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MEASURING ECOSYSTEM INTEGRITY (GOAL A) IN THE POST-2020 GLOBAL BIODIVERSITY FRAMEWORK: THE GEO BON SPECIES HABITAT INDEX

Note by the Executive Secretary

I. BACKGROUND

1. The Executive Secretary is pleased to circulate herewith, for the information of participants in the third meeting of the Open-ended Working Group on the Post-2020 Global Biodiversity Framework, an information document by the Group on Earth Observations Biodiversity Observation Network (GEO BON) on the GEO BON Species Habitat Index (SHI). The information is provided in the form and language in which it was received by the Secretariat.

Measuring Ecosystem Integrity (Goal A) in the Post-2020 Global Biodiversity Framework: the GEO BON Species Habitat Index (SHI)

The integrity of ecosystems is broadly defined by the status of their component species and the ecological processes they support and require. Integrity can be assessed by the degree of change (loss and gain) in the set of species and associated processes observed within an ecosystem and its habitats. The Species Habitat Index (SHI) measures this change and specifically captures alterations in the connectivity and ecological intactness of ecosystems. Built on species-level data it also informs about trends in the health of species populations and potential changes in their genetic diversity. The index is globally comparable at high spatial resolution. Annual, country-level SHI values for 2001 onward are provided through GEO BON for a growing range of species, and SHI can also be customized or calculated entirely independently with national information.

1. Background

1.1 Goal A and Ecosystem Integrity

Goal A of the first draft of the post-2020 Global Biodiversity Framework (GBF) focuses on the integrity of ecosystems. Ecosystems have integrity when their core ecological characteristics – such as the diversity, composition, and abundance of species and the structure, functions, and ecological processes these species support – are within their natural range of variation and resilient to perturbations (wg2020-03-03-add2; CBD/SBSTTA/24/3/Add.2/Rev.1, [1]). Ecosystems are comprised of species, the habitats they require to interact with one another, and the physical environment. To maintain integrity, ecosystems must contain a variety of habitats with sufficient size, quality and connectivity required by the species that drive the systems' ecological processes. Losses or gains in these necessary species habitat attributes manifest themselves as changes in i) the diversity, composition, structure, and function of species communities, ii) the distribution, sizes, resilience, and extinction of species, and iii) the genetic diversity of species.

1.2 Species Habitat Index (SHI)

The Species Habitat Index (SHI) measures changes in the estimated connectivity, size, and quality of species habitats. The SHI uses species as core units of analysis, thereby capturing the individual ecological processes species represent that are central to ecosystem integrity[1]. The index is also spatially explicit at a resolution of single pixels, e.g. 1 km^2, and their species assemblages. When aggregated across species in a defined geographic unit (landscapes, seascapes, mountains, regions, and country) it measures changes in the area's ecological integrity and, specifically, connectivity. Evaluated over species' geographic ranges, it measures trends in species population size, distribution, health, and, as proxy, genetic diversity.

1.3 Essential Biodiversity Variables (EBVs)

The properties of the Species Habitat Index properties are enabled by it being directly derived from Species Population Essential Biodiversity Variables (EBVs)[2,3]. EBVs are the first level of abstraction between raw observations and high-level indicators of biodiversity. Species Populations EBVs transparently leverage raw biodiversity data to measure species-level habitat suitability over contiguous spatial units and time. This space–time–species information is characterized for all members of a taxonomically or ecologically defined species group over their respective global extent.

EBVs and EBV-based indicators: - use workflows that connect and integrate core primary data to produce multiple decision-support outputs; - facilitate more coherent and comparable national reporting and the ability for more reliable calculation and measurement of the contribution of national commitments to global targets; - support spatially explicit prioritization of potential actions to best achieve goals, as well as monitoring of actual progress towards achieving goals resulting from implemented actions; - are spatially explicit and, by definition, scalable between sub-national, national, regional, and global scales, thereby allowing for consistent target tracking at all scales; - can be spatially scaled and support a cohesive and comprehensive approach to the monitoring and reporting of national and global targets.

1.4 GEO Biodiversity Observation Network (GEO BON)

The SHI is part of a new generation of EBV-generated indicators, developed by the GEO Biodiversity Observation Network (GEO BON) community[4] (https://geobon.org/ebvs/indicators; sbstta-24-item3-geobon-technical-support-en). GEO BON operates as a global community of practice seeking to ensure best practices, interoperability and convergence of methods to address essential biodiversity in an operational manner. GEO BON is improving the acquisition, coordination and delivery of enhanced biodiversity information for timely and effective policy-making for conservation. GEO BON also guides the design and implementation of national, regional and thematic Biodiversity Observation Networks (BONs) worldwide. Integrating EBVs within well-designed BONs can directly underpin national implementation of the post-2020 Global Biodiversity Framework, and transform the capacity to detect, understand and predict biodiversity status and trends [5].

