# Relative efforts of countries to conserve world's megafauna

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# A metric to assess the relative efforts of countries of the world at conserving megafauna

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## Abstract

Surprisingly little attention has been paid to variation among countries in contributions to conservation. As a first step, we developed a Megafauna Conservation Index (MCI) that assesses the spatial, ecological and financial contributions of 152 nations towards conservation of the world's terrestrial megafauna. We chose megafauna because they are particularly valuable in economic, ecological and societal terms, and are challenging and expensive to conserve. We categorised these 152 countries as being above- or below-average performers based on whether their contribution to megafauna conservation was higher or lower than the global mean; 'major' performers or underperformers were those whose contribution exceeded 1 SD over or under the mean, respectively. Ninety percent of countries in North/Central America and 70% of countries in Africa were classified as major or above-average performers, while approximately one-quarter of countries in Asia (25%) and Europe (21%) were identified as major underperformers. We present our index to emphasize the need for measuring conservation performance, to help nations identify how best they could improve their efforts, and to present a starting point for the development of more robust and inclusive measures (noting how the IUCN Red List evolved over time). Our analysis points to three approaches that countries could adopt to improve their contribution to global megafauna conservation, depending on their circumstances: 1) upgrading or expanding their domestic protected area networks, with a particular emphasis on conserving large carnivore and herbivore habitat, 2) increase funding for conservation at home or abroad, or 3) 'rewilding' their landscapes. Once revised and perfected, we recommend publishing regular conservation rankings in the popular media to recognise major-performers, foster healthy pride and competition among nations, and identify ways for governments to improve their performance.

**Significance statement**

The world is experiencing a 'sixth mass extinction' event due to human impacts on nature. Megafauna species appear to be particularly vulnerable due to their low reproductive rates, large spatial requirements and the pressure being exerted through illegal hunting, human-wildlife conflict and other threats (Ripple et al 2016 a). In light of the inadequacy of current conservation efforts (Ripple et al 2016b), we conducted an assessment of the contributions of countries of the world to megafauna conservation based on three metrics: distribution and diversity of megafauna, percentage of land area inhabited by large carnivores and herbivores that is strictly protected, and financial investments in conservation at home and abroad. Our aim was to create a floating benchmark that will enable 'underperformers' to improve their performance by investing in these metrics, thus raising the bar for global conservation efforts.

## Introduction

Over the course of recent millennia, humans have caused the extinction of large numbers of megafauna species (carnivores that weigh more than >15kg and omnivores and herbivores that weigh >100kg) *(Braje and Erlandson, 2013)*. The world's remaining megafauna are greatly imperilled and the list of species threatened with extinction by humans is growing (Ripple et al. 2016b) (Ripple et al. 2017). Recent studies have indicated that 60% of the world's largest herbivores and 59% of the world's largest carnivores are threatened with extinction *(Ripple et al., 2014; Ripple et al., 2015)*. Such extirpations form part of a wider sixth mass extinction event that seems inevitable unless effective conservation strategies are widely and rapidly implemented *(Barnosky et al., 2011)*.

The loss of megafauna species is particularly worrisome for several reasons. Firstly, megafauna have significant cultural and societal value to humans *(Macdonald et al., 2015)*. The idea that large charismatic animals still persist in their natural habitats is greatly valued by large sectors of human society *(Sylven et al., 2012)*. Megafauna thus have existence values that arguably surpass those of most other species. The charisma of megafauna means they are disproportionately important in terms of engendering interest and willingness to pay for conservation among sectors of the general public *(Macdonald et al., 2013)*. Secondly, they tend to play particularly important ecological roles, as megafauna species are often critical to predator-prey cycles, nutrient cycling, seed dispersal and other ecological processes *(Estes et al., 2011; Ripple et al., 2014; Ripple et al., 2015)*. Thirdly, megafauna can have significant economic value if their use values are harnessed appropriately and sustainably. For example, countries such as Kenya, Botswana and South Africa have successfully harnessed the appeal of large mammals to overseas visitors *(Lindsey et al., 2007)*, and wildlife-based tourism now comprises significant proportions of their GDPs (http://www.wttc.org/, accessed October 2015). Finally, megafauna tend to require large areas for their conservation and so are likely to act as umbrella species whereby their conservation will indirectly benefit a suite of other species (Macdonald et al., 2012).

