The difference conservation makes to extinction risk of the world’s ungulates

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Abstract: Previous studies show that conservation actions have prevented extinctions, recovered populations, and reduced declining trends in global biodiversity. However, all studies to date have substantially underestimated the difference conservation action makes because they failed to account fully for what would have happened in the absence thereof. We undertook a scenario-based thought experiment to better quantify the effect conservation actions have had on the extinction risk of the world’s 235 recognized ungulate species. We did so by comparing species’ observed conservation status in 2008 with their estimated status under counterfactual scenarios in which conservation efforts ceased in 1996. We estimated that without conservation at least 148 species would have deteriorated by one International Union for Conservation of Nature (IUCN) Red List category, including 6 species that now would be listed as extinct or extinct in the wild. The overall decline in the conservation status of ungulates would have been nearly 8 times worse than observed. This trend would have been greater still if not for conservation on private lands. While some species have benefited from highly targeted interventions, such as reintroduction, most benefited collaterally from conservation such as habitat protection. We found that the difference conservation action makes to the conservation status of the world’s ungulate species is likely to be higher than previously estimated. Increased, and sustained, investment could help achieve further improvements.

Keywords: conservation impact, counterfactual scenarios, extinction risk, IUCN Red List

La Diferencia que Hace la Conservación en el Riesgo de Extinción de los Ungulados del Mundo

Resumen: Los estudios previos muestran que las acciones de conservación han prevenido extinciones, recuperado poblaciones y reducido las tendencias de declinación en la biodiversidad mundial. Sin embargo, todos los estudios a la fecha han subestimado sustancialmente la diferencia que hace la acción de conservación ya que fallaron en representar de lleno lo que podría pasar en ausencia de esta. Emprendimos un experimento reflexivo con base en escenarios para cuantificar de mejor manera el efecto que las acciones de conservación han tenido sobre el riesgo de extinción de las 235 especies reconocidas de ungulados en el mundo. Hicimos esto al comparar el estado de conservación de la especie observado en 2008 con su estado estimado bajo
escenarios contrafáctico en los cuales los esfuerzos de conservación cesaron en 1996. Estimamos que sin la conservación, al menos 148 especies habrían empeorado su categoría en la Lista Roja de la Unión para la Conservación de la Naturaleza (UICN), incluidas seis especies que ahora aparecerían como extintas o extintas en estado silvestre. La declinación general en el estado de conservación de los ungulados habría sido casi ocho veces peor de lo que se observó. Esta tendencia habría sido mayor si no fuera por la conservación en tierras privadas. Mientras algunas especies se han beneficiado de intervenciones altamente enfocadas, como la reintroducción, la mayoría se benefició colateralmente de la conservación, como la protección de hábitat. Encontramos que la diferencia que hace la acción de conservación en el estado de conservación de las especies de ungulados probablemente sea mayor de lo que se estimó previamente. Una inversión aumentada, y sostenida, podría ayudar a obtener más mejorías.

Palabras Clave: escenarios contrafáctico, impacto de la conservación, Lista Roja UICN, riesgo de extinción

Introduction

Current evidence indicates a growing mismatch between increasing pressures to biodiversity and conservation responses (Tittensor et al. 2014). Success, however, is not uncommon in the field of biodiversity conservation (Sodhi et al. 2011; Balmford 2012). Extinctions of some species have been prevented (Butchart et al. 2006; Brooke et al. 2008), population trajectories have improved (Donald et al. 2007; Deinet et al. 2013; Chapron et al. 2014), and the risk of extinction of wild species has decreased (Hoffmann et al. 2010). There have been increased calls for evidence-based conservation to actively demonstrate this effectiveness to funders, policy formers, and the public (Sutherland et al. 2004). However, while other policy fields of global importance undertake extensive evaluations of success (Ferraro & Pattanayak 2006), evaluations of the outcomes of conservation actions were until recently relatively rare (Sutherland et al. 2004; Kapos et al. 2009). Therefore, opportunities to efficiently allocate limited resources, encourage the application of effective policies, and inspire people to become involved in biodiversity conservation may be missed (Ferraro & Pattanayak 2006).

