Université de Sherbrooke
Chaire de recherche du Canada en
Écologie intégrative August 24th, 2022

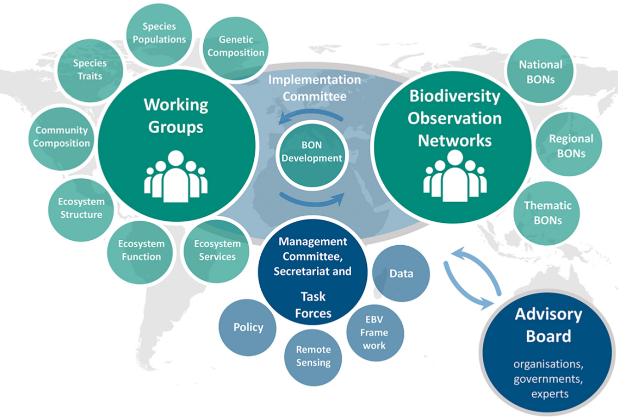
Day 3: Essential Biodiversity Variables

Dominique Gravel

Identify three variables you would collect to monitor biodiversity changes

Improve the acquisition, coordination and delivery of biodiversity observations and related services to users including decision makers and the scientific community

GEO BON structure



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GEO BON structure

Thematic BONs:

FWBON
Freshwater Biodiversity Observation Network

MBON
Marine Biodiversity Observation Network

Soil BON

MIC BON

Regional BONs:

EUROPABON

National BONs:


China


Colombia


France

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Essential Biodiversity Variables

A global system of harmonized observations is needed to inform scientists and policy-makers.

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Reducing the rate of biodiversity loss and averting dangerous biodiversity change are international goals, reasserted by the Aichi Targets for 2020 by

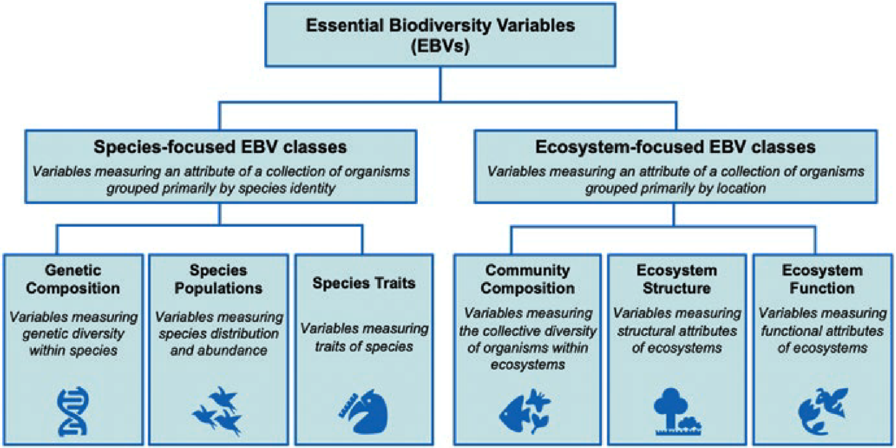
Change (UNFCCC) (*8*). EBVs, whose development by GEO BON has been endorsed by the CBD (Decision XI/3), are relevant to derivation of biodiversity indicators for the Aichi

potentially fit this definition. We developed and tested a process, still ongoing, to identify the most essential (*11*). Dozens of biodiversity variables were screened to identify those

Definition

A measurement required for study, reporting, and management of biodiversity change