In spite of these values, large mammals are under significant and growing threat. Key challenges include habitat destruction and excessive hunting *(Ripple et al., 2014; Ripple et al., 2015)*, the growing international trade in wildlife parts *(Challender and MacMillan, 2014)*, and increasing demand for bushmeat *(Bennett, 2002; Lindsey et al., 2013;* Ripple et al. 2016a) *)*. Human-wildlife conflict represents an additional problem for megafauna in parts of the globe and results in widespread retaliatory killing, particularly of large predators *(Kissui, 2008)*. As a result of these threats, populations of many megafauna species are declining precipitously *(Ripple et al., 2014; Ripple et al., 2015)*.

Megafauna is challenging to conserve. Many megafauna species have large spatial requirements, resulting in significant blocks of wilderness set aside to accommodate them (*Macdonald et al*., 2013). Some megafauna species are dangerous and/or costly for humans to live with and pose a direct risk to human life, crops, livestock and even pets *(Thirgood et al., 2005)*. The high demand for wildlife products means that significant effort and expenditure is required to protect megafauna from poachers (Lindsey et al., 2016).

Key among steps taken to improve the conservation prospects of megafauna and other aspects of biodiversity is the establishment of protected areas as refuges for wildlife. Other mechanisms include allocating funding for conservation, in particular compensation for damages or other financial mechanisms (Dickman et al. 2011), either locally or abroad, to allow for interventions that reduce poaching, trade in wildlife body parts and human-wildlife conflict and promote coexistence between megafauna and people. In contrast, some countries have experienced 'rewilding' as a contribution to re-establish megafauna in areas from which they had previously been extirpated *(Sylven et al., 2012)*.

Given ongoing declines in populations of megafauna, the nature and scale of these interventions are evidently inadequate, and large budgetary deficits for conservation exist, particularly in the tropics *(Bruner et al., 2004; Miller, 2014)*. Thus far in the relatively short history of conservation, despite widespread public support for conservation goals in places like the United States (e.g. Johns, 2011), action to halt or reverse declines in many species has been insufficient. As a step to mobilize political support and action, we conducted an assessment of the contributions of nations towards the conservation of megafauna, with the objectives of establishing a running average of conservation effort and encouraging countries falling below that level to increase their efforts (thereby pushing the benchmark upwards).

Here we present a 'Megafauna Conservation Index' (MCI) as a first attempt at establishing this baseline. Specifically, we estimated the diversity of megafauna conserved and the proportion of land area that such species occupy, the proportion of land occupied by these species that is strictly protected, and lastly, the financial contributions of countries to conservation. The last one is more general than the first two, but remains of direct relevance to megafauna conservation in many developing countries due to the importance of funding for ensuring megafauna effective protection.

We present our index with the hope of achieving two outcomes: a) entrenching the idea that measuring the conservation performance of countries (both relative to other countries and to themselves over time) is a key step towards motivating global elevated effort following (Bradshaw et al., 2010); and b) to present a first attempt at measuring conservation performance, in the expectation that it will be refined over time.

## **Methods**

We examined contributions to megafauna conservation for 152 countries, while excluding disputed territories, dependencies and undetermined regions. Country shapefiles were obtained from http://www.naturalearthdata.com/ (accessed May 2015). All spatial analyses were conducted using the Mollweide global projected coordinate system in ArcMap 10.1 *(ESRI, 2012)*. The MCI for each country comprised ecological, protected area and financial components as detailed below. To be included, a country had to have at least some potential to contribute in all three metrics: thus, for this version of the metric, we have excluded countries with no extant species of megafauna, as they tend to be small island states that would not have any opportunity to score on that metric.

(i) *Ecological contribution - Megafauna cumulative distribution*

We examined the number of extant large mammal species ('megafauna') within each country's borders. Following *(Ripple et al., 2014; Ripple et al., 2015)*, we defined large mammals as species weighing more than $\geq$15kg for carnivores and $\geq$100kg for omnivores and herbivores. We obtained species range maps from the IUCN Red List *(IUCN, 2012)*. We used ArcMap's Intersect tool to calculate the percentage of a country inhabited by each species. These overlap values were summed to produce the total cumulative percentage of a country covered by herbivore and carnivore separately. For example, if 10% of a country is covered by species A, 30% by species B and 5% by species C, the total megafauna diversity value for the country =0.10+0.30+0.05=0.45. This system is additive where more than one megafauna species exists in a given location, taking into account the likely greater costs than if a single species were to occur there. We then multiplied the herbivore and carnivore values to obtained a final ecological contribution metric. We multiplied (as opposed to summing) to avoid distortion created by countries succeeding in herbivore conservation but failing in carnivore conservation.

