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ON INDICATORS FOR THE STRATEGIC PLAN
FOR BIODIVERSITY 2011-2020
Geneva, Switzerland, 14-17 September 2015

# GLOBAL BIODIVERSITY CHANGE INDICATORS: MODEL-BASED INTEGRATION OF REMOTE-SENSING AND IN SITU OBSERVATIONS THAT ENABLES DYNAMIC UPDATES AND TRANSPARENCY AT LOW COST

Note by the Executive Secretary

The Executive Secretary is circulating herewith, for the information of participants in the meeting of the Ad Hoc Technical Expert Group on Indicators for the Strategic Plan for Biodiversity 2011-2020, a technical document on global biodiversity change indicators. The document has been prepared by the members of the GEO BON Working Group on Biodiversity Indicators. It is presented in the language and format in which it was received.

GEO BON

# Global Biodiversity Change Indicators

Model-based integration of remote-sensing & in situ observations that enables dynamic updates and transparency at low cost

GBIF NASA NSF Google Yale UNIVERSITY

CSIRO MOL MAP OF LIFE NATURAL HISTORY MUSEUM Predicts iDiv

# Towards a new generation of biodiversity indicators

**GEO BON with its scientific partners introduces a new generation of global indicators integrating biodiversity observations, remote sensing data, and models for assessing progress towards the CBD Strategic Plan 2011-2020 and Aichi Targets 5, 11, 12, and 19.**

A GEO BON (the Group on Earth Observations Biodiversity Observation Network) consortium involving researchers and organizations around the world has developed a novel set of global indicators to address important gaps in our understanding of biodiversity change across scales, from national to global. These indicators are embedded in open online analysis platforms following GEO data sharing principles and have the long-term commitment of established research institutions.

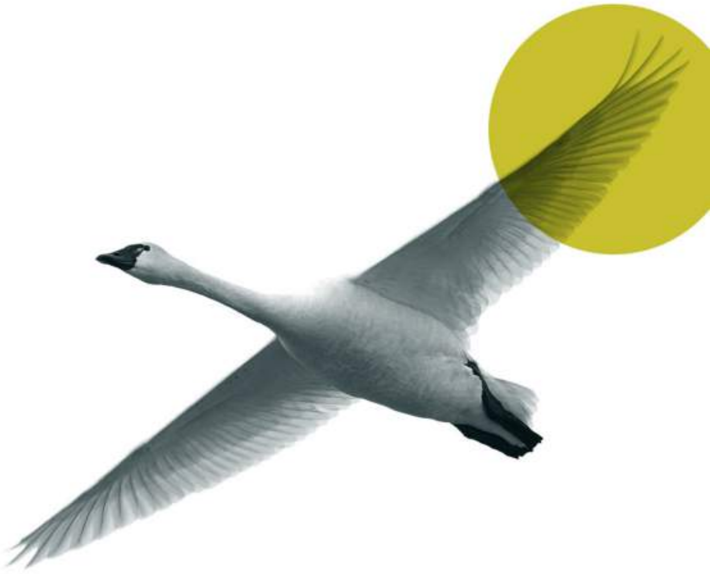
The new set of indicators is characterized by the rigorous use of large global datasets, state of the art remote-sensing based information, model-based integration of multiple data sources and types, including in situ (ground based) observations, and online infrastructure enabling inexpensive and dynamic updates, with full transparency. This has become possible through direct collaboration with technical and research support partners such as Google and NASA, the development of a dedicated infrastructure such as Map of Life, and the engagement of the larger GEO BON community.

The following pages describe five new indicators for assessing and reporting progress against Aichi Targets 5, 11, 12 and 19 and are derived by integrating data from three Essential Biodiversity Variables: species distributions, taxonomic diversity and ecosystem extent. By integrating the complementary strengths of different types of data, the resulting indicators offer some important benefits. For example, they help to fill geographical and taxonomic gaps in the coverage of measures based purely on in situ biological data and are able to translate measures based purely on remote sensing, for example of habitat loss and degradation, into biologically-scaled indicators of likely impacts on biodiversity.

One key advantage of these new indicators is that they cover the entire terrestrial surface of the planet at 1km grid resolution. By operating at this spatial resolution the indicators can effectively account for important relationships between species distributions and patterns of habitat loss and protection that play out at scales much finer than those typically addressed by previous global indicators. This fine resolution of analysis then underpins reporting of the indicators at any desired level of spatial aggregation, including the national level. Such automated national reporting is being integrated into the BON-in-a-Box toolkit of GEO BON.

Developing robust global indicators is a component of a larger GEO BON effort to improve our understanding of the biotic response to global change, by integrating previously disconnected dimensions of biodiversity and also by connecting local trends to regional and global trends, offering tests of the predictive capacity of models in response to global change, a critical step in making ecological forecast more rigorous.

Prof. Henrique M. Pereira
GEO BON Chair



# Species Habitat Indices

**The Species Habitat Indices (SHIs) quantify changes in the suitable habitats of single species to provide aggregate estimates of potential population losses and extinction risk increases in a region or worldwide.**

## Purpose of the indices

To provide annually updated biodiversity change metrics that transparently build on single species data and that can be reported regionally and globally. The indices address trends in the sizes of species potential distributions and populations for habitat –dependent and threatened species. The Species Habitat Indices use remote sensing data, local observations, and models in a web-based informatics infrastructure.