EBV classes

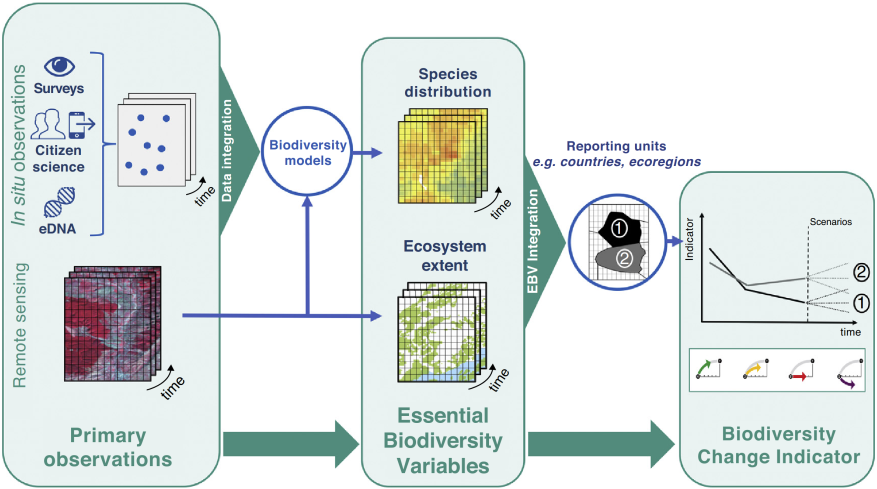


Essential Biodiversity Variables (EBVs)
Species-focused EBV classes
Variables measuring an attribute of a collection of organisms grouped primarily by species identity
Ecosystem-focused EBV classes
Variables measuring an attribute of a collection of organisms grouped primarily by location
Genetic Composition
Variables measuring genetic diversity within species
Species Populations
Variables measuring species distribution and abundance
Species Traits
Variables measuring traits of species
Community Composition
Variables measuring the collective diversity of organisms within ecosystems
Ecosystem Structure
Variables measuring structural attributes of ecosystems
Ecosystem Function
Variables measuring functional attributes of ecosystems

EBV classes

EXAMPLES OF CANDIDATE ESSENTIAL BIODIVERSITY VARIABLES					
EBV class	**EBV examples**	**Measurement and scalability**	**Temporal sensitivity**	**Feasibility**	**Relevance for CBD targets and indicators (*1,9*)**
Genetic composition	Allelic diversity	Genotypes of selected species (e.g., endangered, domesticated) at representative locations.	Generation time	Data available for many species and for several locations, but little global systematic sampling.	Targets: 12, 13. Indicators: Trends in genetic diversity of selected species and of domesticated animals and cultivated plants; RLI.
Species populations	Abundances and distributions	Counts or presence surveys for groups of species easy to monitor or important for ES, over an extensive network of sites, complemented with incidental data.	1 to >10 years	Standardized counts under way for some taxa but geographically restricted. Presence data collected for more taxa. Ongoing data integration efforts (Global Biodiversity Information Facility, Map of Life).	Targets: 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15. Indicators: LPI; WBI; RLI; population and extinction risk trends of target species, forest specialists in forests under restoration, and species that provide ES; trends in invasive alien species; trends in climatic impacts on populations.
Species traits	Phenology	Timing of leaf coloration by RS, with in situ validation.	1 year	Several ongoing initiatives (Phenological Eyes Network, PhenoCam, etc.)	Targets: 10, 15. Indicators: Trends in extent and rate of shifts of boundaries of vulnerable ecosystems.
Community composition	Taxonomic diversity	Consistent multitaxa surveys and metagenomics at select locations.	5 to >10 years	Ongoing at intensive monitoring sites (opportunities for expansion). Metagenomics and hyperspectral RS emerging.	Targets: 8, 10, 14. Indicators: Trends in condition and vulnerability of ecosystems; trends in climatic impacts on community composition.
Ecosystem structure	Habitat structure	RS of cover (or biomass) by height (or depth) globally or regionally.	1 to 5 years	Global terrestrial maps available with RS (e.g., Light Detection and Ranging). Marine and freshwater habitats mapped by combining RS and in situ data.	Targets: 5, 11, 14, 15. Indicators: Extent of forest and forest types; mangrove extent; seagrass extent; extent of habitats that provide carbon storage.
Ecosystem function	Nutrient retention	Nutrient output/input ratios measured at select locations. Combine with RS to model regionally.	1 year	Intensive monitoring sites exist for N saturation in acid-deposition areas and P retention in affected rivers.	Targets: 5, 8, 14. Indicators: Trends in delivery of multiple ES; trends in condition and vulnerability of ecosystems.

