POLICY BRIEF

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Streamlining Habitats Directive Reporting with Open Biodiversity Data: Evidence for the Nature Directives Stress Test

Heliana Teixeira (ORCID 0000-0001-8525-9967)[1]
Ana L. Machado (ORCID 0000-0002-5213-6001)[1]
Rocío B. Cortes Lobos (ORCID 0009-0004-8440-958X)[2],
Quentin Groom (ORCID 0000-0002-0596-5376)[3]
Lina M. Estupinan-Suarez (ORCID 0000-0002-2359-9496)[4]
Maxime Coupremanne (ORCID 0000-0002-9052-9500)[5]
Cristina Preda (ORCID 0000-0002-3513-7344)[6]

[1] CESAM – Centre for Environmental and Marine Studies and Department of Biology, University of Aveiro, Aveiro, Portugal
[2] BIOME Lab, BiGeA Department, Alma Mater Studiorum – University of Bologna, Italy
[3] Bio-Informed, Meise Botanic Garden, Nieuwelaan 38, 1860 Meise, Belgium
[4] iDiv – German Centre for Integrative Biodiversity Research Halle-Jena-Leipzig, Leipzig, Germany
[5] RBINS – Royal Belgian Institute of Natural Sciences, Belgian Biodiversity Platform, Brussels, Belgium
[6] Research Center of the Department of Natural Sciences, Faculty of Natural and Agricultural Sciences, Ovidius University of Constanta, Constanta, Romania

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1. Policy challenge

Biodiversity monitoring under Article 17 of the **EU Habitats Directive (Council Directive 92/43/EEC)** remains inconsistent across European Member States. Although all Member States follow the same reporting framework, national assessments are based on national monitoring programmes that vary considerably in spatial coverage, methodology and taxonomic scope, making consistent assessments across the EU more challenging (Röschel et al., 2020).

At the same time, the Global Biodiversity Information Facility (GBIF) aggregates millions of species occurrence records from monitoring programmes, citizen science initiatives, research projects and museum collections. Despite representing a valuable source of complementary biodiversity information, these data remain largely untapped in formal Article 17 reporting workflows.

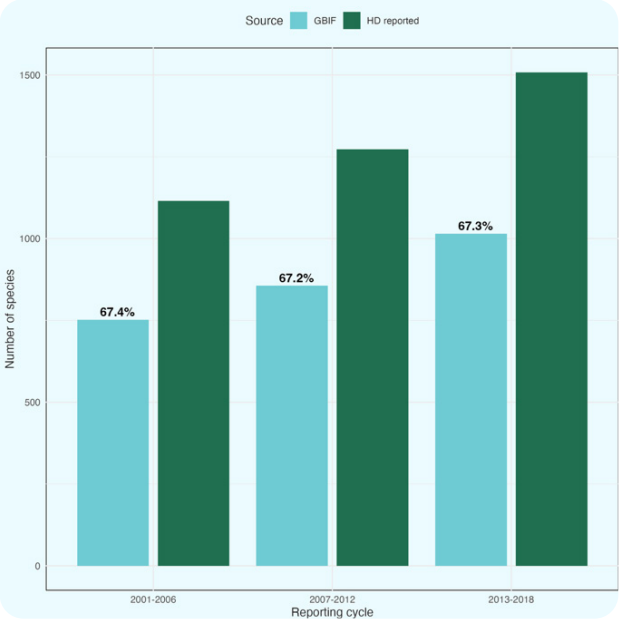
The EU Biodiversity Strategy for 2030 highlights the need for improved biodiversity knowledge and better use of data to support evidence-based decision-making. Also, the Nature Directives are currently undergoing a Commission "*Stress Test*" and are the subject of a proposed Regulation on faster environmental assessments, both seeking to simplify, digitalise, and reduce administrative burden while safeguarding EU competitiveness and environmental goals, with digitalisation and better data access flagged as key to more efficient, transparent permitting and reporting.

Against this backdrop and given that many European species and habitats remain in unfavourable conservation status, and that existing knowledge gaps and underfunding partly contribute to continue missing conservation targets, B-Cubed developed tools to integrate open biodiversity data from GBIF into Habitats Directive policy workflows. B-Cubed's automated, reproducible workflows based on species occurrence cubes aim to facilitate the integration of open biodiversity data into species assessments while supporting FAIR (Findable, Accessible, Interoperable and Reusable) data principles. Scientifically robust, transparent, and reproducible workflows built on open data can make assessments more cost-effective, deliver more frequent and timely biodiversity information for reporting, and complement Member States' targeted monitoring.

