Indicator metadata sheet

Indicator metadata form for compilation of data relating to headline indicators proposed in the first draft of the monitoring framework for the post-2020 global biodiversity framework

1. Indicator name

Species Habitat Index (SHI)

2. Date of metadata update

June 2022

3. Goals and Targets addressed

Primary: **GOAL A**

wg2020-04-crp-01-en:

Option 1
The integrity, connectivity and resilience of [all] [vulnerable and threatened natural] ecosystems are maintained, restored or enhanced, increasing [or maintaining] [by at least 5 per cent by 2030 and [15] [20] per cent by 2050] the area, connectivity and integrity of the full range of natural ecosystems [taking into account a natural state baseline] [and the risk of collapse of ecosystems is reduced by [--] per cent].
[Beginning now,] the [human-induced] extinction of [all] [known] [threatened] species is halted [by 2030] [by 2050], [[and] extinction risk is reduced [by at least [10] [20] [25] per cent] by 2030 and [eliminated] [reduced [to a minimum] [by 50 per cent]] [halved] by 2050,] and the [conservation status] [average population] [abundance] [and distribution] of [depleted populations of] all [wild and domesticated] [native] [threatened] species is [increased [or maintained] by at least [10] [20] per cent by 2030 and] [increased to healthy and resilient levels by 2050].
[The genetic diversity and adaptive potential of [all] [known] [wild and domesticated] species is safeguarded and [all genetically distinct populations are] maintained [by 2030, at least [95] per cent of genetic diversity among and within populations of [native] [wild and domesticated] species is maintained by 2050].]

Option 2
Biodiversity is conserved, maintaining and enhancing the [area,] connectivity [, restoration] and integrity of all [terrestrial, freshwater, coastal and marine] ecosystems [and reducing the risk of ecosystem collapse], halting [from now] [human-induced] extinctions [and reducing extinction risk [to zero by 2050]], supporting healthy and resilient populations of [native] species, and maintaining genetic diversity of populations and their adaptive potential [numerical values to be added].

Secondary: Target 1, 2, 4

wg2020-04-crp-06-en; wg2020-04-crp-06-add1-en

TARGET 1
Ensure that [all] areas are under [equitable participatory] [integrated biodiversity-inclusive] spatial planning [or other effective management processes],
[addressing land and sea use change] [[retaining all]/[minimizing loss of] [intact ecosystems]] [critical and threatened ecosystems] [intact areas with high-biodiversity] [and other areas of high [biodiversity value[s]] [importance] [ecological integrity]], enhancing [ecological] connectivity and integrity, [minimizing negative impacts on biodiversity] [maintaining ecosystem functions and services]
while [safeguarding]/[respecting] the rights of indigenous peoples and local communities [in accordance with the United Nations Declaration on the Rights of Indigenous Peoples and international human rights law.]

TARGET 2
Ensure that [at least] [20] [30] [per cent]/ [at least [1] billion ha] [globally] of [degraded] [terrestrial,] [inland waters,] [freshwater], [coastal] and [marine]] [areas] [ecosystems] are under [active] [effective] [ecological] restoration [and rehabilitation] [measures] [, taking into account their natural state as a baseline [reference]], [with a focus on [restoring] [nationally identified] [[priority [areas] [ecosystems]] such as [threatened ecosystems] and [areas of particular importance for biodiversity]]] in order to enhance [biodiversity and ecosystem functions and services] [[ecological] integrity, connectivity and functioning] and [biocultural ecosystems managed by indigenous peoples and local communities] [, increase areas of natural and semi-natural ecosystems and to support climate change adaptation and mitigation], [with the full and effective participation of indigenous peoples and local communities] [*] [and through adequate means of implementation] [*].

TARGET 4
[Ensure active] [Undertake urgent] [and sustainable] management actions [to] [enable] [achieve] the recovery and conservation of [threatened species] [species, in particular threatened species], [and] [to] [maintain and restore] the [genetic diversity] [within and between populations] of [all species] [[all] [native]

4. Rationale

The conservation of biodiversity and integrity of ecosystems relies on the sustained ecological processes by the species that define them. Changes in the quality and connectivity of habitats that affect the health of systems' species impacts this integrity and ecosystem resilience. The SHI measures changes in ecosystem integrity through health of their component species populations and the associated processes and functions of ecological communities.

The index captures alterations to the quality and connectivity of habitats at the level of single species and at fine spatial scale, addressing single square kilometer assemblages. When aggregated over a larger geographic unit (e.g., landscape, seascape, mountain region, ecological region, or country), SHI can provide a compound measure of an area's ecological integrity and connectivity. When evaluated over species' geographic ranges, the SHI also informs about trends in the health of species populations and potential changes in their genetic diversity.

