PAs (Table S1). To ensure the long-term survival of mammals, global conservation policies must focus on securing those critically important PAs and, at the same time, reward those efforts that ensure reexpansion and recolonization of wildlife populations on territories beyond protected area boundaries. This means focusing on retaining Earth's remaining intact ecosystems that contain key PAs and prioritizing efforts to restore habitat corridors between isolated reserves that best provide opportunities movement and genetic exchange.

ACKNOWLEDGMENTS

This study was funded by the ARC Centre of Excellence for Environmental Decisions. MDM acknowledges support from the EU H2020 programme (H2020-MSCA-IF-2017-793212).

AUTHORS' CONTRIBUTIONS

MP, MDM, and JEMW designed the study. MP analyzed the data. All authors discussed the results and wrote the paper.

DATA ACCESSIBILITY STATEMENT

Data sources for past ranges are available at https://onlinelibrary.wiley.com/doi/10.1002/ecy.2747/suppinfo. IUCN current ranges are available upon request at https://www.iucnredlist.org/. Current ranges not taken from the IUCN Red List for sensitive species are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

Michela Pacifici https://orcid.org/0000-0002-4468-4710
Moreno Di Marco https://orcid.org/0000-0002-8902-4193
James E. M. Watson https://orcid.org/0000-0003-4942-1984

REFERENCES

Bauer, H., Chapron, G., Nowell, K., Henschel, P., Funston, P., Hunter, L. T. B., … Packer, C. (2015). Lion (*Panthera leo*) populations are declining rapidly across Africa, except in intensively managed areas. *PNAS*, *112*, 14894–14899.

Biggs, D., Courchamp, F., Martin, R., Possingham, H. P., Harvest, R., & Trade, L. (2013). Legal trade of Africa's rhino horns. *Science*, *339*, 1038–1039.

Convention on Biological Diversity. (2020). Retrieved from https://www.cbd.int/doc/c/efb0/1f84/a892b98d2982a829962b6371/wg2020-02-03-en.pdf.

Coad, L., Watson, J. E. M., Geldmann, J., Burgess, N. D., Leverington, F., Hockings, M., … Di Marco, M. (2019). Widespread shortfalls in protected area resourcing significantly undermine efforts to conserve biodiversity. *Frontiers in Ecology and the Environment*, *17*, 259–264.

Di Marco, M., Venter, O., Possingham, H., & Watson, J. (2018). Changes in human footprint drive changes in species extinction risk. *Nature Communications*, *9*, 4621. https://doi.org/10.1038/s41467-018-07049-5

Edgar, G., Stuart-Smith, R., Willis, T., & Nature, S. K. U. (2014). Global conservation outcomes depend on marine protected areas with five key features. *Nature*, *506*, 216–220.

Geldmann, J., Barnes, M., Coad, L., Craigie, I. D., Hockings, M., & Burgess, N. D. (2013). Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. *Biological Conservation*, *161*, 230–238.

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., … Cook, W. M. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, *1*, e1500052.

Heller, R., Okello, J. B. A., & Siegismund, H. (2010). Can small wildlife conservancies maintain genetically stable populations of large mammals? Evidence for increased genetic drift in geographically restricted populations of Cape buffalo in East Africa. *Molecular Ecology*, *19*, 1324–1334.

IUCN SSC Antelope Specialist Group. (2018). Saiga tatarica. The IUCN Red List of Threatened Species 2018: E.T19832A50194357. Retrieved from https://doi.org/10.2305/IUCN.UK.2018-2.RLTS.T19832A50194357.en.

Karanth, K. U., Nichols, J. D., Kumar, N. S., & Hines, J. E. (2006). Assessing tiger population dynamics using photographic capture-recapture sampling. *Ecology*, *87*, 2925–2937.

Macdonald, D. W., & Willis, K. J. (2013). *Key topics inconservation biology 2*. Chichester, UK: John Wiley & Sons.

Milner-Gulland, E. J. (2015). Catastrophe and hope for the saiga. *Oryx*, *49*, 577.