Understanding what difference conservation makes is difficult because conservationists are generally preoccupied with reacting to emergencies rather than with quantifying their actions and impacts and it is inherently difficult to know what would have happened without intervention (Rodrigues 2006). Tests of conservation interventions in controlled experiments akin to those in medicine are extremely rare in conservation and often not possible except for small-scale interventions (given the need to ensure everything else remains equal in the control setting). Instead, the impact of specific interventions on biodiversity have been tested using a posteriori analyses of natural experiments through comparisons of biodiversity condition with and without the intervention (e.g., inside and outside protected areas [Joppa & Pfaff 2010; Geldmann et al. 2013]; with and without law enforcement guards [Tranquilli et al. 2012]) or through correlations between the magnitude of the intervention and of biodiversity condition (e.g., protected area coverage vs. changes in extinction risk [Butchart et al. 2012]). However, conservation takes places through a diversity of actions (e.g., protected areas and legislation), with various degrees of synergy among them, and measuring the overall impact of these actions cannot be done by simply summing the impacts of individual actions (Rodrigues 2006).

One way to explore what would have happened without conservation actions is to construct a counterfactual scenario - a hypothetical scenario that estimates what would have happened if conservation actions had not actually taken place (Ferraro & Pattanayak 2006; Ferraro 2009). Hoffmann et al. (2010) previously documented 68 species of mammals, birds, and amphibians known to have improved in conservation status in recent decades due to conservation efforts. They found that, if such conservation successes had not occurred, the overall deterioration in conservation status in these 3 taxa would have been one-fifth worse again than that observed. However, these authors cautioned that their study underestimated true conservation impact because it only examined species that improved in conservation status. In practice, in the absence of conservation, some species that remained unchanged in status may have actually deteriorated or species that deteriorated over the time period considered may have deteriorated further (or even gone extinct). These, too, are conservation successes, but they are less straightforward to identify.

In a different study, Butchart et al. (2006) identified at least 16 critically endangered bird species that likely would have gone extinct between 1994 and 2004 without conservation action. These authors also underestimated conservation impact because they focused solely on the avoidance of species extinctions. However, conservation is not only about preventing highly threatened species from becoming extinct, but also about keeping common species from becoming threatened (Gaston 2010).

We explored further the difference conservation makes by focusing on ungulates as a case study. We investigated how conservation efforts affected their extinction risk by comparing their observed International Union for Conservation of Nature (IUCN) Red List categories between 1996 and 2008 with the conservation status that
we estimated they would have had under a hypothetical scenario where all conservation actions ceased at the start of the period. We then used the IUCN Red List Index (RLI), an established method (e.g., Tittensor et al. 2014) that tracks trends over time in overall extinction risk of species, to compare the observed RLI with that resulting from our hypothetical scenario.

Individual species are likely to differ in terms of how they actually benefit from conservation. For example, some species may benefit from directly targeted conservation actions (such as reintroduction efforts) that mitigate species-specific threats (e.g., Dobson & Lyles 2000), while others may benefit collaterally from more general conservation actions (such as habitat protection). To better understand how ungulate species benefited from conservation, we classified all ungulates according to a typology that related the specificity of actions to the specificity of the threat.

Methods

Species Data

We included in our analysis all 235 ungulates assessed on the IUCN Red List in 2008 in data sufficient (i.e., non-data deficient) categories in the orders Cetartiodactyla (Cervidae, Moschidae, Tragulidae, Giraffidae, Camelidae, Antilocapridae, Suidae, Tayassuidae, Hipppopotamiidae, Bovidae) and Perissodactyla (Rhinocerotidae, Equidae, Tapiridae). We followed the same species concept adopted for the purposes of assessments in 2008, recognizing that many species await reassessment to account for taxonomic revisions. Several new species described recently (e.g., Philotomob walkeri [Colyn et al. 2010]) await formal assessment by IUCN, so they have not been included in these analyses.