(ii) *Protected area contribution - Percentage of megafauna habitat that is strictly protected*

We used the World Database on Protected Areas as our representation of global protected areas (IUCN and UNEP-WCMC, 2016). Following *(Jenkins et al., 2013)*, we assigned "strict protection" to areas classified as IUCN protected area categories I-IV, and excluded from our analyses all areas designated by international conventions or agreements and therefore not nationally gazetted. We assigned overlapping polygons in the WDPA shapefile to the category of stricter protection. Shapefiles of protected areas with Categories I-IV were merged and converted to a raster layer at 100m resolution. The percentage of each country's herbivore and carnivore range that is strictly protected (calculated separately for herbivores and carnivores) was calculated via an intersection of carnivore or herbivore range for each country with that country's strictly protected areas. We then multiplied the herbivore and carnivore values to obtain a final protected area contribution metric. While acknowledging that many Category V and VI parks also contain large viable megafauna populations that live alongside human use, particularly by Indigenous peoples, and that some Category I-IV protected areas encompass towns and intensive agriculture inimical to megafauna, the IUCN categorisation has been adopted globally as a standard despite such inconsistencies in their application (Dudley, 2008). Furthermore, we acknowledge that 'paper parks' exist, and that these strictly protected areas might be subject to numerous stressors that might reduce their effectiveness. In such cases, however, we expect the megafaunal distributions to reflect this to an increasing extent over time.

(iii) *Financial contribution – percentage of GDP allocated to conservation*

The financial contributions of countries through funding for domestic and international conservation efforts were assessed using data from *(Waldron et al., 2013)*, who assembled a large dataset of conservation spending, including both domestic (within-country) spending and donations made to other countries, and found that the 40 most under-funded countries in their analysis were home to 32% of threatened mammals. Given the level of threat posed to megafauna, we expected funding to have a significant bearing on the conservation prospects of those species. We used data from Waldron et al. (2013) on the financial contributions of countries to conservation and adjusted that for national wealth by expressing the sum of the domestic and international spending as a percentage of national gross domestic product (GDP) in international dollars to make it comparable across countries (http://data.worldbank.org/indicator, accessed 2$^{nd}$ March 2015). World Bank data were from 2013, except seven cases where only data from 2012 (5 countries) or 2011 (two countries) were available. If no World Bank data were available, we relied on the CIA World Factbook (https://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html, accessed 6$^{th}$ May 2015). Countries not listed in either of these sources were excluded from the analysis.

*Deriving a Megafauna Conservation Index*

We derived a Megafauna Conservation Index (MCI) by multiplying the ecological, protected area and financial contributions; these values were then logged to correct for over-dispersion of the index.

$$MCI = \log((AH * AC) * (PH * PC) * F)$$

Where AH refers to the cumulative % area of herbivores, AC refers to the cumulative % area of carnivores, PH refers to the % of herbivore range protected, PC refers to the % of carnivore range protected and F refers to the total percent of GDP devoted to conservation funding.

For ease of presentation, the MCI index was then standardised into a 0-100 scale.

In cases where the contributions had a value of zero, these were converted to a very small non-zero value that was still below the second-lowest value for those metrics on a raw scale (0.01 for ecological, protected area contributions and 0.00001 for financial contributions because GDP values tended to be much lower than minimum values for the landscape metrics) so the zero values did not cancel out contributions to megafauna conservation using the other metrics.

Countries were defined as above-average performers if their MCI value was above the mean and below-average performers if their MCI value was below the mean. Countries more than one standard deviation (SD) above the mean MCI were classed as major performers, while those more than 1 SD below the mean MCI were major underperformers.

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**Results**

Fifty-six countries contributed less than the average, with 28 ranked as below-average performers and 28 ranked as major underperformers (Table 1 & S1, Figure S1). The remaining 96 countries were above-average performers, with 19 ranked as major performers. Botswana ranked the highest followed by Namibia, Tanzania, Bhutan and Zimbabwe (Figure 2, Table S1).

