MS33. List of indicators and data sets to be used in the case study IV – Stakeholder-driven case study:

Optimising top-down and bottom-up assessment and reporting of the Habitats Directive in Europe

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Authors: Ana Luísa Machado, Lina Estupinan Suarez, Heliana Teixeira

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1. Introduction

Work Package 6 – Use Cases aims to validate the relevance, usability, and impact of B3 developments through a series of representative case studies. Each use case contributes to assessing:
a) the capacity of B3 newly developed and broadly used indicators, to capture key aspects of biodiversity relevant to the specific context;
b) the ability of B3 workflows to deliver tailored outputs aligned with the spatial, temporal, and thematic requirements of stakeholders;
c) effective strategies for communicating outputs in a policy-relevant and user-friendly manner.

This milestone presents the initial list of datasets and indicators identified for Case Study IV – the stakeholder-driven case study: **Optimising top-down and bottom-up assessment and reporting of the Habitats Directive in Europe**. These datasets will be used to support the evaluation of B3 components in alignment with the objectives of WP6. The goal is to assess the performance of B3 tools and workflows in optimizing both top-down, i.e., from the EU Commission and the EEA, and bottom-up, i.e., from the Member States, assessments and reporting under the EU Habitats Directive. In this context, the case study specifically aims to:

- Enhance the reproducibility and consistency of biodiversity data reported by Member States, with a particular focus on species-level assessments, thereby enabling more automated and reliable bottom-up reporting to the European Environment Agency.
- Support large-scale assessments of species conservation trends and the integration of national-level reports within relevant biogeographical regions, thereby strengthening the top-down evaluation of compliance and consistency.

List of abbreviations

GBIF	Global Biodiversity Information Facility
EEA	European Environmental Agency
EU	European Union
MS	Member States

2. Data sets

This case study will use the datasets on species occurrences from species-level assessments reported within the scope of the Habitats Directive[1] by MS, as well as the EEA harmonised dataset at the EU level. Those datasets are publicly available through the EEA data repository[2]. Additionally, to complement the reported data, GBIF data for the same selected species will be used[3]. These data will be downloaded from GBIF as species occurrence cubes[4,5]. All data on the GBIF platform is also openly available.

2.1.Taxonomic groups

Since this case study focuses on the Habitats Directive, the taxonomic scope will be defined by the species listed in the Directive's annexes. To ensure complementarity with other B3 case studies, which already address plant species, the present work focuses exclusively on animal taxa. Given the high number of animal species included in the annexes, the analysis will pay special attention to those designated as *priority species* under the Habitats Directive, as they represent a subset of particular conservation concern and policy relevance. In the case of *priority species* additionally indicated as *sensitive* by MS data will not be used. Their distribution is not publicly disclosed by the EEA and the MS, since that information may be detrimental to their conservation.

2.2. Spatial scale

The Case Study IV will be conducted at the European level, covering the area of countries obligated to report under the Habitats Directive.
Data will be analysed using the EEA reference grid at a 10x10Km resolution. The complementary data extracted from GBIF are exported as species occurrence cubes at this 10x10Km resolution. The information reported by MS and EEA are georreferenced multipolygon data at national and biogeographical region levels, therefore they were transformed to the 10x10Km grid prior integration with GBIF data for analysis.

2.3. Temporal scale

Temporal scale will correspond to Habitats Directive Article 17 reporting periods, conducted every six years. The evaluation of temporal trends will be carried out over the three cycles reported so far: 2001-2006, 2007-2012 and 2013-2018.

3. Indicators to be used

Several indicators will be used in this case study, which can be found in the tools developed within the scope of B3 project, namely:
- General biodiversity indicators (available on b3gbi R package[6])
- Phylogenetic indicators (available on pdindicatoR R package[7])
- Robustness and uncertainty metrics (available on the dubicube R package[8])
- Compositional dissimilarity (available dissmapR R package[9])
- Species Distribution Modelling (see Suitability cube[10] and Deep Learning[11] developments in B3)

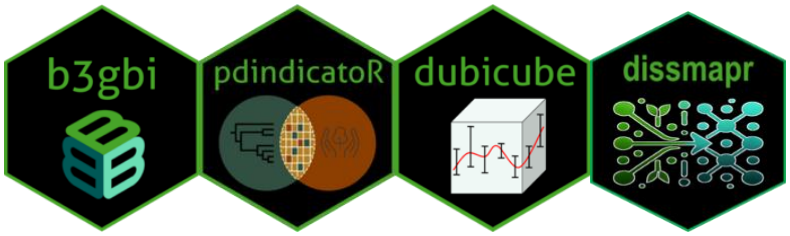

Figure 1. Examples of B3 developed R packages to support the calculation of new and existing biodiversity indicators, that will be tested in case study IV

3.1. Bottom-up approach

3.1.1. General indicators

The bottom-up approach will be based on species-level assessments reported by MS. Using the R package **b3gbi**[6]– General Biodiversity Indicators for Biodiversity Data Cubes, general indicators suitable for single species datasets will be applied, namely:

- Species Occurrences
- Species Range

In addition to reported data, occurrence records from GBIF will also be considered, in order to assess the extent to which this dataset can complement or improve MS reporting.
To complement these analyses, the **dubicube**[8] package will be employed to assess the robustness of the multi-source input data, providing measures of data quality and uncertainty that enhance the interpretation of the resulting indicators.