The SHI offers and integrative measures across Goal A Headline through its capture of key aspects (connectivity, integrity, population distribution, and population size) and its comprehensive relevance to the Goal's elements (Table 1). The SHI has direct pertinence to four of eight elements of Goal A, and a primary or secondary pertinence to the other four. Its combination of biodiversity observations with standard, near-global remote sensing products supports immediacy (e.g., annual updating), geographic comparability and near-global representation, disaggregation to kilometer- and landscape scale, species-level interpretation, and independent national computation.

Table 1: Relevance of the SHI to the different components and elements of Goal A.

Goal Milestones, Components		**SHI**	**SHI Relevance**
Ecosystem integrity	Area	Captures changes in the area available to the system's individual species in support of its ecological processes.	Secondary
	Ecological Connectivity	The SHI measure compositional and functional connectivity of ecosystems. (Its current connectivity measures captures within-patch connectivity, but can be complemented or substituted with an among-patch metric)	Primary
	Integrity	The SHI provides a composite measure of change in the ecological intactness of assemblages	Primary

Species Population Health and Extinction	Extinction rate	The count of species with SHI equal to 0 over time provides an estimate of extinction rate.	Primary / Secondary
	Extinction risk, Threat status	Increases in species extinction risk and threat status are a concave-upward function of decreasing suitable area and connectivity, the two components of SHI.	Secondary
	Population size and abundance	Changes in species population sizes are directly related the area and connectivity of their habitats, as measured by SHI.	Primary
	Population Distribution	The area component of SHI directly measures changes in population distribution.	Primary
Species Population Genetics	Genetic diversity	SHI measures the "Proportion of populations, or geographic range, maintained within species" to assess the potential loss of genetic diversity and unique adaptations.	Primary / Secondary

Integrity, area, and connectivity of ecosystems

The SHI measures changes to the ecological units, species, that together with the abiotic setting define ecosystems and that drive their ecological processes and integrity. For any defined area, the SHI assesses temporal change in hundreds or thousands of species and provides a compound signal of change in ecosystem integrity.

Indicator "A.0.1 Extent of selected natural and modified ecosystems" is poised to deliver an important, but basic capture of the area element of Goal A. Remote sensing enables a high-resolution delineation and tracking of ecosystem modification and areal change. Expert-based quality metrics could add further relevance to indicator A.0.1, and it could be expanded to address structural connectivity (based on land cover change data). But necessarily based on single geographic layers of abutting ecosystems (and thus a single dimension), the A.0.1 measures are naturally limited in their capture of ecological connectivity and integrity.

The SHI shares similarity with indicators of fragmentation focused on select ecosystems (e.g., forest fragmentation, river fragmentation, mangrove fragmentation), with a more direct measurement of ecological integrity. For example, the change in the connectivity of a region's forest ecosystems as measured with the forest fragmentation index would essentially be the same as that measured with the SHI applied to a single forest species inhabiting that full region (assuming the same landcover change products and connectivity metrics are used).

By including many different forest species of the region and thus accounting for their many functions and roles for the ecosystem, the SHI captures connectivity with direct relevance for the overarching aspiration of Goal A, the ecological integrity of ecosystems. The SHI connectivity component is currently using a within-patch metric (distance to suitable patch edge), but this could readily be expanded or substituted with an among-patch metric (e.g. patch neighbor distance or isolation), and for consistency the same metric could be applied to the ecosystems types (A.0.1) and species habitats (SHI).

Population Health and Extinction rate/risk

The SHI, specifically through its area component, uniquely and primarily addresses trends in species population size, abundance, and distribution. Its connectivity measure additionally informs about populations' functional and genetic health.

For extinction rate and risk, SHI complements periodically possible national expert assessments through temporal immediacy and geographic specificity.

Genetic diversity

In the absence of comprehensive genetic sampling to characterize separate populations and their genetically effective sizes, SHI offers a scalable alternative method to monitor loss of genetic diversity. SHI directly measures the "Proportion of populations, or geographic range, maintained within species", one of two main indicators for measuring genetic diversity recommended by the GEO

BON Genetic Diversity Working Group, with support from IUCN Conservation Genetics Specialist Group and others.

The indicator 'The proportion of populations within species with a genetically effective population size > 500' can offer a more direct quantification of genetic diversity when sufficient, range-wide genetic sampling allows. Where sufficient genetic data are lacking, estimates of changes in the minimum sizes of (connected) populations are recommended as alternative which the SHI area and connectivity components address. While or where range-wide genetic sampling for remains limited to a very specific subset of species, the SHI can be a proxy for trends in genetic diversity for a larger and more representative portion of biodiversity.

FAQs

1) What are some differentiating general attributes of the SHI?