2. Species Habitat Index Methodology

2.1 Methods Overview

The SHI is calculated and validated using species occurrence data combined with environmental change data informed by remote sensing[2,6-11]. 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 by parties with national data, such as national biodiversity monitoring data or land-cover classifications (see 2.2). A full suite of annual country-level indicator values and extensive species-level data and metadata supporting it are made available through GEO BON (see 2.3), and parties can readily use these directly for their reporting or use it to augment their own calculations.

Species level maps and trends: For each species, change in two metrics is assessed for a point in time relative to the baseline period (Fig. 1):

- Size of suitable habitat (Area; in km2): This is given by the product of summed suitability (continuous range of 0 – 1) of individual landscape pixels and their size. For suitability expressed in binary form (presence-absence maps) for 1 km^2 pixel, this is simply the total presence pixel count.

- Connectivity of suitable habitat (Connectivity; in km). As basic measure this is given as the average distance to edge of suitable area across all suitable pixels, a widely-used, robust measure of connectivity (GISfrag

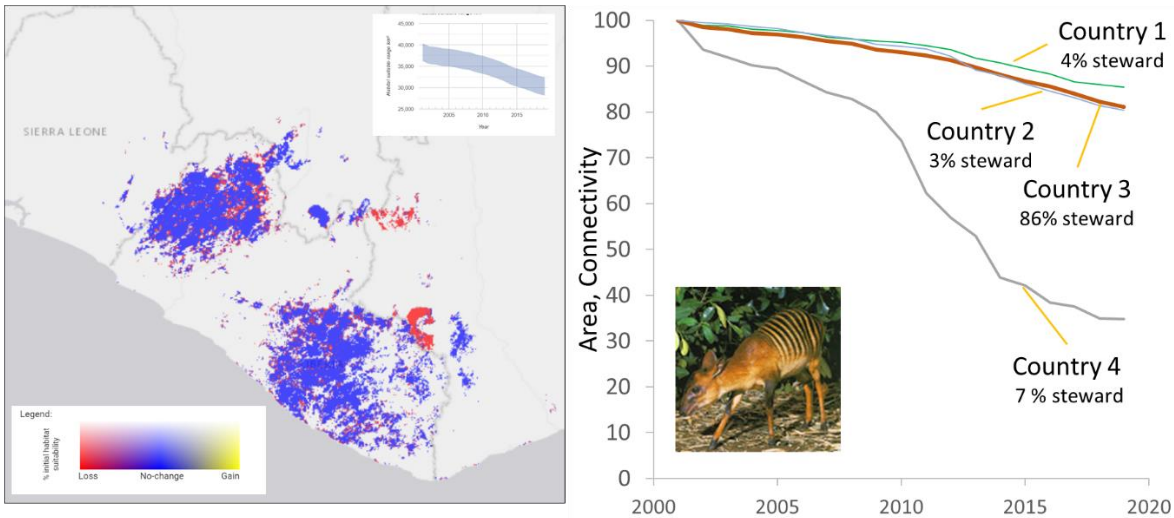

Figure 1: Example of species-level SHI metrics (here for the Zebra Duiker in West Africa) that, combined across many species in a region, drive overall SHI. The Area and Connectivity of suitable habitat within the species' potential distribution (mapped at $1km^2$ resolution, left panel) is assessed for a reference year (here 2001) and re-assessed annually (right panel). The species-level SHI metric can be expressed as relative change in Area, in Connectivity or their combination compared to a baseline of 100 and can be assessed globally or for individual countries or other administrative units or regions. Countries' stewardship (steward) is defined as their portion of species' suitable habitat at baseline. Explore further at https://mol.org/species/habitat-trend/Cephalophus_zebra

metric [12,13]). For custom calculations at national level this can be extended to include other information, e.g. measures that weight the distance among habitats by the resistance to movement of the intervening landscape.

A combined species-level SHI metric is given as the average species Area and Connectivity at a given point in time compared to the reference period. For example, a 4% and 6% decrease in Area and Connectivity, respectively, would result in species-level SHI = 95 (average between 96 for Area and 94 for Connectivity) compared to a baseline SHI = 100. Note that the previous version of SHI used just the Area component. A reporting of both the Area and Connectivity components of SHI is urged, and an alternative SHI formulation would use the minimum rather than average of these two components to provide an even more sensitive metric of ecological change.

Country Aggregation: The SHI of a geographic unit is given as the mean of SHI values of the species in that unit, at a given point in time (Fig. 2). SHI vales for a country can either be computed as simple mean across species (National SHI) or by weighting species-level values by the proportion of the global population the country is estimated to hold (Steward's SHI)[14].

In addition to reporting on the separate Area or Connectivity aspects of SHI, indicator subsets can address different species groups, e.g. species dependent on certain habitats and ecosystems, rare or threatened species, or those with particularly rapid recent habitat changes.

2.2. Methodology for calculation by parties

In addition to using index calculations or species-metrics provided through GEO BON (see 2.3), 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, is able to provide capacity support. The calculation follows these specific steps:

Step 1: Determine baseline species distributions. At the most basic level, this can include expert range maps, acknowledging their high false presence rate[15]. 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.