This policy brief presents the findings of a stakeholder-driven case study, with stakeholder consultation, undertaken to explore the integration of open biodiversity data into the species-level assessment of the Habitats Directive Article 17 reporting. For over 1500 taxa mentioned across the latest assessment cycles of the Habitats Directive (2001/2006; 2007/2012; 2013/2018), there are more than two decades of data available in GBIF (Figure 1).

Open biodiversity data available through GBIF can help Member States improve species assessments under Article 17 of the Habitats Directive by complementing national monitoring, reducing reporting costs, increasing transparency and improving the reproducibility of assessments, while maintaining national ownership of reporting decisions.

Despite its great taxonomic coverage and the exponential increase of data published through GBIF, nearly one third of the Habitats Directive species in each reporting cycle had no information in GBIF (Figure 1). Many taxa listed at sub-species level regionally do not appear as such in GBIF, with data occurrences often reported at species level, which partially explains the missing taxa information.



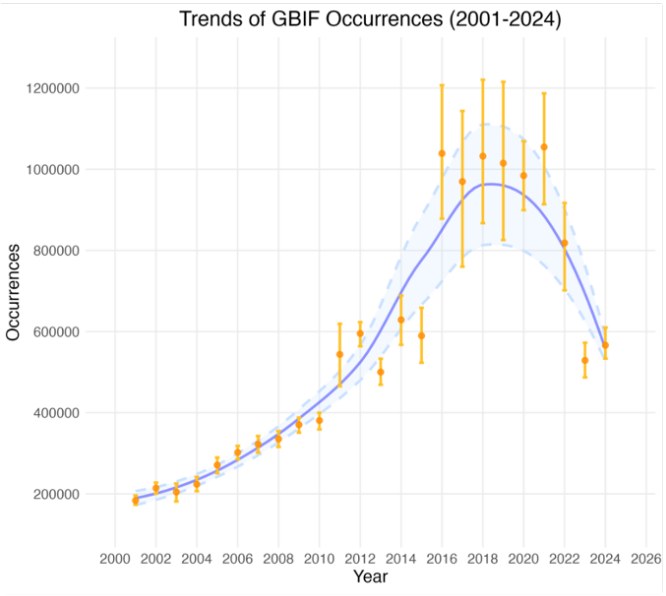


Figure 1. Overview of the percentage of species listed in the annexes of the Habitats Directive (Art. 17) of the three past reporting cycles, 2001 to 2018 (left), with data available in the Global Biodiversity Information Facility (GBIF); orange points represent the observed annual total number of GBIF occurrence records, with yellow error bars indicating the 95% bootstrap confidence intervals. The solid blue line shows the smoothed temporal trend, and the light blue shaded area represents the confidence interval around the smoothed trend (right).

2. Stakeholder perspectives on GBIF integration

Insights gained on current reporting practices, barriers to the integration of data available through GBIF and reproducibility of workflows, from discussions with Member State representatives, GBIF National Nodes and European institutions, were digested into recommendations in support of future reporting.

There is considerable variation in current practices regarding the use of data available through GBIF in the Habitats Directive reporting (Machado et al., 2026). While some Member States integrate GBIF records into their national workflows, others relied exclusively on national monitoring data. These different approaches reflected varying levels of experience with open biodiversity data, as well as differences in national reporting systems, institutional practices, and confidence in the use of occurrence data available through GBIF.

2.1 Current practices

There are contrasting levels of experience with the use of GBIF-mediated data in Habitats Directive Article 17 reporting. While some organisations already consider or integrate data available in GBIF into their reporting workflows, others still do not use data on GBIF for this purpose.

The diversity of practices suggests that the integration of open biodiversity data into Article 17 reporting remains uneven. Many countries use the data on GBIF as a complementary source of information alongside closed monitoring programmes, rather than as a replacement for existing reporting systems.

The perceived value of data in GBIF also differs by taxonomic group. Groups requiring greater identification expertise raised more concerns about data quality on open platforms and were more likely to be discarded, while taxa with less structured monitoring coverage were more likely to be integrated into national reporting. Stakeholders not using GBIF-mediated data tended to view these data as a single source, rather than a large number of different datasets, each with its own data quality control and scope.

