

*Research*

# Mapping and navigating mammalian conservation: from analysis to action

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Although mammals are often seen as important objects of human interest and affection, many are threatened with extinction. A range of efforts have been proposed and much work has been done to try to conserve mammals, but there is little overall understanding of what has worked and why. As a result, there is no global-scale, coordinated approach to conserving all mammals. Rather, conservation efforts are usually focused at jurisdictional levels where relevant legislation and policies are in force. To help build the framework for a global-scale approach, in this paper we review the many ways that have been proposed for conserving mammals. First, we examine the overall pattern of threat faced by mammals at the global level. Secondly, we look at the major structuring issues in prioritizing and planning mammal conservation, examining in particular the roles of values and scale and a set of approaches to conservation, each of which varies along a continuum. Finally, we lay out the steps necessary to move from planning to implementing mammalian conservation.

**Keywords:** mammal conservation; strategies; implementation; scale; values

## 1. INTRODUCTION

Mammals have been a focus of human attention for a long time and continue to serve as the traditional focus of government spending on wildlife conservation. While birds have equalled mammals in public interest during the past century, and amphibians are rising fast, mammals are often regarded as the primary object of conservation. Not surprisingly then, the scientific investment in mammals—particularly large-bodied ones—is much greater than for all other groups [1].

The fondness with which humanity views mammals has not prevented many species in this group from being threatened with extinction: at least one-fifth but probably as much as one-third of all mammals are estimated to be threatened [2,3]. The rich and diverse body of scientific work on mammals also has not created the knowledge base nor mobilized the global community to develop a coherent, coordinated plan for reversing this pattern of threat and conserving the global mammal fauna. Over the last 100 years, many approaches to save certain species or groups of mammals have been proposed (c.f. [4]). However, few of these approaches have been implemented, and of those that have been put into practice, even fewer have been documented, let alone evaluated.

As a result, it is difficult to know what does and does not work in mammalian conservation. This challenge is compounded by the enormous variability in

the ecological and political contexts in which mammal conservation takes place, making it impossible to know whether an approach that worked in one setting would work in another. Yet, despite these complications, there is an opportunity to combine the broad-scale analyses of mammal conservation such as those found in this theme issue with what is known about the practice of mammal conservation to build a foundation on which a global mammal strategy could be developed. Such a foundation would be constructed from a conceptual mapping of the range of approaches to mammal conservation that have been proposed or tried and the conceptual architecture that underpins them. It is hoped that this will ultimately facilitate both a global strategy as well as more successful mammal conservation at all scales.

In the past, a set of unconnected individually-led efforts were rarely evaluated or documented and were often not strongly tied to the large academic literature. This is changing however, as academic scientists are expressing growing concern for the relevance of their work to practice and the development of new networks of individual, governmental and non-governmental organization (NGO)-based efforts. Increasing preoccupation with whether or not these myriad techniques/approaches have met with success is due to a combination of improvements in the documentation of the continued population and range declines of many large-bodied high-profile species [5] and expanded rigour in evaluating the outcomes of conservation actions [6].

In this paper we lay out a framework for understanding the many ways that have been proposed for conserving mammals. First, we examine the overall

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One contribution of 14 to a Theme Issue 'Global strategies for the conservation of mammals'.

pattern of threat faced by mammals at the global level. Secondly, we look at the major issues structuring the prioritizing and planning of mammal conservation. In particular, we examine: (i) the roles of values and scale; and (ii) a set of the issues underlying mammal conservation. Finally, we lay out the steps necessary to move from planning to implementing mammalian conservation. Our focus in this paper is on mammals that have been the objective of broad-scale conservation attention and therefore we have not dealt with all mammalian species.

## 2. MAMMAL CONSERVATION IN CONTEXT

The most recent comprehensive assessment of the global-scale conservation status of all known mammals was completed by the International Union for Conservation of Nature (IUCN) [7]. It revealed that a minimum of 21 per cent of all species are threatened. The negative trends are confirmed by the Living Planet Index: using aggregated trends for 1307 populations of 360 terrestrial mammal species, it suggests an average decline of 25 per cent for the period 1970–2007 [8]. Moreover, about 15 per cent of all mammals are classified by IUCN as Data Deficient: if this group had similar distribution of threat level, the percentage of threatened species would be about 25 per cent [2]. In particular, 188 species are Critically Endangered, but 29 of them, such as the Yangtze River Dolphin or Baiji (*Lipotes vexillifer*) in China, may already be extinct. The distribution of extinction threat is highly heterogeneous across body sizes, taxonomic classes and geographical areas: for example, large mammals (>20 kg) face threat levels (39%) that are almost double those of the class as a whole. In addition, 50 per cent of all primates and 36 per cent of the 120 marine species are threatened. South and Southeast Asia as well as most of the mountain ranges of the tropics are the areas of special concentration of threatened species [2].