They are designed to measure and report on progress in relation to CBD Aichi Targets 5 and 12.

**CBD Aichi Target 5**

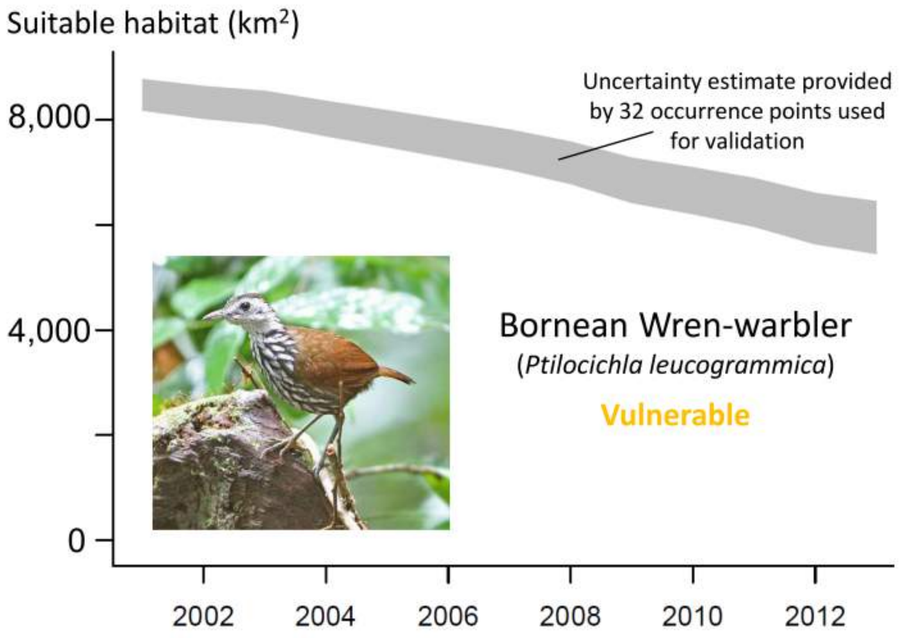
Habitat loss halved or reduced

**CBD Aichi Target 12**

Reducing risk of extinction

## Coverage

The indices use environmental and species data addressing all terrestrial areas of the world at 1 km spatial resolution. They can be aggregated at spatial levels ranging from 1 km to small regions, countries, biomes, and the whole planet. The indices build on land cover information available annually from Landsat and MODIS satellites since 2001 onwards. With continuation of these remote sensing products, this enables annual update of indices, including reporting Aichi Target 5 and 12 achievements, for ten data points from 2011 to 2020.



Example of a species-level trend informing the SHIs. Remotely sensed land-cover change indicates significant decrease in forest habitat suitable for the Bornean Wren-warbler in its range in Southeast Asia. The indices are derived from these single-species estimates and aggregated for all species occurring in a reporting region or country.

## Methods

Indicators addressing Aichi Targets 5 and 12 are typically constrained in their adequate geographic representation, the level of disaggregation they allow, their temporal resolution, and their scientific underpinning and transparency. The Species Habitat Indices are part of a new generation of indicators that address these limitations by utilizing ongoing, spatially and temporally highly resolved remote sensing at near global-extent, together with biodiversity observations, and adequate and transparent modeling frameworks.

The indices build on detailed, remote-sensing informed maps of suitable habitat for single species. Maps are modeled using literature- and expert-based data on habitat restrictions and published land-cover products from MODIS and Landsat satellites available annually at 30 m and 1 km resolution. These detailed maps of habitat suitable for a species are validated with field data on species locations from surveys and citizen science.

Modifications in the area and fragmentation of individual species' remaining habitat are quantified annually and changes in extinction risk are estimated. The species-level metrics are then aggregated and reported over user-defined regions, such as countries.

Separate indices can be calculated for species dependent on certain habitats types (e.g. natural forests), and for threatened species. The indices can also be subset to species with particularly rapid recent habitat changes, and they can account for countries' stewardship of species (their portion of a species' global range).

All underlying data and metrics are available through a dedicated dashboard in the Map of Life web interface that has been developed with Google Earth Engine as technology partner. Currently, the Species Habitat Indices are based on > 20,000 species of terrestrial vertebrate and invertebrate, and plant species, and validated with > 300 million location records, a growing number.

**Essential Biodiversity Variables:**
Species distributions
Ecosystem extent and fragmentation

Bornean
Wren-Babbler
*Ptilocichla leucogrammica*

Habitat Associations ON OFF
Elevation ON OFF
0 - 700 meters
Tree cover: ON OFF
75 - 100%
Landcover ON OFF
Woodlands: Forests, Woody Savannas
Cultivated: Cropland, Cropland Mosaics
Shrublands: Open, Closed
Barren Urban: Barren, Urban
Herbaceous: Savannas, Grasslands
Water: Wetlands, Water Bodies

Modeled prediction of 1 km pixels with habitat suitable for the Bornean Wren-warbler. Where data exists (blue circles), the accuracy of this estimate is validated with recent observations. The loss (or gain) of suitable pixels is then assessed over time. This information is accessible and updated for all species through this online dashboard developed in partnership with Google.

