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Supplementary information

Include biodiversity representation indicators in area-based conservation targets

In the format provided by the authors and unedited

Supporting Information

Contents:

Figure 1 and 2 data and calculations

Overview

Our species range data and range refinement analytical methods follow earlier work[1-6] (https://mol.org/indicators), with recent data updates (https://mol.org/datasets) and ongoing improvements aimed at advanced species distribution EBV characterizations as basis[7]. Further background and example uses of the Species Protection Index (SPI) are available here: IPBES Core Indicator Set: https://www.ipbes.net/core-indicators-0; Biodiversity Indicators Partnership: https://www.bipindicators.net/indicators/species-protection-index; Environmental Performance Index : https://epi.yale.edu/epi-results/2020/component/spi; Map of Life: https://mol.org/indicators.

Spatial data

Distribution information for the Zebra duiker (*Cephalophus zebra*) (Fig. 1) is based on the expert range map from ref[8], subsequently refined to habitat-suitable range (excluding non-suitable land-cover and elevation) following the methods and habitat crosswalk of ref[1] (https://mol.org/species/protect/Cephalophus_zebra). For Figure 1 and 2, expert range maps for birds[9,10], mammals[8], reptiles[5], and amphibians[11] were compiled and harmonized by Map of Life. All datasets are available from their original sources and accessible or (where redistribution is not permitted) viewable at https://mol.org. For intersections with country borders we used the Global Administrative Areas database, GADM, V 3.0 (https://gadm.org).

Protected area (PA) data were derived from the December 2020 version of the World Database on Protected Areas (WDPA)[12]. We followed the WDPA's recommendations on cleaning data for calculations of global coverage and removed PAs without designated, inscribed, or established status, points without a reported area, marine reserves, and UNESCO Man and Biosphere Reserves. For PAs lacking polygons and represented only as points, we created a buffer around data with the area of the buffer equal to the reported area of the PA[13]. The PA polygons and buffered points were dissolved together, and intersected with a coastline from GADM 3.0. The results were then rasterized to a 1 km grid with values indicating percentage of PA cover in each grid cell, and then transformed to a Behrmann equal-area projection using bilinear interpolation.

Species Protection Index calculations

The Species Protection Index (SPI) quantifies annual trends in the proportion of species' reserve targets met. It can be flexibly aggregated at the levels of species, nations and the globe. At the national level, the SPI applies a species-level weight to account for different national stewardships of species as determined by the portion of a species' global habitat a country holds. The SPI is directly derived from the species distribution Essential Biodiversity Variable and is based on a comprehensive and growing global species occurrence information[7]. This protected area and species range input used can be flexibly improved, updated, or replaced with national/regional sources.

Calculation:

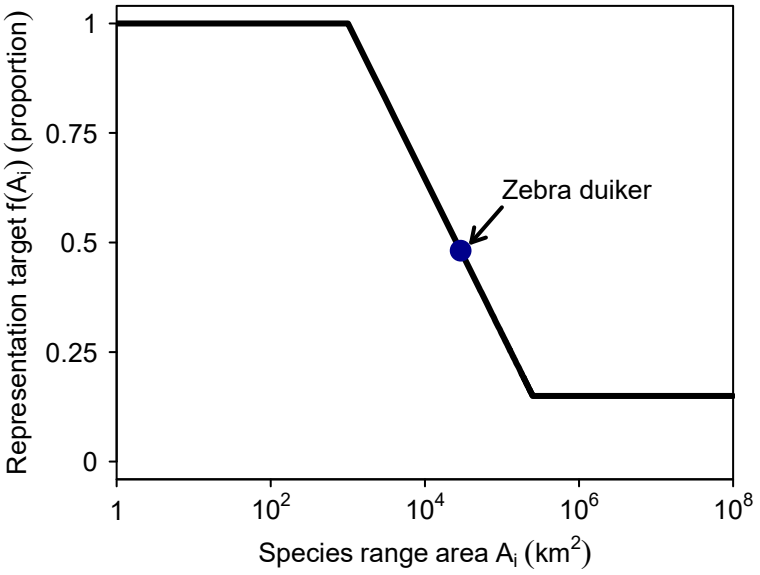
Let a_{ij} represent the amount of habitat area of species i in country j. The total range area of species i is then given by

$$A_i = \sum_j a_{ij}.$$

The species representation target T_i represents the amount of total range area to protect and is determined by a piecewise log-linear function $f(A_i)$[6,14] (Fig S1), such that

$$T_i = f(A_i)A_i.$$

The precise shape of this function for setting targets is somewhat arbitrary, but ensures that the most range-restricted species have the highest representation targets. We also constrain $T_i \leq 1{,}000{,}000$ km^2, providing an upper bound conservation target for the most common species. The Fig. 1 example species Zebra duiker (*Cephalophus zebra*) has a representation target of approximately 48% of is range area (https://mol.org/species/protect/Cephalophus_zebra). This currently applied target formula will benefit from more a specific accounting for variation in area requirements of minimum viable populations and the use of habitat-suitable range information. This is an area of ongoing research[15] that can be accounted for in future updates to the SPI.



Supplementary Figure 1: A piecewise linear function used to determine representation target, with an example species shown. The Zebra duiker has a range area of roughly 29 000 km^2, resulting in a representation target of 0.48.

The *stewardship weight* of country j for species i is given by

$$w_{ij} = \frac{a_{ij}}{A_i},$$

and represents the proportion of species i habitat found in country j.

The species conservation target t_{ij} describes the amount of total range area of species i to protect in country j, and is calculated as

$$t_{ij} = w_{ij} T_i.$$

Note that these country-level species conservation targets will reflect the species representation targets when expressed as proportion of range area. In the case of the zebra duiker, this translates to 48% of total habitat within each country.

Let p_{ijk} represent the amount of habitat area of species i in country j in year k. Then the percentage of conservation target t_{ij} met in year k is given by

$$m_{ijk} = 100 \min\left(\frac{p_{ijk}}{t_{ij}}, 1\right).$$

which we call the Species Protection Score (SPS). The SPS ranges from 0 to 100.

The SPI of a country j in year k is then given as a weighted average of these SPS values across the species in which it shares stewardship, such that

$$SPI_{jk} = 100 \frac{\sum_i w_{ij} m_{ijk}}{\sum_i w_{ij}}.$$

The Species Protection Index reflects the average amount of area-based conservation targets met across all species within a given country in a given year, weighted by a country's stewardship. When an area a_{ij} is close to total range area A_i, country j has more stewardship of species i, and consequently more responsibility for meeting the conservation target of species i. When $a_{ij} = A_i$, it follows that $t_{ij} = T_i$.

Strategic and targeted protection of species habitat will generally result in a country's SPI increasing, but once a country meets an individual species' target t_{ij}, subsequent additional protection of habitat will not increase the country's SPI. Likewise, any protection of land that does not also protect species habitat will not increase a country's SPI. Greater amounts of protected area generally translates to higher SPI values, but is dependent on the placement of protected areas.

Species Habitat Index

The Species Habitat Index (SHI) follows a rationale and calculation that is very similar to the SPI [1]. Instead of the Species Protection Score a species habitat value based on the habitat-suitable range (see above) is compared to a baseline. Species values are then aggregated for a region and assessed over time in the same way as for the SPI. Through its aggregate capture of change in high-resolution habitat quality across a range of species the metric addresses vital aspects of landscape and ecosystem integrity. For original formulation and subsequent updates see refs[1,16], with related concepts and prior work including [17-19].

Supplementary References

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