EBV process



In situ observations
Surveys
Citizen science
eDNA
time
Remote sensing
time
Primary observations
Data integration
Biodiversity models
Species distribution
time
Ecosystem extent
time
Essential Biodiversity Variables
EBV Integration
Reporting units
e.g. countries, ecoregions
1
2
Indicator
Scenarios
2
1
time
Biodiversity Change Indicator

BIOLOGICAL REVIEWS
Cambridge Philosophical Society
Biol. Rev. (2018), **93**, pp. 600–625.
doi: 10.1111/brv.12359

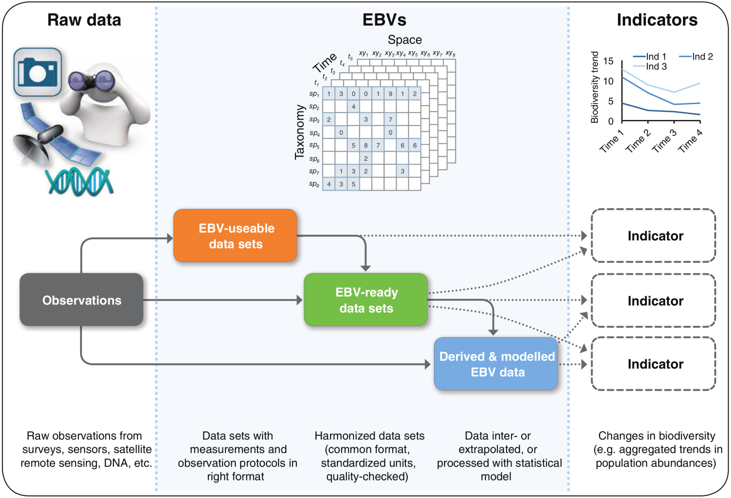
Building essential biodiversity variables (EBVs) of species distribution and abundance at a global scale

W. Daniel Kissling[1,*], Jorge A. Ahumada[2], Anne Bowser[3], Miguel Fernandez[4,5,6], Néstor Fernández[4,7], Enrique Alonso García[8], Robert P. Guralnick[9], Nick J. B. Isaac[10], Steve Kelling[11], Wouter Los[1], Louise McRae[12], Jean-Baptiste Mihoub[13,14], Matthias Obst[15,16], Monica Santamaria[17], Andrew K. Skidmore[18], Kristen J. Williams[19], Donat Agosti[20], Daniel Amariles[21,22], Christos Arvanitidis[23], Lucy Bastin[24,25], Francesca De Leo[17], Willi Egloff[20], Jane Elith[26], Donald Hobern[27], David Martin[19], Henrique M. Pereira[4,5], Graziano Pesole[17,28], Johannes Peterseil[29], Hannu Saarenmaa[30], Dmitry Schigel[27], Dirk S. Schmeller[13,31], Nicola Segata[32], Eren Turak[33,34], Paul F. Uhlir[35], Brian Wee[36] and Alex R. Hardisty[37]

The EBV 'species distribution' can be defined as the presence or absence of species, based on observations with specified spatial and temporal dimensions.

In most cases, the species distribution EBV is therefore represented through a binary variable that reflects presence–absence of a species across its geographic range.

EBV Distribution



From raw data to the cube

- Geostatistics for interpolation
- Species distribution modelling
- Data imputation
- Machine learning (e.g. deep neural networks)

	EBV attributes			
Dimension	Extent	Resolution	Measurement units	Uncertainties
Space	Geographical coverage (e.g. of grid cells, sampling locations, satellites, etc.)	Spatial resolution (e.g. grid cell size, polygons, resolution of satellite sensors, volume, etc.)	Meters, cubic meters, kilometers, degrees, etc.	Precision and accuracy of coordinates and volumes, wrongly recorded coordinates, imprecise sampling locations
Time	Temporal coverage (e.g. length of time series, continuous recording, time period of collection of records, etc.)	Temporal grain (e.g. date or time window of sampling, sampling frequency)	Hours, days, weeks, months, years, decades, etc.	Variation in length of time series, precision of time of collection, etc.
Taxonomy	Taxonomic coverage (e.g. how many and which species are documented)	Species, genus, higher taxonomic level, etc.	Taxonomic entity for which species distribution and abundance data are sampled	Identification and observation uncertainty, ambiguous scientific names, synonyms, differences in taxon concepts, etc.