# BHI Biodiversity Habitat Index

CSIRO

**The Biodiversity Habitat Index uses biologically-scaled environmental mapping and modelling to estimate impacts of habitat loss, degradation and fragmentation on retention of terrestrial biodiversity globally, from remotely-sensed forest change and land-cover change datasets.**

## Purpose of the index

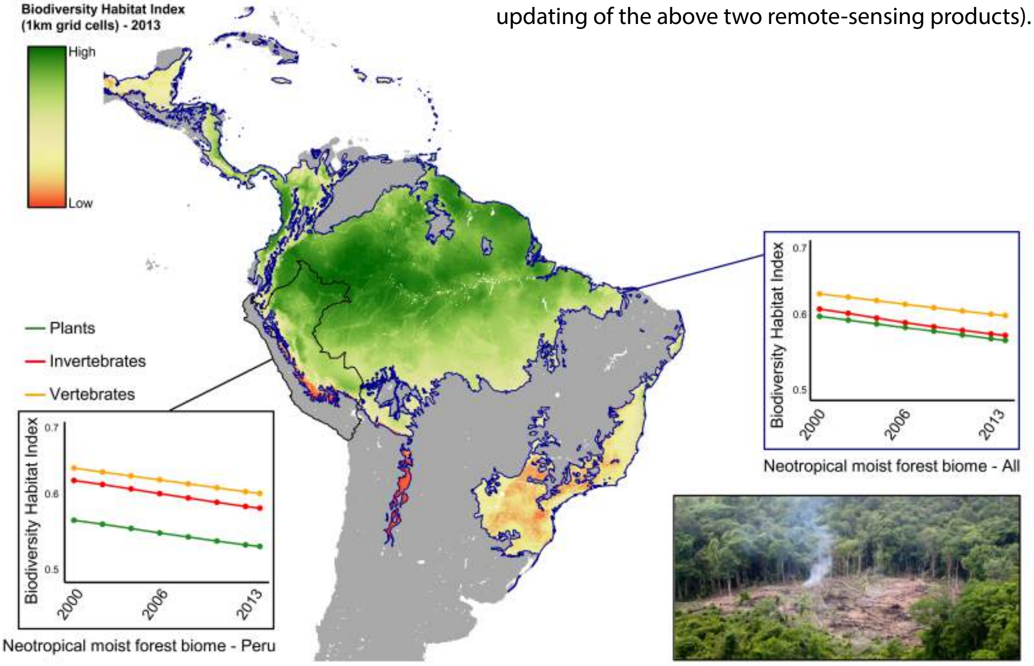
To provide a rigorous, yet cost-effective, approach to estimating impacts of habitat loss, degradation and fragmentation on biodiversity globally, by linking remotely-sensed forest change and land-cover change datasets to recent advances in biodiversity informatics, ecological meta-analysis, and macro-ecological modelling. The Biodiversity Habitat Index is designed specifically as an indicator for measuring and reporting progress in relation to the Convention on Biological Diversity's Aichi Target 5.

**CBD Aichi Target 5**
Habitat loss halved or reduced

## Coverage

The approach uses data covering the entire terrestrial area of all countries of the world, at 1km grid resolution. This allows the Biodiversity Habitat Index to be calculated and reported at any desired level of spatial aggregation, ranging from individual 1km grid-cells up to whole ecoregions, countries, biomes and realms, or the entire planet.

The approach utilises the full temporal coverage of Hansen *et al.'s* (2013, *Science* 342: 850-853) Global Forest Change dataset, i.e. 2000 onwards; and NASA's (Friedl *et al* 2010, *Remote Sensing of Environment* 114: 168-182) MODIS Land Cover Change dataset, i.e. 2001 onwards. Changes in the Biodiversity Habitat Index can therefore be reported annually, including reporting Aichi Target 5 achievement for ten annual data points from 2011 to 2020 (assuming ongoing annual updating of the above two remote-sensing products).



Reporting of the Biodiversity Habitat Index for an example combination of realm (Neotropics) and biome (moist tropical forest), based on analysis of Hansen et al's Global Forest Change dataset. The two charts depict changes in the index between 2000 and 2013, for the three major biological groups, aggregated across Peru alone, and across the entire biome, respectively. The map depicts values of the index for individual 1km grid cells across the biome, in a single year (2013), averaged across all three biological groups.