Many datasets accessible through GBIF already originate from national monitoring programmes, research institutions, and public authorities. However, not all

of them use the platform to automate the data flow into their own national reporting. The added value of GBIF lies not only in data access, but also in facilitating harmonisation, reuse, and reproducible analyses across Europe. For that, data flows must be streamlined.

2.2 Barriers to Integration

Countries that do not currently use data on GBIF identified a range of barriers to its integration into Article 17 reporting. The most frequently cited challenges were concerns about data quality and trust, particularly regarding the suitability of opportunistic occurrence records for regulatory assessments, together with limited awareness of the potential contribution of data available through GBIF to national reporting. Citizen science data, for example, now one of the largest sources of biodiversity data within GBIF, continue to raise concerns regarding their reliability among many institutions.

Additional barriers reflected national and institutional contexts rather than common concerns. These included technical difficulties in integrating records in GBIF with national datasets, the need for tools and capacity-building to facilitate data use, and challenges related to sensitive species records and the interoperability of institutional databases. **GBIF's adoption of the Catalogue of Life** is a step that will facilitate the harmonisation of databases and help overcome taxonomic discrepancies when merging data from different sources.

2.3 Approaches Where Integration Exists

Countries using data available through GBIF described a range of approaches to integrate these data into Article 17 reporting. Rather than replacing standard monitoring programmes, GBIF data were primarily used to complement existing datasets, particularly by filling distribution gaps or supporting species assessments where additional occurrence records were available.

Integration approaches varied across institutions. Some reported developing independent, repeatable workflows, while others worked in coordination with their national GBIF node. It was also emphasised that, often, integration practices remain dependent on institutional capacity and project-specific requirements.

Most countries using data available through GBIF reported applying some form of data quality evaluation before using occurrence records in reporting. The approaches described included selecting records within known species ranges, verifying taxonomic or author information, checking geographic coordinates, tracking and selecting data according to provenance and applying institutional quality assurance and quality-control. These responses indicate that data available through GBIF are generally treated as complementary evidence requiring appropriate quality assessment rather than being incorporated directly into reporting workflows.

Key barriers identified by participants

- Concerns about data quality and fitness for purpose
- Difficulty assessing data quality, selecting reliable data, and reporting on it
- Limited awareness of the potential of data on GBIF
- Technical challenges in integrating records in GBIF and national datasets
- Need for tools, capacity building and interoperable data infrastructures
- Limited understanding of how differences in species detectability affect quality-control decisions and error-mitigation strategies

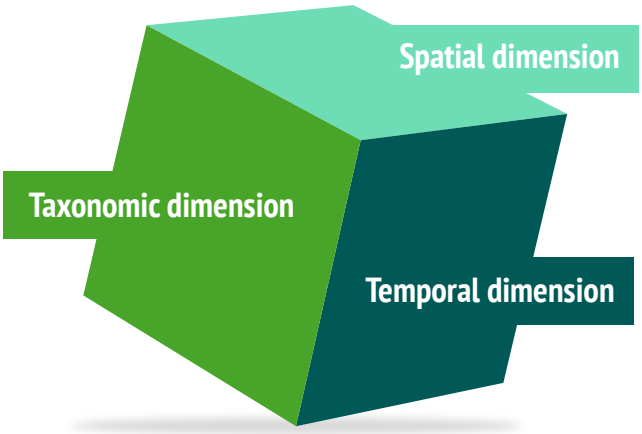
3. What B-Cubed Workflows Offer

3.1 Species Occurrence Cubes

B-Cubed has developed a data structure — the *species occurrence cube* — that aggregates occurrence records available through GBIF into spatial and temporal cells. This enables consistent analysis across taxa, regions, and time periods, providing a common framework for biodiversity indicators that can support policy reporting.

In doing so, the value of data in GBIF shifts from individual datasets to the collective value created through their aggregation. Consequently, the approaches required to extract meaningful signals from aggregated data differ from those used to evaluate bias in individual datasets. Another added value of the species occurrence aggregation service is the capacity for filtering systemically the data sources before aggregation, for example only camera trap data or museum collections.

Use Cubit[3] to generate your own data cubes and merge them with data cubes from GBIF data.



3.2 Automated and Reproducible Indicator Workflows

By embedding quality checks, uncertainty quantification, and indicator calculation into scripted, reproducible pipelines, B-Cubed workflows allow reporting bodies to update assessments efficiently as new data become available, with b3gbi[1] facilitating calculation of indicators and maps (Figure 2).