The SHI leverages Essential Biodiversity Variables for Species Populations and is supported through the observation networks and capacity of the GEO Biodiversity Observation Network. The indicator is quantitative, offers temporal immediacy, directly and transparently links back to data, and it can be aggregated and disaggregated to the national level.

2) Is the SHI peer-reviewed and has it been used before in assessments?

The SHI was published in peer-reviewed papers in Jetz et al (Nature Ecology & Evolution, 2019), Powers & Jetz (Nature Climate Change, 2019) and Hansen et al (Conservation Letters, 2021). The SHI was peer-reviewed and approved by the Biodiversity Indicators Partnership. The SHI was also peer-reviewed and approved as a Core Indicator of IPBES (https://ipbes.net/core-indicators-0). It was used in the IBPES Global Assessment and IPBES National Assessments.

3) Given its use of categorical land-cover data, how does the SHI invoke habitat quality

The SHI uses both categorical and continuous data on habitat change, as captured through remote sensing. The current product, pre-calculated by GEO BON, uses continuous 30m Landsat tree cover information and 300m ESA CCI land cover information, available annually. Future updates will use additional Landsat data and 10m resolution Sentinel satellite data on habitat type and quality, and countries can use their own preferred products. Aggregated to 1km, or to larger landscapes and regions, the measurement at these fine scales offers the most robust capture of change in habitat quality currently possible over large extents.

4) I find the currently used connectivity metric of the SHI limiting. Could the SHI also address among-patch connectivity?

The SHI connectivity component is currently using a within-patch metric (distance to suitable habitat (patch) edge). With the core workflow in place (see below), it is straightforward to expand or substitute this with an among-patch metric such as patch neighbor distance or patch isolation. GEO BON is currently exploring such an update with partners.

5) Does the SHI measure abundance?

Yes. The SHI measures changes in species' abundance and population size through its range-wide assessment of changes in number and suitability of all habitat pixels available to a species. For a few charismatic, large-bodied species in select place, direct abundance counts of individuals might be more informative, but such survey data is insufficiently available to address whole populations or to representatively cover species or regions.

6) Is the SHI available for marine and freshwater ecosystems?

The current indicator methodology applies to marine systems and, with small adaptations, to freshwater. For marine systems, SHI calculations have been prototyped for ca. 13,000 marine fish and mammal species based on global layers of human impact (destruction, pollution, shipping, etc.) and habitat change maps for coral reefs, mangroves, and seagrasses. This can be advanced and shared by COP15. The SHI methodology can be applied to freshwater species, with data on dams and other barriers defining edge pixels for species with impacted movement. This can be implemented over a 12-18 month time frame.

5. Definitions, concepts and classifications

5.a Definition:

The SHI is given as the average size and connectivity of species' suitable habitat in a specified geographic unit (e.g., country) at a given point in time relative to the reference period (Powers & Jetz 2019, Hansen et al. 2021, Jetz et al., 2021).

The index is calculated as an aggregate of single 'species habitat scores' (SHS) and is expressed relative to a baseline of SHI = 100. For example, a 6% and 8% decrease, respectively, in habitat size and connectivity of Species A would result in an SHS of 94 for that species (average of 96, for size, and 92, for connectivity). If Species B in a region has SHS = 102 and Species C has SHS = 98, the resulting SHI for the region based on these three species is 98 (average of 94, 102, and 98), a decrease of two percentage points compared to a baseline SHS of 100.

In practice, scores from hundreds or thousands of species are aggregated to inform the SHI of a region, and the SHI is thereby sensitive to change in a range of associated functions and processes. To explore patterns, see https://mol.org/indicators/habitat; e.g. https://mol.org/species/habitat-trend/Cephalophus_zebra.

For country reporting, the SHI can additionally take national stewardship for native species into account, i.e., weight more strongly changes in species and ecosystem aspects that occur in few or no other countries. Compared to the *National SHI*, defined as the arithmetic mean of a country's SHS values, *Steward's SHI* is based on a weighted average of SHS values, with the proportion of the global population a country is estimated to hold as weights.

The SHI is calculated and validated using species occurrence data combined with environmental change data informed by remote sensing. Calculations use best-possible predictions of species geographic distributions (Species Populations EBVs), based on a variety of sources combined with species habitat information.

The SHI can be calculated independently with national or subnational information, such as national biodiversity monitoring data or national land-cover products. A full suite of annual country-level indicator values and extensive species-level data and metadata supporting it are made available through GEO BON and its associated Species Population EBV platform Map of Life, and parties can readily use these directly for their reporting or use them to augment their own calculations.

SHI subsets can address specific taxonomic or functional groups, migratory species, groups characteristic of certain habitats and ecosystems (forests, alpine zone, coral reefs, mangroves, etc.), groups of rare or threatened species or groups with particularly rapid recent habitat changes. Such subsets allow measuring change in biological integrity as experienced by these specific systems.