## Methods

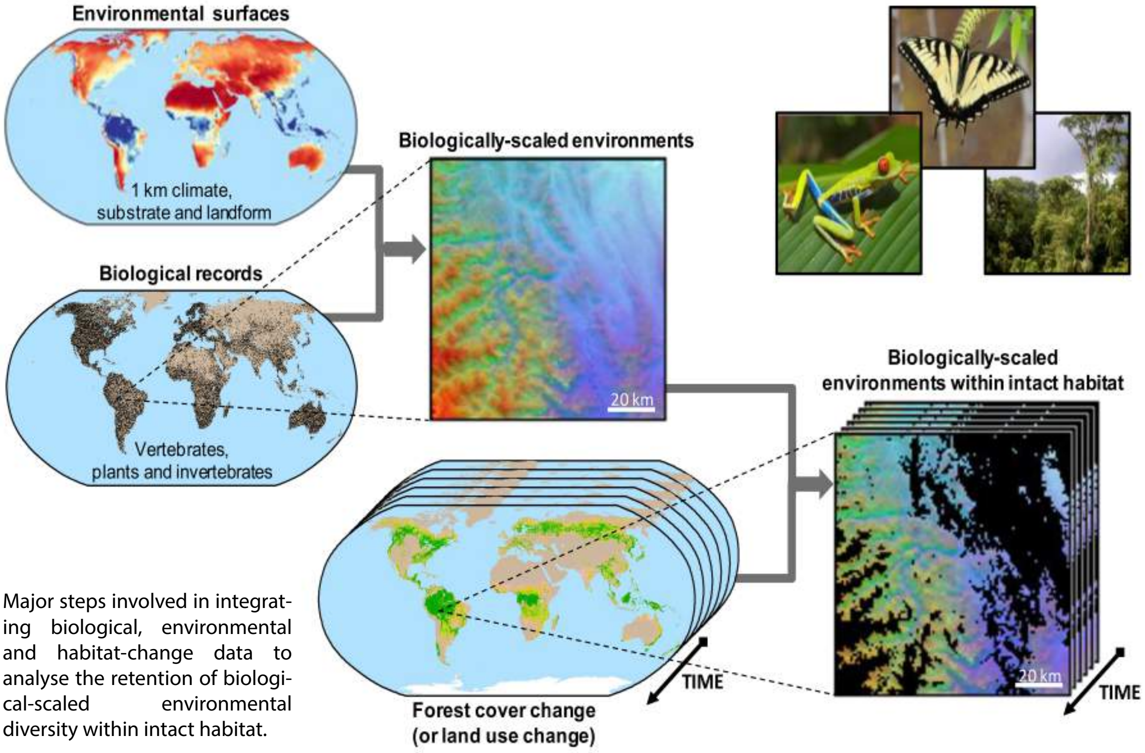
Changes in habitat degradation and fragmentation are estimated across all terrestrial biomes by translating remotely-sensed land-cover change (NASA's MCD12Q1 dataset) into land-use change through statistical downscaling of coarse-scale land-use mapping to 1 km resolution, and using the PREDICTS meta-analysis (Newbold *et al* 2015, *Nature* 520: 45-50) to assign habitat-condition scores to resulting land-use classes. Mapping of habitat change in forest biomes is further refined by incorporating Hansen *et al.'s* 30m-resolution Global Forest Change dataset.

These habitat-change layers are then integrated with global modelling of fine-scaled spatial variation in biodiversity composition (beta diversity), derived by scaling environmental and geographical gradients using >300 million location records for >400,000 plant, invertebrate and vertebrate species.

The Biodiversity Habitat Index resulting from this integration estimates change in the proportion of collective biological (gamma) diversity retained within any specified spatial unit (e.g. an ecoregion, a country, or an entire biome) as a function of habitat loss, degradation and fragmentation across that unit.

Habitat condition, derived from remotely-sensed land cover and statistically-downscaled land use, being used to estimate the Biodiversity Habitat Index across all biomes

**Essential Biodiversity Variable:**
Taxonomic diversity



Major steps involved in integrating biological, environmental and habitat-change data to analyse the retention of biological-scaled environmental diversity within intact habitat.

# SPI Species Protection Index

MOL MAP OF LIFE

**The Species Protection Index (SPI) measures how much suitable habitat for single species is under protection and estimates the regional or global biodiversity representativeness of terrestrial protected areas.**