Calculating Observed and Counterfactual Red List Indices (RLI)

We followed the standard RLI method (Butchart et al. 2004, 2007) that combines information on species’ red-list status at a given time to obtain an aggregated measure of extinction risk for a group of species. Changes in the RLI over time result from genuine changes in species red-list status between assessments: improvements in status contribute to an increase, whereas deteriorations contribute to a decline in the RLI. Thus, RLI trends reflect the net outcome of these improvements and deteriorations.

An RLI has been previously derived for all mammals based on genuine observed changes in extinction risk between 1996 and 2008 (Hoffmann et al. 2010, 2011). The year 2008 corresponds to the date when mammals were last assessed globally (Schipper et al. 2008). The 1996 and 2008 red-list categories for ungulates from Hoffmann et al. (2010, 2011) are hereafter termed the 1996 observed red-list category and 2008 observed red-list category, respectively (modifying the categories for 6 species where new information suggested a change was required to previously published categories; see Supporting Information). We used these categories to calculate an observed RLI for ungulates as a measure of their real conservation trajectory between 1996 and 2008. To build our counterfactual RLI, we estimated what each species’ red-list category would have been in 2008 if all conservation actions (see below) had ceased in 1996 (hereafter, the 2008 counterfactual red-list category). This premise may seem preposterous, but to derive an estimate of the difference global conservation effort is making it is necessary to imagine a world where such effort entirely ceased. Scenarios are by definition based on a subjective narrative of what might happen; however, whereas scenarios are usually forward-looking (e.g., Sala et al. 2000), our scenario was retrospective. At least one recent study has developed an institutional metric of conservation impact based on a similar scenario and methods (Young et al. 2014).

Our scenario of no conservation action assumed that all land being managed for conservation reverted to another land use in 1996. Such land protection is usually interpreted to correspond to formal protected areas only, but for ungulates (particularly in the southern African context) private land also plays a key role in conservation (East 1999). We therefore distinguished 2008 counterfactual red-list categories under 2 scenarios: scenario A, where private land is not considered as making any contribution to conservation, and scenario B, where private lands managed for conservation purposes were treated as if they were formal protected areas. Unless otherwise specified, results refer to scenario A as our primary counterfactual scenario, because private land is not usually supported out of conservation budgets.

Data were not available to conduct detailed population modeling to quantify probability of extinction in the absence of conservation action. Instead, adapting the approach used by Butchart et al. (2006), we used information available to us on population size and trends, knowledge of severity of threats, their scope and intensity, and ongoing conservation interventions to determine as objectively (and conservatively) as possible how the extinction risk of each species would have changed had conservation action ceased in 1996 (see Supporting Information). We used information contained in the accounts for ungulates published on the IUCN Red List website, IUCN action plans (e.g., Shackleton 1997; East 1999; Mallon & Kingswood 2001; Moehlman 2002; Pucek et al. 2004; Gates et al. 2010), status reports (e.g., Emslie et al. 2012), and reference works (e.g., Kingdon & Hoffmann 2013) supplemented with our own experience and with direct communication with species experts (see Acknowledgments).

In estimating each species’ 2008 counterfactual red-list category, we considered, in addition to our best estimate, an optimistic and pessimistic category for each species (see Supporting Information). The results for both
Defining Conservation Action

We defined conservation action as any action that could be categorized according to the IUCN-Conservation Measures Partnership classification of conservation actions (Salafsky et al. 2008). We did not include research actions, although we acknowledge these often have conservation value. This categorization leaves many philosophical issues to consider in deciding whether or not a particular intervention should be included in determining the 2008 counterfactual red-list category. Some actions that have positively benefitted species may or may not have a true biodiversity conservation motivation or intent behind them. For example, we did not consider public-order actions (e.g., firearm bans) as conservation action, unless they have been explicitly presented as being in the interests of conservation and not for calming public unrest. Likewise, some traditional or religious activities have a beneficial impact in terms of biodiversity conservation (e.g., nilgai \(Bosefaphus tragocamelus\) benefits from Hindu beliefs in India, but has been extirpated in Pakistan), but we did not include these as conservation actions because these activities generally are not included in conservation budgets and the effect of loss of conservation budgets, sensu lato, ultimately is the situation addressed here. The result of both such decisions above (i.e., excluding research actions and excluding difficult to quantify measures, such as religion) is a more conservative counterfactual.