Monsarrat, S., & Kerley, G. I. (2018). Charismatic species of the past: Biases in reporting of large mammals in historical written sources. *Biological Conservation*, *223*, 68–75

Nellemann, C. (Editor in Chief), Henriksen, R., Kreilhuber, A., Stewart, D., Kotsovou, M., Raxter, P., Mrema, E., & Barrat, S. (Eds). (2016). The rise of environmental crime—A growing threat to natural resources peace, development and security. A UNEPINTERPOL Rapid Response Assessment. United Nations Environment Programme and RHIPTO Rapid Response–Norwegian Center for Global Analyses. Retrieved from www.rhipt o.org

Newmark, W. D. (1995). Extinction of mammal populations in western North American national parks. *Conservation Biology*, *9*, 512–526.

Nielsen, C., Thompson, D., Kelly, M., & Lopez-Gonzalez, C. A. (2015). Puma concolor (errata version published in 2016). The IUCN Red List of Threatened Species 2015: E.T18868A97216466. Retrieved from https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T18868A50663436.en.

Pacifici, M., Cristiano, A., Burbidge, A. A., Woinarski, J. C. Z., Di Marco, M., & Rondinini, C. (2019). Geographic distribution ranges of terrestrial mammal species in the 1970s. *Ecology*, *100*, e02747.

Pacifici, M., Rondinini, C., Rhodes, J. R., Burbidge, A. A., Cristiano, A., Watson, J. E. M., … Di Marco, M. (2020). Global correlates of range contractions and expansions in terrestrial mammals. *Nature Communications*, *11*, 1–9.

Phelps, J., Biggs, D., & Webb, E. L. (2016). Tools and terms for understanding illegal wildlife trade. *Frontiers in Ecology and the Environment*, *14*, 479–489.

Sillero-Zubiri, C. (2013). Tragelaphus buxtoni. In J. Kingdon & M. Hoffman (Eds.). *VI. Pigs, hippopotamuses, chevrotain, giraffes, deer, bovids* (pp. 159–162). London, UK: Bloomsbury Publishing.

Suárez, E., Morales, M., Cueva, R., Utreras Bucheli, V., Zapata-Ríos, G., Toral, E., … Vargas Olalla, J. (2009). Oil industry, wild meat trade and roads: Indirect effects of oil extraction activities in a protected area in north-eastern Ecuador. *Animal Conservation*, *12*, 364–373.

UNEP-WCMC & IUCN. (2016). *Protected Planet Report 2016*. Gland, Switzerland and Cambridge, UK.

UNEP-WCMC, IUCN and NGS. (2018). Protected Planet Report 2018. UNEP-WCMC, IUCN and NGS: Cambridge UK; Gland, Switzerland; and Washington, DC, USA.

Venter, O., Fuller, R. A., Segan, D. B., Carwardine, J., Brooks, T., Butchart, S. H. M., … Watson, J. E. M. (2014). Targeting global protected area expansion for imperiled biodiversity. *PLoS Biology*, *12*, e1001891.

Visconti, P., Butchart, S. H., Brooks, T. M., Langhammer, P. F., Marnewick, D., Vergara, S., … Watson, J. E. (2019a). Protected area targets post-2020. *Science*, *364*(6437), 239–241.

Walston, J., Stokes, E. J., & Hedges, S. (2016). The importance of Asia's protected areas for safeguarding commercially high value species. In L. Joppa, J. Baillie, & G. Robinson (Eds.), *Protected areas: Are they safeguarding biodiversity?* (pp. 190–207). Chichester, UK: John Wiley & Sons, Ltd.

Watson, J. E. M., Dudley, N., Segan, D. B., & Hockings, M. (2014). The performance and potential of protected areas. *Nature*, *515*, 67–73.

Woodroffe, R., & Ginsberg, J. R. (1998). Edge effects and the extinction of populations inside protected areas. *Science*, *280*, 2126–2128.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Pacifici M, Di Marco M, Watson JEM. Protected areas are now the last strongholds for many imperiled mammal species. *Conservation Letters*. 2020;e12748.
https://doi.org/10.1111/conl.12748