North/Central America had a relatively high proportion of above-average performing countries (90%) and the highest proportion of major performers (30%), whereas South America had a high proportion of above-average performers (67%) but no countries in the major performer category (Table 1, Figure S1). North America and Africa had 90% and 70% countries with above-average MCI scores, respectively (Figure S1). The five best-performing countries for the ecological component were Botswana, Tanzania, Zimbabwe, Kenya and Zambia, with the first 22 countries for this component of MCI all being from the African continent (Table S1). The five best-performing countries for the protected area component were Bhutan, Taiwan, Sri Lanka, Equatorial Guinea and Thailand (Table S1). The five best-performing countries for the financial component were Denmark, Italy, Canada, Namibia and Switzerland, with the richest countries allocating a disproportionately large share of their GDP to conservation (Table S1).

The mean wealth of all countries with an above-average MCI score was US$15,586.9 ±US$15,843.71 per capita adjusted for purchasing power parity, significantly less than those with a below average MCI score (US$ 24,145.73 ± US$27,506.22) (Welch two-sample $t = -2.131$, $df = 76.686$, $p = 0.036$), indicating that per capita wealth may be an important driver of whether MCI scores fall above or below the mean. Overall, countries in Africa had the highest mean MCI scores (255.99 ± 825.97), followed by those in North/Central America (78.51 ± 132.80), Asia (36.11 ± 170.85), Europe (21.42± 75.10) and South America (3.29 ± 6.43) (Table 2).

Continents varied markedly in the relative contribution of each component to their overall MCI (Figure 3, Figures S2, S3, S4). Oceania was excluded from these comparisons as it was represented solely by Australia. African countries scored highly on the ecological component, with 324±274 % occupied by herbivores (255±112% occupied by carnivores) compared to next-best continents, with an average of 83±73 % for herbivores in Europe and 200±97 % for carnivores in Asia (Table 2). Asiatic and North/Central American countries scored the best for the protected area component for herbivores (9.9 ± 14.8 % for Asia and 9.9 ± 6.7 for North/Central America) and carnivore (7.9 ± 10.2 % for Asia and 10.5 ± 7.2 for North/Central America) (Table 2, Figure S3). The MCI scores of European countries were particularly affected by a limited spread of their megafauna (Figure 3), but European and North/Central American countries compensated by contributing more funding to conservation than those in other continents (Table 2, Figure S4).

## <u>Discussion</u>

Megafauna impose a disproportionately large cost on the range states that conserve them. The MCI offers a new way to acknowledge those countries that are investing satisfactorily in megafauna conservation, and to encourage countries that are avoiding this responsibility to do more. We expect that refinements of this index will yield an increasingly robust indicator of global investment in megafauna conservation.

### Geographic variation in the nature of contributions to conservation

Continents and countries differ in the scale and types of contributions they make to the conservation of megafauna. Some countries have limited protected area networks and few large mammals, but contribute to conservation through financial support for conservation in other countries. Some countries have vast protected area networks and significant populations of megafauna, but limited means to protect them. The top performing countries in our analysis, such as Botswana, Tanzania and Zimbabwe, score comparatively highly for two or all three of our metrics. We caution, however, that scoring highly relative to other countries does not necessarily mean that efforts by a particular country are adequate, and in some such countries wildlife populations are declining in many areas (*Lindsey et al. 2017*). Examples are some African countries where wildlife populations even in many protected areas are declining and depleted (Lindsey et al. 2014, 2017). The worst performers, on the other hand, tended to score poorly on all three components. Asia, which has the most countries performing below the mean MCI score, is characterised by particularly steep declines in wildlife populations and high rates of land clearing in protected areas *(Nagendra, 2008; Di Marco et al., 2014)*.

Below-average performer and major underperformer countries benefit from the global ecosystem services, existence values and direct use values associated with megafauna and wild lands in other countries without incurring the costs *(Balmford et al., 2003)*. These inequalities in contribution (or burden) provide a framework for those countries contributing less to conservation to identify the extra commitment required to match the level of those performing best, or at least to the average level. Elevated investment by countries performing below the mean would gradually increase the global megafauna conservation standard, thus motivating elevated effort from other countries. In its present form, countries would be able to improve their ranking, depending on their circumstances, by 1) upgrading or expanding their domestic protected area networks, 2) increasing funding for conservation at home or abroad, or 3) 'rewilding' their landscape. Refinements of this index might also recognise alternative types of contribution.