5.b Method of computation

I. Workflow:

Step 1: Determine baseline geographic distribution and habitat-suitable range of species:

The first input is an expert range map or a prediction from a species distribution model.

The second input is information on species habitat preferences (e.g., "a forest species restricted to <500m elevation").

The third input consists of global or national land cover maps and other layers on landcover condition. Linked to species habitat preferences these enable a detailed mapping of a species' habitat-suitable range for the baseline/reference period (Figure 1).

For all three inputs, parties can use (or further modify) existing data and predictions provided by GEO BON partners or independently use national information.

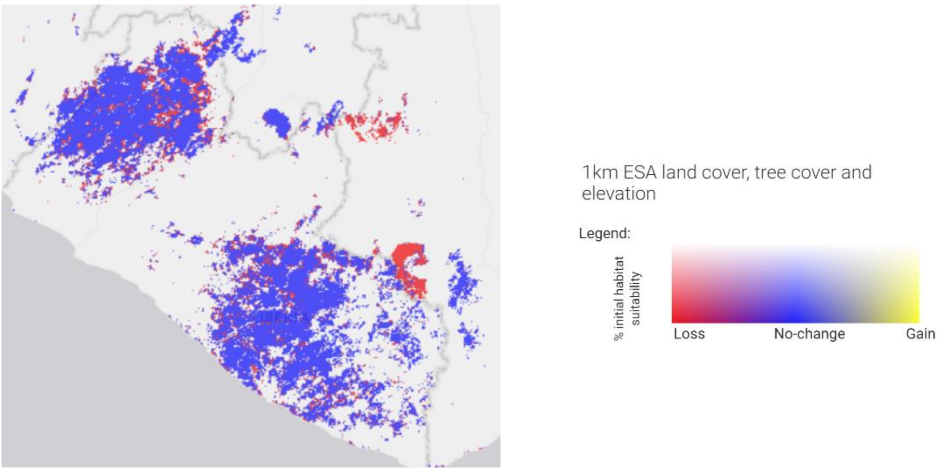

Figure 1: The product of Step 1, the habitat suitable range of a species in the reference period (Year 2001). Non-blue pixels experience a suitability change 2001-2019, affecting area and connectivity of the species' populations. For details, see https://mol.org/species/habitat-trend/Cephalophus_zebra

<u>Step 2: Calculate Species Area and Connectivity Scores in relation to baseline</u>

For any year addressed by global or national landcover or relevant remote-sensing products, standard GIS procedures support a calculation of species' country-wide total suitable habitat area (summed pixel suitability) and of habitat connectivity (e.g. average distance to edge of patch, or among patches). The Area and Connectivity Scores for the baseline/reference period (e.g. 2001) are set to 100, and any subsequent year is expressed as percent difference to that period (Figure 2).

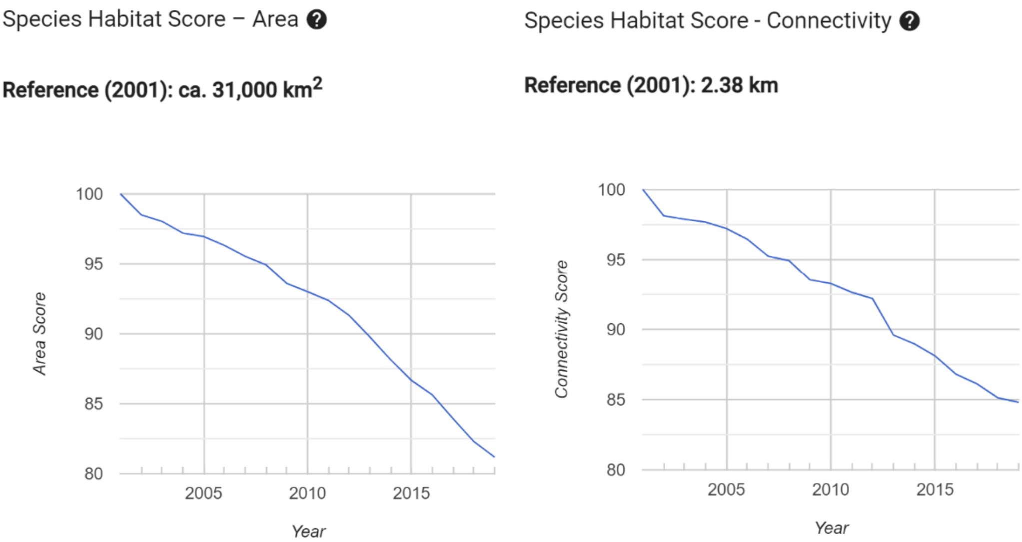

Figure 2: The product of Step 2 for a single country and species, as pre-calculated by GEO BON and partner MOL based on ESA CCI landcover data and Landsat tree cover. For details and download see https://mol.org/species/habitat-trend/Cephalophus_zebra

<u>Step 3: Aggregate species scores to country SHI</u>

In the final step, for a particular year the Area and Connectivity Scores of all species in country are combined and the SHI is given as their average (Figure 3).