Step 2: Calculate core metrics and SHI for the baseline period. 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 [16-19] for the reference period. 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 [12,20]). These values 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)[14]. The same species values can also be averaged for each pixel and its composition of species as informed by the species distribution maps.

<u>Country 1</u>

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**

<u>Country 2</u>

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

Figure 2: Example SHI calculation (aggregation of species-level SHI values) for two countries based on five species. The countries share species C. Steward: country stewardship value, used as weight for Steward's SHI.

Step 3: Calculate change in core metrics and 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 [21,22], 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. SHI is given as the average change in area and connectivity, expressed as percent difference to the reference period, set at SHI = 100.

2.3. Availability of calculated indicator values for countries

Through GEO BON partner Map of Life and associated data, technology and science partners, the SHI has currently (2021) been calculated annually 2001-2019 for all countries, addressing terrestrial vertebrates and select vascular plant groups (https://mol.org/indicators). Inclusion of select marine/coastal, invertebrate, and additional plant groups is in progress. The metrics are informed by a rapidly increasing number of occurrence records from the Global Biodiversity Information Facility and other sources, currently > 500 million records. The current terrestrial environmental change products used are the annual ESA- CCI land-cover[23] and U Maryland tree cover[24], both standard products used in other UN reporting procedures (e.g. SDG indicator 15.3.1). For mountain regions, partner Global Mountain Biodiversity Assessment (GMBA, https://www.gmba.unibe.ch) supports mountain-specific species assessments. For marine systems, the current source is change in abatable human modification[22,25]. With continuation of these remote sensing products, this enables annual updates, including reporting through 2030.

SHI values and associated metadata are already or will be available through the GEO BON portal, the UN Biodiversity Lab, and a forthcoming the CBD indicator dashboard. Indicator values, underlying data, and species level maps and tools are available through a dedicated dashboard in the Map of Life web interface that has been developed with technology partners (https://mol.org/indicators).

3. SHI measurement of Goal A progress

The SHI complements the other Goal A Headline Indicators through its capture of key aspects, most notably connectivity, and comprehensive relevance to all Goal elements (Table 1). The SHI has primary or unique pertinence to four of the eight listed elements, and a potential 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), comparability, representation, disaggregation to kilometer-level and landscape scale, and species-level interpretation.

Goal Milestones, Components		SHI	SHI Relevance
A1: Natural systems	Area	Captures changes in area available to the system's individual species in support of its ecological processes	Secondary
	Connectivity	**Captures the compound connectivity experienced by individual species that define the natural system and its ecological processes**	**Primary**
	Integrity	Aggregated across species provides a composite measure of change in ecological intactness of assemblages (species composition and associated structure and functions) and departure from original range.	Primary
A2: Species Populations	Extinction rate	The count of species with SHI equal to 0 over time provides an estimate of extinction rate. Full extinction assessments, however, require careful surveys and expert input.	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 abundance (size)	Changes in species abundances and population sizes are closely determined by changes in the Area and Connectivity suitable for the species.	Primary

	Population Distribution	The Area component of SHI directly measures changes in population distribution.	Primary
A3: Species Genetics	Genetic diversity	SHI provides the proposed main genetic diversity indicator "Proportion of populations, or geographic range, maintained within species"[26] to assess potential loss of unique adaptations. In the absence of comprehensive genetic sampling, SHI offers a consistent way to approximate changes in genetically effective population size[27].	Primary / Secondary

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

3.1 Milestone A.1:

Net gain in the area, connectivity and integrity of natural systems of at least 5 per cent.

For this milestone SHI addresses all milestone elements, and in particular measures connectivity. It measures changes to the many units, i.e. species, that define ecosystems and 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 a basic but important capture of the area element of this milestone. 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. But necessarily based on single geographic layers of abutting ecosystems (and thus a single dimension), the A.0.1 extent measure is naturally limited in the capture of ecological connectivity and integrity.

3.2. Milestone A.2

The increase in the extinction rate is halted or reversed, and the extinction risk is reduced by at least 10%, with a decrease in the proportion of species that are threatened, and the abundance and distribution of populations of species is enhanced or at least maintained.

The SHI, specifically through the Area component, uniquely and primarily addresses the second portion of Milestone A.2 by capturing trends in species population abundance and distribution.

For the first milestone part, Indicator '*A.0.3 Red list index'*, and in particular national red-listing efforts, the SHI provides a periodic assessment of 'Extinction risk' and 'Threat status' and, as possible, through expert networks carefully assess "Extinct" status. Species-level SHI values and maps can offer vital information, supporting expert threat assessments by providing temporal immediacy, regional/national specificity, and geographic specificity.

3.3. Milestone A.3

Genetic diversity of wild and domesticated species is safeguarded, with an increase in the proportion of species that have at least 90 per cent of their genetic diversity maintained.

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[27]

The indicator 'A.0.4 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 [26] 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.

4. Further Resources and Literature:

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