**The case for upgrading protected area networks**

Countries are being encouraged to invest in their own protected area networks and to work towards the Aichi targets set by the Convention for Biological Diversity for 2011-2020, whereby at least 17% of terrestrial and inland water and 10% of coastal waters should be protected. These protected area networks are expected to be ecologically representative, well managed and well connected with surrounding ecosystems *(Bertzky et al., 2012)*. If countries with MCI scores below the mean (and others with under-sized or poorly resourced protected area networks) could be encouraged to invest more in their own protected area networks, this would help ensure that protected area coverage is more evenly spread across the globe, and also ensure that priority areas for the conservation of various taxa are encompassed *(Jenkins et al., 2013)*. Expanding protected areas could confer improved ecosystem services, such as the retention of clean water supplies or carbon sequestration *(De Barros et al., 2014)*, and encompass habitats and species that are currently poorly represented in existing protected area networks *(Beresford et al., 2011)*. Expanded protected area networks could also provide opportunities for tourism, local employment and economic growth *(Sylven et al., 2012)*.

**The case of increasing funding for conservation**

Global funding for conservation is inadequate and unevenly distributed, both in terms of donors and recipients *(Balmford and Whitten, 2003)*. Protected area networks have expanded in many countries, and yet conservation budgets have often declined *(Balmford et al., 2003; Cumming, 2004; Bertzky et al., 2012)*. Effective protection of megafauna is particularly expensive due to the large areas required, the associated human-wildlife conflict and the extreme measures often required to protect such species from poachers *(Leader-Williams et al., 1990; Lindsey and Taylor, 2012)*. Total domestic expenditure on biodiversity conservation equates to ~USD14.5 billion/year, 94% of which is spent in developed countries by developed countries *(Waldron et al., 2013)*. The funding shortfall for the existing global protected area network range has been estimated at USD3.9 billion/year *(McCarthy et al., 2012)*. These shortfalls frequently manifest in a failure to protect megafauna and other aspects of biodiversity from anthropogenic pressures, such as poaching and human encroachment *(Nature Editorial, 2014)*. While some of the data used on funding for conservation are outdated, our analysis suggests that this shortfall could be met if underperforming countries increased funding for conservation to the 0.03% of GDP recommended by *(Mansourian and Dudley, 2008)*. However, a much greater amount, of USD76.1 billion/year, would be required to protect all terrestrial sites of significance for birds and other taxa *(McCarthy et al., 2012)*, not to mention marine systems. Over time, such an amount could conceivably be approached if the international MCI mean level increased.

*Investing more in conservation domestically*

The economic and ecological values associated with megafauna and protected area networks dwarf the costs of protection in many parts of the world *(Watson et al., 2014)*. However, often those benefits (or the potential for deriving them in future) are not recognised, which may explain the reluctance of some countries to invest in the protection of their megafauna or in the management of protected areas. Even in Africa, where 70% of countries perform well, only a handful have invested sufficiently in protection of their wildlife and in development of appropriate infrastructure to allow for the derivation of significant benefits from wildlife-based tourism *(Lindsey et al., 2014)*. Many other African countries invest far less than is necessary for effective conservation *(Packer et al., 2013; Lindsey et al., 2016)* and will likely ultimately lose many of their most valuable biological assets before reaching the potential to benefit from them. Investing in conservation at home helps protect natural assets and secure ecosystem services, and even modest increases in investment can dramatically improve conservation effectiveness *(Bruner et al., 2004)*.