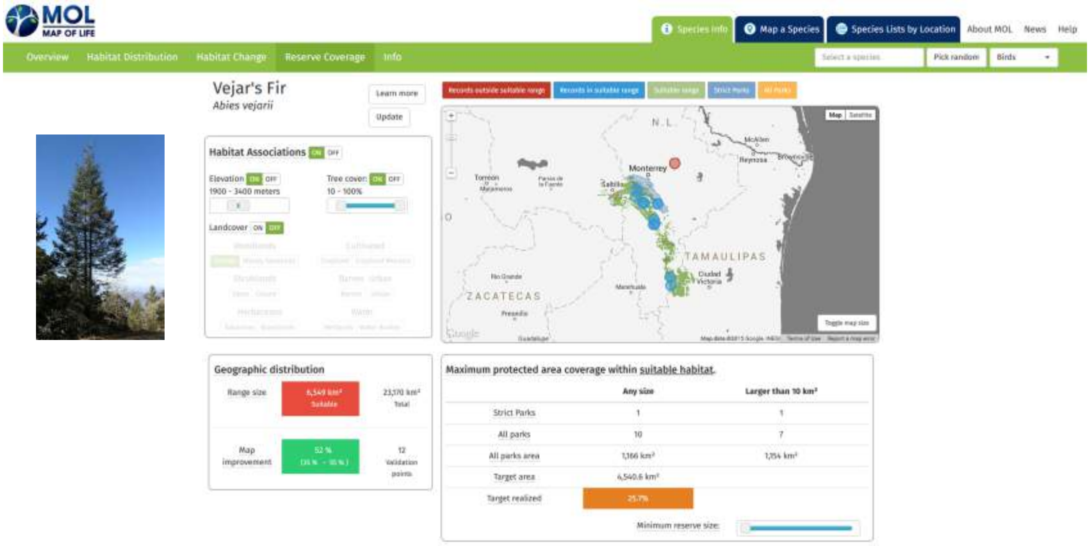
## Purpose of the index

To provide an annually updated, remote-sensing informated, spatially explicit, and global metric of how well terrestrial species are represented in terrestrial protected areas. The Species Protection Index capitalizes on detailed remote sensing data, a global biodiversity informatics infrastructure and integrative models. It is designed to measure and report progress in relation to CBD Aichi Target 11.

**CBD Aichi Target 11**
Protected Areas

## Coverage

The index uses environmental and species data addressing all terrestrial areas of the world at 1km spatial resolution. It can be aggregated at spatial levels ranging from 1km to small regions, countries, biomes, and the whole planet. The index uses land cover information available annually from Landsat and MODIS satellites since 2001 onwards. With continuation of these remote sensing products, this enables annual index updates, including reporting Aichi Target 11 achievements, for ten data points from 2011 to 2020.



Vejar's Fir
*Abies vejarii*

Habitat Associations ON OFF
Elevation ON OFF 1900 - 3400 meters
Tree cover: ON OFF 10 - 100%
Landcover ON OFF

Geographic distribution

| | | |
|---|---|---|
| Range size | 6,549 km² Suitable | 23,170 km² Total |
| Map improvement | 52 % [illegible] | 12 Validation points |

Maximum protected area coverage within suitable habitat.

| | Any size | Larger than 10 km² |
|---|---|---|
| Strict Parks | 1 | 1 |
| All parks | 10 | 7 |
| All parks area | 1,166 km² | 1,154 km² |
| Target area | 4,540.6 km² | |
| Target realized | 25.7% | |

Minimum reserve size:

Information supporting the SPI calculations for the Vejar’s Fir in Mexico. The 1 km pixels modeled as suitable for a species in a given year (see SHI) are overlaid with the protected areas existing in a region at that time. This informs to which degree the areal conservation target for that species is achieved. This information is then aggregated for all species occurring in an reporting region or country. This dashboard and underlying data are available online for all species included in the indicator (see http://species.mol.org/pa for examples).

## Methods

Indicators addressing Aichi Target 11 are typically constrained in their adequate geographic representation, the level of disaggregation they allow, their temporal resolution, and their scientific underpinning and transparency. The Species Protection Index is part of a new generation of indicators that utilize ongoing, spatially and temporally highly resolved remote sensing at near global-extent, together with biodiversity observations and adequate modeling frameworks, to help address these limitations.

The Species Protection Index builds on detailed, remote-sensing informed species distributions and their overlap with protected areas. These species maps are modeled using literature- and expert-based data on habitat restrictions and published land-cover products from MODIS and Landsat satellites available annually at 30m and 1km resolution and validated with field data on species locations from surveys and citizen science. Modifications in the area of individual species' overall distribution and the proportion under protection are quantified and updated annually based on changes in protected areas and available suitable habitat.

The index represents the aggregate of species-level metrics over any specified spatial unit such as countries or biomes. It can be calculated for different minimum sizes or categories of protected areas and be separated by biological group. A version of the index can also account for countries' stewardship of species (their portion of a species' global range, according to the best-available estimate).

All underlying data and metrics are available through a dedicated dashboard in the Map of Life web interface that has been developed with Google Earth Engine as technology partner. Currently, the Species Protection Index is addressing all protected areas of the World Database on Protected Areas and is calculated for >30,000 species of terrestrial vertebrates and invertebrates, and plant species, and validated with

> 350 million location records. This list is growing rapidly as more species and data are entering the database.

**Essential Biodiversity Variable:**
Species distributions

# Protected Area Representativeness & Connectedness (PARC) Indices

**The Protected Area Representativeness & Connectedness Indices use biologically-scaled environmental mapping and modelling globally to assess the extent to which terrestrial protected areas are ecologically representative and well connected.**

## Purpose of the indices

To provide a rigorous, yet cost-effective, approach to assessing global terrestrial protected-area representativeness and connectedness at an unprecedentedly fine spatial resolution. This is achieved by harnessing the power of recent advances in remote environmental mapping, biodiversity informatics, and macroecological modelling. The PARC Indices are designed specifically as indicators for measuring and reporting progress in relation to the Convention on Biological Diversity's Aichi Target 11.