Species occurrence records represent only one component of Habitats Directive (HD) reporting[7], which also requires locality-specific information on species status, habitat, and conservation. While GBIF cannot replace national reporting, its extensive species occurrence data can complement the occurrence and distribution component by providing a more complete and timely pan-European perspective. In particular, B-Cubed workflows facilitate the detection of changes in species distributions, where biodiversity data available through GBIF can provide valuable complementary evidence for Habitats Directive reporting.

3.3 Data Quality and Uncertainty

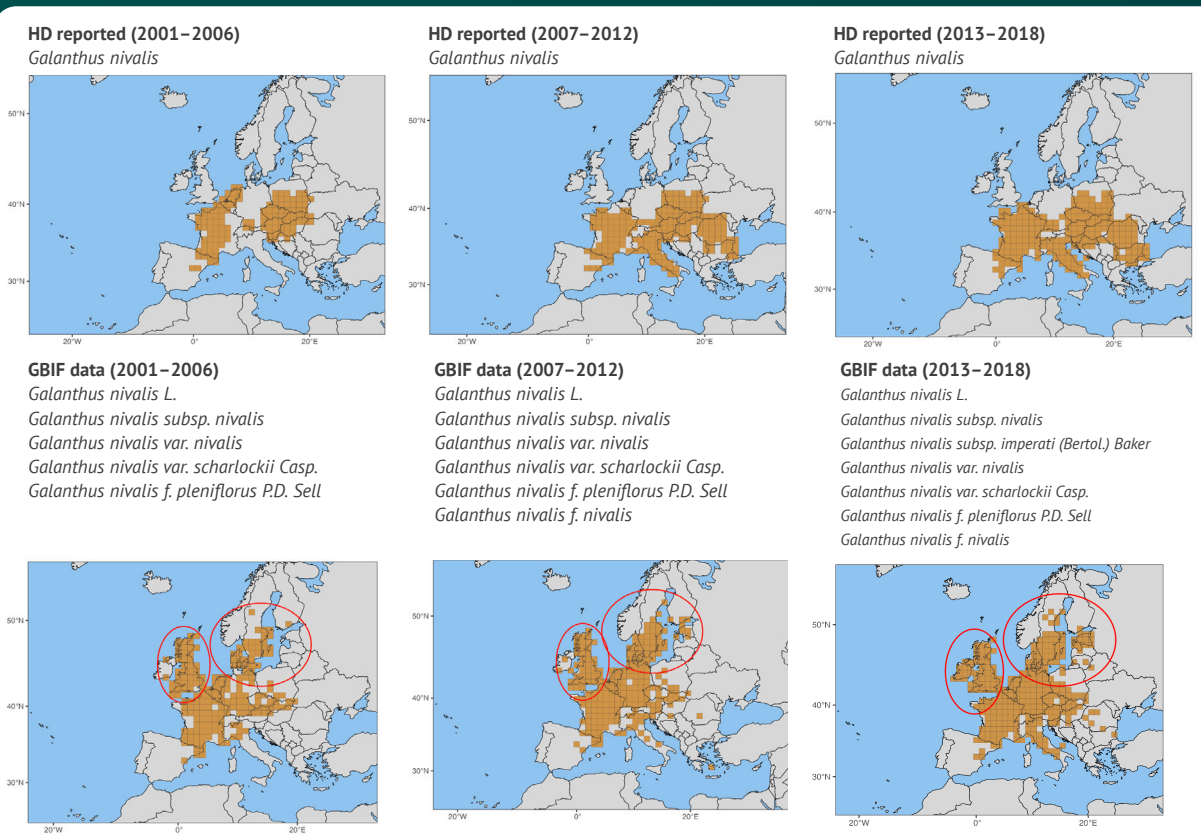
Recognising that concerns about data quality and trust were among the main barriers identified by countries, B-Cubed developed reproducible workflows that integrate data preparation and bias diagnostics (Figure 3), data selection based on information quality, such as temporal structure (Figure 4), indicator calculation and uncertainty assessment within a transparent analytical framework.

These workflows enable biodiversity indicators derived from species occurrence cubes to be generated consistently while explicitly quantifying and communicating both statistical uncertainty and evidence stability, supporting more transparent interpretation of results for policy applications.