*Increasing international funding for conservation*

Industrialised countries have never fulfilled agreements made at the 1992 Rio summit to allocate USD2 billion/year in international conservation aid *(Miller, 2014)*; currently, they donate only ~USD1.1 billion/year, a figure that has remained roughly constant since 2002 *(Miller, 2014)*. Furthermore, our data indicate that richer countries were less likely to be above the mean MCI than poor countries. Such countries could improve their MCI score by contributing more funding to conservation efforts internationally. Such contributions could be important as the discrepancy between funding needs and funding availability is higher in poorer tropical countries than in the developed world *(Bruner et al., 2004)*, a gap of 95% for protected areas in Africa, compared to ~80% in Europe, 50% in Oceania and <20% in North America *(Balmford et al., 2003)*. Many African countries are experiencing high rates of human and livestock population growth, poverty and a high degree of reliance on natural resource consumption, resulting in severe pressure on megafauna from illegal hunting, human-wildlife conflict and habitat loss *(Nagendra, 2008; Lindsey et al., 2012)*. Species diversity and vulnerabilities are higher in the tropics than in temperate latitudes *(Balmford et al., 2003)*, including for megafauna. Investing in conservation in the tropics is likely to be most cost-effective owing to lower land prices, reduced need to rehabilitate human-modified lands, lower protected area management costs *(Bruner et al., 2004; Mansourian and Dudley, 2008)* and, for foreign investment, better exchange rates (*Garnett et al., 2011*). Investing in conservation efforts internationally can also potentially help to stimulate job creation, economic growth and economic diversification by helping to protect assets which can provide the basis for development of tourism industries (Lindsey et al. 2016).

**The case for rewilding landscapes**

Nations from which megafauna has been partially or completely extirpated could increase their MCI score through a process of rewilding by reintroducing or tolerating natural expansions of large animals that were previously in the landscape. Although inhabitants of developed countries have been unwilling, in some cases, to live with large dangerous animals while expecting other (often poorer) people to do so in the tropics *(Wilson, 2004)*, rewilding has gained increasing attention in recent years *(Sylven et al., 2012)*. In some instances, rewilding may occur naturally. For example, rewilding in many European countries has resulted from societal and land-use changes, which have reduced hunting of ungulates for food and persecution of predators *(Breitenmoser, 1998)*. Rewilding can help to re-establish lost ecological processes and improve ecological functioning *(Sandom and Macdonald, 2015)*, confer significant happiness through existence values *(Sylven et al., 2012)* and potentially enhance tourism industries.

**The validity of our approach**

We recognise that measuring contributions to conservation is complicated and is likely to be contentious. However, we feel that measurements of national conservation performance are lacking and, if they were in place, countries would be encouraged to put in greater effort – which is so urgently needed in the face of the current extinction crisis. We thus present our paper as a statement of need, and as a first attempt at developing a measurement of performance.

We recognise that our metric does not capture many of the nuances associated with the different ways that countries contribute to conservation. However, the metric does capture three key areas in which countries contribute to conservation – through the setting aside of land (which is important for all aspects of terrestrial biodiversity), financial contributions to conservation (which are required to safeguard biodiversity from anthropogenic impacts) and through the preservation of megafauna, which is important for ecosystem processes and cultural, human psychological, and economic reasons. Authors considering refinements of our index might incorporate measures of biodiversity more generally, or include measures of effectiveness regarding the conservation of other terrestrial taxa or marine species.

We also acknowledge there are some challenges with the metrics we have used. For example, as noted above, some countries have large and diverse populations of megafauna in protected areas of categories other than those considered in our paper. Similarly, our measure of performance related to megafauna does not measure trends in the distribution or populations of megafauna species, and it is certainly the case that some countries that we identified as being performers are currently undergoing drastic losses of megafauna, although this is likely to be captured by the index via a decline in the MCI over time. One way our index could be improved is by introducing a measure of megafauna diversity and distribution relative to that of a decade or two previously, challenges with data availability notwithstanding. The data we have used could also be refined. For example, the wolf distribution in the best performing European country –Norway–is smaller than indicated by the IUCN Red List (Chapron et al. 2014), and the financial contribution to predator conservation in Norway probably includes funds aimed at keeping predator population as low as possible (Immonen & Husby 2016), which hardly qualifies as conservation (Trouwborst et al. 2017). Similarly, data on global financial contributions to conservation require updating and refining.

Some countries lost their megafauna during the Pleistocene and so are not able to score as highly as countries where such extinctions did not happen. However, we argue that such countries do not have to grapple with the challenges of living with such species, and so could contribute to global conservation in other ways, such as through funding for conservation or through setting aside land that preserves other aspects of biodiversity. The substitutability of the metrics means that countries can be recognised for contributing to conservation in different ways, acknowledging differences in wealth and environmental history.