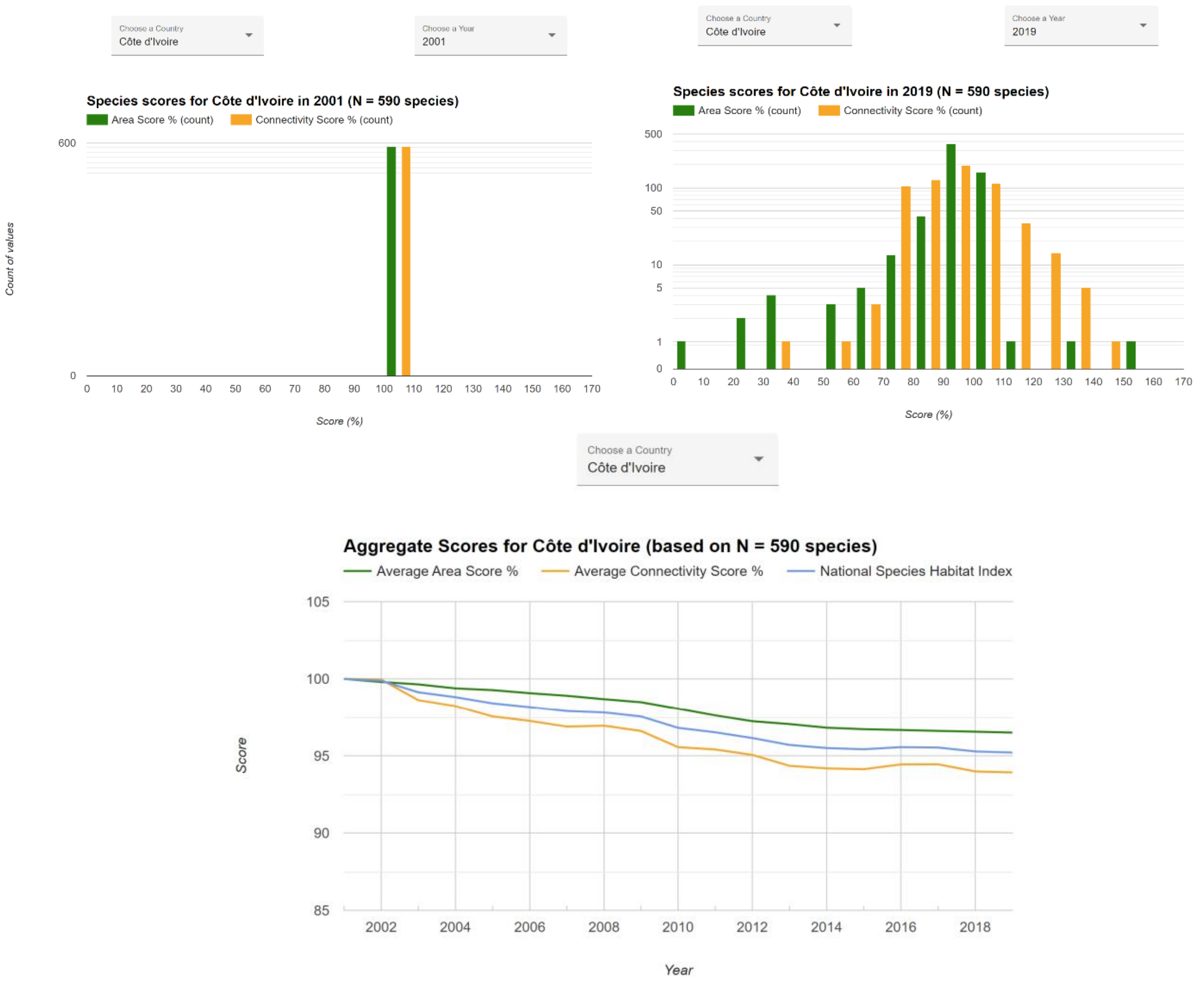

Figure 3: The Area and Connectivity Scores of all assessed species in an example country for the reference year (top, left 2001) and a subsequent year (top right, 2019), and the resulting average scores and SHI over time (bottom). To explore these and other pre-calculations see https://mol.org/indicators/habitat/regions.