The case of *Galanthus nivalis* L. illustrates GBIF added value. The species is native in some European biogeographic regions but non-native in others, meaning that HD reporting captures only its natural distribution as defined under the Article 17 reporting framework. Consequently, distribution maps do not reflect its full occurrence across Europe, including naturalised populations outside the native range (Figure 2).

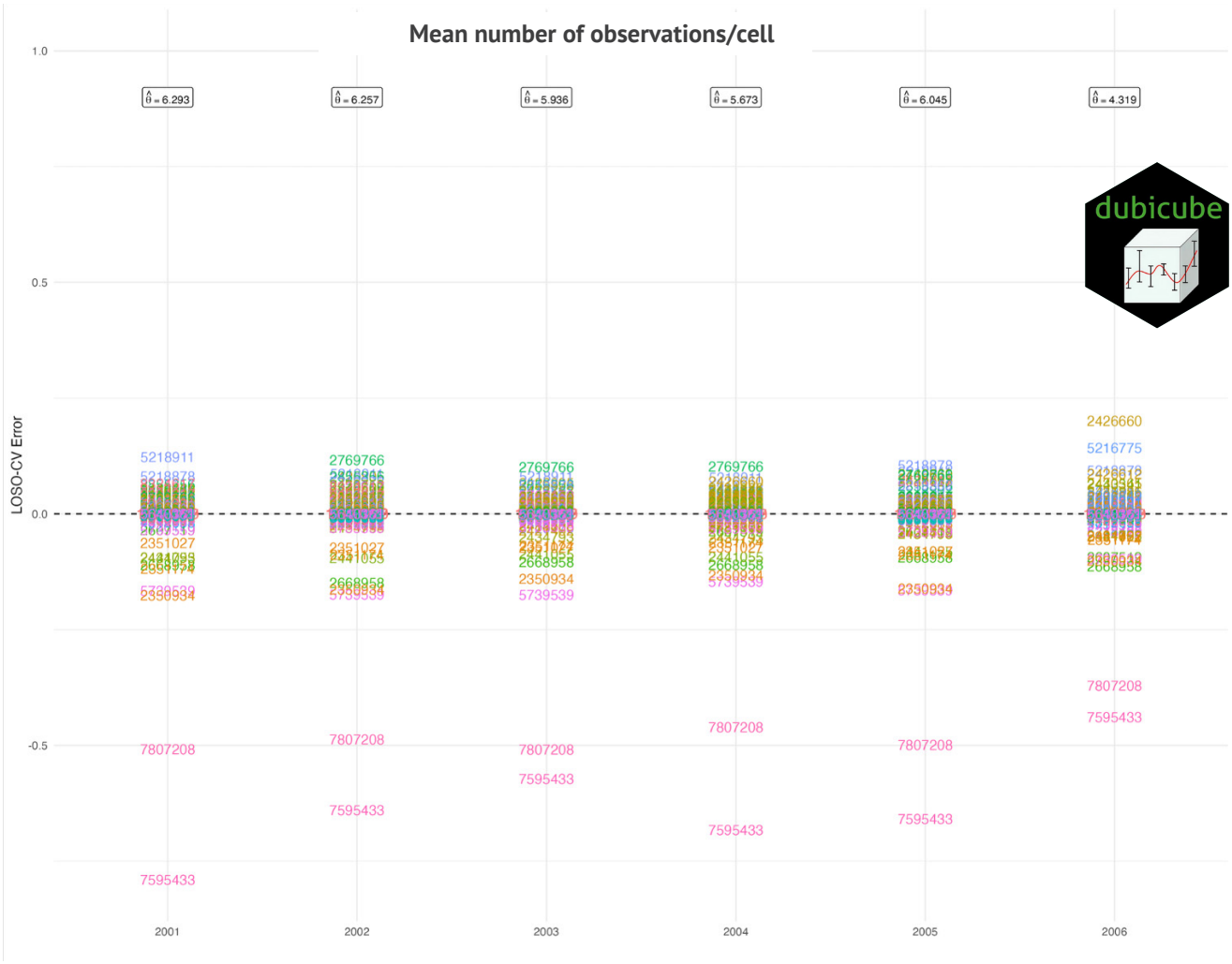
Integrating GBIF occurrence data with HD reporting can help identify emerging range expansions that may otherwise remain undetected, supporting early awareness and more informed conservation and policy responses. More broadly, this example illustrates the challenges of aggregating and interpreting national reporting into a coherent pan-European assessment and highlights the value of open biodiversity data in complementing existing reporting frameworks

The correspondence of GBIF taxonomic keys in the GBIF Backbone Taxonomy to the taxa reported under the EU Habitats Directive (Article 17), for the 2001-06, 2007-12 and 2013-18 cycles, is available in the **B-Cubed ZENODO community** (Machado & Teixeira, 2026) for reproducibility.