Lastly, Newton (2011) highlights the risk associated with establishing indicators, due to Goodhart's law, which essentially states that 'When a measure becomes a target, it ceases to become a good measure', because of a tendency of those being measured to manipulate information to score well according to the measure. This is clearly a consideration, and so the application of an index like our MCI would require caution and cognizance of this rule. Newton (2011) suggests that the risks associated with applying indices might be overcome through the development of an independent monitoring authority to manage the reporting and assessment process.

**Conclusion**

Our study provides a first attempt at quantifying inequities among countries in their contributions to the conservation of megafauna, and establishing a mechanism for handling that aspect of biodiversity as a global asset and a shared responsibility. We present our index to initiate a discussion on measuring international contributions to conservation. Ultimately, we would like to see annual conservation rankings published in the popular media, recognising major-performers, fostering healthy pride and competition among countries and identifying the best ways for governments to improve their performance. Such rankings would require dedicated data compilation for each of the metrics but is warranted given the value of the biodiversity assets under threat.

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**Table 1:** Number and percentage (%) of countries in each continent that are major performers, above-average performers, below-average performers or major under-performers in terms of Megafauna Conservation Index.

| | Major performer | Above average | Below average | Major underperformer |
|---|---|---|---|---|
| Africa | 10 (21) | 23 (49) | 8 (17) | 6 (13) |
| Asia | 3 (8) | 17 (42) | 10 (25) | 10 (25) |
| Europe | 3 (7) | 23 (55) | 7 (17) | 9 (21) |
| North America | 3 (30) | 6 (60) | 0 (0) | 1 (10) |
| Oceania | 0 (0) | 0 (0) | 0 (0) | 1 (100) |
| South America | 0 (0) | 8 (67) | 3 (25) | 1 (8) |

**Table 2:** Ecological, protected area and financial contributions to the Megafauna Conservation Index scores for five continents (average ± SD).

| | Ecological herbivores | Ecological carnivores | Protected area herbivores | Protected area carnivores | Financial | Standardised MCI score |
|---|---|---|---|---|---|---|
| Africa | 324 ± 275 | 255 ± 112 | 6 ± 5 | 7 ± 11 | 0.0075 ± 0.0149 | 72 ± 21 |
| Asia | 76 ± 74 | 201 ± 98 | 8 ± 10 | 10 ± 15 | 0.0033 ± 0.0087 | 59 ± 27 |
| Europe | 84 ± 55 | 86 ± 89 | 6 ± 6 | 6 ± 5 | 0.0191 ± 0.0323 | 64 ± 23 |
| North America | 78 ± 45 | 158 ± 41 | 10 ± 7 | 10 ± 7 | 0.018 ± 0.0264 | 79 ± 19 |
| South America | 65 ± 33 | 181 ± 84 | 6 ± 6 | 6 ± 6 | 0.0019 ± 0.0014 | 67 ± 19 |

**Supplementary table legend (see attachment)**

**Table S1:** Data for all 152 countries: protected area components (herbivores: PA.H, carnivores: PA.C), ecological components (herbivores: Eco.H, carnivores: Eco.C), financial (GDP) component, Megafauna Conservation Index (MCI), ranking and performer status.

**Figure legends**

**Figure 1:** World map of standardised Megafauna Conservation Index scores.

**Figure 2:** Standardised Megafauna Conservation Index scores for the 20 top performing countries.

**Figure 3:** Relative importance of the ecological (herbivores: Eco.H, carnivores: Eco.C), protected area (herbivores: PA.H, carnivores: PA.C), and financial (GDP) components in the Megafauna Conservation Index scores of countries in five continents.

**Supplementary figure legends**

**Figure S1:** Major performer countries, above-average performers, below-average performers and major under-performs, according to their Megafauna Conservation Index scores

**Figure S2:** Ecological contribution score obtained by each country based on the cumulative proportion of national land areas occupied by megafauna.

**Figure S3:** Protected area contribution score obtained by each country based on the proportion of megafauna distribution in areas under strict protection (IUCN protected area categories I-IV).

**Figure S4:** Financial contribution score based on the percentage of GDP allocated to conservation funding.

**Figure S5:** Relative importance of the ecological (herbivores: Eco.H, carnivores: Eco.C), protected area (herbivores: PA.H, carnivores: PA.C), and financial (GDP) components in terms of the average Megafauna Conservation Index scores for all 152 countries.