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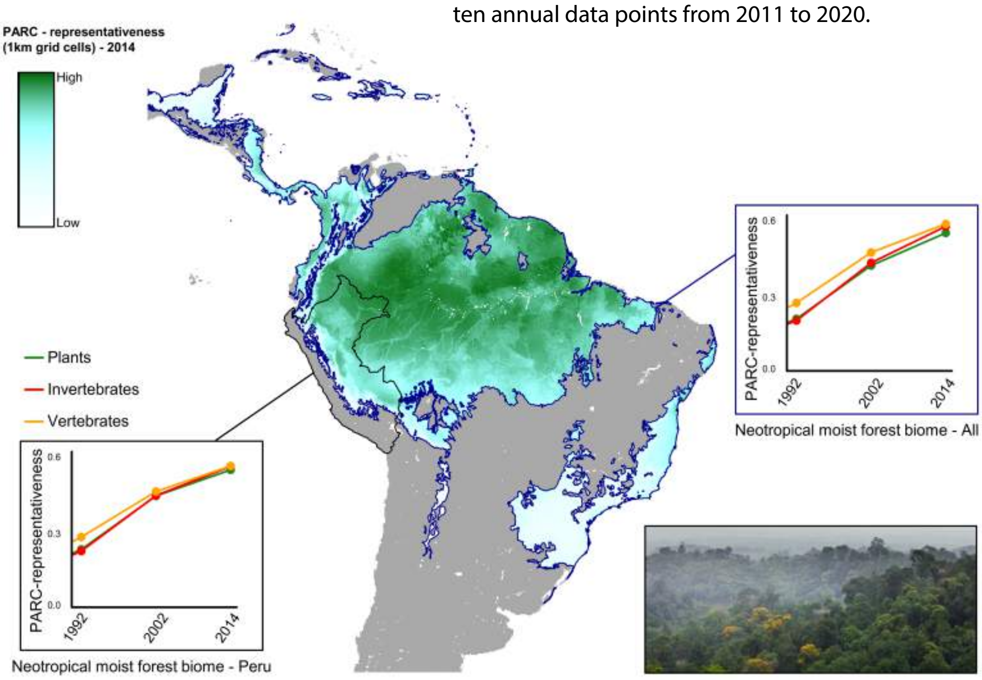
**CBD Aichi Target 11**
Protected Areas

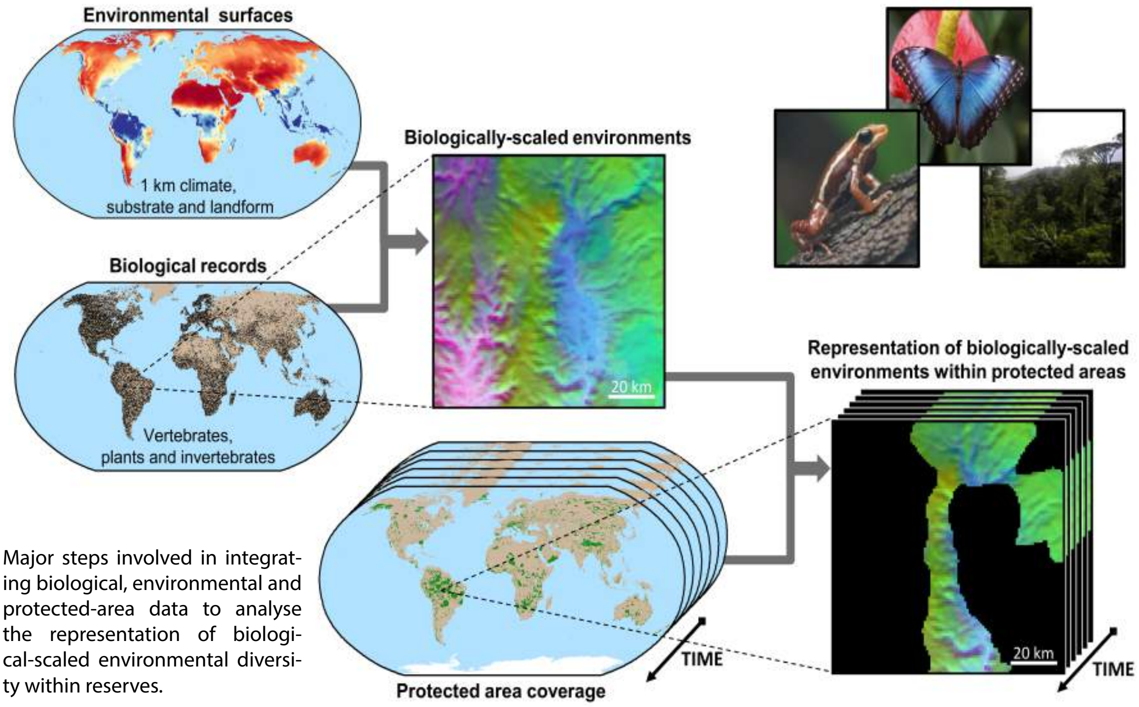
## Coverage

The approach uses data covering the entire terrestrial area of all countries of the world, at 1km grid resolution. This allows the PARC Indices to be calculated and reported at any desired level of spatial aggregation, ranging from individual 1km grid-cells up to whole ecoregions, countries, biomes and realms, or the entire planet.

The approach utilises the full temporal coverage of the World Database on Protected Areas (WDPA) and of NASA's (Friedl *et al* 2010, *Remote Sensing of Environment* 114: 168-182) MODIS Land Cover Change dataset (2001 onwards). The PARC Indices can therefore report changes in the representativeness and connectedness of protected areas annually, including reporting Aichi Target 11 achievement for ten annual data points from 2011 to 2020.