Classifying Species According to Conservation Benefits

Just as individual species may be directly affected by targeted threats or collaterally affected by more general threats, so species are likely to benefit directly from targeted conservation actions and collaterally from less specific actions. We distinguished 6 types of species profiles based on the degree to which they were the subject of targeted conservation action relative to the degree to which they were directly targeted by threats in 1996–2008 (Fig. 1). We then allocated each data-sufficient ungulate species to 1 of these 6 types (A, B, C, D, X, or Y).

Type A species are affected by direct targeted threats, but they also benefit from targeted conservation actions. These are typically larger-bodied, high-profile species (but may also include smaller species of high commercial value) that have been specifically affected (e.g., hunted because of their high value or because their presence is in direct conflict with human presence) and hence are invariably highly threatened, but they have also been subject to targeted conservation actions (such as reintroduction and translocation efforts, anti-poaching patrols, and species-specific hunting restrictions).

Type B species are affected collaterally by non-specific threats and benefit collaterally from conservation actions. These species are typically not directly targeted. However, they may be generally affected by threats like agricultural expansion (i.e., the stress, in keeping with the language of Salafsky et al. [2008], is at the ecosystem or community level, not directed at the species) and are not especially subject to any dedicated conservation efforts (but rather benefit from more general measures, such as habitat protection or measures put in place for other species).

Type C species are affected collaterally by non-selective threats, but they benefit from targeted conservation actions once their plight has been established.

Type D species are affected by direct targeted threats, but they benefit only collaterally from conservation actions. Compared with type B species, these species are typically directly targeted by threats like hunting or persecution (i.e., the stress is at the species level and results in direct killing or damage to the species). However, like type B species, they are not especially subject to any dedicated conservation efforts. Rather, they benefit from more general measures, such as habitat protection or measures put in place for other species.

Type X species are unaffected or little affected by threats, either directly or collaterally. They may nonetheless benefit directly from targeted conservation efforts, benefit collaterally, or not benefit at all. These species may occur in very remote regions or display a high degree of adaptability or resilience to anthropogenic disturbance and withstand moderate levels of hunting.

Type Y species do not receive any conservation action. They may be affected by direct threats, affected collaterally by non-specific threats, or be unaffected or little affected by threats. This category includes all species neglected by conservation and those for which conservation interventions are impossible (e.g., because they occur in a region of high instability), even though they may be affected by direct threats.

Results

Observed and Estimated Trends

The observed trend in the RLI (Fig. 2) for ungulates showed that their overall status deteriorated from 1996 to 2008; index values declined by 2.5% (average 0.2%/year). This exceeds the observed background rate for all
Figure 1. Typology of species types based on the degree to which species benefit from targeted conservation action relative to the degree to which they are directly targeted by a specific threat. The axes relate to the specificity of conservation actions or threats, not their intensity (e.g., species directly targeted by hunters are classified as “species affected by direct targeted threats,” even if they are only targeted by a few hunters; species for which anti-poaching patrols are in place are classified under “species benefits from targeted conservation actions,” even if these patrols are not making much difference). Key: 1, not the same as least concern, which includes species that are affected by threats, but where threats are offset by conservation; 2, for such species, stress resulting from the threat does not affect the species directly; rather, the ecosystem or community in which that species lives is affected; 3, for such species, stress resulting from the threat affects the species directly. See methods for further explanation of typology. Example species and photo credits: A, saiga (Saiga tatarica) threatened by illegal hunting for horns and meat; actions include intense anti-poaching and protection efforts combined with international trade controls (photo by N.J. Singh); B, Kirk’s dik-dik (Madoqua kirkii) threatened mainly by agricultural expansion, but not subject to targeted actions though present in numerous protected areas (photo by Steve Riall); C, pygmy hog (Porcula salvania) threatened by loss and degradation of habitat due to settlement, agricultural encroachment, and burning, but subject of a major conservation program, including conservation breeding and reintroduction (photo by Goutam Narayan); D, topi (Damaliscus lunatus) subject to hunting across much of its range, but not subject to targeted interventions, although present in many protected areas (photo by Peter Steward); X, nilgai (Boselaphus tragocamelus), a common, adaptable species not obviously affected by any major threat, but occurs in protected areas (photo by Kausik Patel); Y, beira (Dorcatragus megalotis) threatened by agricultural expansion and hunting, but its distribution in Horn of Africa means no conservation actions in place (photo by Catrin Hammer).
Figure 2. Observed and counterfactual (scenarios A and B) trends in International Union for Conservation of Nature Red List indices (RLIs) for ungulates during 1996–2008: (a) all conservation action ceased in 1996 and (b) same as (a), but conservation on private land was considered conservation action and ceased. The observed trend corresponds to actual change (sensu Hoffmann et al. 2010, 2011). The difference between the observed and each of the counterfactual RLIs is an estimate of what trends in extinction risk for ungulates would be without conservation action.