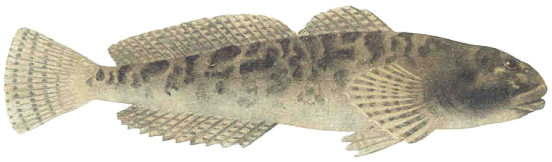
Galanthus nivalis
In the Global Register of Introduced and Invasive Species (GRIIS) list for: Belgium, France, UK, Denmark, Sweden, Estonia, Lithuania, Netherlands

Figure 2. Distribution of *Galanthus nivalis* reported by national assessments in the Habitats Directive national reports (top) and observations available in GBIF (bottom), a species listed in the Global Register of Introduced and Invasive Species (GRIIS) for Belgium, France, UK, Denmark, Sweden, Estonia, Lithuania, Netherlands. The biogeographical range distribution reported under Habitats Directive assessments overlooks its range expansion and current distribution.



Salmo salar

© Scandinavian Fishing Year Book



Cottus gobio

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Figure 3. Bias-detection diagnostics generated using the dubicube[4] functions in the B-Cubed R package. The diagnostics show inflated mean numbers of observations per grid cell for *Salmo salar* (speciesKey = 7595433) and *Cottus gobio* (speciesKey = 7807208), attributable to methodological bias in fish-trapping sampling datasets. This bias may reduce evidence stability by making the resulting patterns and conclusions sensitive to the inclusion or treatment of these datasets. The y-axis shows the Leave-One-Species-Out Cross-Validation (LOSO-CV) Error, representing the change in the estimated mean number of observations per grid cell after removing each species from the analysis. Species with large absolute LOSO-CV Error values have a disproportionate influence on the indicator.