Indonesia, Mexico, India, Brazil and China have the highest number of threatened species, a reflection of the countries' large size and high species diversity [9]. Carwardine *et al.* [10] analysed the area required to represent a target of 10 per cent of the geographical range of each mammal species and found that the greatest amount of irreplaceable area is in Indonesia, Mexico and Papua New Guinea. The forest biome has the highest number of mammal species and the largest proportion of threatened species, especially in the tropical areas of South America, Central Africa and Southeast Asia [9].

The IUCN Red List Index is an aggregated measure of extinction risk based on the reclassification of species in a series of assessments [11]. For mammals, it shows a 0.8 per cent decline during 1996–2008 [3] when 156 species were reclassified in a worse threat category. About half of all species, including those currently non-threatened, are declining in numbers and many local populations are disappearing, leaving wide gaps in species distribution and increasing the vulnerability of remaining fragments. This pattern is mirrored in trends in changes in range extent, an important criterion for conservation status [12]. In a comparison of historic

and current distributions of 173 declining mammal species from six continents, Ceballos & Ehrlich [5] found that these species had collectively lost over 50 per cent of their historic range area, particularly in areas where human activities are most intensive. At a smaller geographical scale, Laliberte & Ripple [13] compared historic and current ranges of 43 North American carnivores and ungulates, finding that 17 species had experienced range contractions over more than 20 per cent of their historic range.

## 3. MAJOR FOUNDATIONAL ISSUES IN PRIORITIZING AND PLANNING MAMMALIAN CONSERVATION

Underpinning many approaches to mammal conservation are choices that people make about what species they prefer. Though seldom discussed explicitly, support for mammal conservation is dominated by such preferences. Even though prioritization schemes are often meant to be objective or quantitative, the basis of such schemes—the starting point—is often driven not by science, but by values. Values are defined here as the worth, importance or usefulness of something to someone. What is important to one person is not necessarily so to someone else and as such there are no absolute values and no common currency that can be used to prove or disprove values. Influencing these values are the social, spatial, temporal, political and financial scales at which actors operate. We contend that making explicit these values is an important first step in mapping the full sweep of mammalian conservation.

Below we discuss the nature of the values themselves, how they are measured and how scale influences the valuation process. These categories are not mutually exclusive, i.e. the same mammal can be prioritized on the basis of more than one of these values.

### (a) *High extinction risk*

Highly threatened mammals are those in imminent danger of global extinction—usually defined as 'Critically Endangered' by IUCN [14]. Prioritizing extinction prevention is underlain by the value people place on the continued existence of a species and argues that, since all species should be conserved, those that are at greatest risk of extinction should be the highest priority.

Modern species conservation approaches that define successful conservation as preventing extinction are underlain with this value of 'extinction avoidance' [15]. Although the Red List is not meant to be a priority list for conservation action [16], it is inevitable that the Red List process of IUCN [14] and the extensive global cooperation that underpins it focus attention and effort on species based on threat level. IUCN's system for classifying threatened species is almost universally used for assignment of global threat status. This system was designed to measure the symptoms of extinction risk, through evaluation along five independent criteria that relate to rates of declines or small sizes of populations and/or range [16]. This approach is extended by the Alliance for Zero Extinction (AZE), a consortium that strives to prevent extinctions by identifying and safeguarding key sites, each one of which is the last remaining refuge of one or more globally

Endangered or Critically Endangered species. AZE focuses on species that face extinction either because their last remaining habitat is being degraded at a local level or because their small global range makes them especially vulnerable to external threats [17].