mammals, where the RLI declined by 0.8% from 1996 to 2008 (average 0.07%/year) (Hoffmann et al. 2010).

In scenario A (no conservation action), we identified 112 ungulate species that we estimated would have deteriorated in conservation status by one or more IUCN Red List categories over the analyzed period (compared with 25 that actually did). Of these species, nearly one-third would have deteriorated from least concern to either near threatened (21; cf. 3 that did) or threatened (15; cf. 1 that did). The counterfactual RLI under this scenario would have declined by at least 20.4% (average 1.7%/year) and varied between 6.2% and 74.1%, respectively, for the most optimistic and alarmist assessments.

The trends in RLI values described in each of the scenarios above can be more directly compared if converted into a more intuitive or easily understood unit of the equivalent number of ungulate species deteriorating by one IUCN Red List category between 1996 and 2008: 21 in the observed trends, 148 in scenario A, and 166 in scenario B.

**Direct versus Collateral Benefits of Conservation**

More than half of all ungulate species (n = 178; type A or D combined) were subject to targeted threats (mainly hunting). Of these only a small fraction benefited from direct conservation action (n = 30; type A), but many more (n = 148; type D) benefited from indirect conservation. In addition, at least 25 species (type B and...
C combined) were affected by indirect threats (mainly habitat loss due to agriculture or logging), including 3 that received direct conservation attention (type C) and 22 that benefited collaterally from conservation (type B). Twenty-five species were not substantially affected by any threats (type X).

The largest contribution to the difference between the observed RLI and the counterfactual RLI as quantified under scenario A was by species of type D, accounting for 76% of the total impact (Fig. 3). Seventy-seven (of 148) species had a more favorable (i.e., less threatened) 2008 observed red-list category in 2008 than they would have had in the absence of conservation actions. The second largest contribution (18% of the difference) was by type A species (of which \( n = 16 \) had a more favorable 2008 observed red-list category than the counterfactual), followed by type B (6% of the difference; 10 species). Types C, X, and Y species had no difference between their 2008 observed and counterfactual red-list categories and hence made no contribution to the slope of the counterfactual RLI. Approximately half of all species in each type had a better conservation status in their observed categories than in the counterfactual.

**Discussion**

**The Difference Conservation Makes**

We asked whether observed trends in the world’s ungulate species between 1996 and 2008 would have been different if all conservation interventions entirely ceased at the start of this period. Our best estimate (scenario A) suggested that the overall decline in the conservation status of ungulates would have been nearly 8 times worse than observed, corresponding to an average of 12 ungulate species deteriorating by one red-list category per year from 1996 to 2008 (compared with the observed average of fewer than 2 species that actually did undergo a deterioration over this time). Nearly half of all species would have deteriorated in status by one category between 1996 and 2008 and 30 would have deteriorated by 2 or more categories (Supporting Information). The proportion of ungulates collectively categorized as threatened would have increased from the 46% of non-data deficient species observed in 2008 to 58% (owing to an additional 31 species moving from least concern or near threatened to a threatened category).