II. Algorithms:

I. Species Area and Connectivity Scores:

Let s_{hi} represent the suitability of pixel *h* for species i, which is varying from 0 to 1, which could be expressed in binary form (0 or 1). The size of suitable habitat area in region *j* for species i, A_{ji}, is then given by the summed product of the pixel-level suitability of *h* in *j* and the pixel size *a* (assumed constant, e.g., 1 km^2): $A_{ij} = a \sum_h s_{hi}$

The connectivity of suitable habitat area for species *i* in region *j*, C_{ij}, is given by the GIS fragmentation (GISfrag) metric calculated over a binary version of the pixel-level suitability map. First, for each of the *p* suitable pixels the distance d_{hi} to the closest edge pixel is calculated (edge includes any non-passable, natural or artificial barriers). The GISfrag metric is the average of these distances:

$$C_{ij} = \frac{\sum_j d_{hi}}{p}$$

For a particular year *k* both metrics are then set relative to the reference year of k = 1. The area score (*AS*) and connectivity score (*CS*) for year *k* is given as:

$$AS_{jk} = 100 \frac{(A_{j1} - A_{jk})}{A_{j1}} \text{ and } CS_{jk} = 100 \frac{(C_{ji} - C_{jk})}{C_{j1}}$$

The Species Habitat Score *SHS* for species *i* in region *j* and year *k* is then defined as the mean of these Area and Connectivity scores for that year: $SHS_{ijk} = \frac{(AS_{jk}+CS_{jk})}{2}$

II. Species Habitat Index:

National SHI of country *j* in year *k* is given as the average of the *n* Species Habitat Scores in that year: $SHI_{jk} = \frac{\sum_i SHS_{ijk}}{n}$

Steward's SHI is calculated similarly, but as weighted average using national species' stewardship weights. Let the global habitat-suitable range area of species i in the reference period be $A_i = \sum_j A_{ij}$.

The *stewardship weight* of country j for species i is then given by $w_{ji} = \frac{A_{ij}}{A_i}$,

and represents the proportion of the global habitat-suitable range of species i found in country j.

Steward's SHI of country j in year k is then simply given as a weighted average using these stewardship weights: $SHI_{jk} = \frac{\sum_i w_{ij} SHS_{ijk}}{\sum_i w_{ij}}$

5.c Data collection method

See above for description of data inputs. These include primary species occurrence data, literature-based or model-supported species distribution predictions, literature or data-derived habitat associations, land cover and ecosystem extent change information.

Independent national SHI calculations can replace the nationally disaggregated global calculations. Indicator data for each species and country combination are available through GEO BON (see above) and can either partly or fully be replaced. Countries can use national biodiversity monitoring or map datasets and national land cover data and apply the same methodology. National SHI values calculated with national data consistently over time can be fully interpreted temporally and harmonized with global, disaggregated SHI values. To support harmonization and interpretation of national difference, national calculations should include metadata on the species and datasets used.

5.d Accessibility of methodology

The Species Habit Index was peer-reviewed and published in Powers & Jetz (Nature Climate Change, 2019), with further peer-reviewed descriptions and extensions in Hansen et al. (2021) and Jetz et al. (2021). The methodology has been used in the IPBES global assessment and the indicator is part of the Biodiversity Indicators Partnership (BIP) indicator suite. See reference list. For additional description of the SHI methodology see CBD/WG2020/3/INF/6.

The methodology is laid out in further detail in this present document to support full replicability at the national and regional scale. The methodology can be repeated by other scientists and agencies. Use of the same publicly available data inputs will yield the same overall results. The same methodology can be used at national and regional scale with partially or fully separate data inputs, such as national biodiversity or land cover data. It is equally applied to coastal and marine data.

5.e Data sources

At the global scale:

Map of Life (MOL, https://mol.org/indicators/habitat); habitat-suitable range maps, habitat-suitable range area and connectivity calculations, country SHS values.

Global Biodiversity Information Facility (GBIF, https://www.gbif.org) through its national nodes.

European Space Agency (ESA); e.g., through its global CCI land cover product https://www.esa-landcover-cci.org.

NASA/USGS/U Maryland: e.g. through the Landsat Satellite program supporting the production of annual land cover and tree cover data (https://landsat.gsfc.nasa.gov).

Marine and coastal habitats: maps of ecosystem extent as available for coral reefs, mangroves, and other marine ecosystems and seascapes. Maps of human impacts (Halpern et al. 2015).

River barriers (Grill et al. 2015, 2019), with non-passable dams defining range edges for, e.g., freshwater fishes.

At the national scale:

As available: National biodiversity occurrence and map data, National land cover products,

5.f Availability and release calendar

The indicator is available now. New data on habitat changes are available annually at the global scale from standard remote-sensing supported products. Biodiversity records provided through GBIF and other partners are updated on an ongoing basis, sub-annually. GEO BON through its partner platform Map of Life is committed to extending the data coverage to many more species groups, and specifically to marine, coastal, and freshwater groups, and to delivering standardized SHI products for countries annually. Countries using national data may select different time intervals for updates

5.g Time series

2001-2020 (for a more limited version (lacking 30m remote sensing data): 1993-2020)

5.h Data providers

See also data sources.