Type of data	Examples	Advantages	Disadvantages
Species distribution data			
Opportunistic incidence records	Presence-only data from museum or herbarium collections	Vast amounts of data available, easily aggregated across infrastructures, common minimum data set	Mostly opportunistically collected, often without details of survey effort or method, usually no true absences, hard to estimate detection probabilities, wide variation in data quality
Presence–absence data	Checklists, atlas or camera-trap data	More information content (absences) than opportunistic incidence records	Measuring absences is time consuming and depends on species and habitats
Repeated surveys	Monitoring schemes, repeated atlas projects	Standardized protocols for sampling, occurrences from multiple points in time	Often restricted geographically to Europe and North America, temporal extent varies among surveys
Abundance data			
Opportunistic population counts	Large-scale citizen science projects, eBird, aerial surveys of wide-ranging or aggregating fauna, some vegetation surveys	Massive amount of data	Not sampled repeatedly at fixed sites, sometimes sampled without standardized protocols
Population time series	Soay sheep on St. Kilda, capture histories, North American Breeding Bird Survey, UK Butterfly Monitoring Scheme, LTER Network, TEAM	Repeated population surveys with standardized protocols at fixed sites over multiple years	Available for few species, spatial and temporal resolution depends on organism size and life history, geographic bias towards Europe and North America, variation in sampling protocols or their applicability, some methods are resource-intensive

Characteristics	eBird	TEAM	LPI	BALTIC
Spatial extent	Global (predominately Western Hemisphere)	Tropical forests worldwide	Global	Baltic Sea
Spatial resolution	Three million local sites, model resolution is 3 km^2	23 tropical forest sites (120–200 km^2 resolution)	5598 sites with varying resolution, not stratified	26 marine stations in the Baltic Sea
Temporal extent	2000–present	2007–present	1970–present	2006–present
Temporal resolution	Hourly and daily, weekly after modelling	7-day time periods, annual after modelling	Varies among locations	Monthly
Taxonomic extent	Birds	Ground-dwelling mammals and birds	Vertebrates	Zooplankton
Taxonomic resolution	Species	Species	Species	Species
Measure of species distribution or abundance	Checklists (counts of individuals of a species during a search)	Presence/absence derived from camera-trap records	Population size, density, catch per unit effort, or abundance indices	Number of individuals per m^3
Statistical model or data analysis	Spatiotemporal exploratory model (STEM)	Bayesian dynamic occupancy model	Generalized Additive Model (GAM)	Summary statistics
Data after modelling or analysis	Predicted relative abundance, trends, habitat use	Geometric mean of relative occupancies	Geometric mean of average change in abundance or average annual rates of changes	Mean abundance
Key references	Fink *et al.* (2010); Kelling *et al.* (2015); Sullivan *et al.* (2014)	Ahumada *et al.* (2013); Beaudrot *et al.* (2016); Jansen *et al.* (2014)	Collen *et al.* (2009); Loh *et al.* (2005)	http://sharkdata.se/; Appendix S1

ILLUSTRATION : LIVING PLANET INDEX PIPELINE

Original method published in :

Loh J, Green RE, Ricketts T, Lamoreux J, Jenkins M, et al. (2005) The Living Planet Index: using species population time series to track trends in biodiversity. Phil. Trans. Roy. Soc. B 360: 289–295


WWF
CANADA
LIVING PLANET
REPORT CANADA
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Science

Half of Canada's wildlife species are in decline, WWF finds

Endangered species continue declining despite federal protection

Emily Chung · CBC News · Posted: Sep 13, 2017 9:00 PM ET | Last Updated: September 14, 2017

Woodland caribou was listed under the Species at Risk Act as threatened in 2003, but its 'recovery strategy' wasn't released until 2012. (Mike Bedell/CPAWS/Canadian Press)

By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

Living Planet Database

- Data from scientific and grey literature
- 27 963 populations, 4 911 species
- Focus on vertebrates
- Taxonomic, geographic and many other biases
- Abundances transformed in unitless quantities

Computing the LPI Step 1

Smooth time series with a GAM to remove error measurement and environmental stochasticity

Portrait de la population (788)