The estimated rate of decline increased further when the contribution of private land to conservation was factored into our counterfactual (scenario B); 14 species deteriorated by one red-list category per year, demonstrating the under-appreciated biodiversity contribution of private ranch land (Davies-Mostert 2014).

For one species, the common wildebeest (*Connochaetes taurinus*), we estimated that conservation actions prevented a dramatic deterioration from least concern to critically endangered. Indeed, the migratory population of the Serengeti-Mara ecosystem accounts for some 70% of total population (Estes 2013), and we estimated that disruption of migration (e.g., by the construction of roads [Holdo et al. 2011]) and increased hunting pressures (e.g., west of the Serengeti National Park...
Table 1. Species estimated to be listed as extinct (EX) or extinct in the wild (EW) in 2008 under counterfactual scenario A (private land makes no contribution to conservation).

<table>
<thead>
<tr>
<th>Species</th>
<th>1996</th>
<th>2008</th>
<th>2008 observed</th>
<th>counterfactual</th>
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<tbody>
<tr>
<td>Bos sauveli</td>
<td>CR(PE)</td>
<td>CR(PE)</td>
<td>EX</td>
<td></td>
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<tr>
<td>Oryx leucoryx</td>
<td>EN</td>
<td>VI&lt;sup&gt;b&lt;/sup&gt;</td>
<td>EW&lt;sup&gt;c&lt;/sup&gt;</td>
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<tr>
<td>Axis kuhlii</td>
<td>EN</td>
<td>CR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>EW&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
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<tr>
<td>Equus ferus</td>
<td>EW</td>
<td>CR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>EW&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
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<tr>
<td>Rhinoceros sondaicus</td>
<td>CR</td>
<td>CR</td>
<td>EX&lt;sup&gt;c&lt;/sup&gt;</td>
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</tr>
<tr>
<td>Rhinoceros unicornis</td>
<td>EN</td>
<td>VI&lt;sup&gt;b&lt;/sup&gt;</td>
<td>EX&lt;sup&gt;c&lt;/sup&gt;</td>
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<sup>a</sup>Abbreviations: EN, endangered; CR, critically endangered; CR(PE), critically endangered (possibly extinct); EW, extinct in the wild; EX, extinct. No footnote, no change in category.
<sup>b</sup>Improvement in IUCN category between 1996 and 2008.
<sup>c</sup>Deterioration in IUCN category.

[Thirgood et al. 2004]) would have led to steep declines in this population. Hence, for this species, without existing habitat protection measures, declines likely would have been sufficient to warrant listing as critically endangered in 2008, based on a decline exceeding 80% over 3 generations (~24 years).

We estimated that conservation actions have prevented the rapid demise and probable extinction of at least 2 species, Javan rhinoceros (*Rhinoceros sondaicus*) and greater one-horned rhinoceros (*R. unicornis*) (Table 1). The former species has nonetheless been extirpated from Vietnam in the period we considered, an event attributed to the cessation of conservation efforts in the mid- to late-2000s (Brook et al. 2014). Increased pressures due to no conservation would also, we estimate, have removed any doubt concerning the possible survival of the kouprey (*Bos sauveli*), listed as critically endangered (possibly extinct) in 1996 and 2008.

We estimated further that 3 species would have been listed as extinct in the wild were it not for conservation action (Table 1). The Arabian oryx (*Oryx leucoryx*) did go extinct in the wild, after the last individuals were hunted out in Oman in the 1970s, but it has been subject to extensive captive breeding and reintroduction efforts since the early 1980s (Stanley Price 1989) and was recently classified as vulnerable. The cessation of conservation actions in 1996 would surely have reversed any gains made in the 14-odd years since reintroduction efforts began. Similarly, Przewalski’s horse (*Equus ferus*) would not have been elevated from extinct in the wild in 1996 to its observed category of critically endangered in 2008 if reintroductions and management had ceased. The third species, Bawean deer (*Axis kuhlii*), very likely would have been extirpated from its highly restricted range due to hunting and habitat loss, but it would have survived in some private collections.