Whereas the Red List is defined by extinction at the global scale, extirpation at sub-global scales is also a key concern. Many countries and sub-national units (e.g. states and provinces) have created endangered species lists that tend to be linked to legislation and/or institutional actors that have relevance only at that scale [18]. Such lists govern allocation of resources to conservation activities, with a large focus on species with a high risk of extinction. The protocol for assigning threat status is variable across countries [19], although there is an increasing use of IUCN criteria applied at regional scales [16,18]. It is not uncommon for there to be a mismatch between endangered species lists at the global versus national scale [20], particularly in countries located at the edge of a species' geographical range, or when a species is characterized by unusually high levels of regional abundance or is globally common and stable but locally rare or declining [16,20,21].

#### **(b) Direct exploitation**

Around the globe, mammals have always been a favourite target of human hunters. In North America and Europe, 'game species', particularly wild ungulates commonly hunted for sport, have been a traditional focus of wildlife management efforts since the beginning of the twentieth century. Mammals are also used for other products, such as ornaments, fur and skin. In tropical forests, larger bodied ungulates and primates comprise the major portion of biomass harvested by human hunters [22]. The social value placed on game species drives allocation of research and management support, although in North America the relationship between sport hunting and natural resource management has been weakening [23]. There is regional variation in preference for game species based on historical, social and zoogeographic factors.

#### **(c) Charisma and symbolic importance**

Charismatic species are those that have the ability to inspire enthusiasm, interest or affection in people. Research has shown that large eyes, paedomorphic shape, short dense fur and other factors increase human interest in and support for a species (c.f. [24]). Many of these species are mammals. Beauty and awe are also characteristics that cause humans to classify certain species as charismatic and of greater importance for conservation. Charismatic species often attract charismatic researchers who themselves develop followings, further focusing attention on the species. Another term for this category is 'flagship species' which are defined as those species which draw public support for their conservation and for conservation in general [25].

Charismatic species are the most 'popular' species with the public and are featured in advertising campaigns, T-shirts and magazine covers. A great many programmes use the attractive quality of certain mammalian species to garner support for their conservation and, sometimes, the conservation of their habitats. These

include organizations devoted to species or species groups such as cetaceans, big cats and gorillas. A subset of charismatic species contains those with strong cultural or historic ties to certain human groups; therefore, this characteristic can vary by region. These may be due to origin myths such as the wolf in many Eurasian cultures, to spiritual beliefs in jaguars for peoples of northern Mexico, to extensive subsistence reliance on bison in North America for Native Americans, or to tigers as symbols of other worlds for peoples of Southeast Asia.

#### **(d) Evolutionary distinctiveness**

The valuing of evolutionary distinctiveness is a valuing of the amount of evolutionary history contained in a given species [26]. For example, a species like the Long-beaked Echidna (*Zaglossus bruijnii*) would have greater evolutionary distinctiveness than one of the numerous species of *Sorex* shrews. Conservation of those mammal species with high evolutionary distinctiveness would therefore ensure conservation of a high proportion of what it means evolutionarily to be a mammal.

Conservation priority setting based on phylogenetic diversity has frequently been proposed [27], but only recently has a programme been designed to conserve it. The Zoological Society of London created the EDGE programme, which combines measures of evolutionary distinctiveness with global endangerment to create a list of 100 mammal species that collectively represent a high proportion of total global mammalian evolutionary diversity. Many of these species are not usually recognized as conservation priorities in other approaches and are often not the beneficiaries of targeted protection [26,28]. Evolutionary distinctiveness refers to a species and can therefore only be measured at one taxonomic scale.

#### **(e) Rarity**

Value is placed on rare species, even though it may be difficult to determine exactly how 'rare' is being defined. Rare species are often ones with the highest extinction risk, but their rarity can vary with factors such as ecological specialization, distribution, population size and habitat specificity [29]. As such, rarity is not always a predictor of extinction risk [30,31]. Despite the complexity of these interacting variables, rarity is considered by some to be a priority for conservation.

Whether or not an animal is rare is a relative concept. Although this can be identified through empirical means, there is no agreed-upon threshold for rarity *per se*. This category varies in interesting ways depending on the spatial scale. At the global scale, most species are naturally rare by any measure and most common species are rare in large parts of their range [32]. As a result, when their ranges cross political boundaries, they may be rare in some political units even if common globally. This is especially evident in regions with high administrative fragmentation such as Europe where the size of countries and autonomous sub-national units are often very small compared with the range of most European mammals.