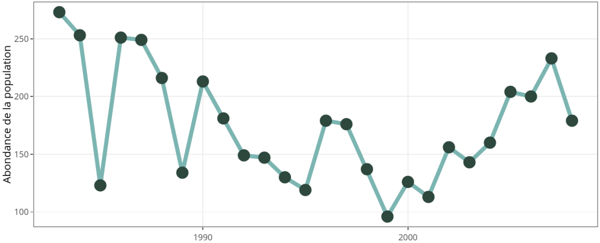
Rangifer tarandus

Mammifères

-0.7%
Stable

26
ans suivis

Suivi de la population (Rangifer tarandus)



Source des données: WWF/ZSL (License: CC BY 4.0)

Unités d'abondance (de la source originale): Number of individuals

Chaque point est une mesure de l'abondance de la population à un point dans le temps. L'Indice Planète Vivante se base sur le taux de changement entre ces points pour estimer une tendance moyenne des changements d'abondance de plusieurs populations.

Compute annual growth rate for each population i

$$d_{i,t} = log_{10}\left(\frac{N_{i,t}}{N_{i,t-1}}\right)$$

Average annual growth rate across all populations

$$\overline{d}_t = \frac{1}{n_t} \sum_{i=1}^{n} d_{i,t}$$

Convert the average index into an index of relative abundance

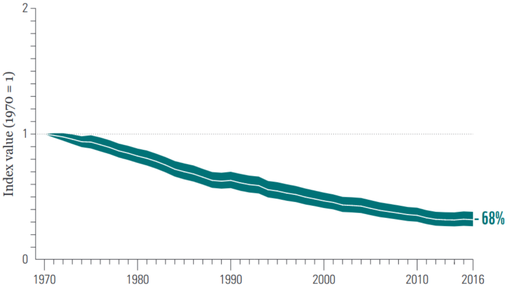
$$I_t = I_{t-1} 10^{\overline{d}_t}$$

Figure 1: The global Living Planet Index: 1970 to 2016
Average abundance of 20,811 populations representing 4,392 species monitored across the globe declined by 68%. The white line shows the index values and the shaded areas represent the statistical certainty surrounding the trend (range: -73% to -62%). Source - WWF/ZSL (2020)[107].

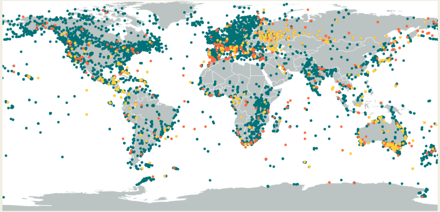
Key

Global Living Planet Index

Confidence limits



The LPI explained



How to read the Living Planet Index

- In 2020, the LPI shows an average rate of decline in population size of 68% between 1970 and 2016.
- The LPI now tracks the abundance of almost 21,000 populations of mammals, birds, fish, reptiles and amphibians around the world.
- The LPI includes data for threatened and non-threatened species – if it's monitored consistently over time, it goes in!
- Species and populations in the LPI are increasing, declining or stable.
- About half of the species in the LPI show an average decline in population size.

Figure 2: Locations of Living Planet Index species populations
Locations of Living Planet Index species populations. Map showing the locations of the monitored populations in the LPI. Newly added populations since the last report are highlighted in orange or in yellow for species new to the LPI. Source: WWF/ZSL (2020)[107].