Not all Species Benefit Equally from Conservation Actions

The dominance of type D species (targeted threats, collateral conservation) in our data set was not surprising considering that ungulates are a prime target for hunters and therefore subject to over-exploitation. It would perhaps be expected that the overall impact of conservation on such species would not be very high given that, in general, the right threats are not being addressed and species only benefit in a collateral sense from conservation (e.g., through habitat protection or anti-poaching efforts targeting type A species). However, our results (Fig. 3) suggest that non-targeted conservation can make a big difference. Many African duikers (tribe Cephalophini), for example, although able to adapt to disturbed habitats, are subject to high rates of off-take for bushmeat markets (through cable snares or with shotguns at night [Newing 2001]). While there have been few or no species-specific interventions targeted at these diminutive antelopes, protected areas have undoubtedly contributed to forestalling much steeper declines, mainly because they provide circumscribed areas for at least some level of enforcement (e.g., Brashares et al. 2001).

Even among a group as charismatic as ungulates, type A species (targeted threats, targeted conservation) are relatively few in number. However, they account for a substantial fraction of the difference between the observed and counterfactual RLIs. With these (usually highly threatened) species, conservation action is targeted and often works to mitigate transitions between the higher threat categories (e.g., critically endangered to extinct in the wild) (Fig. 4b). In the absence of dedicated actions, for example, Arabian oryx would not have moved from extinct in the wild to vulnerable and greater one-horned rhino probably would be extinct. Type B and type C species are even fewer in number and account for very little to none of the difference between the two RLIs. With type C species, conservation action could result in large jumps in red-list categories as species are rescued from threats that could be easily reversed. For 2 such species, hirola (*Beatragus huntenri*) and pygmy hog, both critically endangered, we felt uncomfortable estimating (other than pessimistically) that either would have gone extinct without conservation; however, there is little doubt that without conservation interventions, the status of both would be perilous.

By definition, type X (no threats) and type Y (no conservation) species make no contribution to the difference between the observed and counterfactual RLIs. Type X species included many small-bodied species that have a higher degree of tolerance for disturbed or modified habitats and simultaneously tolerate a moderate degree of hunting. For these species, the impact of conservation was zero because by definition if there are no threats there is no impact, even if there might be (direct or indirect) conservation. Type Y species did not
Figure 4. The 2008 observed red-list categories versus 2008 counterfactual red-list categories showing (a) all species and (b) type A species (defined in Fig. 3's legend) only. The counterfactual corresponds to scenario A, where no conservation actions would have taken place (private lands not included). Species with the same status are plotted on $x = y$ line (grey) and correspond to those for which conservation had zero or no measurable impact. Species above the line (black) are those whose observed 2008 conservation status is better than what it would have been without conservation action, thus corresponding to species for which there was a positive conservation impact. Size of the circles is proportional to the number of species in each case and scaled to the same size in type A and type B species (LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered; CR, critically endangered; EW, extinct in the wild; EX, extinct).

Extrapolating Results to All Mammals

Hoffmann et al. (2010) reported that the RLI would have declined by an additional 18% for mammals in the absence of conservation actions, showing that conservation efforts are having a non-negligible positive impact. Applying their methods to ungulates only, the RLI would have declined by an additional 35% from that observed (see Supporting Information). Our results, based on a method that takes into account not only the effects of conservation actions on improving species' status, but also accounts for their effects on preventing deteriorations, show that the RLI would have declined by an additional 75% in the absence of conservation actions.