#### **(f) Function**

It is becoming increasingly common for value to be ascribed to species on the basis of the strength of their

contribution to ecosystem function through their trophic position (keystone function) or their role as agents of habitat modification (ecosystem engineers) [33,34]. This has been occurring in tandem with the growing appreciation for the substantial role of biological diversity in maintaining ecological integrity and resilience in a changing world, and the consequences from a systems perspective of the loss of species [35]. For example, top down forces may be exerted by top predators on species at lower trophic levels through a variety of ecological and evolutionary interactions. In cases where these large carnivores have been extirpated, there is evidence that such forcing can be substantially weakened, and ecosystems will subsequently become degraded and simplified [36]. Examples include the ecological role of large carnivores in both terrestrial and marine systems [37,38], and large ungulates that gather in high concentrations at certain times of the year and are thought to play a role in nutrient transfer influencing ecosystem and plant species community structure through herbivory (e.g. [39]). Another example comes from pteropodid fruit bats which are important dispersers of large seeds when at naturally high population densities, but cease to be effective in this capacity even before they are obviously rare [40].

In practice, valuation of mammalian species is more likely to be based on a combination of attributes rather than a single one, particularly because they covary. The combination of being charismatic, highly threatened, in decline, large-bodied and evolutionarily distinct describes those mammals that are most likely to receive conservation attention [41]. Yet, many of these characteristics on their own do not lead to higher valuation, as illustrated by the fact that the vast majority of mammals at risk of extinction receive no attention at all [41]. The same is true for the majority of evolutionarily distinct species, which are small and/or nocturnal, while only those that are large-bodied and charismatic, such as elephants, rhinos and orang-utans, achieve high profiles [1]. More recently, prioritization schemes have been constructed to overcome some of the inherent subjective biases that persist. Such procedures, often quantitative in nature, rank species based on which conservation intervention is most necessary. They use factors such as extinction risk, distribution, biological variables and socio-economic conditions [18,42]. Appreciation of the critical role that values play in prioritization of funding, effort and public support is vital to begin to map global mammal conservation.

#### 4. APPROACHES TO MAMMALIAN CONSERVATION

Mammals exist in a rich diversity of ecological and social settings, and therefore require a varied set of strategies to achieve their effective conservation. Much debate occurs about which approach or set of approaches is most appropriate to deploy and most effective in practice. These debates are often resolvable with good science and a better understanding of the different contexts within which conservation takes place. Disagreements on strategy may be due to differences in the social and biological environment where the conservation is being undertaken. Below we discuss six of the most common arguments about strategies, describing what we believe

to be the continuum along which the most suitable strategy lies.

##### (a) *From protected areas to matrix management*

To some practitioners, protected areas are a *sine qua non* for mammal conservation, while for others they are relatively ineffective and what is more important is the larger matrix of mixed land uses outside protected areas. Though often phrased in these absolute terms, the balance between, and combining of, these two approaches depends on the species in question [43], the nature of the larger landscape and how this landscape is used. For some species, such as Caribou (*Rangifer tarandus*) or nomadic Mongolian Gazelle (*Procapra gutturosa*), existing protected areas will never be large enough to conserve populations and conservation must focus on the larger area used during migration or other large-scale movements [44]. For other species, the landscape context within which conservation efforts take place is a more important variable in influencing the relative importance of a protected area or matrix. In areas of extensive and long-standing human influence on the structure and composition of biodiversity, species may depend on alterations to energy flows, trophic structures or habitat [12]. In such cases, the matrix may actually represent a critical habitat subsidy to areas under stricter protection. Such settings usually also have fewer, smaller protected areas, requiring work in the matrix for successful mammal conservation.

This dynamic can be seen in Europe where the limited protection of less-altered ecosystems make working with the management practices in human-dominated landscapes essential for the conservation of large carnivores. Because of this, conservation of Wolves, Lynx, Brown Bear and Wolverine relies on the management of human–carnivore coexistence at national scales through schemes of regulated harvest and prevention and mitigation of conflicts with livestock [45]. There are a few exceptions, such as the relict Brown Bear population in central Italy whose conservation is restricted to a few protected areas [45]. The dynamic can also be seen in northern boreal forests where natural processes such as fire take place over such large areas that the static nature of protected areas means that they may never be large enough to conserve species adapted to fire-driven landscapes [46,47]. Nevertheless, even when protected areas are too small to encompass the needs of all resident mammals, they serve critical roles in regulating certain land uses that would negatively affect mammal species that are sensitive to human disturbance, such as intensive hunting, forest exploitation, intensive agriculture and roads. Because of this, protected areas have been demonstrated to contribute to the stabilization or recovery of threatened species [48].