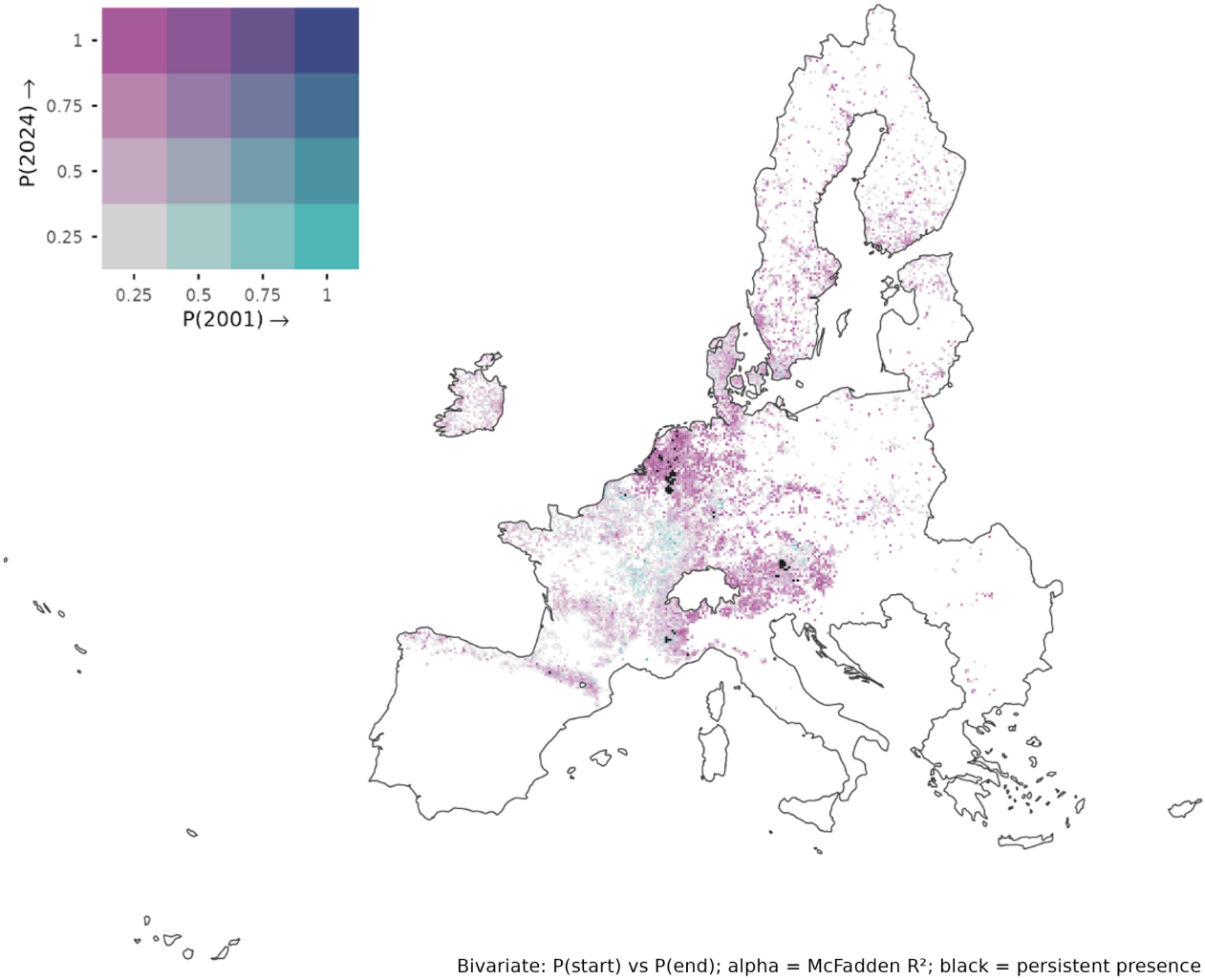

Figure 4. Reporting dynamics of species in GBIF. Example of occurrences of *Rana temporaria* from 2001 to 2024, highlighting the strength of the temporal information for biodiversity trends across Europe. P: probability of presence in 2001 and in 2024; McFadden R^2 (alpha): [0-1].

Related B-Cubed Policy Briefs:

Why countries need the Global Biodiversity Information Facility: Lessons from Belgium — demonstrating national-level value[5]

Data pipelines for policy-relevant indicators — detailing the technical workflow[6]

4. National Experiences and Opportunities for Policy Integration

There is considerable variation in how Member States currently use biodiversity data available through GBIF in Habitats Directive reporting. While some countries have started exploring or integrating GBIF data as a complementary source of information, others rely primarily on national monitoring programmes. None use open data exclusively, even for records of non-sensitive species. Differences reflect variation in national data infrastructures, institutional practices, technical capacity and confidence in the use of open biodiversity data for regulatory assessments.

GBIF National Nodes were recognised as important intermediaries between biodiversity data infrastructures and reporting authorities, providing expertise on data mobilisation, access, quality assessment and workflow development. Strengthening collaboration between reporting authorities, GBIF Nodes and European institutions could facilitate the adoption of more harmonised, effective and reproducible approaches across Member States.

Key opportunities identified during B-Cubed include:

- **Improving technical interoperability** between GBIF data infrastructures and national reporting systems through common standards and reproducible workflows.
- **Building institutional capacity and guidance** to support the appropriate use of open biodiversity data in Article 17 reporting.
- **Strengthening coordination at European level**, with EEA and DG ENV playing a role in promoting harmonised approaches, sharing best practices and supporting cross-Member State learning.
- **Enhancing the role of GBIF National Nodes** as technical support hubs connecting biodiversity infrastructures with national policy needs.
- **Going beyond statistical uncertainty to evidence stability,** B-Cubed complements uncertainty estimates by assessing whether conclusions remain robust to changes in data, assumptions and analytical choices. This provides a more complete picture of confidence in biodiversity assessments.

5. Recommendations

5.1 For Member States

- Explore and pilot the integration of data available through GBIF into future Article 17 reporting, using reproducible workflows and uncertainty tests such as those developed by B-Cubed.
- Strengthen collaboration with GBIF National Nodes during reporting preparation.
- Several EU Member States are still not part of the GBIF network, despite the well-documented benefits of membership.
- Document and share national integration approaches to build cross-Member State learning.
- Use open science to make workflows reproducible and efficient, and the data more useful, transparent and safer.

5.2 For EEA and DG Environment

- Develop guidance explicitly endorsing the use of open biodiversity data (including GBIF) in Habitats Directive reporting.
- Coordinate a shared indicator framework based on harmonised, reproducible workflows.
- Establish a forum for Member States to exchange reporting workflows, quality assurance and data integration practices.
- Integrate Open Biodiversity Data in compliance checking procedures of national assessments and for establishing biogeographic trends.