These results cannot be directly extrapolated to mammals in general. Indeed, we found that different species types contributed differently to the impact of conservation actions (Fig. 3) and ungulates are dominated by species types that are unlikely to be representative of broader mammalian diversity. Whereas type D species (targeted threats, collateral conservation actions) were the most common in our data set, it is likely that most mammal groups are dominated by type B species (collateral threats, collateral conservation). On one hand, habitat loss is the dominant threat among mammals (Schipper et al. 2008), and most species are collaterally covered by existing protected areas (Rodrigues et al. 2004). On the other hand, species in the most speciose mammalian orders (e.g., Chiroptera, Erinaceomorpha, Soricomorpha, Rodentia) are (with a few exceptions) neither specifically persecuted nor specifically targeted by conservation actions and so most are likely to be type B. In contrast, type A species (targeted threats, targeted actions) are benefit from significant conservation action. These included several antelope species in the Horn of Africa (dibatag [Ammodorcas clarkei], beira, Speke’s gazelle [Gazella spekei]), where protected areas are practically non-existent and there are no targeted interventions.

For 55% of ungulate species, we estimated that their 2008 counterfactual red-list categories would have been the same as their 2008 observed red-list categories (Fig. 4a); hence, conservation did not affect their risk of extinction in the wild. However, red-list categories are broad, and so our method cannot detect population changes too fine to trigger change between categories. For example, under criterion A2 of the IUCN Red List Categories and Criteria (IUCN 2012), a population decline $>50$ and $<80\%$ over 3 generations warrants an endangered classification. Hence, a conservation action reducing the rate of a species’ population decline from 70% to 60% over 3 generations (with the species classified as endangered in both cases), would have made no difference to the counterfactual RLI. This contributes to making our results an underestimate of conservation impact.
likely to be rare among these taxa, even if they might be more prevalent in a few groups with large-bodied, higher profile species (e.g., primates and large carnivores).

Overall, we predict that for mammals in general trends in the counterfactual RLI under the same scenario that we imagine here would not be as marked as those we estimated for ungulates because the latter have proportionately more species that benefit from targeted conservation actions. However, because we show that species that benefit collaterally from conservation actions also contributed substantially to the difference between the observed and counterfactual RLIs, we predict that the application of our approach to all mammals would reveal that conservation does make a measurable difference to observed trends in extinction risk. Future research might clarify this by extending our approach to a broader group of species. The limitation with our approach is that creating a counterfactual for each species individually requires a detailed analysis of the history of the threats they are subject to and conservation actions they benefit from. An easier way of extending our method to a large group would be to select a representative (i.e., randomly selected) set of species (as has been done for the calculation of a sampled RLI [Baillie et al. 2008]) and estimating the counterfactual for this subset, from which measures of conservation impact could be statistically generalized.

The primary caveat to our study is the accuracy of our estimates of extinction risk under a no conservation scenario. This may appear extreme, but the aim was not to propose a realistic alternative scenario, but rather a hypothetical one that would allow us to measure the overall impact of conservation. We used the best information available to us to judge the likely trajectory of species in this scenario. This inevitably involved a margin of speculation. Given the hypothetical nature of our study, we attempted to err on the side of caution in determining our best estimates of the 2008 counterfactual red-list categories in order not to exaggerate results. Accordingly, our best estimate of the predicted decline in the RLI (20.4% for scenario A) falls substantially closer to the optimistic estimate (6.2%) than to the pessimistic one (74.1%), and is more likely to be an underestimate of conservation impact than an overestimate.

Our results demonstrate that conservation actions have both helped to keep common species common, or at least prevented swifter deteriorations in extinction risk from lower to higher categories of threat, while simultaneously acting to prevent highly threatened species from disappearing entirely. We also showed that while conservation has functioned to save high-profile species from going extinct, through targeted, species-specific interventions, the majority of species have benefitted from conservation efforts collaterally. Although we presented an improved estimate of conservation impact, it remains an underestimate. We hope our study is just an early effort to help address one of conservation biology’s most difficult questions. Ultimately, our results provide further evidence that conservation action is making a vital difference to trends in biodiversity. Now a massive upscaling in investment (McCarthy et al. 2012) in such efforts is needed to ramp up global efforts and thereby achieve global biodiversity targets.

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Supporting Information

Supporting methods and figures (Appendix S1) and data on counterfactual assessments (Appendix S2) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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