3.1.2. Species Distribution Modelling

For this case study, Species Distribution Models (SDMs) will be applied to link species occurrence data with environmental variables and generate suitability maps. The approach builds on the **Suitability Cube**[10] framework developed in the B3 project, which organizes suitability values in a structured data cube across space, time, and species. This provides a flexible and robust framework for integrating multiple data sources, handling uncertainty, and evaluating species distributions across past, present, and future scenarios, supporting both methodological testing and conservation planning.
In addition, **deep learning methods**, particularly DeepMaxent, will also be applied to enhance SDMs. DeepMaxent extends the MaxEnt framework into a neural network, enabling simultaneous multi-species modeling and handling of large, complex datasets[11]. Strategies to correct for spatial sampling bias, including modeling sampling effort and the Target Group Background method, will be incorporated.

3.2.Top-down approach

3.2.1. General biodiversity indicators

For the top-down approach, the EEA datasets (i.e., based on MS aggregated data) will be used to calculate general indicators with the R package **b3gbi**. The analysis will focus on assessing temporal trends by comparing the three reporting cycles, as well as spatial trends within the

biogeographical regions of interest. To ensure robustness, the **dubicube** package will be applied to evaluate data quality and quantify the uncertainty associated with the derived indicators for species-level assessments:

- Species Occurences
- Species Range

For certain groups of species - either with special conservation interest or with reported knowledge gaps, multi-species indicators may be applied to determine temporal and spatial trends, for instance:

- Observed Species Richness
- Total Occurrences
- Pielou's Evenness
- Williams' Evenness
- Species Richness (Estimated by Coverage-Based Rarefaction)
- Hill-Shannon Diversity (Estimated by Coverage-Based Rarefaction)
- Occupancy Turnover

3.2.2. Phylogenetic indicators

In this case study, we will also apply phylogenetic diversity indicators, implemented in the package **pdindicatoR**[7], to assess the evolutionary diversity among selected groups of species across the EU. These indicators are particularly useful for taxonomically complex groups, such as amphibians and migratory fish, which often have small and/or isolated populations, making genetic and phylogenetic metrics essential to detect evolutionary lineages and patterns of connectivity. By combining occurrence data reported under the Habitats Directive and GBIF occurrence cubes, we will calculate metrics such as Faith's Phylogenetic Diversity and evaluate the phylogenetic diversity within Natura 2000 network, including Special Areas of Conservation (SAC) and Sites of Community Importance (SCI), which were established under the Habitats Directive to ensure the conservation of threatened species and habitats. Using these indicators can allow for the identification of genetic diversity hotspots, the detection of potential gaps in species connectivity, and contribute to the assessment of the effectiveness of the Natura 2000 network in species conservation at a European scale.

3.2.3. Dissimilarity Cubes

In addition to other diversity metrics, we will use **dissimilarity cubes**[9] to assess and map compositional differences and species turnover across the study area. These cubes compile co-occurrence matrices for species within specified geographic regions and integrate georeferenced environmental data. Using workflows such as **MS-GDM** and **zetadiv**, we will map spatial patterns of community dissimilarity, highlighting areas with unique species compositions. This approach can be particularly valuable in providing patterns of compositional turnover across regions.

4. Policy questions

The B3 case study *"Optimising top-down and bottom-up assessment and reporting of the Habitats Directive in Europe"* directly addresses one of the main weaknesses highlighted in the *State of Nature in the EU (2013–2018)* report[12]: the lack of consistent, timely, and comparable

data across MS. By integrating GBIF data and national biodiversity reports (bottom-up) with large-scale EU trend assessments carried out by the EEA (top-down), B3 developments can improve interoperability and consistency between these two levels, while reducing data gaps and ensuring that national assessments feed more effectively into robust EU-wide evaluations of species and habitat conservation status.
For policy purposes, the use of B3 tools and workflows can strengthen reporting under the Habitats Directive by producing a more harmonised and reliable evidence base for decision-making. This contributes not only to streamlining the reporting process for MS, but also to improving the quality of pan-European analyses, making them more robust for tracking progress towards the EU Biodiversity Strategy 2030[13] and the Nature Restoration Regulation[14]. Crucially, by ensuring more timely, cohesive, and comparable reporting, the case study reinforces European policy, while aligning nature reporting with broader EU priorities such as the Green Deal[15] and global biodiversity targets.

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