At the global scale:

GEO BON infrastructure Map of Life (MOL, https://mol.org/indicators/habitat); habitat-suitable range maps, habitat-suitable range area and connectivity calculations, country SHS and SHI values.

Global Biodiversity Information Facility (GBIF, https://www.gbif.org) through its national nodes

European Space Agency (ESA); e.g. through its global CCI land cover product https://www.esa-landcover-cci.org.

NASA/USGS/U Maryland: e.g. through the Landsat Satellite program supporting the production of annual land cover and tree cover data (https://landsat.gsfc.nasa.gov)

At the national scale:

As available

National biodiversity occurrence and map data

National land cover products

5.i Data compilers

GEO BON

The indicator is calculated from Species Population Essential Biodiversity Variables (EBVs). Species Population EBVs are based on globally available biodiversity data, e.g., as provided through the Global Biodiversity Information Facility (GBIF), and global satellite remote sensing products, as provided through NASA and European Space Agency, and calculated and provided through GEOBON infrastructure Map of Life (MOL). The global datasets combined with the indicator standard methodology enable predictions for any country that can then support global aggregation.

5.j Gaps in data coverage

SHI is currently based on several tens of thousands of terrestrial vertebrate species that characterize all land ecosystems. The inclusion of select invertebrate and plant groups is in progress.

SHI calculations are in development for marine ecosystems and expected for late 2022, based on ca. 13,000 marine fish and mammal species (see Rinnan et al., 2021). Currently available inputs on habitat change address coral reefs, mangroves, seagrass (see Goal A ecosystem extent indicator) and from Halpern et al. (2015) for additional human impacts.

The SHI methodology can be applied to freshwater species, with data on dams and other barriers (Grill et al. 2015, 2019) defining edge pixels for species with impacted movement.

5.k Treatment of missing values

See 5.i

6. Scale

6.a Scale of use

The SHI can be calculated at national scale and aggregated to form a global indicator. Conversely, global scale SHI calculations can be disaggregated to the level of small regions. Generally, the SHI can be calculated and aggregated at spatial levels ranging from 1 km to small regions, countries, biomes, and the whole planet. The SHI can be calculated with purely national data and the methodology allows countries which prefer calculating the SHI independently to nationalize the indicator.

6.b National/regional indicator production

In See 5.b for visual workflow. In addition to using index calculations or species-metrics provided through GEO BON, CBD Parties can directly calculate country-level SHI by leveraging national data, expertise, and biodiversity change assessment capacity. GEO BON, through its working groups, and national and thematic Biodiversity Observation Networks, can provide capacity support. The calculation follows these specific steps:

Step 1: Determine baseline geographic distribution and habitat-suitable range of species:
At the most basic level, this is based on expert range maps, acknowledging their high false presence rate. Preferably, predictions are based on species distribution models (SDMs) that follow best-possible data integration practices and leverage raw occurrence data and remote-sensing supported environmental layers. Parties can develop these national distribution predictions entirely independently or use existing predictions (e.g., https://mol.org/species/range/Cephalophus_zebra), further modified or as provided. The species distribution data are combined with remote-sensing supported layers of environmental conditions, such as land-cover, and the data-driven associations species associations have with them. This delivers continuous or binary pixel-level species habitat suitability for the reference period.

Step 2: Calculate Area and Connectivity score over time
Via standard GIS processing, this supports for each species estimates of country-wide i) total suitable habitat area (summed pixel suitability) and ii) habitat connectivity (average distance to edge of suitable habitat area, GISfrag metric [Ripple et al. 1991]). See e.g., https://mol.org/species/habitat-trend/Cephalophus_zebra. These 'Species Habitat Scores' (SHS) are combined for all evaluated species in a country as simple average (National SHI) or as average weighted by the proportion of global population the country is estimated to hold (Steward's SHI). Through standard GIS processing, changes to the baseline levels of suitability of each species-pixel combination are assessed for different time steps using the same or different environmental layers used in Step 2. These layers currently include standard global land-cover and marine change products but can also comprise national change products or a combination of remotely sensed environmental change signals with

high spatial and spectral resolution. Distribution gains beyond the baseline (e.g., through extensive restoration or climatic shifts) are addressed through a rerun of Step 1. For each point in time Step 2 calculations are repeated.

Step 3: Aggregate species scores to country SHI
In the final step, for a particular year the Area and Connectivity Scores of all species in country are combined and the SHI is given as their average.