##### (b) *From habitat management to population management*

Two apparently contrasting approaches to conserving mammals involve focus on the populations themselves, or on the characteristics of the species' habitat in which the populations do, or could, live. For example, reducing the impact of natural resource extraction activities is often done by manipulating habitat under the

assumption that this will conserve target species found within such areas [49], e.g. 'managed forests'. Such an approach contrasts with outright protection of an area in which a species resides, in that rather than changing the governance of the land, the existing land use is modified [50]. An alternative to this indirect approach involves direct focus on mammal populations themselves. As such, conservation goals are achieved through direct manipulation of parameters that determine population growth such as harvest management, predator control and augmentation of populations. For example, predator control to minimize additive sources of mortality has been used to promote recovery of ungulate populations that are in decline and/or reduced to small isolated groups [51]. In other settings where carnivore persistence is constrained by social acceptance, hunting quotas and predator control have been shown to increase persistence [52]. Species for which overexploitation is the principal threat to population stability (such as Brown Bears) will benefit more from measures that reduce mortality than from those directed at improving habitat. Other approaches, such as population augmentations, translocations and reintroductions, are commonly employed means of increasing population sizes and/or recruitment of critically endangered mammals [53].

The tension between management of populations versus habitat is further exacerbated by the fact that the link between the amount of habitat and the population dynamics and/or recruitment of a species is often untested. Many times both approaches will be required to achieve species conservation goals, although the relative emphasis will depend on factors such as degree of endangerment, nature of threatening processes (i.e. the degree to which overexploitation or habitat loss has been the primary driver of population trends) and intrinsic biological traits such as body size [54].

#### **(c) *From preservation to sustainable use***

There is a long-standing argument about whether species of economic and/or cultural importance are most effectively conserved through strict protection with no harvest or through managed harvest programmes. The extinction or near extinction of several mammal species including the Quagga in South Africa and the Bison in North America set the scene for the modern conservation movement's conviction that complete protection is a vital tool in the protection of mammalian species. This conservation perspective tangled with wildlife management, which in the USA takes the shape of the 'North American Model of Wildlife Conservation' based on the public ownership of wildlife, the elimination of markets and the scientific management of wildlife for individual hunters [55].

Different countries have different traditions, practices and efficacy of management regimes, but such tensions continue to underpin many mammalian conservation efforts. Most recently it has reappeared in arguments about farming of mammal species, with farming proponents arguing that regulated, captive production relieves pressure on wild populations and farming critics saying that the farming provides a front for continued wild harvest and promotion of increased consumption [56].

The tradition in conservation has been to lobby for the complete protection of a species once it reaches the status of a 'species of concern', arguing that every individual is important for the survival of the species. Yet, species considered to be threatened can also be very important animals for native and traditional people. Some argue that allowing the killing of limited (and sustainable) numbers of these species helps either build support for their conservation or prevents the illegal killing of many more individuals. When biologically sound management can be effectively implemented, harvesting can increase support for conservation by soothing the tensions between opposing fronts of public opinion, as with brown bear and wolf management in Scandinavia [57]. In other settings, such as in Canada, co-management boards have been established under Canada's northern comprehensive land claims which provide Aboriginal people with key decision-making power over land and wildlife decisions such as setting general policy and harvest levels for various species. These Boards, the main instruments of wildlife management in Canada, are unique governance institutions that have substantial independence from government. They have significantly enhanced Aboriginal peoples' influence over land, wildlife and resource decisions [58].

#### **(d) *From complete protection to triage***

Since the underlying value of much of modern conservation is to prevent all extinction, some efforts are focusing on large-scale attempts to save all species from going extinct with no consideration of cost or effort (e.g. [59]). An emerging perspective disagrees with the 'no extinction' position, believing that given the stark reality of limited resources, focused efforts should be deployed efficiently in pursuit of the optimized return even if this means that some species are allowed to go extinct [60]. This concept of triage is based on the prioritization of species or evolutionary history whose conservation can be ensured with the greatest economy of resources [61].

The existence of these two positions has sparked a lively debate that has been largely focused at two levels: the first centres on whether or not 'sanctioning extinction in the name of efficiency' (e.g. [62]) is advisable. The second concerns the criteria or process by which species should be prioritized (e.g. [59,63]).