5.3 For GBIF (Secretariat and National Nodes) and other Research Infrastructures

- Strengthen node capacity for policy-facing support, including training on Habitats Directive reporting requirements.
- Promote GBIF's expanded capacity to support biodiversity monitoring through the **Humboldt Extension** for Ecological Inventories. This development is particularly relevant for the Habitats Directive, as it enables structured survey data to be more effectively shared and reused.
- Formalise policy liaison roles within nodes to bridge the science–policy interface.
- Improve metadata to support data quality assessments of species and datasets.
- Maintain open, FAIR-compliant tools co-designed with reporting authorities.
- Engage in structured co-creation with Member States and EU institutions to ensure workflows meet real reporting needs.

Definitions

Occurrence cube — A spatially and temporally aggregated data structure used by B-Cubed to standardise species occurrence records for analysis.

Statistical uncertainty — The degree of imprecision in an estimate or result arising from limited data, sampling variation, measurement error, or natural variability.

Evidence stability — The extent to which a conclusion remains consistent when reasonable changes are made to the data, assumptions, methods, models, or analytical decisions.

Repeatable workflow — Can be rerun consistently by the original team.

Reproducible workflow — Provides sufficient transparency and documentation for independent researchers to recreate the analysis and results.

References

B-Cubed tools and resources mentioned in the policy brief

[1]Dove S (2026). b3gbi: General Biodiversity Indicators for Biodiversity Data Cubes. R package version 0.9.3, **https://github.com/b-cubed-eu/b3gbi**

[2]Machado, A. & Teixeira, H. (2026). GBIF taxonomic keys for taxa reported under the EU Habitats Directive (Article 17): reporting cycles 2001-2006, 2007-2012 and 2013-2018 (Version 1.0) [Data set]. Zenodo. **https://doi.org/10.5281/zenodo.21457125**

[3]Pinto, R., Estupinan-Suarez, L., Trekels, M., Golivets, M., Hillaert, J., Preda, P., Machado, A. L., Lobos, R. C., Teixeira, H. (2026). Cubit - Integrating open and private data sources into Species Occurrence Cubes (Version 1.0). This work is available under an MIT License. **https://bio-shiny.ua.pt/Cubit/**

[4]Langeraert, W.& Van Daele, T. (2026). dubicube: Calculation and Interpretation of Data Cube Indicator Uncertainty (Version 0.11.0) [Computer software]. Zenodo. **https://doi.org/10.5281/zenodo.18683750**

[5]Groom, Q., Adriaens, T., Desmet, P., Vanderhoeven, S., & Yovcheva, N. (2025). *Why countries need the Global Biodiversity Information Facility: Lessons from Belgium*. B-Cubed – Biodiversity Building Blocks for Policy. **https://doi.org/10.5281/zenodo.16890980**

[6]Groom, Q., Stoykova, N., Rodrigues, A., Hillaert, J., Estupinan-Suarez, L. M., MacFadyen, S.& Langeraert, W. (2026). Data pipelines for policy-relevant indicators. **https://doi.org/10.5281/zenodo.19604942**

EU COM policy legal doc Habitats Directive

[7]EU Habitats Directive (Council Directive 92/43/EEC) ELI: **http://data.europa.eu/eli/dir/1992/43/2013-07-01**

References cited

Machado AL, Teixeira H, Cortes Lobos R, Pinto R, Estupinan-Suarez L, Preda C, Denkova N, Rodrigues A, Groom Q (2026). Report on the stakeholder driven case study: Optimising species assessment and reporting of the Habitats Directive in Europe. B3 project deliverable 6.4. b-cubed.eu/library

Röschel L, Noebel R, Stein U, Naumann S, Romão C, Tryfo E, Gaudillat Z, Roscher S, Moser D, Ellmauer T, Löhnertz M, Halada L, Staneva A & Rutherford C (2020). State of nature in the EU—methodological paper Methodologies under the nature directives reporting 2013–2018 and analysis for the State of Nature 2000. *European Environment Agency: Copenhagen, Denmark*.

BIODIVERSITY BUILDING BLOCKS FOR POLICY

PROJECT COORDINATOR

Dr Quentin Groom
Meise Botanic Garden
quentin.groom@plantentuinmeise.be

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