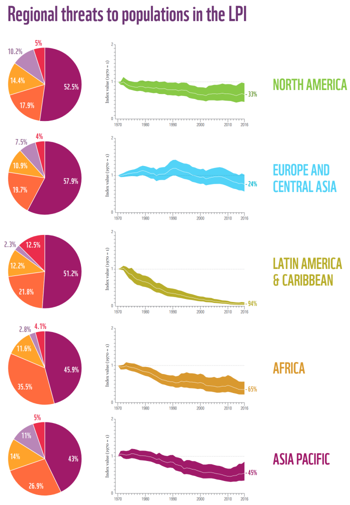
Key

- New species
- New populations
- Existing data

2020 Living Planet Report

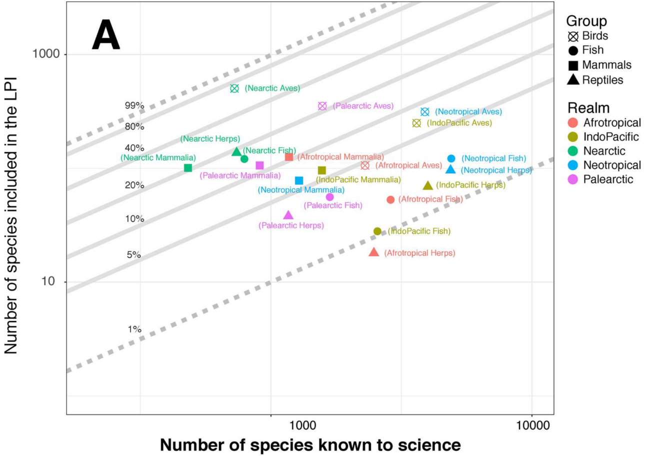
Caveats for interpretation

- The LPI does not account for extinct populations
- A decline in LPI of $X\%$ does not imply that all populations decline by $X\%$
- Neither that $X\%$ populations have been lost



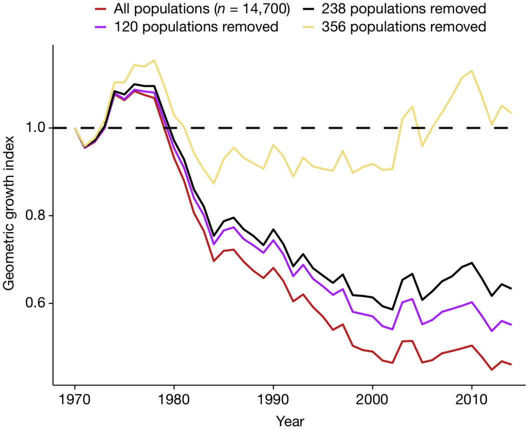
LPI Dashboard for Québec

Technical issues with the LPI Representativity



McRae et al. 2017. PLoS One

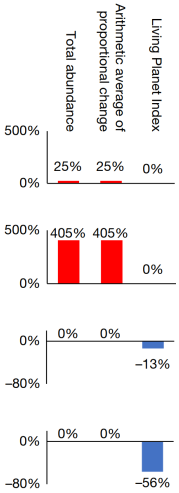
Technical issues with the LPI   Sensitivity to extremes



Leung et al. 2020. Science

Removal of 2.4% most extreme declines (often the shortest time series) shifted the global LPI to positive tend !

		N_{t-1}	N_t	N_t/N_{t-1}	d_t	LPI
a	Pop. A	100	200	2	0.30	
	Pop. B	100	50	0.5	−0.30	
	Average	100	125	1.25	0	1
	Change	+25%		+25%		0%
b	Pop. A	100	1,000	10	1	
	Pop. B	100	10	0.1	−1	
	Average	100	505	5.05	0	1
	Change	+405%		+405%		0%
c	Pop. A	100	150	1.5	0.18	
	Pop. B	100	50	0.5	−0.30	
	Average	100	100	1	−0.06	0.87
	Change	0%		0%		−13%
d	Pop. A	100	190	1.9	0.28	
	Pop. B	100	10	0.1	−1	
	Average	100	100	1	−0.36	0.44
	Change	0%		0%		−56%



Puurtinen et al. 2021. Science

The principle of Jensen's inequality states that the average of a nonlinear function is different from the function of the average, the difference being dependent on the shape of the function near the average.

It is nonetheless possible to approximate the bias using Taylor expansion and get closer to the real expectation and variance.

The expected growth rate can be approximated as :

$$E[d_{i,t}] = log_{10}\left(\frac{N_{i,t}}{N_{i,t-1}}\right) + \frac{\sigma^2_{N_i}}{2(N^2_{it-1} - N^2_{it})} \tag{1}$$

Measurement and process error can propagate up to affect the LPI. The expected index, accounting for various forms of uncertainty, can be approximated as :

$$E[I_t] = I_{t-1} 10^{\overline{d}_t} + \frac{1}{2} 10^{\overline{d}_t} V[d_t] \tag{2}$$

Where the variance in the average trend is :

$$V[d_t] = \frac{1}{n_t} \left[\sum_{i=1}^{n_t} \sigma_{d_{it}}^2 + 2 \sum_{i=1}^{n_t} \sum_{j<1}^{n_t} COV(d_{it}, d_{jt}) \right] \tag{3}$$