#### **(e) *From species to ecotypes***

Despite the ubiquitous use of the term 'species', there is often a marked lack of precision in what is meant by that term and how it is used in conservation planning and prioritization. 'Species' has come to be equated with 'taxonomic category', sometimes less inclusive and sometimes more inclusive than what is usually considered a species. For example, the US Endangered Species Act defines 'species' as including species, subspecies, and for vertebrates only 'distinct population segments' and for salmon 'evolutionary significant units' [64]. Under the Canadian Species at Risk Act, 'designate-able units' are recognized as irreplaceable units of biodiversity critical to the persistence of biological species [65].

For example, there are often said to be four 'kinds' of Gorillas when there are four subspecies. And there are

said to be several ecotypes of Caribou all in the same species. For lower profile species or those that are difficult to distinguish in hand, a 'species' can include multiple species, as with 'White-footed Mice'. Finally, the question of hybrids makes the definition of a species even more complicated, with some arguing that wolf–dog hybrids in Italy should be classified as Wolves, or bison–cattle hybrids in the USA as Bison. Moreover, whereas biologists are more flexible in interpreting the fixity of a taxonomic unit and ready to accommodate splitting and merging of different units, the issue of species as conservation targets is stiffened by the list of species that accompany most of the national and international conservation laws and treaties.

## 5. FROM PLANNING TO CONSERVATION

### (a) *Whose plans? Whose priorities?*

Mammal conservation has drawn the attention of many scientists who have produced a considerable body of literature examining the intricacies of the topic. Much of this work has been largely academic in nature with unfortunately limited influence on those making decisions about, and implementing, conservation—a situation all too familiar in other conservation settings [66,67]. The common lack of engagement between science and effective on-the-ground action is apparent [68]. Despite this fact, generalized planning for mammal conservation by scientists remains common, with little attention paid to the questions of whose plans these are, whose priorities are being identified, what information implementers need and want, and most importantly, who is going to undertake the challenging task of implementing the proposed conservation work. This is often confounded because conservation priorities frequently vary with values, scale and geography. When planning, it is important to ask whose priorities are being represented and who will own, implement and assess any proposed plans.

### (b) *Achieving conservation*

Establishing priorities alone does not achieve conservation. This understanding has been growing in IUCN where their important work on assessing species endangerment has increasingly been incorporating assessment of the actions required at a variety of scales. The Species Survival Commission, although comprising about 8000 global experts in species conservation and supported by a partnership of 11 conservation and research institutions contributing to maintaining and expanding the Red List, has itself acknowledged the limited impact of its own species conservation efforts, particularly its species action plans, pointing out the failures to make clear the intended audience for the recommendations or to make explicit recommendations for action [7].

Once priorities are established, achieving conservation requires a set of steps (modified from the Conservation Measures Partnership project cycle) [69]. These include efforts to first identify *a priori* the desired final condition—success; second, to identify the correct scale for operating; third, to identify and work with the right partners; fourth, to ensure the right policy and funding framework; and fifth, to take the correct actions, monitor, learn, and revise.

### (i) *Defining success*

In order to plan for conserving a species it is imperative to have a definition of successful conservation. The tradition in conservation biology has been to define successful conservation as avoidance of extinction. This is an insufficient definition that will continue to leave conservation in a reactive mode with an ever-increasing accumulation of defeats. A more comprehensive answer to what successful species conservation means provides a forward looking, positively oriented definition. Based on Redford *et al.* [15], we define successful species conservation or recovery as maintaining multiple populations across the range of the species in representative ecological settings, with replicate populations in each setting. These populations should be self-sustaining, healthy, ecologically functional and genetically robust—and therefore resilient to climate and other environmental changes. Redford *et al.* [15] provide definitions for each of these attributes and lay out a categorization of different states of species conservation using extent of human management and the degree to which each of the attributes is conserved.

### (ii) *Choosing the right scale*

Prioritizing, planning and action—all take place at a variety of scales. In mammal conservation, there often is a scale mismatch between prioritization and action. In other words, problems and solutions are often perceived at a different scale than where threats to conservation are acting [70]. For a wide-ranging species, for example, proximate threats may be most evident at smaller scales, but it is only at the ecologically relevant scale where the threats to its persistence can be addressed [70]. There has been a great deal of work on mammal priority setting at the global scale [71]. Yet, there are few actors in mammal conservation operating at this scale to influence. Rather, most conservation action will happen through institutions and actors operating at lower scales (e.g. country and protected areas) with focus of action often restricted by political boundaries [18].