Country 1

Species	*Steward*	Area	Connectivity
A	*0.86*	81	87
B	*1.00*	102	101
C	*0.30*	60	76
National SHI		**81**	**88**
Steward's SHI		**87.8**	**92**

Country 2

Species	*Steward*	Area	Connectivity
C	*0.70*	80	86
D	*1.00*	130	120
National SHI		**105**	**103**
Steward's SHI		**109**	**106**

Example SHI calculation for two countries based on five species. The countries share species C. Steward: country stewardship value, used as weight for Steward's SHI.

6.c Sources of differences between global and national figures

Differences between nationally and internationally (globally) produced SHI values may arise from the use of different input data sources, e.g. national biodiversity or landcover data.

6.d Regional and global estimates & data collection for global monitoring

6.d.1 *Description of the methodology*

Aggregation of country-level SHI values to larger regions or the globe is possible through a simple arithmetic mean. Aggregate SHI for a set of *n* countries 1 to *j* in year *k* is given as follows:

$$SHI_k = \frac{\sum_j SHI_{jk}}{n}$$

6.d.2 Additional methodological details

Regional and global SHI values are directly aggregated from national values (see 6.d.1). The globally harmonized annual SHI calculation that is provided by GEO BON is conducted at national level and thus provides national, regional, and global values. Nations can additionally apply the same standard SHI methodology to their own datasets. These nationally developed SHI values might not be perfectly comparable among countries that use different national inputs (e.g., land cover maps based on different sources or methodology). But with this caveat in mind regional and global aggregation of such nationally developed SHI information are equally straightforward and a simple average of national values.

6.d.3 Description of the mechanism for collecting data from countries

7. Other MEAs, processes and organisations

7.a Other MEA and processes

IPBES

The indicator is an IPBES Core Indicator and was used in the Global Assessment and Regional Assessments.

7.b Biodiversity Indicator Partnership

Y; https://www.bipindicators.net/indicators/species-habitat-index

8. Disaggregation

By species, species group (taxonomic, functional, habitat-based) and any sub-national regional area down to 1 km^2 size.

9. Related goals, targets, and indicators

Related indicators

- "Extent of selected natural and modified ecosystems", Headline Indicator for Goal A: The SHI adds important measures of ecological integrity and connectivity within and across ecosystems. More than using basic ecosystem maps to assess patterns, the SHI assesses the ecological quality and connectivity of ecosystems through their biological species elements.

- "Red List Index", Headline Indicator for Goal A: The SHI is different to this indicator, and complements it, by addressing the Health and Extinction Risk of specie with an observation-based quantitative measure, temporal immediacy, and national/geographic specificity.

- "The proportion of populations within species with a genetically effective population size > 500'", Headline indicator for Goal A: In the absence of comprehensive genetic sampling to characterize separate populations and their genetically effective sizes, the SHI offers a robust, scalable alternative method to monitor changes in genetic diversity. Specifically, estimates of changes in the minimum sizes of (connected) populations are a recommended avenue for measuring changes in genetic diversity and directly addressed by the Area and Connectivity components of SHI. As range-wide genetic sampling will for some years remain limited to a small and atypical subset of species, the SHI offers a general and effective proxy to monitor trends in genetic diversity for a large and representative portion of biodiversity.

- "Species Protection Index (SPI)", Component Indicator for Target 3: The same map information used in the SHI underpins the SPI which assesses ecological representation in conservation areas.

- Complementary indicators "Forest fragmentation index", etc. The SHI shares similarities with fragmentation indicators focused on select ecosystems, and uses the same input (change in landcover, barriers) to support a more direct measurement of ecological integrity. For example, the change in the connectivity of a region's forest ecosystems as measured with the forest fragmentation index would essentially be the same as that measured with the SHI applied to a single forest species inhabiting that full region (assuming the same landcover change products are used). By including many different forest species of the region and thus accounting for their many functions for the ecosystem, the SHI captures connectivity with direct relevance for the overarching aspiration of Goal A, the ecological integrity of ecosystems.

Related Targets:

- Target 1 (Planning): The SHI measures the success of spatial planning activities in retaining the existence and ecological integrity of natural areas

- Target 2 (Restoration): The SHI measures the success of restoration activities in regaining connectivity and supporting the ecosystems with highest priority for healthy species populations

- Target 3 (Area-based conservation): The SHI measures the effectiveness and success of area-based conservation activities in delivering connected protected area networks and stemming the loss of ecological integrity in protected areas.

- Target 4 (Species management): The SHI measures the success in the recovery and conservation of species and their genetic diversity by assessing improvements in the availability and quality of the specific habitats they require.

- Target 5 (Species use): The SHI subset to species harvested, traded or otherwise used measures the sustainability of these uses with view to the population size and survival of the affected species.

- Target 6 (Invasive Alien Species, IAS): The SHI applied to IAS measures their current or potential future spread, the SHI applied to species known to be impacted by IAS addresses the scope for additional ecological impact.

10. Data reporter

10.a Organisation

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10.b Contact person(s)

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