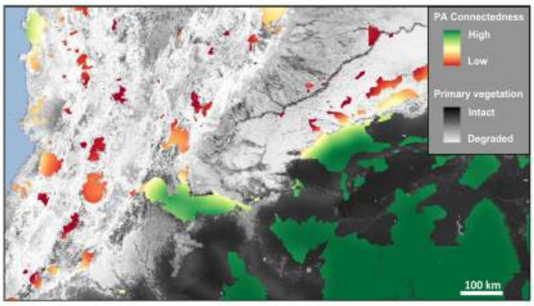
Reporting of the PARC index of representativeness (proportion of biologically-scaled environmental diversity included in protected areas) for an example combination of realm (Neotropics) and biome (moist tropical forest). The two charts depict changes in the index between 1992 and 2014, for the three major biological groups, aggregated across Peru alone, and across the entire biome, respectively. The map depicts values of the index for individual 1km grid cells across the biome, in a single year (2014), averaged across all three biological groups.



Major steps involved in integrating biological, environmental and protected-area data to analyse the representation of biological-scaled environmental diversity within reserves.

## Methods

The PARC Indices are underpinned by global modelling of fine-scaled spatial variation in biodiversity composition (beta diversity) derived by scaling environmental and geographical gradients using >300 million location records for >400,000 plant, invertebrate and vertebrate species. This modelling is then integrated with data on protected-area boundaries (from the WDPA) and land use in surrounding landscapes, derived by translating remotely-sensed land-cover change (NASA's MCD12Q1 dataset) into land-use change through statistical downscaling of coarse-scale land-use mapping to 1 km resolution.



PARC-connectedness - assessing how well protected areas are connected within the broader landscape

Separate indices can be calculated and reported for ecological representativeness (the proportion of biologically-scaled environmental diversity included in protected areas) and for connectedness (a relative index between 0 and 1), or these can be combined into a single composite measure of representativeness and connectedness of protected areas within any specified spatial unit (e.g. an ecoregion, a country, or an entire biome). Likewise, separate indices can be reported for the three major biological groups (plants, invertebrates and vertebrates) or these can be combined into a single measure across all groups.

**Essential Biodiversity Variable:**
Taxonomic diversity

# Species Status Information Index

**The Species Status Information Index (SSII) measures the adequacy of data on the distribution of single species and on the make-up of species assemblages in a location or region.**

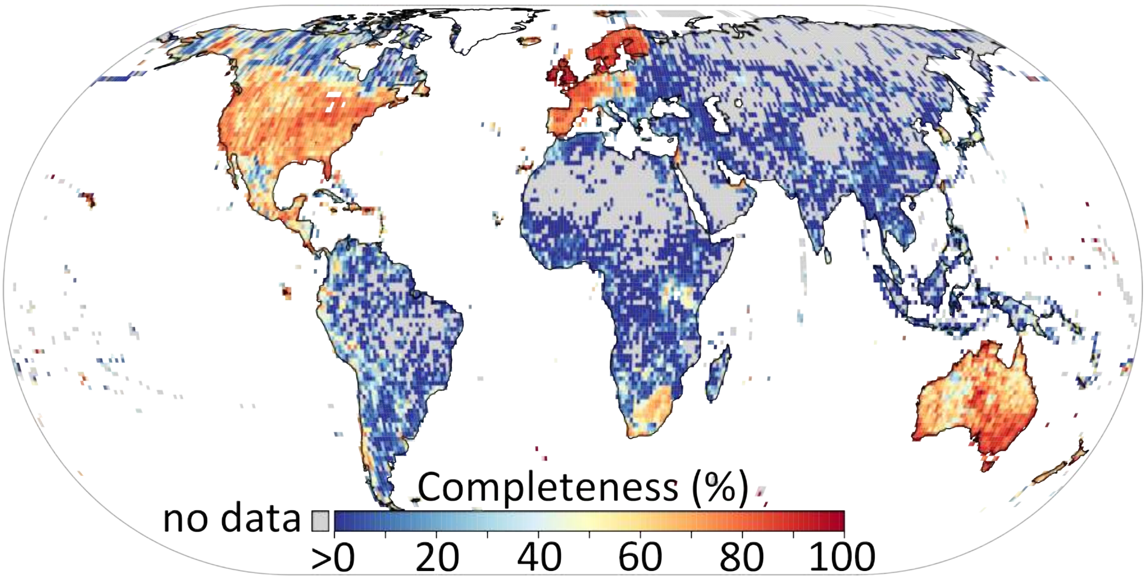
## Purpose of the index

To provide an annually updated metric of how growth in the amount and detail of digitally accessible information on species occurrences in space and time is addressing regional and global information gaps. The Species Status Information Index benefits from a large stack of species distribution data, a continuously updated informatics infrastructure, and interactive reporting tools. It is designed to measure and report progress in relation to CBD Aichi Target 19.

**CBD Aichi Target 19**
Sharing information and knowledge

## Coverage

The index uses species data addressing all terrestrial areas of the world from 100km down to, for some groups, 1km spatial resolution. It can be aggregated at spatial levels ranging from small regions, countries, biomes, to the whole planet. It will be updated continuously with latest mobilized records from GBIF and many other location data sources. This enables at least twice-annual formal index updates and a reporting on Aichi Target 19 achievements for twenty time points between 2011 and 2020.