Patterns of range, abundance and threat vary spatially, yet the pattern of political boundaries is usually not related to these threat patterns. As a result there can be scale discordances such that mammal species which may be common globally may be classified as of conservation importance in countries located at the periphery of that species' range. Or a species in global decline may remain stable (or even be increasing) within a country or region [20]. This, combined with often disparate processes that define conservation action from one neighbouring country to the next, can lead to differences in priorities, and hence action. One example is illustrated by the Canada Lynx, a species that is widespread and often abundant throughout Canada, but whose southern distribution has receded in the past century and is classified as threatened in the USA [72]. Even while the species faces challenges with respect to habitat connectivity in the southern extent of its Canadian range, the overall status of the species in Canada means that it receives little attention, sparking concerns that US Lynx populations will face challenges in sustaining themselves, particularly in a changing climate, if ties to robust

population sources in the north are severed [73]. Most species' distributions include several countries (mean of 5.87 countries/species) and the median size of mammal ranges is 198.326 km<sup>2</sup>, almost three times larger than the median of country sizes (70.904 km<sup>2</sup>—United Arab Emirates) [74]. Even species with restricted ranges are often transboundary in distribution, making it clear that most mammals will be conserved only with cooperation between countries [10].

(iii) *Working with the right partners*

Scientists have long assumed that managers would put into effect whatever they recommended. This is not and will usually not be the case [66]. In fact, much of what is published in the scientific literature is not read by managers for a variety of reasons [67]. Much of what managers know and have learned from experience they do not tend to write down or share broadly. This has created a divide that has prevented improved action and strong partnerships.

Conservation biologists are increasingly learning the importance of informed partnerships and the need to incorporate into planning the perspectives of all stakeholders. As an indication of this growing realization, in its latest species conservation handbook the IUCN/Species Survival Commission (SSC) [7] calls for planning efforts to involve stakeholders including people from relevant governments, conservation NGOs, other conservation specialists (such as law enforcement specialists), species specialists (some of whom may of course work for government agencies and NGOs), representatives of local communities or local authorities (when appropriate), the private sector (for example, logging or mining company representatives, or tourism operators) and other key stakeholders. They define a stakeholder to be an individual or institution that demonstrates some combination of concern for the conservation process, expertise and/or power to influence the conservation effort [7].

A powerful emerging approach to conservation planning called trans-disciplinarity has recently been described by Reyers *et al.* [75]. In this approach, conservation science 'becomes a social process resolving problems through the participation and mutual learning of stakeholders' [75, p. 957]. By involving the right people at the right time, the gap currently facing mammal conservation can be bridged and the work of scientists can much more effectively be targeted and influential in helping conservation action.

(iv) *Ensuring the right policy and funding framework*

Conservation cannot be successful without supportive policy and funding. At the global scale, there are few funding agencies operating and only a severely limited policy framework. Instead, as discussed above, most of the policies to enable successful conservation—and therefore the funding—exist at the national or regional scales. The national level at which most funding is available makes rangewide conservation prioritization and work difficult. Despite this, several efforts have been made to organize and coordinate work for single species including Jaguar [76], Tigers [77] and Bison [78].

Treaties and conventions also have been developed to address cross-border conservation (e.g. Polar Bear, the Porcupine Caribou herd) as well as migratory species (e.g. Convention on Migratory Species) or to focus on populations rather than administrative units as targets of conservation planning (e.g. large carnivores in Europe). Unfortunately, these instruments do not have strong regulatory power, and jurisdictions themselves are in charge of setting up the systems, as well as monitoring and reporting. The results have not been significant conservation of these wide-ranging species. The existence of such international, regional and national regulations combined with local policy instruments directed at conservation has resulted in 'fragmented governance' of species [79]. As these authors point out for species of sport or commercial importance, conservation has been further complicated by fragmentation between conservation and natural resource management regulations. Such a complicated mix of regulation and financing makes it essential to have a clear understanding of the scale at which recommendations are being made and action is to be taken and how this compares to policies and funding.