Expanding the LPI

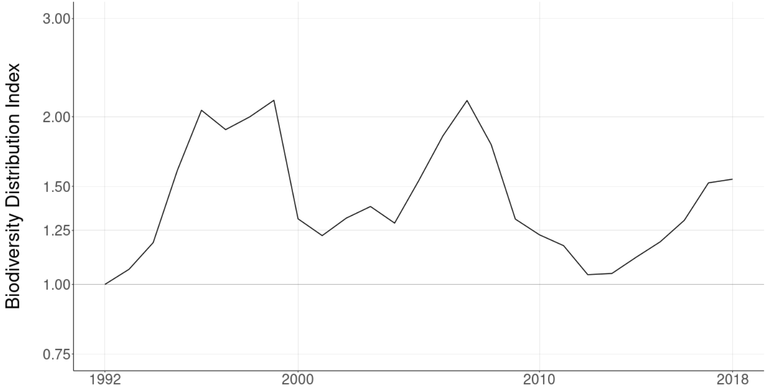
Replacing **population size** by **range size** in the computation of the LPI, we can derive an index tracking changes in the distribution of biodiversity over a certain region.

Range shift dashboard

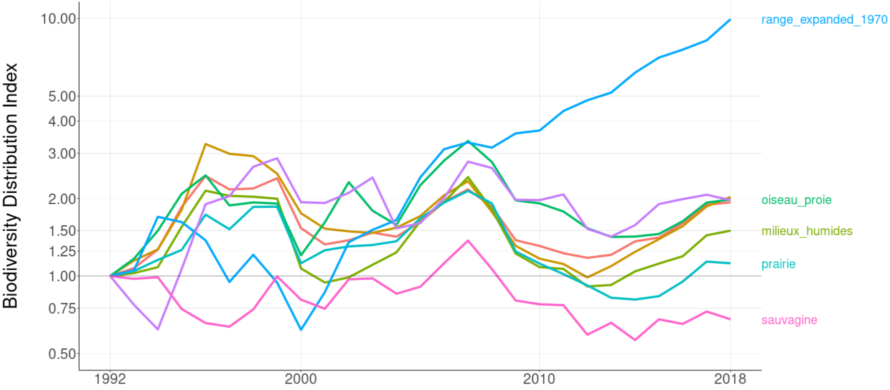
Steps

1. Extract presence-absence sheets from eBird
2. Run spatial interpolation model for 5 years windows
3. Extract range size (km^2) per window for each species per time step
4. Compute trend for each species per time step
5. Aggregate the index across species
6. Compute the BDI

Biodiversity Distribution Index



Biodiversity Distribution Index



What makes a good indicator ?

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Science

Half of Canada's wildlife species are in decline, WWF finds

Endangered species continue declining despite federal protection

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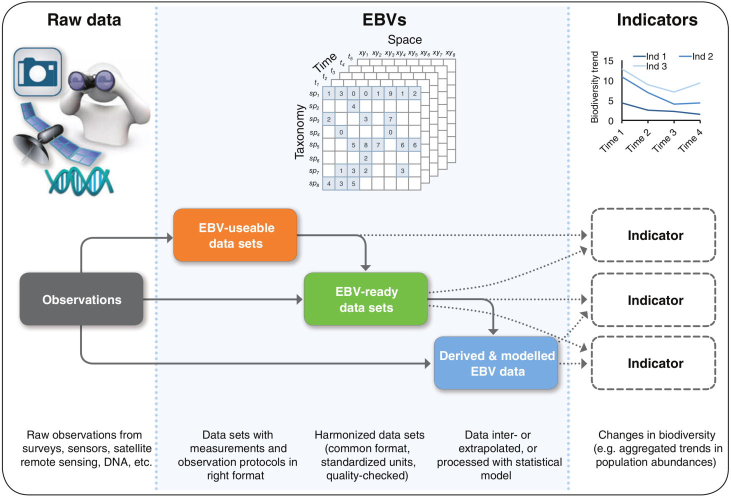
Deliverable for day 3



Deliverable for day 3

- Identify original data source(s)
- Schematize the data model
- Any constraints on data availability ? Sharing ?
- Precisely define the data product
- Are there any transformation to perform ? Data aggregation ?
- Do you need to perform statistics ? Modelling ?
- What indicator(s) do you want to report ?
- How to deal with uncertainty ?