**Completeness of distribution records**
Spatial variation in the adequacy of digital accessible point information (<150 M records)to represent the make-up of species assemblages (%). Based on information on the distribution and occurrence of 21,170 terrestrial vertebrate species and reported for 110 km grid cells. For details see Meyer, Kreft, Guralnick & Jetz, Nature Communications 2015 (online Sep 7).

## Methods

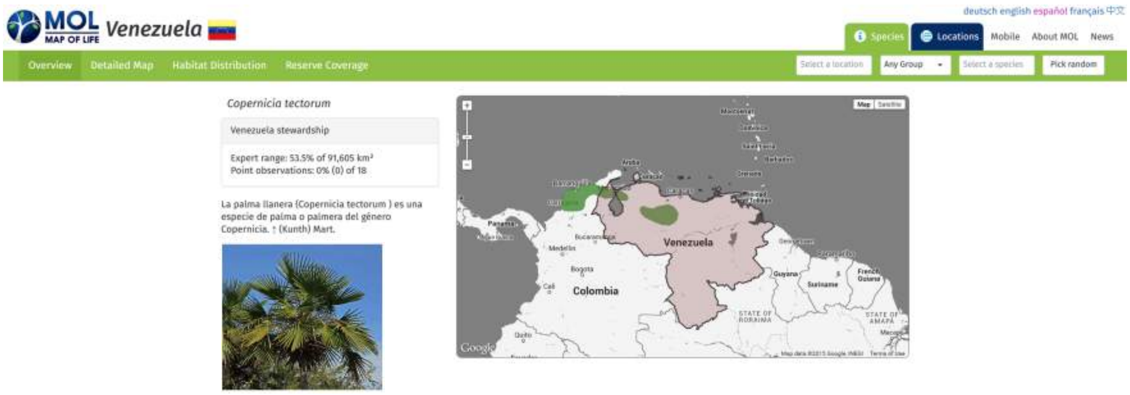
Indicators addressing Aichi Target 19 have limits in their ability to relate knowledge improvements and sharing to the knowledge needs. The data needs to adequately represent biodiversity status and trends increase with the number of species and the spatial extent of their populations. The Species Status Information Index combines data availability and data needs into a single metric that enables a standardized, transparent, and quantitative tracking of how well information gaps are getting filled.

The index builds on model- and expert-based information about the geographic distribution of species, available through Map of Life. It then assesses how well currently accessible digital point occurrence locations for each species are able to spatially represent and ultimately track this distribution over time. In doing this, the index draws on a variety of sources, including GBIF, and takes into account the varying spatial and temporal accuracy of species location records.

The index represents the aggregate of species-level metrics over any specified spatial unit such as countries or biomes. It can be calculated for different cut-offs of spatial or temporal detail and be reported separately by biological group. A version of the index can also account for countries' stewardship of species (the proportion of the range that, according to the best estimate, is restricted to them).

All underlying data and metrics are available through a dedicated dashboard in the Map of Life web interface (see example below). Currently, the Species Status Information Index is available for > 35,000 terrestrial species and validated with > 350 million location records. Extensions to increase species coverage and include freshwater and marine groups are underway.

**Essential Biodiversity Variables:**
Species distributions
Taxonomic diversity



*Copernicia tectorum*

Venezuela stewardship

Expert range: 53.5% of 91,605 km²
Point observations: 0% (0) of 18

La palma llanera (Copernicia tectorum ) es una especie de palma o palmera del género Copernicia. † (Kunth) Mart.

Screenshot of the online tool for country level reporting on species status information, soon available through Map of Life.

# Organisations involved

The Species Protection Index (SP), the Species Status Information Index (SSII) and the Species Habitat Index (SHIs) have been developed within a partnership of the Group on Earth Observations Biodiversity Observation Network (GEO BON) lead by Map of Life (Yale University with University of Florida) in collaboration with NASA, the National Science Foundation, the Global Biodiversity Information Facility (GBIF), and Google Earth Engine as well as many data contributing organizations.

For further information, contact Dr. Walter Jetz (walter.jetz@yale.edu).

The Biodiversity Habitat Index and the Protected Area Representativeness & Connectedness (PARC) Indices have been developed within a partnership of the Group on Earth Observations Biodiversity Observation Network (GEO BON) lead by Australia's national science agency (CSIRO) in collaboration with the Global Biodiversity Information Facility (GBIF), Map of Life (Yale University with University of Florida) and the PREDICTS project (Natural History Museum et al).

For further information, contact Dr. Simon Ferrier (simon.ferrier@csiro.au).

# GEO BON Contact

***Dr. Jörg Freyhof***
Executive Director

German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig
Deutscher Platz 5a
04103 Leipzig
GERMANY

Phone | +49 341 9733141
Email | info@geobon.org
Web | www.geobon.org

***Dr. Miguel Fernandez***
Strategy for the Development of Essential Biodiversity Variables

German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig
Deutscher Platz 5a
04103 Leipzig
GERMANY

Phone | +49 341 9733188
Email | miguel.fernandez@idiv.de
Web | www.geobon.org

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