(v) *Taking the correct actions, monitoring, learning and revising*

With all of the other components of success in place, undertaking the conservation work itself still remains. Deciding what actions to take should be informed by a conceptual modelling process [80] where actions are directly linked to a desired final state, threats, sources of threats and other important contextual elements. Including all potential actors working together towards the same ultimate goal in such an exercise is key, both to derive as complete a picture as possible of the conservation problem, and to clarify intervention gaps that may exist. Combining a conceptual model with the project cycle [69] means that the conservation team puts in place monitoring and revising procedures during the planning phase so that progress relative to the goals of this exercise can be appropriately tracked [81].

Without monitoring the results of action, conservation practitioners cannot learn from implementation (see [82]). This is particularly important given the diverse political and governance settings within which different populations of the same species are found. The tradition is to assume that the correct action has been taken and regard monitoring as a waste of time and money. However, increasingly, when monitoring is done the action has been shown to either not be effective or even produce perverse results (c.f. [83]).

Many successful mammal conservation efforts have not followed this set of steps. However, undoubtedly, even more have either not been successful or have had much more limited success than would have been possible using a more systematic effort to conserving and learning. We are convinced that the future of mammalian conservation lies in a more careful, systematic and consultative conservation such as we outline here.

## 6. CONCLUSION

Throughout history, mammals have been the focus of conservation—from the hunting grounds of the Mongol emperors to the vicuna populations harvested

by Incan emperors and from the rotational hunting patterns of Amazonian Indians to the hedgehog conservation societies of modern Europe. As humans have increasingly become an urban species, the intimate links between mammals, wild and domestic, that used to typify the human condition have been broken. This has not resulted in a lack of interest in mammals but a redefining of the relationship. This redefinition has been part and parcel of the rise of modern approaches to mammal conservation.

Mammals as a group are in trouble globally, threatened by agricultural expansion, natural resource extraction activities, over-exploitation and invasive alien species [3]. Humans have put in place a broad range of responses to these threats. But there is no agreed-upon science or practice of mammal conservation, mirroring the lack of a unified science or practice of conservation itself. Instead, mammal conservation has taken myriad forms depending on the species involved and the human culture, history and geography. Reflecting the general trend in conservation, these responses have been largely directed at prevention of extinction, focusing on species only when they are threatened. The major exception, and not the primary focus of this analysis, has been the set of strategies directed at ensuring game species are abundant enough for continuing harvest. But, in almost all cases, though many efforts have been tried, few have been evaluated and so we are left with no systematic understanding of how best to proceed more effectively and efficiently.

In this analysis, we have made the case that addressing this lack of understanding first requires a conceptual mapping of both the values that underpin many mammal conservation efforts as well as the set of key controversies determining how efforts are framed and conducted. Neither of these two major structuring dimensions is usually discussed in the literature on mammal conservation.

Evidence exists that conservation action can have effects. The rate of deterioration in conservation status of the world's vertebrates would have been at least one-fifth as much in the absence of conservation action [3]. However, there is little evidence of what does and does not work and why. There is a pressing need for development of conservation-based assessments and decision-making [6]. We have come to understand, for example, that though protected areas are very important for many purposes they do not necessarily succeed in conserving all mammal species from all threats (c.f. [84]) and that therefore direct measures of population size and change will probably continue to be vital in assessing the efficacy of different strategies.

Although their coverage may be extensive, protected areas will never be the solution to much of the conservation that mammals require. It is becoming increasingly important to work in the areas not under strict protection and ask how human disturbance affects the most sensitive mammalian species, or 'how much disturbance is too much?' The best prospects for curtailing the extent and intensity of the human footprint are in areas where it is currently limited and where proactive conservation opportunities involving a range of governance types can address broad-scale impacts of human resource use. This approach need not be confined to species

found in areas with large swathes of relatively unaltered ecosystems like the boreal forests, but may be equally true for species with little remaining habitat such as the Mediterranean ecosystems of Europe and North Africa.

Finally, studying and understanding alone will not save mammals—only successful, sustained action will. We need to understand how to involve all those whose support is necessary to achieve successful species conservation [15] as well as to understand that conservation is forever. As shown by Scott *et al.* [85], for the USA, 67 per cent of the mammals listed under the US Endangered Species Act are 'conservation reliant', requiring continuing species-specific interventions by humans. To avoid increasing the number of mammalian species whose fate is directly in our hands, we must develop a proactive, forward-looking approach to conservation that offers hope and action to a world anxious to keep its treasured mammal fauna intact.

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